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Abstract

This paper summarizes the research and policy issues relating to climate change impacts, adaptation research and loss and damage assessments for rural India with focus on agriculture and water sectors. The climate change impact assessments have recently been proliferated by statistical models which primarily assess the role of weather as opposed to climate, thereby biasing the extent of impacts. Though the interface between climate change adaptation research and policy has evolved from a broad geographic understanding to the field level challenges of implementation, there is considerable overlap between developmental activities and adaptation activities. Further, it is expected that the climate change impacts will exceed adaptation limits manifesting in loss and damage due to frequent and/or severe climate extreme events. The loss and damage debate also highlights the challenges that development brings in reducing irreversible and unavoidable losses and damages on one hand and increasing losses and damages attributable to intolerability on the other hand.

Key words: *Climate Change, Climate Risk, Adaptation, Loss and Damages, Climate Policy, Rural India*

JEL Codes: *Q15, Q54, Q56, Q57, Q58, R52, R58*

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INTRODUCTION

Growing scientific evidence on climate change has galvanized the global community to formulate policy responses – especially on greenhouse gas mitigation. Despite several hurdles the global community managed to keep its focus on mitigation of harmful greenhouse gas emissions, as demonstrated by the Paris Agreement. However, climate change adaptation continues to receive limited attention. Indian policy too followed similar trend with relatively less attention on climate change impacts and necessary policy intervention. This paper summarizes the workshop[1] proceedings on climate change impacts, adaptation research and loss and damage assessments in the Indian context and highlights the research and policy issues that emerged from the discussions.

With knowledge on cutting-edge research being an important component of effective policy formulation, there is an acute need for sharing and disseminating the current research in the field of climate change impacts. The paper is structured as follows: The next section sets the context by providing a brief background of the current knowledge and potential issues for deliberations in three sub-fields namely, climate change impacts, adaptation research and loss and damage assessment. The subsequent section provides a summary of the workshop across the three broad sub-fields. The last section highlights the research directions and relevant policy issues that emerged from the workshop deliberations.

CONTEXT AND POTENTIAL ISSUES

Climate Change Impacts

For both mitigation and adaptation policy formulation, one of the crucial inputs needed is the potential impacts due to climate change on various climate sensitive sectors. For mitigation, such information would provide

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the required justification for de-carbonizing the energy systems. On the other hand, in the context of adaptation, knowledge on climate change induced impacts will be helpful in prioritizing the adaptation in the most needed sectors and regions. Further, climate change impacts estimated with proper accounting of adaptation will be helpful in identifying the factors that ameliorate the adverse effects of climate change. Where do we stand with regard to research on climate change impacts in India? While this section highlights some of the issues concerning climate change impacts with focus on agriculture, a brief overview is provided below on the potential impacts of climate change on Indian agriculture.

The climate change impacts on agriculture vary across studies based on the methodologies followed; types of crops considered; scenarios of future climate change; the range of adaptation and coverage of geographic regions. The aggregate impacts of climate change on yields of rice and wheat crops are summarized here to provide a broad idea on direction and extent of impacts. The irrigated rice yield is expected to reduce by about 4 percent in 2020 while rain-fed is to decline by 6 percent. While the irrigated rice yields are likely to be reduced by 7 percent and 10 percent in 2050 and 2080, respectively, the rain-fed rice yields are projected to reduce only marginally (Naresh Kumar *et. al.*, 2013; Mall *et. al.*, 2017). Wheat yields are projected to reduce by 6 percent and 15 percent by 2050 and 2080, respectively if sown on time or by 28 percent and 35 percent respectively, if sown late (Naresh Kumar *et. al.*, 2014). Given that climate has already changed to some extent, few studies provided hind-casting estimates of the climate change on rice and wheat yields. The average rice yield would have been 8.4 percent higher had the pre-1960 climatic conditions prevailed over the period 1969-2007, implying average annual production loss of 4.4 million tons per year (Pattanayak and Kumar, 2014). Similarly Gupta *et. al.* (2016) estimate that the wheat yields in India were lowered by about 5.2 percent due to climate change observed over the period 1981-2009.

Methodological Debate

The climate change impacts have traditionally been assessed in terms of physical impacts (such as yield and area changes), or the associated economic impacts. Over the years there has been steady increase in both categories of studies, but significantly larger increase in physical impact studies than the economic impact studies. Further, there has been proliferation of 'statistical' methods as a preferred method of impact estimation – both for physical as well as economic impact assessment.

Statistical models relying on cross-sectional data have been in use from mid-nineties in the field of climate change impact literature. Referring the cross-sectional statistical model based approach as Ricardian approach, Mendelsohn *et. al.* (1994) in their study of climate change impacts on the US agriculture compare farms across different places – each of which is adapted to local climatic conditions, to empirically estimate equilibrium climate response of farms to climate. One of the main advantages of the Ricardian approach (also referred as hedonic approach in the literature) is that it would take into account the full range of farm level adaptation possibilities. However, in practice it is very difficult to control for *all* factors that affect long-term farm profitability. The omitted variables lead to misspecification of the model and bias the estimates of the effects of climate change. To overcome some of the limitations of the cross-sectional models, there has been a steady growth of panel fixed-effects models on the lines proposed by Deschenes and Greenstone (2007). As comprehensively reviewed by Dell *et. al.* (2014), there has been extensive use of panel fixed-effects models for studying climate change impacts in many sectors including agriculture, labour productivity, industrial output, health, energy, crime etc. The panel approach enables assessment of the influence of weather shocks on many outcomes of interest, being at large free from statistical bias and with significant precision. However, in addition to possible limitation of failing to control for time-varying omitted variables that are correlated with weather shocks, the panel fixed-effects models estimate impacts due to weather shocks, and not necessarily impacts due to climate change.

In line with the global trends, there has been increasing use of statistical models in Indian agriculture context too – both for physical impacts assessment (see for example, Auffhammer *et. al.*, 2006; Auffhammner *et. al.*, 2012; Lobell *et. al.*, 2011; Krishnamurthy, 2012; Birthal *et. al.*, 2014; Gupta *et. al.*, 2014; Pattanayak and Kavi Kumar, 2014; Saravanakumar, 2015) and for economic impact assessment (see for example, Guiteras, 2007; Kavi Kumar, 2011; Birthal *et. al.*, 2014; Kar and Das, 2015). While these studies could be accurately assessing the impact of weather shocks, attribution to climate change could be misleading for several reasons highlighted by Dell *et. al.* (2014). Even though the panel models correctly identify the causal effect of weather shocks on contemporaneous economic outcomes, they may not estimate the structural equation of interest for understanding the likely effects of future climate change. Further, the estimates from panel fixed-effects models may not reflect either the upper bound or the lower bound for the climate change effects. The effects of weather shocks (as estimated by the panel fixed-effects models) will be larger than the effects of climate change if adaptation plays dominant role. On the other hand, the effects of weather shocks will be smaller than the effects of climate change if variation in temperature and precipitation become more intense.

Other Concerns

Some of the other concerns associated with climate change impact assessment include:

Which climate variables matter: There is considerable uncertainty with regard to choice of climate variables in the model specification. While most studies in India still use standard climate variables such as mean temperature and annual rainfall as primary variables of concern in the model specification, there is increasing evidence in the literature to suggest need for incorporating other variables like maximum temperature, minimum temperature, standard deviation of rainfall etc. to effectively capture the climate sensitivity. For example in a study on the rice crop cultivation in India, Pattanayak and Kumar (2017) show that magnitude and distribution of simulated impacts of historical changes in climate on rice yield are significantly different when estimated based on a model that includes maximum temperature when compared to a model that includes only minimum temperature. Thus, there is still considerable scope for research on appropriate model specification in climate impact research.

Need for comprehensive impact estimates: Despite several years of research in the field of climate change impacts, there are still not many studies on estimating economy-wide impacts due to climate change in India. In fact, with the exception of agriculture sector, there have been very few studies assessing aggregate impacts of climate change on other climate sensitive sectors such as forestry, health etc. Such aggregate studies are needed to put in perspective the critical importance of climate change problem.

Impacts at policy relevant levels: As adaptation needs are becoming more and more real, the climate change impacts are needed more at policy relevant scales. For effective policy making, there is urgent need to improve our understanding about the impact distribution across geographic regions as well as various socio-economic groups.

Broadly, the potential issues for deliberation in the context of climate change impacts on agriculture and water include:

- Lessons and insights from National Innovations in Climate Resilient Agriculture (NICRA);

- Merits and limitations of different methodologies of assessment including agronomic-economic approach, cross-sectional (or Ricardian) approach, and panel data approach;
- National and state specific water-agriculture interface and challenges;
- National and regional assessments for agriculture and water sector impacts and vulnerability with focus on distributional issues and promotion of climate resilient agriculture;
- Scope for (i) creating National and Regional data warehouses to minimize duplication as well as ensuring consistent assessments; (ii) greater dissemination of research for effective policy formulation as well as capacity building at various levels; (iii) enhanced collaboration between physical and social sciences; and (iv) research focusing on horticulture crops, livestock and milk production, irrigation, water use efficiency etc.

Climate Change Adaptation: Research and Policy

Research on adaptation in the climate change context has evolved over the past two decades in line with the shift in the climate change policy from greenhouse gas mitigation. Klein *et. al.* (2017) provide a comprehensive summary of the evolution of climate change adaptation research juxtaposing it with the changing climate change policy context. In particular they identify four generations of adaptation research so far. These four generations of adaptation research are given below along with their broad features:

(i) First generation of adaptation research examined potential impacts of climate change along with costs and benefits of adaptation

(ii) Second generation of adaptation research explored the role of social factors in exacerbating vulnerability to climate change. This strand of research also focussed on understanding the role of adaptive capacity and factors that could improve it.

(iii) Third generation of adaptation research focussed on distributional and financing issues as well as the policies/institutions to support adaptation activities.

(iv) Fourth generation of adaptation research is examining how adaptation actually works at the ground level. With the focus on implementation, this strand of research is exploring the approaches to 'mainstream' climate change adaptation.

One way to understand the evolution of these different generations of adaptation research could be to view them with reference to the temporal and spatial scales that these studies deal with. While the first generation studies focused on adaptation needs at aggregate geographical regions and in distant future, the fourth generation studies are more concerned about adaptation at specific locations, and in response to the weather/climate shocks that are experienced currently.

In Indian context there have been varying degrees of focus on these strands of adaptation research. While there were only a few studies that systematically analysed the role of adaptation in climate change impact studies (i.e., the first generation of adaptation research), a large number of studies focused on vulnerability assessment. Many of the vulnerability assessments, however, tend to capture generic vulnerability rather than vulnerability in the climate change context. Studies that could be classified as those in the third generation of adaptation research are still evolving. A major challenge concerning these studies remains in establishing climate change connection. Notwithstanding such concerns there has been a proliferation of studies in India that broadly fall in the category of fourth generation adaptation research studies. In their pursuit to implement the climate change action plans, many state governments are currently implementing several adaptation activities across India. However, the climate change context is often unclear in these activities, and as a result many such activities could be seen as activities implemented to bridge the existing 'development deficit'.

Broadly, the potential issues for deliberation in the context of climate change adaptation include:

- Methodological issues concerning linkages between adaptation and climate change impacts;
- Relevance of adaptation instruments such as migration and insurance, and understanding adaptation pathways;
- Relevance of climate smart agriculture and climate smart villages in addressing development deficit as well as climate change challenges;
- Scope and relevance of climate proofing of rural infrastructure such as water supply systems; rural access roads and bridges; reservoirs and irrigation systems; river banks/ flood protection measures and health and education infrastructure etc.

Loss and Damage

Given the growing evidence of climate science and slow pace of progress in greenhouse gas mitigation, it is widely believed that climate change impacts will exceed adaptation limits – at least in some contexts. The residual impacts are referred in the literature as loss and damage. Currently, such residual impacts are observed in the context of climate-related events like cyclones, floods, droughts, salinization etc. It is expected that the developing and the least developed nations, in particular, bear relatively larger impacts from such events. Actual loss and damage however crucially depends on several traits such as attributability, irreversibility, unavoidability and intolerability.

Climate change impact assessments over time have started shifting focus from academic to more operational level. While the initial impact work focused on tracing incremental impacts due to gradual climate change (intended mainly to inform greenhouse gas mitigation policies), an emergent perspective assesses risk as shaped by both climate variability and climate change and seeks to support climate risk management (CRM) at different scales. CRM aligns disaster risk reduction

(DRR) – which focuses on sudden-onset hydro-meteorological and geophysical events, with climate change adaptation, to address both slow-onset and sudden-onset climate-related impacts. Overall aim of CRM is to anticipate, avoid, prevent, and finance risks as well as absorb remaining impacts.

Current greenhouse gas mitigation efforts may not prevent global warming from going beyond the target of 2^{o}C aspired by the 2015 Paris Agreement. At the same time, despite increasing focus on climate change adaptation, climate-related risks may exceed adaptation possibilities of communities and countries. One of the notable features of Paris Agreement was the endorsement of Warsaw International Mechanism (WIM) for Loss and Damage (L&D). Despite several unresolved issues including exact definition and policy framework, this endorsement established L&D as a distinct pillar of climate negotiations.

For several years now, the Parties to the UNFCCC have been struggling to address loss and damage amid fundamental disagreements about how the issue should be framed and understood. Science has remained mostly on the sidelines – most notably, on attribution of impacts. This gap between science and policy, combined with the difficulties in finding common ground among the Parties, has led to a situation in which the loss and damage is one thing on paper, as outlined in the language on the Warsaw Mechanism, and another in the broader policy discourse. The COP decisions and the Paris Agreement focus mostly on risk management, but advocates and many governments are still keen on compensation. Vulturius and Davis (2016) argue that further research is needed to clearly understand the key traits of that include:

(a) *Attributability* – If WIM were to include a compensation scheme, attributing specific events and specific losses and damages, to climate change could be very challenging, as there are multiple uncertainties and social vulnerability is a key factor influencing the realized losses and damages.

(b) *Irreversibility* - The science distinguishes between physically and socially irreversible impacts. Physically irreversible risks often involve "tipping points" in the Earth system. There is a growing body of evidence on tipping points and thresholds, on the global and local scales. The factors that make some impacts socially irreversible are however less well understood.

(c) *Unavoidability* – Focusing on 'hard' limits to adaptation might simplify WIM mandate, as there is extensive evidence that adaptation finance and technology transfer fall far short of vulnerable country's needs.

(d) *Intolerability* - An equity and/or human rights perspective is important in defining what is "intolerable", to ensure that action under the WIM does not perpetuate inequalities that force poor and vulnerable communities to tolerate worse conditions than wealthier people.

It is also interesting and relevant to understand the interface of the above traits of L&D and development. For instance, it is possible that with development one can usually anticipate reduction in the share of irreversible and unavoidable losses, but at the same time development could increase society's intolerability towards losses and damages.

Broadly, the potential issues for deliberation in the context of climate change loss and damage include:

- Methodologies for assessing and quantifying residual impacts associated with climate related events – including both sudden and slow onset events;
- Complementarity of adaptation instruments/pathways in the context of climate change adaptation and loss and damage;
- Synergy between disaster risk reduction and climate change adaptation, and scope for climate risk management in India;

- Need and scope for institutional reforms for mainstreaming climate change adaptation at the national and regional levels.

SUMMARY OF THE WORKSHOP

This section presents the summary of the workshop deliberations across the three sub-fields discussed in the previous section, namely climate change impacts, climate change adaptation, and climate risk.

Assessment of Climate Change Impacts at Policy Relevant Scales

Rural India houses most of the country's population which depends on agriculture as the main livelihood option. Given the enormous population size and limited livelihood options, water assumes significant role as scarce natural resource in rural India. The ever increasing water demand for direct as well as indirect use is likely to face lower supply of water triggered by changing climate and its influence on the hydrological regimes in different ecosystems in India. The climate crisis has the capacity to disrupt the food production system of the country through its impact on water sector. Assessment of climate change impacts in rural India thus needs to consider the climate-water-food nexus.

Climate Change Impacts on Agriculture and Water

The Government of India launched the National Innovations in Climate Resilient Agriculture (NICRA) initiative with the objective of making rural India (including crops, livestock, and fisheries) more climate resilient in the face of climate variability and change. Besides strategic research on impacts and adaptation, NICRA aims to develop and implement site-specific technology packages to deal with current climate variability. Prabhakar (2018) discussed the broad-based experience of the NICRA initiative including strategic research pertaining to assessment of climate change impacts on different natural resources, impact assessment across sectors including crops, fisheries and livestock, and the impact of climate resilient villages. A number of issues are highlighted pertaining to Indian agriculture and climate in recent years that included declining crop response to fertilizer, declining nitrogen use efficiency, delay in onset of monsoon across all sub-regions, mid-season drought, non-seasonal rains and increasing incidence of cyclones – all of which have relevance in the context of climate change impact and adaptation assessment. Climate change projections for the sub-continent highlighted similar challenges in future. Climate change impact estimates for agriculture suggest that important crops could witness significant yield losses - e.g., yield loss for rice between 4-6 percent, for wheat between 6-23 percent and for maize up to 18 percent - by 2020s (2010-2039). A number of adaptation strategies including improved irrigation facilities, sowing time adjustments, supplying heat-tolerant crop varieties, fertilizer management, use of short-duration cultivars etc. have been implemented under the initiative. Similarly, in the livestock sector, climate change induced heat stress is likely to reduce milk production up to 2 percent of total milk output of the country. A number of impacts including changes in breeding season, spawning activity shifting toward cooler months, marine fish availability extending to deep waters are also observed as impacts in the fishery sector. Further, impacts assessed on natural resources under various climate change scenarios include changes in soil organic carbon (SOC), water footprint, changes in groundwater table etc. The NICRA initiative of 151 climate smart villages across the country also facilitates introduction of short-duration drought tolerant crop varieties, resilient inter-cropping systems, diversification, rainwater harvesting, crop-residue incorporation etc.

Assessment of climate impact at the village and community level with focus on water sector is important from food security standpoint. Most impact assessment studies tend to look at aggregate community level impacts, and tend to ignore impacts in terms of the ecological costs. Biodiversity damage and depletion of ground water in places of acute water crises have huge ecological costs including impact on aquatic biodiversity. Srinivas (2018) highlighted that the imminent water and the food crises and extreme weather events are the three most important risk factors threatening the water-energy-agriculture nexus. In the last four decades, water use in agriculture has remained around 90 percent. Moreover, 60 percent or more of irrigated area water demand and 80 percent or more of domestic water needs are met from groundwater. There is severe temporal water scarcity for about 8-12 months in a year for India.

Focusing on the Southern state of Karnataka, Srinivas (2018) highlights that in approximately 75 percent of the talukas groundwater has depleted due to overexploitation which may be classified as `critical'. Ban on drilling bore-wells thus has been put forth as a policy response. Climate change and variability projections for the state suggest that drought years are going to increase. This could have significant implications in terms of digging of more bore-wells, reducing groundwater levels further, and may lead to crop stress and crop failure and thereby reducing crop productivity. A study of the Mysore region - where more than 50 percent of the bore-wells dug in the past 10 years are dysfunctional - suggest that most food insecure households were small and marginal farmers. The survey suggests that non-climatic factors including access to credit, depleting groundwater, depletion in soil fertility, crop response to fertilizer, reduction of microbial in the soil, increasing aspirations, peer pressure and failures in the bore-well have made many small and marginal farmer households more vulnerable**.**

Methodological and Distributional Issues in Climate Change Impacts Assessments

In the context of agriculture both crop modelling as well as statistical modelling approaches are used to assess climate change impacts. Studies comparing both approaches find little or no difference in their estimates. Presenting a methodological review of the statistical approaches employed in the literature to quantitatively assess the climate change impacts on agriculture, Pattanayak (2018) examined adaptation potential as assessed under the purview of agricultural impact assessment studies, focusing on the more recently developed long-difference approach (Burke and Emerick, 2016).

Past statistical studies of climate change impacts have largely used cross-sectional information (say, at district level) on agricultural revenue or land values and climate to estimate underlying the empirical relationship, which could then facilitate calculation of climate change impacts. These models by their construction account for all potential adaptation possibilities. This method however failing to control for large number of confounders could present a biased quantitative estimate of the sensitivity of agricultural outcome to climate parameter of interest. To overcome such limitations, use of panel models has become more popular in the literature.

While controlling for other potential confounders, panel models tend to exploit temporal weather variability information at district scales to estimate the statistical relation between weather variables and outcome of interest. However, these models essentially capture effects of weather shocks and not climate change and are devoid of capturing adaptation possibilities. More recently the long-difference approach has attempted to overcome the limitations of both the cross-sectional and the panel approaches. By exploiting longer-term (e.g., decadal variations) in climatic parameters, this approach allows for removing the influence of unobserved confounders while in effect estimating effects of longer-term changes in climate on agricultural outcome.

Pattanayak (2018) focusing on India, employed the long-difference approach to assess effects of climate change on rice productivity using district level data on rice productivity and compares the results with those studies using panel approach. The study findings suggest that adaptation plays some role in mitigating short-term weather effects - approximately 21 percent of the short-term adverse effects are mitigated through longer-run adjustments.

While assessing the effects of climate change at broader scales, such as national or regional levels, is important for country- or regional-level adaptation planning, these effects may not be evenly distributed across stakeholders within a region. Therefore, farmers may get differential welfare impacts within a given region. Assessment of the distributional effects of climate change impacts on agriculture thus becomes crucial. Taking the aggregate impact estimates and using a general equilibrium framework Gupta (2018) examined how the effects of these impacts translate into changes in food price and welfare of the poor.

The first and second order economic/welfare effects of climate change impacts assumes that climate change does not change the allocations of factor inputs such as labour, and the price changes in agriculture thus are under-estimated. Landless poor farmers whose expenditure share of food is more than 60 percent in their total expenditure would be more adversely affected. Climate change affecting agricultural productivity could influence prices and therefore household welfare differently.

Further, the study examines the role of trade in providing a cushion for the adverse climatic impacts. Thus, the prices could change differently depending on whether the economy is closed or an open economy. Compared to the counterfactual scenario of no climate change and pollution, past climate changes have resulted in price changes and changes (losses) in welfare of much higher magnitude for a closed economy compared to an economy with trade. The study findings suggest substantial losses for the poor even with moderate climate change when the economy is closed. However, losses to the poor are reduced if the economy is open. Loss due to climate change would be witnessed by all agents - landless poor and farmers with land holding. However, losses will not be equally borne by all farmers. Moreover, losses to the poor alone are likely to be 3-6 times greater than the first order impacts that do not account for price changes.

Adaptation Instruments

Assessing the effectiveness of various adaptation options in coping or ameliorating the present and future vulnerability to climate change has been a key objective of adaptation assessment which thereby could feed into adaptation policy. While the typology of adaptation has been well-discussed in the literature, existing literature provides little guidance towards quantitative measurement of adaptation costs and benefits. To a large extent this depends on the scale at which impact is assessed and the methodology employed to assess impacts. Notwithstanding the direction of adaptation research, the workshop took a broader view of adaptation mechanisms that may be in place in rural India. Two such mechanisms include of migration and insurance.

Role of Migration

In the context of agriculture at a farmer's level, adaptation options include adoption of heat-tolerant crop varieties, improved irrigation, and other management practices which are required explicitly to deal with climatic stresses. In the broader rural livelihood context however adaptation options could also involve the choice of the farmer to migrate either temporarily or permanently from its original location in order to cope with or ameliorate the impacts due to the climate stress. Exploring such mechanism becomes important not only in the `local' context, but also in the more `global' context of climate induced distress migration. Migration as a response strategy to natural calamities, sea level rise etc. has been well-known in the literature. However, a much less discussed aspect is that of migration as a response strategy to the slow changing mechanism of weather and climate induced impacts on agriculture. In particular, it is important to understand whether climate effects on agriculture could induce migration.

To explore this issue in the context of Indian agriculture, Viswanathan (2018) employed a structural modelling approach using district level information on migration and climate or weather over several decades. The study findings suggest that climate induced agricultural output losses tend to increase the incidence of out-migration - a form of distress migration. Further, the nature of out-migration pattern is mostly dominated by rural-to-rural and intra-district migration. However, these estimated effects on out-migration, which are influenced by climate/weather, are found to be low.

To infer from this that weather/climate induced agricultural migration would be similarly low under future climate change would however be misleading. While existing economic theories of migration based on rural-urban wage differential and stages of development tend to predict a higher migration, lower migration levels historically and currently observed could be seen as a puzzle in the Indian context. Attempts to resolve the puzzle would at least inform the conditions under which such induced migration levels could be low. Presence of social insurance amongst the poorer households involving transfers from social networks for consumption smoothing could dampen the motivation to migrate. Similarly, non-portability of welfare benefits across states could be seen as a significant deterrent on the choice of a person to migrate.

Future work in the context of climate change induced agricultural migration literature in India needs to address questions including, for example, : (a) whether climate induced migration of agricultural farmer is short-term or long-term in nature and whether short-term and long-term migration are influenced similarly or differently by different climatic stressors?; (b) whether internal migration (short-term or long-term and intra-state or inter-state) are more important mechanisms and whether these migrations could be expected to be more pronounced compared to international migration as focused much in the migration specific global climate policy literature?; and (c) whether policies on food-security and welfare programmes have anything to contribute to the arrest climate induced distress migration?

Role of Insurance

A key institutional mechanism that has been well-discussed in the agricultural risk management and more recently in the climate risk management literature has been the role of insurance in coping with or adapting to climate change impacts. The role of insurance has been studied at multiple scales in the developing country context, knowing its wide-spread application in the developed countries. In the Indian agriculture context, both crop and indemnity based insurance as well as index-based (weather) insurance have been in existence.

Gaurav (2018) highlighted some of the fundamental issues with crop insurance and how their design and implementation have changed rapidly in India. Both forms of insurance have been implemented keeping in view their idiosyncratic features and limitations and therefore have met with varying degree of successes across the board. The Government of India through its National Agricultural Insurance Scheme (NAIS) or the Pradhan Mantri Fasal Bima Yojana (PMFBY) has been instrumental in making India the country with the largest crop insurance coverage in the world. Crop insurance has fundamental issues of adverse selection and moral hazard that make insurance products unattractive from the standpoint of insurance provider. Their compulsory provision with formal institutional credit is the key for such wide outreach in India.

On the other hand, index-based insurance while avoiding some of these basic limitations of crop insurance is fraught with major challenges such as `basis risk' - a spatial indicator of the extent of error introduced when insurance pay-out is made farther from the place where weather measurement occurs in a given locality. The presence of basis risk ensures that risk-averse farmers cannot be provided with full insurance by charging an actuarially fair premium on the insurance. Addressing the issue of basis risk has been a key research priority and is likely to benefit the effective management of climate risks. Several such issues have led to the reduction of index-based insurance uptake in recent years. If insurance as an institutional mechanism is to help cope with future risks arising due to climate change, a number of measures which include design of more robust incentive structures, including incentives pertaining to technology as well as subsidies needs to be borne in mind.

Lack of trust, lower ability to pay etc., have been cited as some of the reasons of low uptake of index-based insurance in India. Increasingly, policy guidelines have been put forth to use technology to offer insurance at smallest level possible. Kramer (2018) examined whether insurance provision through the use of mobile-phone pictures can be an effective means to avoid the issues of moral hazard and adverse selection. Based on field experiments in North-West states of Punjab and Haryana, the study undertakes loss assessment through the use of pictures based insurance (PBI) and finds that PBI could improve demand for insurance. While not altering the willingness to pay for the products, the product also didn't induce moral hazard and adverse selection. While technology can help by improving upon the pay-out time-scales and ensuring transparency in its implementation, their viability would be well-placed by examining the dynamics of moral hazard and examining how bundle of risk-reducing technologies could aid the objective of insurance provision. Further, a number of issues relating to the viability of PBI, given the value of the crop insured and given the distribution of risk, presence of any collective incentive for PBI need to be assessed.

Climate Change: Risk, Resilience and Loss and Damages

In the deliberation of the climate change challenge, risks can be classified as either climatic risks or non-climatic risks, with possibility of either type of risk influencing and/or reinforcing the other. Climate risks can be further classified based on the degree to which associated risks can be averted (or translated in potential loss terms the extent to which such losses could be mitigated or reduced). These include: avoided risks, unavoided risks and unavoidable risks. Recent scientific and geo-political developments have attempted to identify the latter two forms of climatic risks as the risks attributable to climate change induced loss and damages. While acknowledging the complex inter-play of all forms of risks, the notion of resilience attempts to provide one way to address or mitigate these risks. Therefore, there is an increasing need to recognize the concepts of risk and resilience together in the context of socio-economic-environmental policy making, particularly in the context of climate change policy. Climate resilient development must take into account the synergies and trade-offs existing between the process of identifying and assessing all forms of risks – climatic, non-climatic as well as L&D – and the process of identifying ways and means to address such risks through measures to enhance resilience and increase capacity to adapt. In many cases these synergies and trade-offs may not be so obvious.

In the assessment of risk and resilience, the complexity involved in dealing with the inter-play of climatic- and non-climatic stressors at multiple scales was highlighted by Dasgupta (2018). The objective climate risks or impact assessment at local scale outcome is most likely to meet the challenge of increasing influence from non-climatic stressors or confounders as the final scale of analysis is approached. Although this renders such assessments significantly complex, it provides the scope to delineate and identify the synergies and trade-offs at each scale.

The importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events was recognized in the Paris agreement. Climate change L&D came to become an important part of climate change policymaking in the Warsaw International Mechanism (CoP 19, UNFCCC). However, the basic notion became prominent in the scientific community with the IPCC report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX). Recent scientific literature has seen a proliferation of studies attempting to understand, examine and quantify the extent of the climate induced L&D, which are particularly relevant from developing country perspective. In nutshell, these damages represent the residual impacts which are realized after optimum levels of adaptation and mitigation efforts have been undertaken. While several features of L&D need examination including a quantitative assessment of the economic and non-economic L&D, resilience is an important aspect which has emerged in the context of climate induced disasters. The issue of resilience while familiar in the ecology literature has however not been studied well in the L&D context and thus could inform policy surrounding climate change L&D.

Assessment of Risk and Resilience

Hydro-climatic events such as drought, flood and cyclones tend to be responsible for much of agricultural output losses and to some extent income and livelihood loss across vulnerable communities in India. Several crops which are important from ensuring food-security and sustaining livelihood are vulnerable to such disasters. The government of India has taken several measures to deal with such situations to enhance the resilience of Indian agriculture to extreme climatic events such as floods, droughts, cyclones etc. These include policy to expand irrigation, use of better technology, and development of drought-resistant crops etc. However, whether and to what extent these measures have played their role in enhancing resilience of agriculture is not well-studied.

Treating rice as a benchmark crop in Indian agriculture, Birthal (2018) examined whether rice in India have become more resilient to droughts over the years. The study uses district level data on rice productivity and drought index (DI) - a composite measure of rainfall and temperature deviations from their normal. A key observation of the study is that between 1969 and 2005, moderate drought events have increased leading to slight increase in the affected area where rice is grown while severe drought events have decreased. Notwithstanding this trend, however, percentage deviation in rice yield for all categories of drought events have declined. Employing statistical methodologies the study finds that while drought reduces rice yield, the crop has become less vulnerable to drought over time and also has become less susceptible to severe droughts - implying increasing resilience of the crop to the event. The effects of irrigation in inducing such resilience are highlighted. Irrigation is a mechanism through which harmful effects of severe droughts are moderated. Yield without irrigation at varying drought intensity is lower as compared to yield with irrigation. With higher levels of irrigation, drought induces lower yield losses. However, positive effects of irrigation have slowed down. Adoption of improved drought-tolerant varieties and practices aimed at improving water use efficiency can provide clear adaptation benefits.

While role of government intervention could be important in improving resilience of agricultural system, the role of local enabling features in enhancing community resilience during a disaster cannot be undermined. In the context of cyclone related disasters in the Eastern coast of India, Das (2018) examined this issue. Using combination of survey and secondary data in Andhra Pradesh and Odisha, the study assesses the effects of two major cyclones that struck the eastern coast in 2013 and 2014. The time to recover completely from the disaster could be around 2 months in some places, whereas for some it could range between 6 months to two years. Modelling results of the study suggest that local endogenous features such as width of the mixed vegetation at the coastline and vegetation surrounding the house helped reduce the impacts of the cyclones. These effects were significant over and above other socio-economic characteristics including whether a household is female-headed, has higher educated family members and whether house had a more robust structure. Some of these local features may therefore be seen to have enhanced static resilience - by reducing immediate damage - to the communities.

Assessment of costs of L&D

For effective policy making surrounding climate change L&D, quantitative assessments are equally important to be undertaken. The notion of L&D has been vaguely defined in the literature. However, broadly they can be classified as economic L&D and non-economic L&D. Economic L&D (ELD) are damages which can be assessed directly in terms of monetary losses. Non-economic L&D (NELD) on the other hand including psycho-social stresses are difficult to quantify. Existing literature suggest that the extent of NELD could be much more significant compared to ELD.

Using farmer surveys in Western Indian state of Gujarat, and employing environmental valuation techniques Bahinipati (2018) attempted to measure both notions of L&D in the context of drought. The study considers several indicators to capture economic and non-economic L&Ds. Indicators such as loss of agricultural crops and additional expenditure on irrigation are taken to capture economic damages, whereas depletion of groundwater and psycho-social stress associated with drought are considered to represent non-economic L&Ds. While highlighting several conceptual difficulties in such assessments, the study falls in line with the literature that the extent of NELD tends to be much higher than the ELD.

Framework for Climate Risk Management

The concept of L&D was originally motivated in terms of compensation for the Small Islands Developing Countries (SIDC) and Alliance of Small

Island States (AOSIS). While L&D has garnered significant geopolitical debate in recent decades, until recently identifying the scope of the debate with strong scientific grounding was missing. Climate Risk Management has thus emerged as an umbrella framework with disaster risk management and climate change adaptation as the main leverage points to reduce adverse impacts of climate risk on natural and human systems.

Highlighting the current typologies of L&D – which are just beginning to be formalized, applied and debated – Mechler (2018) presented an overview of the CRM, with an application of the framework to the Indian state of Tamil Nadu. As highlighted in the previous section, existing typology of L&D defines it to be either (a) avoided – damages which are actually avoided; (b) unavoided – damages that are avoidable but were not avoided due to technological, financial and governance constraints; and (c) unavoidable – damages which could not be avoided through any level of mitigation and adaptation effort. L&D broadly construed to include the unavoided and the unavoidable damages, may thus require both *ex ante* transformative risk management and adaptation and *ex post* curative measures to deal with such impacts.

Existing approaches to deal with L&D have been limited in their applicability since they fall short of the information needs of policy makers and local governments. The CRM attempts to fill this gap by developing and operationalizing a comprehensive framework of risk management at decision-making scales. In the Indian context, CRM framework is developed to support the government to determine its response to eliminate risks at the national as well as at the state level dealing with large scale climate vulnerabilities as well as residual risks that could contribute towards L&D in the country. One of the key features of the CRM framework is that it iteratively informs decision making in a changing world, with continuing uncertainty about severity and time of climate change impacts, acknowledging the limits to effective adaptation. In particular, the framework could be useful in complex situations characterized by large potential consequences, persistent uncertainties, long timeframes, potential for learning, and multiple climatic and non-climatic influences changing over time.

Keeping in view the necessary best practices to be incorporated as its benchmarks, the CRM framework for India consists of six steps to operationalize climate risk management at different scales. These include: (1) providing a comprehensive assessment of climate change and disaster status quo with details of institutions involved, availability and quality of information available and data gaps; (2) identifying the concrete system of interest on which CRM framework can be applied through climate related hotspot and capacity analyses; (3) developing context specific methodology to assess impacts for the system of interest; (4) identifying risks by conducting a qualitative and quantitative risk assessment; (5) evaluating risk tolerance and limits and classification of risks into acceptable, tolerable and intolerable levels; and (6) identifying and assessing feasible options to avert, minimize and address potential climate related loss and damages and terms the efforts to be either incremental, fundamental or transformative.

RESEARCH PRIORITIES AND POLICY ISSUES

The workshop deliberations provided crucial inputs for identifying research priorities in the context of assessing climate change impacts, adaptation strategies and loss and damage. The deliberations also facilitated identification of few important policy issues in the context of climate risk management and adaptation policy. While the previous section highlighted insights from various studies in specific contexts on research directions as well as policy issues, this section provides an overview of the overarching issues that emerged from the deliberations. The discussion on research priorities draws largely from Jayaraman (2018), Somanathan (2018) and Venkateswarlu (2018). The discussion on policy issues is mainly based on Dubash (2018), Byravan (2018) and Chaturvedi (2018).

Research Priorities

It would be relevant to question the source of research agenda per se. For example, excessive focus on "1.5 degree" research agenda promoted among others by the IPCC may shift the focus away from systematic analyses of climate sensitivity of sectors such as agriculture and water to modelling exercises aimed at number crunching to feed into global negotiations. Similarly there could be danger of collapsing complex developmental concepts into numbered lists such as sustainable developmental goals.

The scope of research on climate change impacts on agriculture (and for that matter on any other specific sector) must be expanded to study multi-dimensional aspects that take analysis beyond exclusive focus on climate change and agriculture interface. For example, it is important to study the influence of worsening pollution (especially due to fertilizer misuse) and water scarcity on agriculture while studying climate change impacts on agriculture. Similarly, it would be insightful to study the negative impact of higher temperatures on labour productivity in both manufacturing and agriculture. The possible adverse equity impacts of adaptation solutions also merit attention.

Methodologies adopted in the study of climate change need to evolve to become more relevant to context and make predictions for an "uncertain" future. Thus there is need for use of robust simulation methods that draw on experimental evidence, foresee the unprecedented changes expected in climate phenomena and take into account extended chains of causation. To facilitate such analyses there is urgent need for trans-disciplinary research that exhorts scientists to explore the economic/social/political dimensions of technological solutions, and social scientists to recognize the material/geophysical/biological framing of their concepts.

While research always need not constrain itself to be policy relevant, the research in the context of climate change should strive to engage with policymakers given its complex nature. Although the effect of climate change is real, they are still small in magnitude relative to the shifts brought about by technology or monetary policy. Policymakers do not receive strong enough signals from climate phenomena to act upon them. Thus climate change researchers must continuously reach out to the policy maker to ensure that the findings from climate research help in non-adoption of maladaptive policies.

Researchers should exercise caution in recommending solutions that may potentially have adverse impacts on certain sections of society. For example, rampant fertilizer misuse might prompt economists to recommend reducing fertilizer subsidy, but some farmers who may stand to lose from the move will be prompted to block the policy. This results in a good policy reform becoming a non-starter. In order to move forward, it is important to rethink how we provide social security in a way that does not incentivize pollution and distribute the gains from policy fairly.

There is need to develop tools/techniques that practically assess the synergies and trade-offs involved in achieving climate resilient development, much in the same way it is done in the case of mitigation.

There is need for developing tools that attempt to delineate clearly the nature of climate adaptation in terms of its institutional, behavioural and technological dimensions to enable better understanding of adaptation pathways.

Policy Issues

Enough evidence exists to suggest that the poor are vulnerable to climate change. But, not everyone vulnerable to climate change is necessarily currently poor or vulnerable to poverty. Against this backdrop, it would be useful to highlight the differences and complementarity between what is referred in the literature as 'development deficit' and 'adaptation deficit' and the nature of adaptation policy.

If poor are vulnerable to climate change at all times, present poor as well as those who are vulnerable to poverty in future are going to be vulnerable to climate change. Put differently, if existing development policy fails to mitigate completely the vulnerability to future poverty of the currently poor, then they are put in harm's way in the future, irrespective of whether climate vulnerability arises or not. Existing literature terms interventions to address this as attempts to reduce `development deficit'.

Those who are not vulnerable to be poor are left out of development policy agenda. However, they could be vulnerable to climate change. Hence, under changed climatic conditions, they may not only continue to be vulnerable to the phenomenon itself but also be poor or vulnerable to poverty. To reduce their potential vulnerability to climate change in future, it is crucial to first reduce their present vulnerability to such risks. With effective climate policy, this could be addressed and can be termed as bridging the `adaptation deficit'.

Reverting to the first category again, the currently poor who are vulnerable to poverty and also vulnerable to climate change would require both development policy and climate policy interventions to bridge both development deficit as well as adaptation deficit they face. In the context of agriculture, this can be explained in the following manner. Presently poor as well as rich farmers could be vulnerable to climatic risks.

The poor farmers may not only require developmental intervention to safeguard them from the existing downsides of being poor (say, through MSP), but also require climate policy interventions (say, through climate resilient seeds or insurance) to protect them from climate change vulnerability. The rich farmers while not requiring development interventions may still require climate policy intervention to safeguard them from future vulnerability to climate change and poverty.

Neither objective - making everybody not vulnerable to poverty or making everybody not vulnerable to climate change - can be the overarching end goal of policy making. Adaptation policy must attempt to address the co-evolving vulnerabilities.

The deliberations at the workshop pertaining to the adaptation policy focussed on the principles and considerations for policymaking, features of current policy framework in India, and prospects for State Action Plan on Climate Change (SAPCC) as a tool to shape adaptation policy in the country. Some of the insights from these deliberations are summarized below:

There is need for the recognition of the complex and multi-dimensional nature of adaptation policy. Adaptation policy can become flash point that exacerbate inequality and generate winners and losers, and hence framing of policy must consider equity, justice and social hierarchy. Prior to implementation, the adaptation policy must analyze stakeholder incentives and understand the social landscape, and should take measures to ensure that the policy does not exacerbate inequality.

It is important to recognize the interconnectedness of development and climate change and the seeming continuum of interventions that extend from development to adaptation. Improvements to general resilience can be considered as development and most adaptation policies may have development co-benefits.

However, caution must be exercised against conflating development and climate adaptation, especially for reasons of convenience and access to funding. This is particularly true in case of Indian climate policy. In the current form, the National and State Action Plans on Climate Change often serve as Trojan horse for raising funds for sustainable development policies.

There is urgent need to transmit scientific knowledge effectively to policymakers especially at the operational levels. Discussion among experts continues to operate in silos, whereas execution is often channelled through narrow government line departments that may not be privy to expert inputs as the nodal agency for climate change (say, Department of Environment) but often more powerful than the nodal agency.

In order to operationalize an integrative adaptation policy, it could be useful to establish convergence structures at the sub-state level and efforts to meet significant capacity gaps for the implementation of the climate agenda through policy-science partnerships and engagement of NGOs/civil society (such as Punjab Agricultural University's close advisory role to the Punjab's agricultural department).

In line with the principles of effective policy making mentioned above, the revision of SAPCC may attempt to put in place a process to build conceptual bridges, identify trade-offs and synergies of different policies through public consultations, multi-criteria decision analysis and adopting a paradigmatic approach rather than a project-to-project approach.

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