Climate Change and Poverty

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Abstract

Climate change and therewith climate variability as well as the frequency of extreme events could slow or possibly even reverse progress that has been made regarding poverty reduction. Developing countries and especially the (rural) poor living there are suspected to suffer most from the impacts of climate change. Reasons for that are geographic and climatic conditions, dependency from natural resources, environmental systems and climate-sensitive sectors as well as limited human, institutional and financial conditions. The paper examines poverty and welfare impacts of climate change on an aggregated level as well as on the microeconomic level. Impacts of climate change on the sectors economic goods and services, water, health and agricultural production are analyzed. After a case study on Mexico adaption strategies in general and in Mexico are examined and policy implications are given.

Key words: Climate change, extreme events, rural poor, poverty, developing countries, greenhouse gas emissions, ecosystems goods and services, water, health, food security, agriculture, adaption strategies, mitigation strategies, integrated Assessment Models, Policy Analysis of the Greenhouse Effect model, Regional Integrated Model of climate and Economy model

Mexico, Bolivia, Brazil, Chile, Peru.

Palabras clave: El cambio climático, los fenómenos extremos, pobres rurales, la pobreza, los países en vías de desarrollo, las emisiones de gases de efecto invernadero, bienes y servicios ecosistémicos, el agua, la salud, la seguridad alimentaria, la agricultura, las estrategias de adaptación, estrategias de mitigación, modelos de evaluación integrados, análisis de políticas del modelo efecto invernadero, modelo regional integrado de clima y de la economía

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Introduction

All in all, there has been substantial decline in the proportion of people living in poverty globally over the last three decades. In the 1980s 52 percent of the world population lived on less than $1,25 a day, by 2005 the rate had been cut half to 25 percent and by 2008 to 22,2 percent (cf. Chen and Ravallion 2010). Even after the financial, food and fuel shocks of 2008/09 this trend continued and is expected to continue even further especially if the emerging and developing countries maintain their income growth rates. Nevertheless, poverty did not decrease in every part of the world: In Sub-Saharan Africa the number of extremely poor people increased from 290 million in 1990 to 356 million in 2008, not last du to high population growth rates.

Among multiple scientists and economists there exist the growing concern that climate change could slow or possibly even reverse progress on poverty reduction. Although there exist a lot uncertainty about the exact magnitudes of the global impacts of climate change, it is widely agreed by the scientific community that climate change is already a reality and that climate variability will likely deviate significantly from its historical patterns (cf. IPCC 2007). New weather patterns have been unfolding worldwide bringing variability of climate and an increase in the frequency of extreme events. Just some weeks ago we have seen the Typhoon Yolanda that desolated large parts of the Philippines, leaving the people that already had few before the Typhoon with nothing.

Climate change will present a significant challenge for developing countries (cf. Adger et al. 2003) as well as it will put pressure on environmental systems and therewith particularly imperil the livelihoods of rural poor people. Impacts of climatic change vary across geographical regions (cf. IPCC 2001b). Whereas in some regions there are positive anticipated impacts of climate change, developing countries are likely to suffer most from the negative impacts of climate change (IPCC 2001b) due to their geographical and climatic conditions, their high dependence on natural resources and their limited capacity to adapt to changing climate. Further reasons for this fact vary from the economic importance of climate-sensitive sectors like agriculture or fisheries until limited human, institutional and financial capacity to anticipate and respond to the direct and indirect effects of climate change or climate-related risks. According to the IPCC (2001b) the vulnerability is highest for least developed countries (LDCs) in tropical and subtropical areas. "Countries with the fewest resources are likely to bear the greatest burden of climate change in terms of loss of life and relative effect on investment and the economy" (IPCC 2001b, Smit et al. 2001).

Over 96 percent of disaster-related deaths in recent years have taken place in developing countries. Especially the (rural) poor populations are very dependent on agriculture and other climate-sensitive natural resources for income and well-being. Further they lack sufficient financial and technical capacities to manage increasing climate risk as well as to manage extreme weather events and catastrophes as we have seen in the case of the typhoon Yolanda. Often extreme weather events set back the development process for decades.

Not only such extreme events but also changing weather patterns in general show that the poor, especially the rural populations, are among the first to feel the effects of increasingly erratic weather patterns as well as the most vulnerable to those effects.

This paper reviews evidence on climate change, its impact on poverty and on developing countries as well as its impact on the poor, especially the rural poor. In the next section we take an aggregated perspective to examine poverty and welfare impacts of climate change. Thereafter we will take a closer look on the microeconomic level. We analyze impacts of climate change on the sectors economic goods and services, water, health and agricultural production. In section III we elaborate a case study on Mexico examining the same sectors for Mexico. In section IV we take a look on adaptation strategies in general as well as adapted to Mexico and give some policy implications. Section V concludes.

Poverty and Welfare Impacts on Climate Change

Aggregated Perspective

Cross-Sectional Historical Data

There exist a lot of studies that examine the relationship between climate and aggregated economic variables in cross-sections of countries or regions. Because they use aggregated historic outcomes, there is no need to rely on a priori assumptions about climate-economy relationships, their interaction or influence on economic outcomes. Further, historical adaptation is already incorporated in the estimates of the long-run relationship between climate and aggregated output.

Dell et al. (2009) show by using cross-sectional historical data from 134 countries that each additional degree Celsius is associated with a statistically significant reduction of 8.9 percentage points in GDP per capita. They further provide evidence of this elasticity within countries and even within states using municipal-level data for twelve countries in the Latin America and Caribbean region.

Andersen and Verner (2010) examine the relationship between temperature and welfare at the municipality level of the Latin American countries Bolivia, Brazil, Chile, Mexico and Peru. They provide an estimate of the long-run relationship between temperature and welfare inclusive of adaptation and then use them to simulate the impact of climate change using the Intergovernmental Panel on Climate Change (IPCC) for the next 50 years. Their simulation results should not be interpreted as forecasts and are rather simply indicative of the direction and magnitude of the effects that might be expected (cf. Andersen and Verner 2010). This paper can be criticized for using as baseline a world without climate change and not the current situation, for assuming a distribution-neutral change in the mean level of welfare and therewith not accounting for the growing gap between rich and poor as well as for being based on the distribution of income per capita among municipalities and not households.

Assunção and Chein Feres (2009) use cross-sectional data to estimate the poverty impacts of climate change at the municipality level in Brazil. They find that climate change will decrease the agricultural output per hectare in Brazil by 18 percent in general. Looking at the municipality level this estimate ranges from -40 to 15 percent. Further, they predict that climate change will increase the poverty rate in rural areas by 3.2 percentage points. Bearing in mind that the current poverty rate in Brazil is 40 percent, they suggest that the number of poor people in rural areas are likely to increase by about eight percent. Moreover, they find geographical heterogeneity: the North will be most affected in absolute terms, whereas the South will gain a poverty rate reduction of 0.9 percentage points (cf. Assunção and Chein Feres 2009). Using a measure of total poverty that takes into account all residents in each municipality they account for adaptation measures through changing sectors or occupations and by using a migration-adjusted poverty measure. They allow for labor mobility across sectors and across municipalities. Using these, they find that there are further heterogeneous effects within Brazil, with increasing poverty in the already poorer North and decreasing poverty in the already richer South. The impacts on poverty depend on the ability of adaptation through changing of sectors and municipalities. As this study does not take into account the likely increase of per capita income from economic growth over the next 40 years, it overestimates the impacts of climate change on poverty in Brazil. This lack can be accounted for by using Integrated Assessment Models (IAM) that take into account future growth.

Integrated Assessment Models

Integrated Assessment Models, which are used intensively in climate-change literature to model climate-economy interaction, are general equilibrium models that rely on micro-evidence to quantify various socioeconomic dimensions of climate change and aggregating these to estimate a net effect on national income. There exist various studies based on the PAGE (Policy Analysis of the Greenhouse Effect) model as well as the RICE (Regional Integrated Model of Climate and Economy) model, which I will present in the following.

Studies using the PAGE model

Anderson (2006) estimates future output and growth with and without climate change for Sub-Saharan Africa and South Asia based on the PAGE 2002, that predicts that climate change in India and Southeast Asia and Africa and the Middle East will cause GDP losses of approximately 2.5 percent and 1.9 percent respectively compared with a situation in a world without climate change. Assuming that average household income grows at 0.8 times the rate of GDP per capita and the distribution of income remains constant, Anderson converts these output and growth projections into poverty impacts and finds that by 2100 climate change could cause that up to 12 million more people in South Asia and 24 million more people in Sub-Saharan Africa will be living on less than $2 a day (cf. Anderson

2006). The Stern Review (2007) objects that it is likely that IPCCs A2 scenario is likely to be too pessimistic and therefore Anderson's poverty impacts that rely on this data may be overestimated.

Studies using the RICE model

There are three scenarios using the RICE model developed by Nordhaus (2010). In the first scenario, called baseline, we have a world without climate change. In the second scenario, called Business as usual (BAU), the current trends in economic growth and greenhouse gas emissions (GHGs) on climate are reflected as well as the impact of climate change on the overall economy without any abatement policies (cf. Skoufias 2011b). The third, called optimal abatement is based on Nordhaus's calculation of an emission abatement path, with full participation by all countries that maximize global inter-temporal economic welfare (cf. Skoufias 2011b).

Olivieri, Rabassa and Skoufias (2010) use historical estimates of growth-poverty elasticities to translate the implications of these different growth scenarios for poverty. Under the baseline in a world without climate change they predict an annual global real per capita output growth rate of 2.2 percent up to 2055 (cf. Olivieri et al. 2010). Using growth-poverty elasticities they find that this would contribute to more than halving the world poverty rate at the $2 a day level to 14.1 percent by 2055 (cf. Olivieri et al. 2010). Under the BAU scenario with climate change they find a GDP in 2055 that is 1.5 percent lower than the baseline GDP whereas the estimated number of poor would be 10 million people higher, compared to the no climate change scenario (cf. Olivieri et al. 2010). Most of the additional poor will be located in Africa and South Asia according to the authors (cf. Olivieri et al. 2010). Under the optimal abatement scenario they find that people in poverty will be still high at nine million (cf. Olivieri et al. 2010). Their explanation for the only slightly improvement under optimal abatement is that the effects of abating global emissions of GHGs on aggregated economic damages necessarily accrue more to higher-income countries (cf. Olivieri et al. 2010). Unlike adaptation, emissions mitigation does not specifically target the poor (cf. Olivieri et al. 2010). On longer horizons like by 2100 the major gains in poverty averted by following the optimal abatement strategy would indeed occur according to the authors (cf. Olivieri et al. 2010).

Although these models do not imply that impacts will be equally distributed among the population, they only look on aggregated effects and can therefore make no statements on the household level or the channels through which climate change can affect household welfare. In the following we therefore look on approaches that use household level data to analyze how climate change will affect specific population sectors through different channels.

Microeconomic Perspective

Households' welfare can be affected by climate change through various channels. There is evidence that climate change will particular affect the poor people's livelihoods through its effects on climate-sensitive sectors such as ecosystem goods and services, water, agriculture and food security as well as health. In the following I will explain how the poor people's livelihood will be affected through those channels as well as I will review current literature on these issues.

Ecosystem goods and services

Climate Change will increase the vulnerability of ecosystems because they are highly sensitive to even small changes. For example small increases in water temperature may damage coral reefs, worsening other stresses such as pollution and over-fishing and thereby cause a reduction in fish stocks and compromising fish- and tourism-dependent livelihoods (cf. OECD 2003). Especially poor people are often directly dependent on goods and services from ecosystems (cf. OECD 2003), which make them highly vulnerable to ecosystem degradation. Ecosystem goods and services provide primary or supplementary source of food, fodder, building materials and fuel (cf. OECD 2003). Climate change and accompanying results such as problems with soil, local economic and social conditions can drive poor people further into marginal areas and force them to exploit natural resources to support their livelihoods. As climate change further erodes the quality of the natural resource base, conditions of poverty will be fortified (cf. OECD 2003). The ability of ecosystems as important life support systems will be limited by climate change which will have important impacts on key economic sectors such as water supply and agriculture. In the next sections we therefore take a look on water as well as agriculture.

Water

Today water scarcity is already a problem especially for the world's poor in various regions. Independent of climate change, water scarcity is projected to increase from about 1.7 billion people to around five billion people by 2015 (cf. IPCC 2001b). According to the OECD (2003), climate change is projected to further reduce water availability in many water scarce regions such as the subtropics, whereas precipitation is expected to increase in equatorial, middle, and high latitudes which tend to suffer less from water scarcity. In regions that already suffer from sufficient water availability droughts will be more frequent, evaporation increased as well as changes in rainfall patterns and run-off will occur. In regions that tend to suffer less from water scarcity on the contrary, floods will increase endangering human settlements and infrastructure (cf. OECD 2003). The retreat and loss of glaciers as well as their varying timing in stream flow will have downstream effects on agriculture (cf. OECD 2003). Not last due to this problem we will have a look on agriculture and food security in the last subsection after we had a closer look on the impact of health.

Health

It is very difficult to gauge the impact of climate change on human health. Nevertheless, it is likely that climate change will have direct as well as indirect adverse effects on human health. Those will increase vulnerability and reduce opportunities by interfering with education and working abilities (cf. OECD 2003). One of the direct effects is an increase in temperature-related illnesses as well as deaths (cf. OECD 2003). Mortality and morbidity rates may be increased through longer heat waves especially if coupled with humidity and particularly among the urban poor as well as the elderly (cf. OECD 2003). Further, extreme weather events that are likely to occur more often such as flooding, landslides and storms will lead to an increased number of death and injured people. Nowadays, already 96 percent of disaster-related deaths in recent years have taken place in developing countries (cf. World Bank 2001) which once again shows the extremely affect on poor countries.

Moreover, changes in temperature and rainfall will shift geographic ranges of vector-borne diseases such as malaria and dengue fever, exposing new populations to these diseases for example in parts of Brazil, Southern Africa and the Horn of Africa as well as cities that are currently not at risk because of their high altitudes such as Nairobi and Harare (cf. OECD 2003). On the contrary, it is likely that in a few areas such as parts of Namibia and the West African Sahel malaria risk may fall due to excessive heat (cf. OECD 2003). The net effect of climate change on malaria infections is still uncertain and impacts vary from region to region (cf. OECD 2003). But we should not forget that if it is too hot for mosquitoes to live and breed, it is most likely not a good livelihood for humans as well.

Further, will flooding and other extreme events degrade and reduce potable water supplies and increase water associated diseases such as cholera and diarrhea especially in areas without adequate sanitary infrastructure (cf. OECD 2003).

Agriculture and food security

Agriculture is especially important for least developed countries that highly depend on that sector as well as the rural poor that most often highly depend on agricultural production. According to the OECD (2003), climate change could worsen the prevalence of hunger through direct negative effects on production and indirect impacts on purchasing powers. Changes is temperature and precipitation as well as the higher incidence of extreme weather events are likely to reduce quality of land areas for agricultural production, which will be particularly problematic for areas in which droughts and land degradation, including desertification are already severe (cf. OECD 2003). Sea level rise next to impacts on marine resources will lead to salinization making agricultural land unproductive.

Concerning food supply, significantly regional varying impact of climate change will be likely. According to the IPCC (2001b), crop yields are projected to decrease in most tropical and subtropical regions due to changes in temperature and rainfall imposing therewith real risk of worsening food security and exacerbating hunger in some developing-country regions. In the short term, it is however projected that greater impact on food security will be placed through more often occurrence of severe extreme weather events (cf. FAO 2002). According to the OECD (2003) especially in Africa the impact of climate change on food security will be problematic, especially combined with already discussed changes in water supply. Livestock activities and crop yields for many countries in Latin America are also projected to decrease (cf. OECD 2003).

Literature has focused largely on the poverty impacts related to agricultural output and therewith the impacts of climate change on agricultural productivity at regional and country levels. Most of these studies find negative affects varying across countries and regions. Often, these effects are then used to predict changes in rural household welfare or ultimately changes in poverty rates and find that climate change would significantly affect poverty. These findings should be exercised with caution because there are some mediating factors that deserve to take a deeper look such as the extent of autonomous adaptation by households through migration or switching employment between agricultural and non-agricultural sectors as well as the extent of policy-induced adaptation through prices and explicit government programs like access to credit and insurance. Further the distribution of productive endowments such as irrigated and non-irrigated land or skilled and unskilled labor make a difference. Moreover, we should have a closer look on the households itself. As they have a dual role as consumer and producer the effect depends on whether they are net consumer or net producer. If they are net consumer they will undoubtedly suffer deeply from agricultural production setbacks. If they are net producer on the contrary they will benefit from rising prices due to less availability of agricultural products and hence benefit.

Hertel, Burke and Lobell (2010) use disaggregated data on household economic activity within 15 developing countries and a general equilibrium global trade model to explore the link between poverty and changes in agricultural productivity. Their model distinguishes different types of households such as net consumers and net producers allowing them to be affected differently by the prices of agricultural goods. They find that large changes in grain prices do not necessarily translate into large changes in the cost of living due to the adjustment of the consumption bundles of consumers to account for the new price patterns (cf. Hertel et al. 2010). “While world prices for staple grains rise by an average on more than 30 percent […], the average impact on the real cost of living at the poverty line is more modest – just 6.3 percent” (Hertel et al. 2010). Further, they find that the portion of the poverty change driven by cost-of-living changes is largest for the urban wage labor household stratum whereas the agriculture-dependent households show the smallest change (cf. Hertel et al. 2010). The authors use the following three scenarios of how climate change affects agricultural productivity: low productivity, medium productivity and high productivity. For the low productivity scenario that is characterized through higher temperature, they find that rising world commodity prices translate into increased returns to factors employed in agriculture (cf. Hertel et al. 2010). Accordingly, earnings increase in the agricultural sector and poverty rates drop among the agricultural self-employed households (cf. Hertel et al. 2010). On the contrary, poverty rises among the non-agricultural specialized households due to falling earnings given the relative price decline of non-agricultural commodities compared with agricultural goods (cf. Hertel et al. 2010). Under the high productivity scenario that is characterized by a relatively modest increase in temperature these results are reversed (cf. Hertel et al. 2010). Ultimately, under the medium productivity scenario, characterized through medium-climate-change they find no apparent effect on poverty (cf. Hertel et al. 2010). An exception of these finding are most African countries, where the yield impacts of climate change has severe impacts and leads to poverty increase whereas no type of household profit from significant poverty reductions.

This model can be criticized for not allowing sufficient heterogeneity between households. That is why Jacoby, Rabassa and Skoufias (2011) apply a more flexible framework for quantifying the distributional impacts of climate change in rural economies. In a study focusing on India they control for type of land owned by households meaning irrigated and non-irrigated land as well as type of labor, meaning skilled or unskilled labor. Thereby they estimate the impacts on climate change in 2040 on agricultural productivity and wages by taking into account adaptation through district-level cross-sectional-data as well as by assuming imperfect mobility of labor, meaning that one can’t move from the agricultural sector to the non-agricultural sector. Further they do the same without taking into account adaptation which leaves them with household-specific impacts of climate change on consumption. They find that the substantial fall in agricultural productivity by 2040 which is 17 percent overall with adaptation, will translate into a much more modest consumption decline of six percent on average for most households (cf. Jacoby et al. 2011). They explain this by stating that these households derive the lion’s share of their income from wage employment and rural wages are estimated to fall by only a third as much as agricultural productivity (cf. Jacoby et al. 2011). This pattern can also be observed without adaptation (cf. Jacoby et al. 2011). Furthermore, they find heterogeneous impacts of climate change across geographical areas and across income distribution: Ignoring cereal prices, climate change has a progressive effect. This is the case because wealthier households suffer proportionally higher consumption losses driven by the skewed land distribution and the fact that larger landowners are concentrated in higher income percentiles (cf. Jacoby et al. 2011). On the contrary, temperature-induced wage declines are relatively more costly to the poor than to the rich because the poor tend to engage in climate-sensitive agricultural employment (cf. Jacoby et al. 2011). If rising cereal prices are taken into account, the impacts of climate change are regressive in urban and rural areas, falling more heavily on the poor than on the rich.

Many of these studies have the shortcoming of microeconomic studies in general: they rely on respondents' perceptions and answers. Sometimes respondents are exaggerating in their answers because they hope to receive (financial) help from the interviewers.

Many of these studies also rely on respondents' perceptions regarding the incidence of different types of shocks or they use rainfall and temperature data as instrumental variables to analyze the effects of shocks to income, consumption or investments in human capital. However, studies barely use actual weather data to examine the general relationship between weather and the level of welfare.

Ahmed, Diffenbaugh and Hertel (2009) use the percentage of annual total precipitation from events exceeding the 95th percentile in the 1961-90 period, the maximum number of consecutive dry days and the heat wave duration index to model the channels and estimate the poverty impacts of extreme weather events such as extreme heat, droughts and floods. From 1971-2000 they find substantial increases in the occurrence and magnitude of extreme heat events, with the occurrence of the present 30-year-maximum event increasing by more than 2,700 percent in parts of the northern Mediterranean and the magnitude of the 30-year-maximum event increasing by 1,000-2,250 percent in much of central Africa (cf. Ahmed et al. 2009). A lot of countries also show increases in the occurrence and magnitude of of extreme dry events up to changes of over 800 percent and 60 percent respectively in Mediterranean Europe. These large and heterogeneous changes in climate volatility suggest that the impacts on poverty could also be large and heterogeneous. According to Ahmed et al. (2009) countries with the highest shares of populations entering poverty because of extreme weather events include Bangladesh, Malawi, Mozambique, Tanzania, Zambia and Mexico.

Further, there is one study by Skoufias and Vinha (2012) that analyzes if climatic variability, measured by deviations in rainfall and temperature from their long-run means, significantly affect the average well-being of rural households in Mexico. This study will be presented in course of the case study about Mexico in the next section.

Case Study Mexico

In the following case study about Mexico we will investigate the same sectors we investigated above when we had a look on the microeconomic perspective. Then we will give some specific information about important sectors and characteristics in Mexico. The information for that part mainly relies on the Galindo Report 'La Economía del Cambio Climatico en Mexico' as well as the OECD Environmental Performance Review for Mexico 2013. Further we will have a deeper look investigating the influence of climate change on consumption patterns of poor rural households in Mexico. In section IV we will further have a deeper look on adaptation and mitigation strategies in Mexico.

Ecosystem Goods and Services

Ecosystem goods and Services are increasingly under threat due to climate change. Using a Ricardo model, the Galindo report shows that Mexico will loose a significant share of biodiversity and the loss will increase over time (cf. Galindo 2009). This will have negative impacts on agricultural production. The loss will be made outside the market and can therefore not be measured in monetary or income costs (cf. Galindo 2009). The estimated present value of biodiversity and the economic value for the losses show that the current pricing structure is understating prices and therewith subsidizing ecosystem goods and services. The results are overexploitation and severe damages of ecosystems as well as loss of biodiversity.

Water

The projected water demand of Mexico will grow significantly even without considering effects of climate change until the year 2100 (cf. Galindo 2009). The report further estimates the impact of temperature on the demand and supply of water in three sectors: private use, agricultural use and industrial use. A positive impact of temperature on water consumption is found. According to the report it is very difficult to identify potential impacts of temperature on the natural availability of water resources, because natural water availability is influenced by a huge amount of parameters that influence the hydrological cycle. To estimate the impact of temperature on water availability the report uses the relationship between precipitation, evaporation and temperature and finds that an increase in temperature will decrease the level of water availability in Mexico. Moreover, water will be short especially in the Northern parts of Mexico that are already suffering under water shortage making those parts more vulnerable to climate change.

Health

Climate change has significant consequences on the health of Mexican population through changes in temperature, precipitation and extreme weather events (cf. Galindo 2009). These effects arise mainly through indirect channels such as air quality, water quality, the quantity of food as well as agriculture and ecosystems goods and services. The Galindo Report (2009) finds that climate change will increase geographic limits for contagious diseases and will cause health problems through heat waves.

Agricultural Sector

The agricultural sector is a key sector of the Mexican economy regarding its share of GDP, the direct and indirect employment generated as well as according to the share of agricultural rural farmers. The available evidence suggests that the evolution of the Mexican agriculture depends on investment, the combination of inputs, fertilizers, technology, irrigation, type of risk management, pesticides, employment, CO_2 emission levels, soil characteristics and climatic factors (cf. Galindo 2009). It is very difficult to estimate impacts of climate change on agriculture, because the impacts can be very specific and are also determined by planting and harvesting cycles. The Galindo Report (2009) uses three different models to estimate the impacts of climate change to agriculture in Mexico.

All three models find significant impact of climate change on Mexican agriculture but differ in its respective magnitudes.

One of the models use production functions that include available information, labor, capital, seed, fertilizers and other inputs such as climate and irrigation water quota (Fleischer et al. 2008). Empirical evidence for Mexico then shows a concave relationship between temperature and yield and accordingly production (cf. Galindo 2009). This can also be named as converted U after the Kuznets-U-hypothesis but adopted to the relationship of temperature and climate change. Temperature initially stimulates growth of crops and agricultural production but after a certain threshold it leads to substantial decrease (cf. Doering et al. 2002; Galindo 2009). Water also has a non-linear effect on agricultural yields and production (cf. Galindo 2009).

Other models used to estimate impact via the Ricardo model (cf. Deschênes and Greenstone, 2007; Mendelsohn, Nordhaus and Shaw, 1994). The model is based on the assumption that the value of agricultural land reflects the productivity of land. Therefore the climatic variations that affect the productivity can be captured through agricultural income. Another model is the conditional heteroscedasticity model (Engle, 1982). This model estimates the increasing volatility of the series that is associated with the presence of increased uncertainty and risk in the sector as a result partly of more volatile weather conditions (Just, 1974).

All in all, the following results are viewed as consensus of these models:

Yields and agricultural production depend on the weather with heterogeneous regional and nonlinear impacts that increase over time. Each production cycle and each product is differently sensitive to the temperature and precipitation even across regions which are extreme such as in the case of maize. The joint analysis of climatic effects shows that, within certain ranges, it is possible to compensate temperature increases with a greater amount of water. However, this method has limitations and is not sustainable in the long run because it generates negative externalities associated with the overexploitation of water resources. Galindo (2009) further finds a significant drop in agricultural yields by 2100 which will take place mainly in the second part of the century. Some regions such as Nayarit show high yields although projected high temperature which stresses the importance of adaptation (cf. Galindo 2009).

Unfortunately, hardly any studies use actual weather data to analyze the general relationship between weather, agriculture and the level of welfare on a microeconomic level. Considering that millions of poor households in rural areas all over the world depend on agriculture, there are concerns that climate change will make rural households even more vulnerable. A study by Skoufias and Vinha (2012) examines whether climatic variability measured by deviations of rainfall and temperature from their long-run means significantly affect the average of well-being of rural households in Mexico.
The authors use the first two waves of the nationally representative Mexican Family Life Survey (MxFLS) carried out in 2002 and 2005/07. They find that the timing of the rainfall or temperature shock makes a substantial difference in its estimated impact on welfare. The effects of weather shocks on household expenditure not only vary according to the timing of the shock, but also by climatic region (cf. Skofias, Vinha 2012). Per capita expenditure are 14 percent higher if the prior agricultural year that lasts from October to September was at least on standard deviation drier than the average of a previous 35-year period from 1951 to 1985 (cf. Skoufias, Vinha 2012). If the rainfall shock were to occur during the wet season of that same year from April to September, neither a positive nor negative rainfall shock appeared to affect household per capita expenditures. Compared to other authors, Skoufias and Vinha do not find evidence that food expenditures are more protected than non-food expenditures to the effect of climatic shocks. Although they find that the average household in their sample can smooth consumption such that no weather shock reduces expenditures, when the households are grouped by the average precipitation of their municipality, the authors also observe some households that cannot smooth consumption. Households in arid areas are especially at risk to lower expenditures after weather shocks. In arid regions, colder or drier-than-average weather during the pre-canicula period that is the period between July and August that influences farmers' planting decisions, negatively affects household consumption.

All in all climate change will have significant impacts on the environment and economy of Mexico (cf. Galindo 2009). However, adaptive mechanisms in the agricultural sector, the water sector, and changes in land use, biodiversity, tourism, infrastructure and health of the population is expected (cf. Galindo 2009). The impacts will be heterogeneously across regions with some regions having first a gain of temperature increase and therewith of climate change (cf. Galindo 2009). However, negative economic consequences will outweigh the temporary gains in the long run (cf. Galindo 2009).

Regarding extreme events it is furthermore recognized that climate change will increase the occurrence of extreme weather events (cf. IPCC 2001a, Stern Report 2007, Galindo 2009, OECD 2013). Potential impacts also include storms and heavy seasonal rainfall in the South as well as increased hurricane activity and intensity (cf. OECD 2013). Further a sea level rise of 20 cm by 2050 is expected (cf. OECD 2013). Available evidence for Mexico indicates that there are 25 municipalities that exhibit the greatest historical vulnerability of the 153 municipalities of the country (cf. Galindo 2009). Costs regarding economic and social impacts will rise in the future and the economic costs that will appear in 2100 will be at least three times higher than the costs of mitigating 50 percent of the emissions (cf. Galindo 2009). Moreover, the Galindo Report (2009) states that the the costs of inaction are higher than the participation in an international agreement that recognizes the common but differentiated responsibilities of countries and tries to abate the worst impacts of climate change by inalienable immediate and decisive action.

It is necessary to build adaptation strategies with various instruments with a long-run perspective to minimize climate change impacts as well as it is necessary to reduce GHGs (cf. Galindo 2009). Therefore, we will have a look on adaptation strategies in general as well as adapted to Mexico in the next section.

Adaptation to climate change

The effect of climate change on poverty and poor households depend on the extent of households' adaptation. Adaptation to climate change is the adjustment of a system to moderate the impacts of climate change, to take advantages of new opportunities or to cope with the consequences.

Autonomous adaptation strategies

There are different forms of adaptation. One important type of adaptation are autonomous adaptation strategies (cf. Jacoby, Rabassa and Skoufias 2011) that can be defined as market-based responses to climate change by individuals, households, or firms, typically by adjustments over time in their production and consumption patterns. Examples for autonomous adaptation strategies are changes in cropping patterns, input use and technology. Jacoby et al. (2011) find that these forms of adaptation are likely to reduce the average long-term loss in per capita consumption from climate change by about a half compared to not undertaking those strategies. Autonomous adaptation next to the ability to migrate or switch employment between agricultural and nonagricultural occupations, include as well the most extreme adaptation measure: Migration. Skoufias (2011b) proposes to invest in human capital to increase employment opportunities for the poor. Migration should further be facilitated to help the poor to reach areas with better economic opportunities (cf. Skoufias 2011b).

Policy-induced adaptation strategies

Further there exist policy-induced adaptation strategies through prices and explicit government safety-net programs such as access to credit and insurance (cf. Cline 2007; Hertel and Rosch 2010). Often access to credit and insurance market is not given, especially for the rural poor. Access to credit as well as to public works projects in communities can help households coping with shocks and thereby play a strong role in protection from weather-related shocks. Skoufias, Essama-Nssah and Katayama (2011) find that the availability of credit, social protection and community-based programs are among the strongest factors mitigating the impacts of extreme weather events on well-being of rural households.

Therefore Skoufias (2011b) advises the creation of well-targeted, scalable safety-net systems and the strengthening of the institutions needed to implement and scale-up such programs as a a critical component of country-level adaptation strategies. Especially countercyclical safety-net systems such as conditional and unconditional cash transfers, workfare programs and social funds will enable countries to deal with extreme events and results from climate change as well as with economic crises and other shocks (cf. Skoufias 2011b).

Furthermore, the provision of the (rural) poor with access to credit and insurance markets is an important measure. Moreover, investment in transportation and communication infrastructure as well as in irrigation and water management to deal with extreme precipitation events will be necessary (cf. Skoufias 2011b). To find a remedy investment in adaptive agricultural research and in information and extension services will be necessary in addition to improvement of common-pool natural resource governance (cf. Skoufias 2011b).

Before-the-fact adaptation strategies

There exist some risk management strategies of rural households to cope with hard times aimed at protecting household welfare such as adopt low-return, low-risk crop and asset portfolios (cf. Rosenzweig and Binswanger-Mkhize, 1993), draw upon savings (cf. Paxson 1992), taking loans from the financial sector (cf. Udry 1994), selling assets (cf. Deaton 1992) or diversifying the occupations held by the adult member of the household (cf. Menon 2009). These are so-called before the fact strategies, meaning that they will be undertaken before the fact to spread the effects of weather-induced shocks through difficult times.

After-the-fact adaptation strategies

Further, there are after-the-fact adjustments to supplement income such as sending children working instead of sending them to school (cf. Jacoby and Skoufias 1997). Moreover, household participants may hold multiple jobs and engage in further informal economic activities (cf. Kochar 1999, Morduch 1995).

These risk management strategies are associated with increased poverty and lower investment and growth leading to poverty traps because poor households that are credit constrained will choose activities that reduce income variability but also generate lower expected incomes that the activities chosen by wealthier households (cf. Elbers, Gunning, Kinsey 2007). Traditional adaptation also includes borrowing money from relatives or friends.

The impact on household welfare will depend in part on the risk management strategies and adaptation strategies employed by the households. Further, it depends on the effectiveness of those strategies in mitigating the impacts as well as the general distribution of impacts across many different households. Certain individual characteristics such as lower education and fragmentary access to the financial sector and therewith to insurance may increase the vulnerability of households to risk management (cf. Skoufias 2007).

According to the OECD (2003) and further development agencies, adaptation to climate change should be a priority to assure effectiveness of investment in poverty eradication as well as sustainable development in the long term (cf. OECD 2003). The IPCC as well acknowledges adaptation if pursued in the sustainable development framework, as measure to diminish the damage from future climate change and climate vulnerability. Through the decisions of the United Nations Framework Convention on Climate Change (UNFCCC) work has been initiated to develop the adaptive capacity of poor people and least developed countries to cope with the impacts of climate change (cf. UNFCCC 1992). As addressing poverty implies also preparing for climate variability and extreme weather events, climate change and adaptation and mitigation should go hand in hand with poverty eradication. The OECD (2003) further recommends that efforts should be made to recognize and address the vulnerability of the poor in development programs. Any activity that undermines the capacity of the poor to cope with climate variability and climate change should be avoided (cf. OECD 2003).

Most authors pledge for integrating adaptation measures into sustainable development and poverty reduction strategies. Adaptation mechanisms will be supported by reaching efforts in areas such as good governance, human resources, institutional structures, public finance, and natural resource management (cf. OECD 2003). Progress in these areas builds the resilience of countries, communities, and households to all types of shocks, including climate change impacts. Further, learning from experience and exchanging knowledge in general could support such efforts. The OECD (2003) lists the following points to support adaptation to climate change in an integrated poverty eradication and sustainable development program:

- Improved governance that should include an active civil society and be an open, transparent, and accountable policy and decision making process.
- Mainstreaming climate issues into all national, sub-national and sectoral planning processes such as Poverty Reduction Strategies (PRS) or national strategies for sustainable development.
- Encouraging a ministry with a broad mandate, such as planning or finance, to be fully involved in mainstreaming adaptation, especially in countries where major climate impacts are expected.
- Combining approaches at the government and institutional level with bottom-up approaches rooted in regional, national and local knowledge.
- Empowerment of communities so that they can participate in assessments and feed in their knowledge to provide useful climate-poverty information. They will also need full access to climate relevant information systems.
- Vulnerability assessments that fully addresses the different shades and causes of poverty.
- Access to good quality information about the impacts of climate change. This is key for effective poverty reduction strategies. Early warning systems and information distribution systems help to anticipate and prevent disasters.
- Integration of impacts into macroeconomic projections. Rate and pattern of economic growth is a critical element of poverty eradication, and climatic factors can have a powerful bearing on them.
- Increasing the resilience of livelihoods and infrastructure as a key component of an effective poverty reduction strategy. Similarly, adaptation strategies should build upon, and sustain, existing livelihoods and thus take into account existing knowledge and coping strategies of the poor. Traditional risk-sharing mechanisms such as asset pooling and kinship should be complemented by micro-insurance approaches and infrastructure design and investment.

According to Adger et al. (2003) all societies are fundamentally adaptive and there are many situations in the past where societies have adapted to changes in climate and to similar risks. The authors propose to decrease sensitivity by avoiding building settlements and infrastructure in high-risk locations and by strengthening existing systems so that they are less likely to be damaged by unusual events (cf. Adger et al. 2003).

The IPCC recognizes different forms of adaptation, but also states that there is little evidence that efficient or effective adaptation to climate change risks will be taken autonomously (cf. Smit et al. 2001). Therefore intervention is necessary to enhance adaptive capacity or the ability to adapt to new or changing conditions without becoming more vulnerable or shifting towards maladaptation. To reach this an increase in financial resource flow is needed which include bilateral, multilateral and non-governmental development assistance, the new funds created by the UNFCCC, the Global Environment Facility (GEF) and the financial mechanisms of the UNFCCC.

Fortuitously, many of the proposed policies to effectively reduce the impacts of climate change on poverty are the same policies that promote sustainable development, poverty reduction and economic growth. Therefore it should not be longer waited to include climate change and its impacts in sustainable development and poverty programs. In the next section we will have a look on actual adaptation strategies in Mexico and the recommendations by Galindo (2009) to improve these efforts.

Adaptation and mitigation strategies in Mexico

Mexico has very high GHG emissions which are increasing over time (cf. OECD 2013). Without mitigation strategies and additional policy measures total emissions could increase by 70 percent by 2050 compared to the 2000 level. One essential need for an efficient and effective climate mitigation policy is adequate price signals. Although Mexico has assigned high political priority to tackling climate change little progress has been made in the goal of reforming energy prices and subsidies. According to the OECD a package of measures should be adopted to reduce emissions. Mexico is one of the very vulnerable countries in respect to climate change. 15 percent of the country, 68 percent of the population and 71 percent of GDP are highly exposed to climate change risk (cf. OECD 2013). The SEMARNAT estimates that the costs of resulting loss of agricultural production, reduced water availability, deforestation, effects on health and loss of biodiversity could range from 3.7 to 7 percent of GDP by 2050.

Not least to those numbers, especially adaptation plays an important role. There have been identified eight areas for developing adaptation policies including water, agriculture, ecosystems, health, energy and transport infrastructure (cf. OECD 2013).

According to Skoufias and Vinha (2012) erratic weather affects agricultural productivity dependent on how effective a household's risk management strategies may translate into lower income. Rural households in Mexico have developed traditional strategies for managing climatic risk such as that they undertake before-the-fact income-smoothing strategies and adopt low-return, low-risk crop and asset portfolios (cf. Rosenzweig and Binswanger 1993). According to Eakin (2000) in Mexico especially smallholder farmers have adapted to climatic risk in Tlaxcala. There, farmers plant fast-maturing but low-yield corn as well as slow-maturing but high-yield varieties. Some also switch from the more-profitable corn to wheat depending on the prevailing weather. Further, farmers undertake measures such as changing fertilizer and pesticide depending on climate as well as they diversify their plots of land in geographically different regions.

Raising occurrence of negative weather patterns and extreme events are likely to reduce the effectiveness of these coping mechanisms and therewith will lead to increased vulnerability of households (cf. Skoufias, Vinha 2012). There is little evidence available on how successful the traditional risk management strategies are in protecting household welfare from weather shocks in Mexico. Studies from Skoufias (2007) and De la Fuente (2010) rely on perceptions about the incidence of different types of shocks rather than using actual meteorological data and are therefore prone to shortcomings and overstatements by households.

According to the Galindo Report (2009) Mexico acclaims the necessity and the possibilities of mitigation and adaptation. To reach both it is necessary to cooperate and collaborate with international institutions, agencies and donors (cf. Galindo 2009). To reach adaptation and mitigation monetary and financial resources are necessary to construct infrastructure, to build safety nets and to invest in education (cf. Galindo 2009). New financial instruments for climate protection, adaptation, forest protection and technology transfer may also be part of possible policy implications. Especially regarding technology and mitigation as well as adaptation a partnership with other countries could be useful (cf. Galindo 2009).

One good example may be the project "Climate Change and Justice" in which the Potsdam Institute for Climate Impact Research among others analyzes the interactions between mitigation and dangerous climate change and the reduction of world-wide poverty. One core question of the project is how fair burden sharing in climate protection can be organized within a global deal for climate and development policy and how dangerous impacts of climate change can be mitigated for the poor. In order to arrive at a joint global strategy the dialogue between representatives of different countries and cultures about climate impacts and adaptation strategies plays an important role in the project.

The Galindo report (2009) criticizes that externalities are often not incorporated in the sense of costs. Therefore neither adaptation nor mitigation makes economically sense and is often not considered. It is necessary to design an efficient adaptation strategy that according to Galindo (2009) should contain the following aspects:

Ecosystems goods and services

There are some ecosystems that are highly sensitive. In that case adaptation options may include limitation of other pressures such as pollution and sediment run-off. It is further necessary to build or expand protected areas, natural corridors and reserves. Soil conservation, ecosystem management as well as monitoring are adjuvant tools. It is necessary to reduce and manage the stress of species and ecosystems, associated with climate change factors such as fragmentation, destruction, overexploitation, desertification and acidification. A policy of a value-added tax could contribute to ecological conservation of forests and biodiversity.

Health

In the health sector it is important to apply specific policies to reduce the risk of sensitive populations to climatic impacts with a focus on the big cities and the possible transmission of infectious diseases in rural areas.

Water

In the water sector water management should be improved in general. Water demand should be managed to make it more efficient as well as infrastructure should be build to allow efficient water management.

Agricultural Sector

In the agricultural sector Galindo (2009) proposes a range of measures to improve adaptation. These include:

- Changes if farming practices
    - Introduction of more crop varieties
    - Studies about resistant crops to flood, temperature and drought and the spread of such crops
    - New irrigation schemes for arid regions
    - Appropriate use of fertilizers
    - Implementation of a system of plague and disease control
    - Reduction of the effects of contamination of water produced by the use of pesticides and herbicides
    - Moving agriculture that is sensitive to climate to the highlands and regions with more water without substantially changing land use
- Spread agricultural and livestock insurance based on weather index. These policies of insurance allow farmers to better manage risk and encourage investment in agricultural activities which require a higher initial investment
- Providing information about climate change through government agencies
- Apply international norms on the use of agrochemicals
- Promoting agro forestry to encourage land use marginal for perennial crops as well as to promote conservation tillage

We have seen that there are a lot measures to improve adaptation and mitigation in a sustainable way. What is halting is implementation. A fair international solution that curtails GHGs should be found. This is also a research area of the Potsdam Institute for

Climate Impact Research. Partnerships on all levels should be building to help countries to embed the measures stated above in their development and poverty eradication programs.

Conclusion

We have seen that there exist a lot of studies that support the claim that the impacts of climate change will mainly hurt poor (rural) vulnerable households and decrease efforts in eradicating global poverty. On the aggregated level we have seen Cross-Sectional Historical Data models as well as Integrated Assessment Models such as the PAGE and the RICE model. Examining households via the microeconomic perspective we have seen that climate change will indeed have severe impacts on ecosystem goods and services, water, health and agriculture and food security. As poor households mainly rely on climate-sensitive sectors, they will suffer terrible from the impacts of climate change on these sectors. In a case study we have seen those effects that will unfold in Mexico and it can be stated that Mexico and especially its rural poor are going to feel the impacts of climate change in a severe manner. That is why adaptation and mitigation strategies become more and more important. In the last paragraph we have seen that it will be necessary to induce policy-induced adaptation strategies as autonomous adaptation strategies are hardly undertaken and are not sufficient in the long run. Actual risk management strategies of households are associated with increased poverty and lower investment and growth leading to poverty traps because poor households that are credit constrained will choose activities that reduce income variability but also generate lower expected incomes that the activities chosen by wealthier households. An international approach is needed that includes bilateral, multilateral and non-governmental development assistance as well as it includes climate change and adaptation strategies in sustainable development and poverty eradication strategies. We have further seen that there is also a lot research being done about adaptation strategies and how to limit effects of climate change on the population. The next step is the introduction of these measures. We should no longer wait and start with mitigation as well as adaptation measures. Although Mexico shows progress in strengthening its institutional framework to support climate change policy development and implementation (cf. OECD 2003) for example through the implementation of the Inter-Ministerial Commission on

Climate Change (CICC) to elaborate national plans and strategies addressing climate change, still a lot need to be done to really introduce and enforce laws and regulations.

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