CLIMATE CHANGE IMPACT ON AGRICULTURE AND FOOD SECURITY IN INDIA

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Climate change is a critical issue in the context of the Indian economy. The country's geographical dynamics and the presence of high level of poor and food insecure population add to its vulnerability to climate change. India is home to about 24.5 per cent of the undernourished people in the world. Increased occurrence of temperature extremes, increase in the number of warm days and nights, altered rainfall patterns, increased frequency of deficit monsoons and heavy precipitation events have been observed in the country. Further, these trends are projected to continue. In this context, the study discusses the climate change trends and their impact on agriculture and food security in the country. The empirical analysis using Ordinary Least Squares (OLS) and Instrumental Variables ((IV) regressions shows that climate especially temperatures adversely impact both agriculture and food security. The importance of promotion of appropriate strategies to address agricultural productivity especially enhanced irrigation facilities, infrastructure and adoption of direct interventionist measures addressing food insecurity in the country is underlined by the research article.

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JEL classification: O13,Q54

1. Introduction

Climate change is not a new phenomenon and awareness on the same has been increasing since the 1992 Rio Earth Summit. The Summit in fact led to the adoption of the UN Framework on Climate Change (UNFCCC) with the objective of "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"(United Nations Framework Convention on Climate Change, Article 2). Over the years, several international

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agreements and negotiations have been undertaken to address the issue. The 1997 Kyoto Protocol is one such landmark agreement which set legally binding targets for green house gas emissions by developed countries. Though the agreement was adopted in 1997 its first commitment period began only in 2008 and ended in 2012. The second commitment period commenced from 2013 and will end in 2020. The recently adopted Sustainable Development Goals (SDGs), the successors of the Millennium Development Goals (MDGs) have also stressed on adopting policies addressing climate change and global warming. In fact, SDG 13 addresses the need to "take urgent action to combat climate change and its impact" (United Nations, 2015). The recently concluded United Nations Climate Change Conference, 2015 (COP 21) held in Paris, France led to a new agreement to contain the increase in average global temperatures to a maximum of 2°C above the pre-industrial levels which in turn would help curtail the damage being caused by global warming.

Climate change as defined by Intergovernmental Panel on Climate Change (IPCC) "refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer" (IPCC 2013). Climate changes include changes which occur due to internal and natural processes as well as the ones caused by external factors especially human activity induced pollution and its impact on natural resources, biodiversity, land use etc.

Climate change is a critical issue especially in the Indian context. The country with its diverse geography comprising of mountains, coasts, forests, deltas and deserts divers is highly vulnerable to climate change due to threats like glacial melts, rising sea levels, extreme heat waves, droughts, desertification, floods, storms and loss of farm lands, grasslands, biodiversity and marine ecosystems. These extreme weather events also amplify the occurrence of heat strokes, vector and water borne diseases adversely affecting human health and productivity. Further, the presence of a high absolute number, as well as, a large proportion of the world's poor population also augment the country's vulnerability with the poorest people in the poorest countries expected to be the worst affected due to climate change (Stern Review, 2006 and IPCC Fourth Assessment Report (AR4, Parry et al. 2007)). Nearly 35 per cent of the World's poor live in the region. About 18.8 of the population in South Asia survives at less than 1.9 $(2011 PPP) a day. Further, the prevalence of undernourishment in the region is also high at nearly 16 per cent. Climate change affects this large poor and food insecure population through a number of ways including their livelihoods, food availability and affordability.

Climate change affects all dimensions of food security. Rising temperatures and changes in rainfall patterns affect agricultural yields, of both rain fed and irrigated crops, directly affecting the availability of food. The unchecked rise of sea levels leads to loss of land, landscape and infrastructure affecting availability and access dimensions of the food system. Access to food is largely a matter of household and individual-level income and of capabilities and rights. Food utilization, to attain nutritional well-being, depends upon water and sanitation and will be affected by any impact of climate change on the health environment. . The stability of whole food systems may be at risk under climate change, as climate can be an important determinant for future price trends as well as the short-term variability of prices (Wheeler and von Braun, 2013).

With this background, the present study discusses the climate change impacts on agriculture and food security in India. The climate change trends are discussed from the regional perspective of South Asia as well as specifically in the Indian context in section 2. An assessment of the food security situation of the country is undertaken in section 3. Section 4 discusses existing literature on the impact of climate change on agricultural production and food security. Section 5 gives an overview of the data and empirical strategy employed in our analysis of the impact of climate change on agricultural production and food security in the country. Section 6 discusses the results of our empirical exercise. Section 7 concludes from a broad policy perspective.

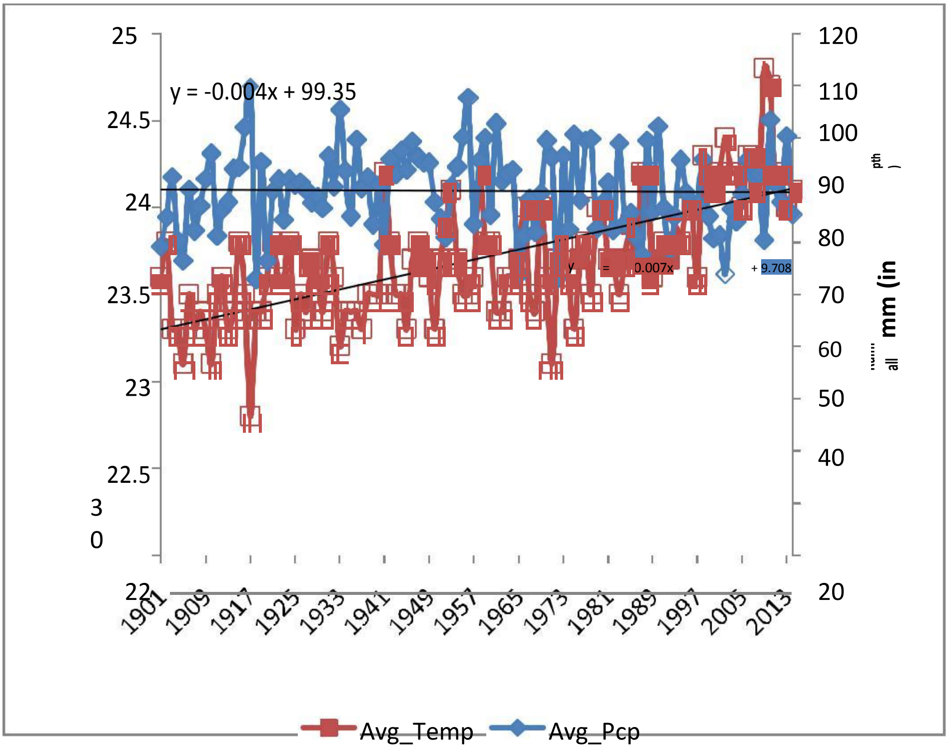
2. Climate Change Trends in South Asia and India

According to the World Meteorological Organization (WMO) estimates the five year period, 2011-15, has been the warmest five-year period on record. The world experienced several extreme weather events such as heat waves[i] primarily a result of the ongoing climate change (WMO 2015). The IPCC's fifth Assessment Report (AR5) on Climate Change, Working Group (WG) I, also states that the earth has been successively warmer in the last three decades compared to any preceding decade since 1850 (IPCC, 2013). Further, the thirty year period from 1983 to 2012 was the warmest 30-year period of the last several hundred years. The combined land and ocean surface temperature (averaged globally) have risen by about 0.85 °C over the period 1880 to 2012 with almost the entire globe experiencing surface warming. Over the period 1901 to 2010, global mean sea level rose by 0.19 m, an increase not experienced in the last two millennia. Regarding future projections the report states global mean surface temperature is projected to rise by 0.4-2.6°C by 2050, with increase in the likelihood of heat wave occurrences. Intense precipitation events would occur more frequently and the contrast in precipitation between wet and dry regions and between wet and dry seasons will also increase. Global mean sea level will also continue to rise with increased warming and acidification of oceans (IPCC, 2013).

Climate Change Trends in South Asia: According to IPCC's WGI's Report (IPCC, 2013) temperature extremes (in the form of heat waves) and in general an increase in the number of warm days and nights observed throughout Asia reflect the climate change that the region is experiencing. The growth and development in South Asia in particular is being challenged by the country level warming that the region has been experiencing since the last century. Altered rainfall patterns with lower average seasonal rainfall and greater variability over the decades, increased frequency of deficit monsoons and heavy precipitation events have also been observed in the region. Further, these trends are projected to continue. Land areas in the region are likely to experience temperature increases of greater than 3ºC by the middle of the current century. Extreme precipitation events, increases in average seasonal rainfall and its variability are also expected with high likelihood. Sea level rise is also a serious risk potentially affecting livelihoods and pushing migration both at national and sub-national levels in the region.

Climate Change Trends in India: As per IPCC's WGII's Report increase in extreme rains in northwest India during summer monsoon and lower number of rainy days along east coast of the country have been observed in recent decades (Cruz et al, 2007). Further the report predicted increasing trends in annual mean temperature with 0.68°C increase per century with more pronounced warming in the post monsoon and in winter seasons.

Figure 1: Annual Average Temperature and Precipitation Trend (India: 1901-2014)

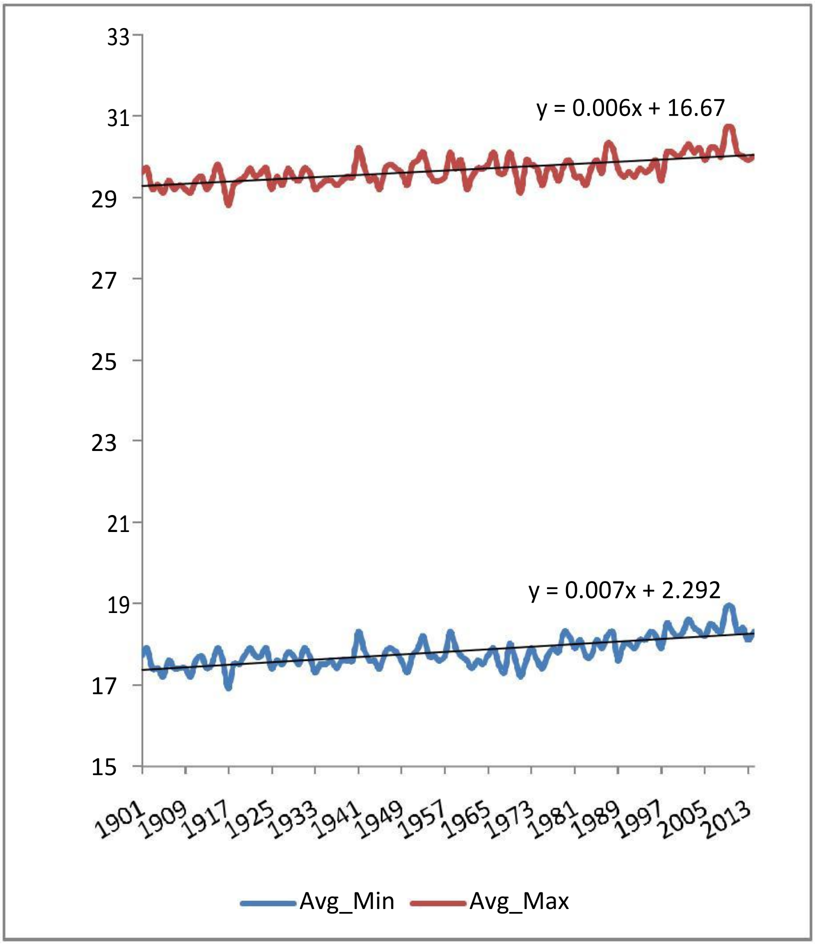


Source: Based on data from CRU TS3.23.

Based on our analysis of annual averaged data from Climatic Research Unit (CRU), University of East Anglia; CRU TS3.23. (Harris, I. and P.D. Jones, 2015) it is observed that the annual average temperature has been around 23.7 Degree Celsius for the period 1901-2014 (Figure 1). The annual average temperatures have reflected a positive (and significant) trend growth rate of 0.007 Degree Celsius. The average rainfall exhibits a declining (but not significant) trend for the period considered. India has been experiencing an increase in average decadal temperatures since the 1960's. The average decadal temperatures of have been the highest in the recent most ten year period of 2001-10 for the country. In fact, the highest ever average temperatures over the entire period were experienced in 2009 at 24.8 degree Celsius. Average precipitation levels in the decade of the 90's were lower for India compared to the previous decade. Further though average precipitation levels increased in the subsequent decade the levels attained were lower than experienced in the 80's.

Breaking down the average temperatures and considering average maximum and minimum temperatures separately (Figure 2), these too also reflect a significant increasing trend for the country. Average minimum temperatures have been increasing at a higher rate of 0.0079 Degree Celsius annually while average maximum temperatures have been been increasing at a higher rate of 0.0066 Degree Celsius.

Figure 2: Annual Average Minimum and Maximum Temperature Trend (India: 1901-2014)



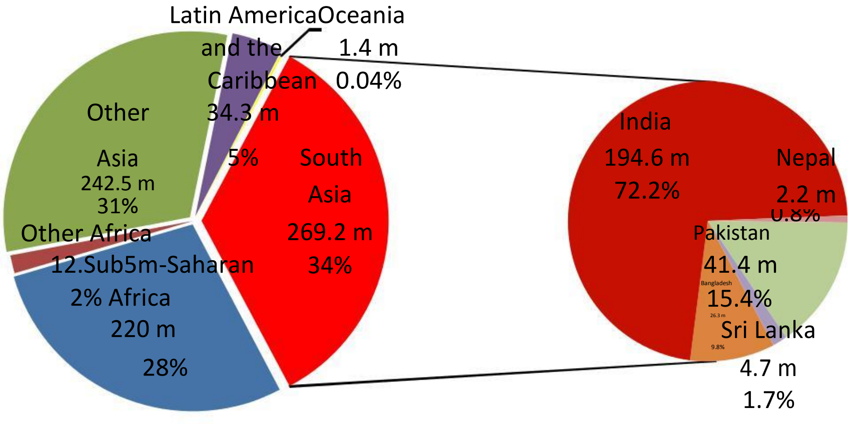
Source: Based on data from CRU TS3.23.

3. Food Security in India

Discussions on the Sustainable Development Goals (SDGs), the successors of the Millennium Development Goals (MDGs) have ensured a renewed commitment to end hunger and global poverty by 2030. The second SDG, calls for measures "to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture" (von Grember et al., 2015).

Progress has been made by the developing world in reducing hunger since 2000, with the level of hunger in these countries as a group having fallen by 27 per cent. However, the state of hunger in the world remains unacceptably high. According to the State of Food Insecurity (SOFI) in the World Report, 2015, 795 million people (or just over one in nine) in the world are undernourished. Sub-Saharan Africa has about 220 million undernourished people compared to 511.7 million in Asia (FAO, IFAD and WFP, 2015). South Asia is home to about 40 per cent of the undernourished people in the world. Though the prevalence of undernourishment is higher in Sub-Saharan Africa at 23 per cent (compared to 16 per cent for South Asia) the food security situation in the region is worrisome due to the higher absolute numbers. Within South Asia, the number of malnourished people in India stands at a staggering figure of 194.6 million or about 24.5 per cent of the total undernourished people in the world (FAO, 2015). Pakistan, Bangladesh, Afghanistan, Sri Lanka and Nepal have about 15, 9.5, 3, 1.7 and 0.8 per cent of the undernourished people in the region due to their relatively lower populations compared to India (Figure 3).

Figure 3: Undernourishment in the World, South Asia and India (2014-16)



Source: Based on data from FAO-Food Security Indicators, 2015. Available at: http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.Vkoy9XYrLrc, accessed on 7/11/2015

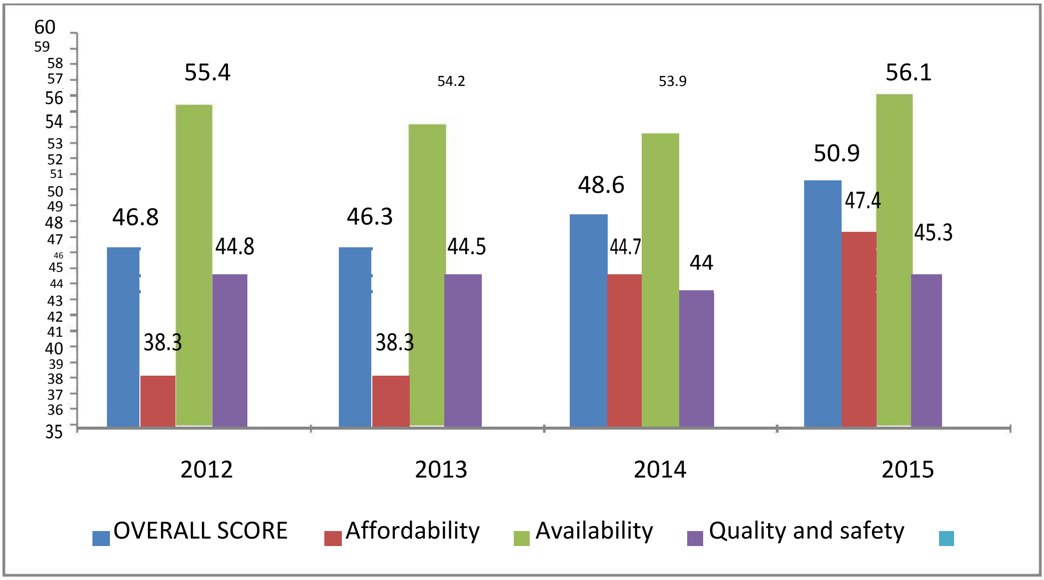
Food security is defined as the state in which people at all times have physical, social, and economic access to sufficient and nutritious food that meets their dietary needs for a healthy and active life. Using this definition adapted from the 1996 World Food Summit, the Global Food Security Index (GFSI) considers the core issues of affordability, availability and utilization. *Affordability* measures the ability of consumers to purchase food, their vulnerability to price shocks, and the presence of programs and policies to support consumers when shocks occur. *Availability* measures the sufficiency of the national food supply, the risk of supply disruption, national capacity to disseminate food, and research efforts to expand agricultural output. *Utilization as measured by Quality and Safety* is estimated by looking at the variety and nutritional quality of average diets, as well as, the safety of food. Figure 4 gives the overall GFSI Index for the country for the recent most four years along with their sub-indices of Affordability, Availability and Quality and Safety.

Addressing food insecurity through the categories of 'affordability', 'availability' and 'quality and safety' (with respective weights as 40 per cent, 44 per cent and 16 per cent), India has constantly improved on its GFSI (since 2012) and currently has a GFSI of more than 50. In general all South Asian countries are better performers in the 'availability' category and so is India. 'Quality and Safety' is the most serious concern for the country.

Few pertinent observations on each of the sub-components of 'affordability', 'availability' and 'quality and safety' (Appendix Table A1) are as follows:

Affordability: This is based on components such as GDP per capita, food consumption as a per cent of household expenditure, percentage of population below the poverty line, access to financing for farmers and presence of food safety net programs. In India the share of monthly per capita expenditure on food is relatively much lower about 30 per cent (down from about 50 per cent in 2012 and 2013). The percentage of population living below the poverty line in India is close to 70 per cent. Food safety net programs measure the public initiatives to protect the poor from food related shocks. The GFSI (2015) report categorizes India's food safety nets as having a national coverage, with very broad, though not deep coverage of these programs (rating of 3 out of 4). For access to financing for farmers implying limited multilateral or government farmer financing programs, India gets a relatively high ranking of 3 (highest being 4) implying broad, but not deep, farmer financing.

Figure 4: Food Security in India Based on GFSI (2012-2015)



Source: Based on data from GFSI, 2015

Availability: This is based on components such as average food supply (kcal/capita/day), public expenditure on agricultural Research and Development (R&D) and volatility of agricultural production. In terms of average food supply, the figure for the country has improved from 2321 kcal/capita/day (2013) to 2549 kcal/capita/day (2015). Volatility of agricultural production based on standard deviations of agricultural production is 0.1 for all the years considered. Public expenditure on agricultural R & D as a per cent of GDP gets the lowest rating of 1 (rating from 1-9) for all the four years. Road infrastructure also gets a poor qualitative assessment of 1 (out of 0-4) for the periods considered.

Quality and Safety: This is based on components such as diet diversification, intake of protein, safety and health of food, and percentage of population with access to potable water. Diet diversification seems to have improved for the country moving from 38 to 41 per cent. Considering the quality of protein intake, it has also improved over the years from 37 to 38.6 grams.

4. Climate Change, Agricultural Production and Food Security

Climate change affects all dimensions of food security. Rising temperatures and changes in rainfall patterns affect agricultural yields, of both rain fed and irrigated crops, directly affecting the availability of food. The unchecked rise of sea levels leads to loss of land, landscape and infrastructure affecting availability and access dimensions of the food system. Access to food is largely a matter of household and individual-level income and of capabilities and rights. Food utilization, to attain nutritional well-being, depends upon water and sanitation and is affected by any impact of climate change on the health environment. The stability of whole food systems may be at risk under climate change, as climate can be an important determinant for future price trends, as well as, the short-term variability of prices (Wheeler and von Braun, 2013).

The availability of food is impacted by climate change via impacts on agricultural outcomes. Predicted increase in global temperatures could lead to rise in seawater levels resulting in a reduction of available agricultural lands along with the influence on growing conditions for different crops. Increase in temperatures and erratic rainfall patterns can lead to short-run crop failures and long-run production declines, posing a serious threat to food security.

According to a World Bank Report (World Bank, 2009), a few climate change risks that India is exposed to include

Exposure of agriculture, water resources, and ecosystems to extreme weather events and more variable precipitation

Impact of glacial melt on water resources quantity, biodiversity, and low-lying agriculture

Vegetation shift in forests and biodiversity, regime shifts in rangelands, and decreased agricultural yields in tropics and sub-tropics

A number of studies have been undertaken at the regional level assessing the impact of climate change on agricultural production and productivity. Climate change is projected to have a significant adverse impact on agricultural production in South Asia (Nelson et al. 2009). They shows that crop yields in South Asia are likely to experience declines due to climate change. Specifically for the developing countries taken together the decline in yields of wheat is expected to be lower between 29.2 and 33.5 per cent. For maize, in fact, the developed countries are expected to experience increase in yield rates between 1.8 and 11. 2 per cent while South Asia experiences a decline between 8.9 and 18.5 per cent.

A number of other studies have also projected a similar decline in agricultural productivity in South Asia. It is expected that both rice and wheat yields would decrease in the region, with the impact on the latter being considerably higher (ADB, 2013). According to the IPCC Report rice production is likely to decrease most in the northern parts of the region, while wheat production is expected to decline in the Indo-Gagentic plains (IPCC, 2014). Pakistan is the only country for which the Report estimates the impact of climate change favorable for wheat yields. Another study, Kelkar and Bhadwal (2007), also project that further global warming is expected to negatively impact rice and wheat yields in tropical parts of South Asia. These crops are already being exposed to high temperatures and further increases would imply an exposure beyond their tolerance capacity.

A study from the International Maize and Wheat Improvement Center (CIMMYT) details possible climate shifts in the Indo-Gangetic Plains of South Asia, a region of 13 million hectares that extends from Pakistan across northern India, Nepal and Bangladesh, and which grows 15% of the world's wheat. According to the study, by 2050 more than half of its area may become heat-stressed for wheat, with a significantly shorter season for the crop.

Simulation studies of climatic models portray a negative impact of future climatic variations on agricultural output in the Indian context. In most places of north India, grain yields are likely to decline by 15-17 percent for every 2 Degree Celsius increase in temperature. In Rajasthan, production of pearl millet and in Madhya Pradesh, soybean yields are likely to decline by 10-15 per cent and 5 per cent respectively for every 2 Degree Celsius increase in temperature. Overall, an increase of 2 Degree Celsius in temperature will reduce rice production by about 0.75 tonnes per hectare and an increase of 0.5 Degree Celsius in winter temperature will reduce wheat production by about 0.45 tonnes per hectare (Lal et al., 2010). According to the Stern Review (2007) crop yields across Northern India may be reduced by between 30-60 per cent with extremes up to 70 per cent as a result of climate change. Only a 1 Degree Celsius rise in temperature could reduce wheat yield in Uttar Pradesh, Punjab and Haryana. In Haryana, night temperatures during February and March in 2003-04 were recorded 3°C above normal, and subsequently wheat production declined from 4106 kg/ha to 3937 kg/ha in this period (Cooshalle, 2007).

5. Data and Empirical Methodology

In our econometric analysis, the impact of climate variables on agricultural production and food insecurity measured via two indicators- Prevalence of Undernourishment and Depth of Food Deficit is undertaken. The prevalence of undernourishment expresses the probability that a randomly selected individual from the population consumes an amount of calories that is insufficient to cover her/his energy requirement for an active and healthy life. The depth of the food deficit indicates how many calories would be needed to lift the undernourished from their status, everything else being constant. The average intensity of food deprivation of the undernourished, estimated as the difference between the average dietary energy requirement and the average dietary energy consumption of the undernourished population (food-deprived), is multiplied by the number of undernourished to provide an estimate of the total food deficit in the country, which is then normalized by the total population.

We use Ordinary Least Squares (OLS) regression as well as Two Stage Least Squares (2sls) Instrumental Variables (IV) regression analysis.

The data used in this paper are sourced from World Development Indicators (WDI), 2015 and Food and Agricultural Organisation (FAO). The data for Gross Domestic Product, GDP_{pc} (at 2011 PPP US$), irrigation (irrigated land as a percentage of agricultural land) and agricultural employment (as a percentage of total employment) are taken from WDI, 2015. Data on prevalence of undernourishment, depth of food deficit, infrastructure (both road and rail density) and percentage of population with access to improved drinking water source is sourced from FAO, Food Security Indicators, 2015. The Agricultural Production Index (base 2004-06) is sourced from FAO Production indices. The Climate data has been collected for the period 1901-2014 from Climatic Research Unit (CRU), University of East Anglia; CRU TS3.23. (Harris, I. and P.D. Jones, 2015). The period of our study is 1990-2014 and we use three year moving averages. The long period climate data is used to measure deviations. Square of deviations from the long term means in the pre climate change era (1901-50) are considered in our analysis. Squares are used to give larger weightages to larger deviations.

As a first exercise, we study the impact of climate variables- average temperatures, average maximum and minimum temperatures and average precipitation levels on agricultural production. We specifically use the Agricultural Production Index (base

2004-06) sourced from FAO Production indices as our dependent variable to measure agricultural production in the country.

Specifically we study the following relation.

$$- \quad = \alpha + \beta \quad + \qquad (1)$$

where CV represents the climate variables mentioned above. Specifically in our analysis rainfall deviations are considered in all models along with average temperatures, average maximum or average minimum temperatures to avoid multicollinearity[3].

For a better specification of the model other relevant inputs for agricultural production are included in the specification represented by equation 2 with different combinations of rainfall and temperatures as mentioned above.

$$- \quad = \alpha \quad + \beta \quad + \beta \quad + \beta \quad + \beta \quad + \qquad (2)$$

This is followed with an estimation of the impact of climate variables on food insecurity. As previously mentioned we measure food insecurity via the indicators of Prevalance of Undernourishment and Depth of Food Deficit. The data for the same have been taken from FAO, Food Security Indicators, 2015.

$$= \alpha + \beta + \qquad (3)$$

$$= \alpha + \beta \quad + \qquad (4)$$

Since food security depends on the dimensions of food availability, food accessibility and food utilization we specifically estimate the following relations.

$$= \alpha + \beta \quad + \beta \quad + \beta \quad + \qquad (5)$$

$$= \alpha + \beta \quad + +\beta \quad + \beta \quad + \qquad (6)$$

[3] We also checked for the correlation between average temperatures and precipitation levels and found it not to be significant.

Food accessibility involves both economic and physical access and both of them are considered in the analysis. Economic access is measured via GDP_{pc} (at 2011 PPP US$) and physical access through the infrastructure parameter of rail density. Percentage of population with access to improved drinking water source is employed to appraise food utilization.

Food availability is directly dependent on agricultural production and thus is an endogenous variable, inclusion of which would lead to multicollinearity. 2sls IV regression is employed to incorporate this variable. In the first stage agricultural production is the instrumented variable. Irrigation is considered to be the instrument and the following first stage regression is estimated.

$$= \alpha + \beta \quad - \quad + \beta \quad + \beta \quad + \beta \quad + \beta \quad + \qquad (7)$$

In the second stage the estimates of agricultural production obtained from the first stage are considered to be an additional independent variable, along with rail density and percentage of population with access to improved drinking water source, in the regression of prevalence of undernourishment and depth of food deficit. The regressions specifically estimated are given by equations 8 and 9.

$$= \alpha + \beta \quad - \quad + \beta \quad + \beta \quad + \beta \quad + \qquad (8)$$

$$= \alpha + \beta \quad - \quad + \beta \quad + \beta \quad + \beta \quad + \qquad (9)$$

6. Empirical Results

Climate variables both temperature and precipitation deviations have significant impact on agricultural production (Table 1). Excessive deviation of rainfall from its long term average leads to a fall in agricultural production. Increase in deviations of average temperatures and average minimum temperatures tend to positively and significantly impact agricultural production while higher deviations of average maximum temperatures significantly reduce agricultural production.

Table 1: Impact of Climate Change on Agricultural Production

	Agr_Prod (Agricultural Production Index)		
	(1)	(2)	(3)
Rainfall (Square Deviation)	-0.072** (0.031)	-0.072** (0.031)	-0.074** (0.034)
Average Temperature (Square Deviation)	19.899*** (3.870)		
Average Maximum Temperature (Square Deviation)		-0.696*** (0.147)	
Average Minimum Temperature (Square Deviation)			0.004*** (0.001)
Constant	98.232*** (3.404)	315.151*** (43.313)	48.426*** (8.046)
N	24.000	24.000	24.000
R^2	0.276	0.265	0.307
Adj_R^2	0.207	0.195	0.241

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2 gives the results of the regression of agricultural production on climate variables considering other agricultural inputs as well. The impact of deviations of rainfall becomes smaller in magnitude as well as significance (they were significant at 5 per cent earlier but are now significant only at 10 per cent) with the introduction of other agricultural inputs. Temperature deviations no longer significantly impact agricultural production once other agricultural inputs are considered. The importance of irrigation especially in the context of climate change is apparent from the results. Increases in irrigated land as a per cent of agricultural land significantly raise agricultural production. In fact, an increase by one percent of irrigated land increases agricultural production index by 1.47 -1.49 depending on which temperature variable is considered. Infrastructure in the form of road density also is a significant variable positively impacting agricultural production. Employment in agriculture has a negative though non significant impact on agricultural production. This is expected due to the large amount of disguised unemployment in the sector in India.

Table 2: Impact of Climate Change on Agricultural Production (with other inputs)

	Agr_Prod (Agricultural Production Index)		
	(1)	(2)	(3)
Rainfall (Square Deviation)	-0.034* (0.016)	-0.034* (0.017)	-0.033* (0.017)
Average Temperature (Square Deviation)	0.552 (4.431)		
Average Maximum Temperature (Square Deviation)		-0.015 (0.152)	
Average Minimum Temperature (Square Deviation)			-0.000 (0.001)
$Irrigated_{Land}$	1.487** (0.642)	1.488** (0.646)	1.493** (0.648)
Agr_{Emp}	-0.577 (0.667)	-0.573 (0.668)	-0.538 (0.655)
$Infrastructure_{Road}$	0.259** (0.109)	0.261** (0.109)	0.278** (0.120)
Constant	59.100 (67.030)	63.397 (81.791)	57.323 (68.037)
N	22	22	22
R^2	0.932	0.932	0.932
Adj_R^2	0.910	0.910	0.910

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3 gives the results of the regression impact of climate variables both temperature and precipitation deviations have significant impact on prevalence of undernourishment and depth of food deficit.

Precipitation in depth does not significantly impact food insecurity. Average maximum temperatures significantly increase food insecurity as is apparent from the results for both the variables. Average minimum and average temperatures on the other hand significantly reduce food insecurity.

Table 3: Impact of Climate Change on Prevalence of Undernourishment and Depth of Food Deficit

	Prevalence of Undernourishment			Depth of Food Deficit		
	(1)	(2)	(3)	(1)	(2)	(3)
Rainfall (Square Deviation)	0.000 (0.009)	-0.000 (0.009)	0.001 (0.009)	-0.009 (0.067)	-0.010 (0.067)	-0.007 (0.069)
Average Temperature (Square Deviation)	-5.387*** (1.193)			-34.692*** (8.049)		
Average Maximum Temperature (Square Deviation)		0.188*** (0.044)			1.212*** (0.297)	
Average Minimum Temperature (Square Deviation)			-0.001*** (0.000)			-0.007*** (0.001)
Constant	21.404*** (0.759)	-37.147** (13.298)	34.917*** (2.547)	149.609** (5.259)	-227.882** (89.488)	235.176** (18.296)
N	24	24	24	24.000	24.000	24.000
R^2	0.405	0.388	0.448	0.373	0.359	0.402
Adj_R^2	0.348	0.330	0.396	0.314	0.298	0.345

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Tables 4 and 5, report the results of regressions of food insecurity variables on climate variables and variables measuring food accessibility and food utilization. A few pertinent observations from both the tables are noted below.

(i) The results obtained w.r.t the climate variables hold irrespective of whether other aspects of food security are considered or not. Precipitation continues to not significantly impact food insecurity. Average maximum and average temperatures continue to significantly increase and decrease food insecurity respectively Average minimum temperatures in two cases significantly reduce both depth of food deficit and prevalence of undernourishment. The exception being when economic access via GDP_{pc} is considered.

(ii) Economic access primarily has a significant negative impact on food insecurity. With GDP_{pc} increasing both depth of food deficit and prevalence of undernourishment significantly decrease in three cases out of the six reported. An exception does occur when we consider average minimum temperatures.

(iii) Physical access has the most robust, negative and significant impact on food insecurity. With infrastructure improving via increases in rail density food insecurity decreases in all the models considered. This has important implications in the Indian context and calls for improvements in infrastructure facilities to combat foods insecurity.

(iv) Food utilization measured through population with access to improved drinking water source gives mixed and insignificant results. It has a negative but insignificant impact on food insecurity analyzed via prevalence of undernourishment while the impact becomes positive (insignificant) when we consider the depth of food deficit.

Table 6 reports the results of the 2sls IV regression. The results of the first stage regression are given in Table A2 of the appendix.

As is apparent, food availability measured via the instrumented variable agricultural production index does not significantly impact food insecurity. Rainfall deviations and food utilization (population with access to improved drinking water source) also do not have a significant impact on food insecurity. Average maximum temperature deviations and infrastructure (physical accessibility) in terms of rail density significantly impact food insecurity. The former increases food insecurity while the latter helps control it. Thus the importance of infrastructure cannot be ignored for improving food security in the country.

Table 4: Impact of Climate Change on Prevalence of Undernourishment Considering Other Dimensions of Food Security

	Prevalence of Undernourishment								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rainfall (Square Deviation)	-0.008 (0.009)	0.003 (0.010)	-0.001 (0.009)	-0.008 (0.009)	0.002 (0.010)	-0.002 (0.009)	-0.008 (0.009)	0.008 (0.009)	0.007 (0.010)
Average Temperature (Square Deviation)	-1.788* (0.976)	-6.885** (2.582)	-4.906** (1.856)						
Average Maximum Temperature (Square Deviation)				0.061* (0.033)	0.224** (0.087)	0.159** (0.061)			
Average Minimum Temperature (Square Deviation)							-0.000 (0.000)	-0.002*** (0.000)	-0.002** (0.001)
GDP_{pc}	-0.002*** (0.000)	0.001 (0.001)		-0.002*** (0.000)	0.001 (0.001)		-0.002*** (0.000)	0.002* (0.001)	
$Infrastructure_{Rail}$		-65.673*** (22.756)	-43.624*** (13.819)		-60.166** (21.752)	-40.893*** (13.448)		-84.677*** (23.229)	-67.852*** (20.451)
$Water_{Access}$			-0.008 (0.107)			-0.035 (0.103)			0.226 (0.175)
Constant	25.080*** (0.966)	145.051*** (41.451)	105.543*** (18.919)	6.159 (10.550)	65.421*** (17.456)	52.830*** (10.485)	29.311*** (2.762)	200.694*** (47.125)	154.757*** (33.318)
N	24.000	24.000	24.000	24.000	24.000	24.000	24.000	24.000	24.000
R^2	0.693	0.780	0.770	0.692	0.768	0.764	0.692	0.804	0.793
Adj_R^2	0.647	0.733	0.721	0.645	0.719	0.714	0.645	0.763	0.749

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Impact of Climate Change on Depth of Food Deficit Considering Other Dimensions of Food Security

	Depth of Food Deficit								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rainfall (Square Deviation)	-0.062 (0.067)	0.027 (0.073)	-0.007 (0.067)	-0.063 (0.066)	0.018 (0.074)	-0.013 (0.066)	-0.064 (0.071)	0.056 (0.065)	0.052 (0.077)
Average Temperature (SquareDeviation)	-12.033 (7.005)	-51.856** (19.109)	-37.051** (14.240)						
Average Maximum Temperature (Square eviation)				0.412* (0.236)	1.697** (0.650)	1.202** (0.470)			
Average Minimum Temperature (Square eviation)							-0.002 (0.002)	-0.013*** (0.003)	-0.013** (0.005)
GDP_{pc}	-0.010*** (0.002)	0.009 (0.007)		-0.010*** (0.002)	0.008 (0.007)		-0.010*** (0.002)	0.016* (0.008)	
$Infrastructure_{Rail}$		-513.084*** (172.844)	-329.300*** (106.584)		-474.455** (166.041)	-308.910*** (103.659)		-628.170*** (175.926)	-507.338*** (155.841)
$Water_{Access}$			0.310 (0.822)			0.112 (0.786)			2.038 (1.324)
Constant	172.750*** (7.248)	1110.053*** (315.028)	756.062*** (145.982)	44.725 (76.020)	512.051*** (136.853)	357.830*** (78.592)	199.414*** (20.310)	1470.813*** (355.603)	1119.734*** (253.680)
N	24.000	24.000	24.000	24.000	24.000	24.000	24.000	24.000	24.000
R^2	0.622	0.736	0.714	0.620	0.723	0.707	0.617	0.751	0.740
Adj_R^2	0.565	0.680	0.654	0.563	0.665	0.645	0.559	0.699	0.685

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Impact of Climate Change on Prevalence of Undernourishment and Depth of Food Deficit IV Regression

	Prevalence of Undernourishment	Depth of Food Deficit
Agricultural Production Index	0.091 (0.137)	0.615 (1.028)
Rainfall (Square Deviation)	0.003 (0.012)	0.019 (0.090)
Average Maximum Temperature (Square Deviation)	0.197** (0.083)	1.460** (0.626)
$Infrastructure_{Rail}$	-60.064** (28.956)	-439.081** (217.406)
$Water_{Access}$	-0.072 (0.121)	-0.138 (0.920)
Constant	71.654*** (25.288)	485.639** (190.492)
N	24.000	24.000
R^2	0.747	0.687
Adj_R^2	0.676	0.600
Durbin Score#	8.34***	8.41***
Wu-Hausman#	93.78***	99.14***

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

#Exogenity Tests with Ho: variables are exogenous

7. Conclusion and Policy Implications:

Climate change is a harsh reality that the World is facing. Given the exceptional vulnerability of the Indian economy to this threat, it is important that appropriate strategies addressing agricultural productivity and food security through building of appropriate food stocks be designed.

Increasing Public Investments in Agriculture: With the decline in agricultural productivity associated with climate change it is important to focus on technologies and research that enhance crop and livestock productivity with development of varieties and breeds that are adaptable to a range of production environments. Agricultural investment can help enhance productivity levels that have been stagnant or declining. Agriculture investments have been traditionally low in South Asia. For instance, agricultural capital stock per worker did not show any increase over the period 1987-2007 (FAO, 2012). In the region, since the scope of expanding arable land and water resources for agricultural purposes is limited yield increases remain crucial for increase in production, thereby increasing the need for agricultural R & D. Public investment in agricultural R & D is especially important in this context. Though total public agricultural R&D spending in South Asia more than doubled between 1996 and 2009, the amount is still very low compared with other developing regions around the world. For instance, public expenditures on agricultural R&D as a share of agricultural GDP for the region for 2009 was only 0.25 (excluding India) (FAO, 2012). Further, public spending per worker in South Asia in fact was only 79 US$ (Constant 2005 PPP) in 2005-07, much lower than in high income countries. The Agricultural Orientation Index (AOI) provides a way to assess whether government expenditures on agriculture reflects the economic importance of the sector. It is the share of agriculture in total government expenditure divided by the share of agriculture in total GDP. For South Asia the AOI was only 0.27 in 2005-07, a value lower than all regions of the world (except Sub Saharan Africa). The AOI for East Asia and the Pacific was the highest at 0.59, followed by that of Latin America and the Caribbean and Middle East and North Africa at 0.38 and 0.3 respectively.

Regional linkages and cooperation in respect of agricultural research is also required so as to avoid wasteful duplication, ensuring efficiency in utilization of limited resources and sharing of experiences to encourage adoption of best practices applicable due to common challenges faced by the countries in the region.

Improved and sustained agricultural productivity in the long run would have accompanied benefits of alleviating poverty with its concomitant impact on building resilience of farmers to combat climate change, reduced food prices and increased employment opportunities.

In addition to developing techniques that directly impact agricultural productivity it is important to develop rural infrastructure for ensuring diffusion of new techniques, increasing market access and lowering transaction costs. To mitigate the adverse impact of climate change on the poorest sections of the society also necessitates promotion of risk management schemes including climate insurance and contingent credit schemes Thus it is important to increase public investments in agriculture in terms of development of rural roads, agricultural research and extension facilities and for improvements in irrigation facilities including water harvesting schemes.

Building of Food Stocks and Undertaking Direct Interventions to Address Food Insecurity: Food price surges of 2007-08 and 2010-11 saw prices of nearly all food commodities soaring above their long term averages (Sajeev, Kaur and Kaur, 2015). The food price increases affect food access and affordability and thus are a challenge to food security. The food price rise with increasing volatility have been attributed to various factors such as low harvests, increased demand from China and India, the exchange rate of the dollar, high oil prices and increased biofuel use (Abbott, 2009). Climate change and increased occurrence of extreme weather events have also contributed to further volatility in food prices. Though India is considered to be food surplus, it is essential to maintain emergency stocks especially in the wake of unpredictability of weather patterns leading to substantial losses in agricultural production.

Food price inflation not only threatens macroeconomic stability but also impairs the welfare levels of most households, especially the poor and vulnerable, for whom food consumption constitutes a relatively large share of total expenditures (World Bank, 2010). For the poorest of households the share of food expenditure of the poor is about 65 per cent for India. Unfortunately, this high percentage makes the population of the country especially the poor extremely susceptible to food price increases. Further, food price rise is expected to increase the number of poor in the region. For instance, Carrasco and Mukhopadhyay (2012) estimate the impact of food price increases on poverty for South Asia and find that the number of poor people in the region would increase by 37.6, 75.2 and 112.8 million respectively (or by more than 2, 4 and 6 per cent respectively) with an increase in food prices by 10, 20 and 30 per cent respectively.

Low food stocks, and the factors that lead to changing stock levels, are important for analyzing food price spikes. Maintaining adequate food stocks are important with respect to access and distribution of food as they support the ability of governments to limit excessive volatility in prices by offsetting supply shocks or sudden surges in demand

(Kaur and Kaur, 2016). It is essential that India maintain emergency stocks especially in the wake of unpredictability of weather patterns leading to substantial losses in agricultural production.

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Appendix

Table A1 Food Security Indicators and Sub-Components of Affordability, Availability and Utilization, India, 2012-15

	Weight	2012	2013	2014	2015
OVERALL SCORE		46.8	46.3	48.6	50.9
1) AFFORDABILITY	40	38.3	38.3	44.7	47.4
1.1) Food consumption as a share of household expenditure	22.22	49.5	49.5	31.3	29.9
1.2) Proportion of population under global poverty line	20.2	68.7	68.7	68.8	59.2
1.3) Gross domestic product per capita (PPP)	22.22	3740	3910	4060	5790
1.4) Agricultural import tariffs	10.1	31.8	31.4	33.5	33.5
1.5) Presence of food safety net programmes	14.14	3	3	3	3
1.6) Access to financing for farmers	11.11	3	3	3	3
2) AVAILABILITY	44	55.4	54.2	53.9	56.1
2.1) Sufficiency of supply	23.42				
2.1.1) Average food supply	73.33	2352	2321	2321	2459
2.1.2) Dependency on chronic food aid	26.67	1	1	1	1
2.2) Public expenditure on agricultural R&D	8.11	1	1	1	1
2.3) Agricultural infrastructure	12.61				
2.3.1) Existence of adequate crop storage facilities	22.22	1	1	1	1
2.3.2) Road infrastructure	40.74	1	1	1	1
2.3.3) Port infrastructure	37.04	2	2	2	1
2.4) Volatility of agricultural production	13.51	0.1	0.1	0.1	0.1
2.5) Political stability risk	9.91	25	25	25	20
2.6) Corruption	9.91	3	3	3	3
2.7) Urban absorption capacity	9.91	4.3	2.9	2.3	3.5
2.8) Food loss	12.61	4.4	4.4	4.4	4.8
3) QUALITY AND SAFETY	16	44.8	44.5	44	45.3
3.1) Diet diversification	20.34	38	38	38	41
3.2) Nutritional standards	13.56				
3.2.1) National dietary guidelines	34.62	1	1	1	1
3.2.2) National nutrition plan or strategy	30.77	1	1	1	1
3.2.3) Nutrition monitoring and surveillance	34.62	1	1	1	1
3.3) Micronutrient availability	25.42				
3.3.1) Dietary availability of vitamin A	33.33	1	1	1	1
3.3.2) Dietary availability of animal iron	33.33	0.6	0.6	0.6	0.6
3.3.3) Dietary availability of vegetal iron	33.33	10.2	10.2	10.2	10.2
3.4) Protein quality	23.73	37	37.6	38.3	38.6
3.5) Food safety	16.95				
3.5.1) Agency to ensure the safety and health of food	32.14	1	1	1	1
3.5.2) Percentage of population with access to potable water	42.86	90	92	89.5	90.7
3.5.3) Presence of formal grocery sector	25	1	1	1	1

Source: Based on data from GFSI, 2015

Table 2A: Impact of Climate Change on Prevalence of Undernourishment and Depth of Food Deficit IV Regression First Stage Estimates

	Agricultural Production Index
Rainfall (Square Deviation)	-0.029*** (0.008)
Average Maximum Temperature (Square Deviation)	-0.215** (0.097)
$Infrastructure_{Rail}$	137.458*** (25.315)
$Water_{Access}$	1.713*** (0.209)
$Irrigated_{Land}$	2.073*** (0.226)
Agr_{Emp}	1.170*** (0.276)
Constant	-373.312*** (41.016)
N	24.000
R^2	0.992
Adj_R^2	0.989

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Instruments used are Irrigated Land and Employment in Agriculture.