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A Structural Ricardian Valuation of Climate Change Impacts on Agriculture in Pakistan

PL ACADEMIC RESEARCH

1 Introduction and Problem Statement

Today there is a broad consensus on the anthropogenic involvement in climate change. The connection between human activity related green house gas emissions and their impacts on temperature and precipitation regimes has been subject of numerous studies. There seems to be enough evidence that changing climatic patterns will impact on economic well-being (DESCHENES AND GREENSTONE, 2007). Harmful effects of climate change are expected worldwide. However, especially to developing countries it poses a far more serious threat as many of their environmental and developmental problems are at risk of being exacerbated (UNFCCC, 2007; CLINE, 2007; MENDELSOHN AND WILLIAMS, 2004). Moreover, developing countries heavily rely on climate sensitive sectors to generate income, most importantly the agricultural sector. Labor in developing countries is highly abundant and relatively inexpensive, thus the economy mainly relies on labor intensive technologies, leaving less room for advanced adaptation options (MENDELSOHN et al., 2001). From a physiographic perspective developing countries located in tropical regions usually have a large share of soils that are unsuitable for agricultural purposes; this additionally increases their vulnerability to potential damage from environmental changes (MENDELSOHN AND DINAR, 1999).

Pakistan, situated in the South Asian region between 24-37°N of latitude and 61-76°E of longitude, with agriculture as its mainstay and responsible for almost 70% of the livelihoods of the population, directly or indirectly linked to the sector and home to a population of approximately 170 million with 32% living below the poverty line, is one such developing country with a high vulnerability towards present and future climate change (ESP, 2007). CRUZ et al. (2007) report evidence on serious increases in the frequency and intensity of extreme weather related events such as extended drought periods, tropical cyclones, flash floods and severe dust storms in the Asian region. In this context, both the frequency and the intensity of climate related extreme events in Pakistan have increased in the recent past. From 1998-2002 the province of Balochistan was hit by severe drought conditions, affecting 84% of the population directly, killing 76% of the province's livestock and causing mass migration due to widespread hunger and disease. Of late in 2010, the country was struck and devastated in large parts by epic floods. Millions were left homeless and important harvest was destroyed, exacerbating issues of food security. In 2008 out of 309 million tonnes (mt) of carbon dioxide (CO2) equivalent total Greenhouse Gas (GHG) Emissions, 39% were contributed by the agricultural

sector (TFCC, 2010). Despite the fact that the country's share in global GHG emissions is marginal, there is enough reason for concern in future when having a look at the annual percentage growth rate of per capita carbon dioxide emissions from 1990 to 2007 (Figure 1.1).

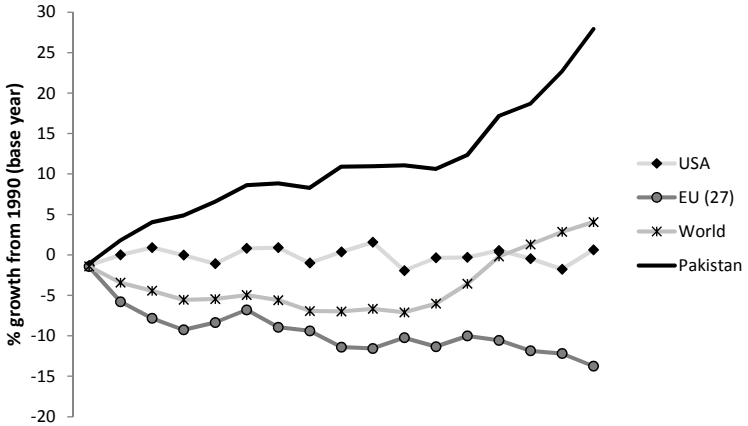

Figure 1.1 Per Capita CO_2 Emissions in selected regions of the world, 1990-2007
Source: own illustration after CAIT 8.0 (CAIT, 2011)

A detailed study conducted by the (Pakistan) Global Change Impact Studies Centre (GCISC) for the period from 1970 to 2000 found significant increases in both, daily minimum and daily maximum Temperatures in 80 percent of the sampled stations (SHEIKH et al., 2009). According to the final report of the country's Task Force on Climate Change (TFCC) published in 2010, mean annual temperature in Pakistan over the period of the last century, in accordance with the global trend, has increased by 0.6 degrees Celsius. Alarmingly, the last fifty years clearly indicate an increased rate of decadal warming, averaging 0.24 degrees Celsius/ decade. Furthermore, data from the Climate Research Unit (CRU) in the United Kingdom relative to the national scale indicate a higher increase in mean annual temperature for Northern Pakistan. In addition, based on data from 1951 to 2000 the TFCC report highlights the general warming trend in mean and maximum temperatures for the summer season (April and May), this throughout the country. For the same time period, the Monsoon Season that spans from July to September has generally shown a decreasing trend in temperatures.

The LEAD Climate Change Action Plan of Pakistan declares the country to be highly vulnerable to climate change. According to the vulnerability index

Pakistan is ranked 12th globally, economic losses of approximately 4.5 billion dollars are anticipated, grassland productivity and consequently crop and livestock yields are expected to suffer severely from climatic change manifested in significantly higher temperatures and decreased surface water availability and changing precipitation patterns (LP, 2008).

In spite of these concerns and forecasts, not many studies have been undertaken in Pakistan on the economic losses and social welfare impacts that are expected to result from climate damage to agriculture, more or less owing to the fact that in the majority of the developing world subsistence farming still remains a pivotal part of agriculture, complicating the economic analysis of environmental change (CHAMBWERA AND STAGE, 2010). Despite an internationally extensive interest in the measurement of the economic impacts of climate change, the empirical research on Asia remains scarce. By using two different climate response functions, one derived from a cross sectional Ricardian study of India (MENDELSOHN et al., 2001) and the other estimated from agricultural-economic simulation results (ADAMS et al., 1999), the Yale University study entitled "Climate Change Impacts on Southeast Asian Agriculture" based on a GIM (Global impact Model) tries to compute the economic impacts of climate change and extrapolates the results to all countries in the region (Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Philippines, Taiwan, Thailand, Vietnam). In summary the study finds that the agricultural impacts of a change in climate are dependent on four factors: the response function, the size of the agricultural sector, the initial temperature and precipitation, and the climate scenario. The study provides some initial evidence on the impact of climate change in this region, predicting losses in the range of two to sixteen billion dollars (mild & extreme scenario) for Pakistan's agriculture until 2100, while at the same time stressing the need for further empirical research in this region, particularly mentioning the need to include more countries than just India, which was used as a proxy for all Southeast Asian Countries. More research is clearly needed to refine the estimates of impacts in this vulnerable region. Potential adaptation measures have to be indentified for both, farmers and governments (MENDELSOHN, 2005). The agriculture sector is facing several issues that can be further aggravated by climate change. Amongst others these problems include: low relative productivity of most crops, slow productivity growth, expansion of cultivable land is no longer possible, fertilizer use is leveling off (less returns to intensification), and productivity growth through technological progress appears to have lost momentum since the green revolution. Increasing temperatures, changes in average precipitation, water stress, monsoon

variability, constrained irrigation water availability and increased frequency of extreme events are of particular concern for the agriculture sector and define the magnitude of its vulnerability. Although climate change studies for Pakistan have been carried out, they so far have concentrated on warming science itself, not addressing the economic impacts of climatic change on the agricultural sector. Crop simulation approaches have assessed future impacts on the basis of current yields, not including adaptations made by farmers. Therefore, these estimates from an economic perspective appear to be rather crude, as they assume that farmer's will continue with the same practices, regardless of climate change. Developing country studies are in short supply, especially studies that address the costs of climate change and analyze likely adaptation measures (MARGULIS et al., 2008).

Although models have been constructed to assess the economic impact of global warming on agriculture, a clear consensus on the methodology and impacts has not yet evolved. According to MENDELSOHN (2000) the literature so far (not much has changed) suggests that over the next hundred years global food supplies in aggregate will not be harmed. In an extensive study for the FAO MENDELSOHN (2000) also states that "*..warming is not expected to affect aggregate production in most developing countries*". However, at the same time results suggest that productivity declines will be inevitable, especially in regions where temperatures are expected to increase and precipitation is predicted to decline. Using an extensive literature survey WASHINGTON et al. (2006) found that Asia alongside Africa, the Middle East and South America has been a neglected region as far as climate research is concerned. They concluded, that this shortcoming is detrimental to climate risk assessment, planning of adaptation and decision making in developing countries. For Pakistan a deficit in climate change research has been identified. To this effect government authorities and research institutions have appealed to the wider research community to fill this gap. On the occasion of a conference organized by the World Meteorological Organization (WMO) the director of the Pakistan Meteorological Department (PMD) clearly stressed the need for intensifying research to study the adverse impacts of climate change on different socio-economic sectors such as water resources and agricultural production in Pakistan (ALAM, 2009). Moreover, he has recommended to enhance capacity building in the use, development and modification of mathematical models for use in climate change related studies. Based on research on climate change in a multiplicity of sectors, the Global Change Impact Studies Centre (Pakistan) has called for developing clear cut government policies to counter the adverse impacts from climate change (ALI et al., 2009). Changes in yield have to be

studied further as no clear evidence exists in which direction aggregate effects will move. Furthermore, shifting rainfall patterns have to be studied. Detailed impact assessment studies are called for, as without research in this direction adaptation strategies will be hard to formulate (WORLD BANK, 2011). In general, the shortage of studies for Pakistan is also reasoned in the fact that it is highly diverse with respect to climate, socio-economy, and environmental characteristics. Not only on the country level but also on the inter and intra provincial scale.

1.1 Objectives

With reference to the above mentioned problems and gaps in the research on the economic impacts of climate change on agriculture for developing countries, and in particular for Pakistan, this study's mandate is to address these shortcomings by developing two different econometric models to assess the economic impacts of climate change on the country's agricultural sector. By using the Ricardian valuation approach developed by MENDELSOHN et al. (1994) as a basis, first a model is constructed for Pakistan, accounting for a multiplicity of shortcomings of the initial model. A unique model is constructed which is adapted to the country's socio-economic and environmental circumstances. The first model's mandate is to unveil the economic impacts for farmers on the aggregate district scale. For this farm level data is aggregated. The analysis focuses on estimating the impacts and their spatial spread, covering districts, provinces and Agro-Ecological Zones. The standard model thus captures implicit adaptations made by farmers and unravels climate sensitivities. Using a micro-level farm dataset a second two-staged structural model is build to understand the true nature of adaptations for the crop sector of the country. The structural model provides additional insights as it models farm level data using a revealed-preference (choice) approach. After estimating the farm-specific choices given certain climatic and socio-economic features, the model also estimates the expected impacts on farm incomes, conditional on the choice made by the farmer. The study specifically mandates to uncover adaptations that farmers are most likely to make with a change in climate and create options for developing relevant policies to facilitate these beneficial adaptations. Global Circulation Model predictions computed by the IPCC are used to simulate future impacts on farmer choices and on farm incomes. The choice model is constructed in order to explore the results from different modeling perspectives, this in particular to the background of a variety of different approaches that are used for modeling climate impacts on the sector with their respective strengths and weaknesses. This study examines the intensity of the impacts to farmers, tries to pinpoint the different zones and regions in the country that will suffer

most and elaborate on farmer adaptations. By considering two different approaches, adaptations outside agriculture shall also be analyzed (*note: land values capture adaptations outside the agriculture sector*). Departing from an intelligent farmer's scenario, where adaptation has ever since taken place, and in conjunction with the research question of how farmers will be affected by Climatic Change and how they will respond, the specific objectives of the study are to identify the impacts of climate change on agricultural production, specifically incomes, to understand the spatial patterns of the impacts, to analyze the seasonality of the impacts (beneficial vs. detrimental impacts), to understand important features that besides climate play a key role in determining agricultural performance, understanding the observed preferences of farmers conditional on climate and other factors, to model their possible future adaptation behavior, and last but not least, to simulate the impacts of climate change on the agricultural sector using GCM scenarios. All these objectives are directed towards the goal of providing a useful starting point for policy interventions on the farm or district level. Given the anticipated changes in climate policymakers and analysts can use these projections to identify policy measures that can make it easier for farmers to switch to new production patterns. Ultimately, the identification of the production patterns that famers are likely to switch to in the wake of global warming shall serve as valuable input for designing a policy guide for planned adaptation by understanding autonomous adaptations.

1.2 Conceptual Approach

Upfront a detailed account on the importance of the Agricultural sector is provided, including geophysical, climatic, hydrological, economic and structural dimensions. This thorough review is followed up by deliberations on the nexus between climate and agriculture, with the aim to clarify interdependencies and present plant-physiological processes that are related to climate and how they can be altered. Ensuing, a historical review on the country's past climate aims at uncovering the vulnerability of the region to specifically climate related extreme events. Subsequent deliberations discuss the different available techniques to estimate the drawn interdependency between agriculture and climate. In fact, the idea is to depict approaches to analyzing the vulnerability of the sector using quantitative research methods. After the review of empirical approaches to the estimation of the economic impacts of climate change, the selected model is presented in detail using a thorough review of existing model related literature. This is followed up by a conceptual description of the standard model. Particular relevance is given to adaptation with its different manifestations in an intersecting literature review. Following this review, and given the weakness of

the first model not to reveal specific adaptations, a conceptual description of the advanced approach termed "Structural Ricardian Model" is presented. After presenting the theory and the revised models for the application to Pakistan (model specification), the data and study area are described. Further deliberations present the empirical or econometric strategy, model estimations alongside specification and robustness tests and discussion of results. A final chapter runs climate change simulations to assess the future sensitivity of the sector to global warming. Ultimately, the study concludes by summarizing the key findings, presenting policy implications, addressing shortcomings of the study and highlighting relevant fields where further research attention is greatly required.