Climate Resilience and Nationally Determined Commitments: Macro-economic assessment of impacts associated with ambitious climate mitigation policy across Indian States

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Abstract— Effective messaging and evidence-based demonstration of implicit economic opportunities in transitioning to leaner 1.5^{0}C pathways can go a long way in creating consensus for massive social mobilization and committed government actions towards deeper decarbonization. In this study we assess the direct and indirect economic impacts of India's Nationally Determined Commitments (NDCs) and beyond at the subnational level using an integrated macro-econometric dynamic simulation model: E3-India. An array of distinct economic trajectories associated with energy decarbonization and energy efficiency targets at national level and state level were simulated using the model. Results reveal that selective investments in ambitious climate mitigation policies will lead to overall economic growth for Indian economy. However, distributional impacts across states, especially those already identified as climate hotspots, will be heterogenous. These regions will therefore need effective policy interventions to manage the transition and ensure resilience in the face of climate change.

Keywords— ***Climate resilience, NDC, Energy transition, green growth, consensus building, India***

I. Introduction

Often, decarbonization targets negotiated at national and international platforms do not provide a clear representation of the complex geography-economy–energy interactions at the regional level there by making it difficult to estimate whether the impacts of the proposed GHG mitigation actions will be augmentative or disruptive. This study evaluates the scope and dynamics of climate resilient growth linked with the negotiated nationally determined commitments for India and further aspired aggressive commitment towards meeting 1.5 ^{0}C by 2030 at the regional level.

A matrix of scenarios was evaluated for the two incremental mitigation pathways of i) Committed 2^{0}C NDCs, ii) Aspired 1.5^{0}C target including combinations of energy decarbonization, process efficiency and carbon sink development actions. The socio-economic outcomes of these pathways were evaluated with respect to change in GDP, income generation, employment and household consumption. The study further takes a cross sectional view evaluating impacts of mitigation pathways for seven diverse Indian states identified as key climate hotspots [1] i.e. [Chhattisgarh (CG), Jharkhand (JH), Madhya Pradesh (MP), Odisha (OD), Gujarat (GJ), Rajasthan (RJ), and Maharashtra (MH)]. The analysis reveal an overall positive impacts of a high renewable capacity addition without substantial energy efficiency initiatives at the aggregate (national level).On the contrary at regional level only renewable capacity addition leads to intensification of adverse impacts (in terms of employment loss) for some states like Chhattisgarh, Madhya Pradesh and Maharashtra. These adverse impacts however could be mitigated using an integrated strategy combining efficiency targets with additional renewable energy capacity.

II. Literature Review

A global trajectory of no or limited (less than 0.1 ℃) overshoot of 1.5 ℃ will requires a fundamental transformative shift in the policy regime. A suite of integrated policies that enables higher socio-technical transition speeds, larger deployment scales, along with the phase-out of existing systems promoting long term lock-in of carbon emissions is discernible [2].

Recent studies reveal that ambitious climate action do not need to cost much more than business-as-usual growth. Bold actions for climate change mitigation and are expected to yield direct economic gain of US$26 trillion globally through to 2030 with potential to generate 65 million low carbon jobs [3,4]However, the distributive impacts of not only anthropogenic climate change but also transition pathways will be disproportionately appropriated globally with depletion in quality of life for poor and vulnerable and over 12 trillion dollars of stranded fossil fuel assets [5,6] across countries.

India uses 6% of the world's primary energy, but sustained economic growth is placing an enormous demand on its energy resources. India's per capita energy consumption grew by 56.4% from 2005-06 to 2016-17, with an annual growth rate (CAGR) of 3.8%. Proactive and sustained actions on climate change mitigation have led to a 21% reduction in the emissions intensity of India's Gross Domestic Product (GDP) over the period of 2005-2014. Recent studies also estimate that the country experienced 431 major natural disasters during the period 1980-2010, resulting in huge loss of human lives, property and resources. India suffered an absolute loss of US$79.5 billion during 1998-2017[7]. Increasing frequency and intensity of disasters related to the climate change impacts on weather systems, ecological dynamics and natural resources, reflect the need to adopt measures for disaster management and climate change adaptation [8].

A recent World Bank Report [1] reveals that climate change impacts are likely to lower the living standards of nearly 600 million Indians i.e. half of India's population. However, the intensity of the impacts will be a function of demography, geography and social status. In India, inland states in the central, northern, and north-western regions emerge as the most vulnerable to changes in average weather. Changes in average weather could therefore have important implications for poverty reduction.

Further, initial impact mapping of the existing renewable integration trajectory in India reveals a dichotomy in India's green growth agenda from both a spatial and sustainability perspective [12]. Spatially, the geography of renewables favours developed western states while the coal bearing eastern states take the burden of prospective economic constrains due to coal curtailment along with adverse socio-economic impacts of mining induced environmental degradation. In addition, many of these coal bearing regions for instance the states of Chhattisgarh and Madhya Pradesh are low-income states home to large tribal populations and have been identified as climate impact hotspots [1].

Cognizant of the inherent climate vulnerability and need for logarithmic expansion in the energy portfolio, the Government of India enacted a comprehensive National Action Plan for Climate Change (NAPCC) in year 2008 comprised of eight missions with ambitious targets for rapid energy transitions, energy efficiency and resilience building through the promotion of sustainable habitat, agriculture, forestry and ecosystem [8]. The NDCs are synthesized from the existing NAPCC program and provide top-down guidelines for formulating both central and state level policies for implementation and facilitation of climate mitigation and resilience [10]. The objective of the study is to evaluate set of policy options using E3-India's integrated analytical framework. The outcomes can be used to inform both state and central level policy making in India about the cost and benefits associated with climate action trajectory implicit in existing NDCs and NDC plus targets.

Many economywide models have forecasted India's economic growth, and how such growth will affect India's carbon footprint. These include not only government forecasting initiatives but also other agencies like multilateral organizations; and non-profits [11]. In addition, sector specific models have been developed to forecast how sectoral demand growth will contribute to India's increasing emissions [12,13]. These models primarily provide a national level forecast using an energy-environment framework with either exogenous economic inputs or endogenous economic treatment using a general equilibrium framework. Although many existing models are sufficiently detailed to understand overall trajectory of energy transitions in India they fall short the of providing policy prescription for actions which are primarily deliberated at the regional or local level. Creating large momentum for climate action will require greater granularity of information at the regional level to assess implicit impacts and growth opportunities of climate action.

We use a comprehensive state level macro-econometric model E3-India to evaluate the distributive economic impacts of committed and aspired climate actions across Indian states. The model provides an internally consistent economy-energy framework for 32 states and union territories of India. The model allows state-level impacts assessment for 39 economic sectors, 21 users of five different energy carriers and 24 power generation technologies. It's a demand led simulation model based on Non-Keynesian theory (further details in Supplement 2). The model provides a key distinction over the commonly used general equilibrium framework for economy- energy linkage in Integrated Assessment Model (IAM), specifically w.r.t. simulating the transition trajectory. It features a nonequilibrium framework which does not impose full employment constrains making it more suitable to represent climate mitigation actions and modelling of economic impacts linked with energy transitions. The framework thus also alleviates the free rider representation of climate mitigation action and maps green growth opportunity implicit in climate action i.e. increase in investment, GDP and employment without prior rise in savings. Further, estimation of distributional impacts is also more pronounced with the possibility of capital and labour (fossil fuel assets) getting stranded and the need to be written off rather than getting reallocated as in general equilibrium models [14].

The power sector in E3-India is represented using a novel framework for the dynamic selection and diffusion of innovations, initially developed by J.-F. Mercure[15]called FTT: Power (Future Technology Transformations for the Power sector). FTT uses a decision-making core for investors wanting to build new electrical capacity, facing several options. The resulting diffusion of competing technologies is constrained by a global database of renewable and non-renewable resources [16]. The decision-making core takes place by pairwise levelized cost (LCOE) comparisons, conceptually equivalent to a binary logit model, parameterized by measured technology cost distributions. Costs include reductions originating from learning curves, as well as increasing marginal costs of renewable natural resources (for renewable technologies) using cost-supply curves (E3-India Manual, 2018). The model provides an endogenous solution for a range of economic parameters like GDP. Sectoral outputs, employment by sector, wage rates, energy consumption prices by fuel type and fuel user along with sectoral emissions.

III. SCENARIO DEVELOPMENT

The modelling inputs and assumptions include compiling policy wise data for economic activity implicit in the three NDC objectives extended to desired 1.5^{0}C representative scenario. The integrated scenario created include three elements of increased renewable capacity addition, reducing the energy intensity of GDP by energy efficiency measures and creation of a carbon sink creation of 2-3 billion tons by investment in the forestry and agro- forestry sectors.

A. Greening the Energy Technologies

India's greenhouse gas emissions rank third in the world with more than 30% of these emissions contributed by coal-based electricity generation [17]. However technological advances and recent cost declines in solar photovoltaic (PV) and wind technologies have made these alternatives increasingly cost-competitive with coal generation and as of 2017, India had already installed 32.8 GW of wind (6.4% of the global wind capacity of 514 GW) and 19.3 GW of solar PV (5% of the global solar PV capacity of 391 GW)[18]. Further, the Indian government has set an ambitious target and created incentives for adding 100GW of wind and 60 GW of wind capacity by 2022 which is expected to achieve existing NDCs commitment to 40% renewable by 2030 [10]. The analysis involves designing three scenarios BAU, NDC and NDC plus adding an incremental combined solar and wind capacity of 158 GW, 322GW and 390GW by 2030.

B. Reducing the Energy Intensity

India pledged to reduce GDP emissions intensity by 33% to 35% by 2030 from its 2005 level for meeting the NDCs. The Bureau of Energy Efficiency (BEE) has initiated a number of energy efficiency initiatives in the areas of large industry emissions reduction targets, standards and labeling, commercial buildings codes, and demand side management in agriculture and municipalities. India has already launched an ambitious energy efficiency scheme i.e. Perform Achieve and Trade (PAT) [19] for industries and other energy-intensive sectors. The scheme covers 478 designated consumers (DCs) and avoided emissions of 31 $MtCO_2$ first phase which is approximately total of targeted energy savings of 19 Mtoe. The distribution of energy efficient LED tube lights resulted in estimated energy savings of 294.45 million kWh per year with an avoided peak demand of 135 MW and greenhouse gas emissions emission reduction of 0.2 MtCO2 per year [20].

The three RE scenarios were augmented by sectoral efficiency targets of selected PAT identified industrial sectors along with household efficiency investment estimates available in Bureau of energy efficiency's, Energy efficiency potential in India report 2018 [21].

C. *Creating the carbon sink*

Amidst growing developmental challenges, India is sustainably managing its natural resources with forest and tree cover accounting for 24.39% of the total geographical area, and the Land Use, Land Use Change and Forestry sector offsets about 12% of the country's greenhouse gas emissions. Approximately 80% of the country's terrestrial biodiversity exists in forests, and more than 300 million people have a high dependency on the forest for their livelihood [8]. The NDCs targets aims to create2.5-3 Billion tons of carbon sinks by 2030. The carbon sink creations are articulated by a series of programs like the national afforestation program, national green India mission, green highway mission and national agroforestry policy. The study estimated the total carbon stock assimilation required to meet the projected NDCs and estimated land cover required to sustain the carbon stock under both forestry and agroforestry initiatives on the basis of the Forest survey of India 2017 report [22]. The total investment appropriation for carbon sink development were estimated using green India mission estimates [23] and have been allocated to forestry and agriculture sector to get estimates of economic activity implicit in terms of sectoral output, employment and income in the existing targets.

The following twelve combinations of integrated scenarios were studied to understand the economywide impacts of the NDC and NDC plus interventions.

TABLE:1 DETAILED INTEGRATED SCENARIOS

POLICY / SCENARIO	Greening Energy Technologies (RE capacity)	Reducing Energy Intensity (EI)	Create Carbon Sink (CS)	Integrated Policy (IS)
BAU	**1. RE (158 GW)**	**4. EI**	**7. CS**	**10. (1+4+7) BAU**
NDC	**2. RE (322 GW)**	**5. EI (-33%)**	**8. CS (2 BT)**	**11. (2+5+8) NDC**
NDC plus	**3. RE (390 GW)**	**6. EI (-41%)**	**9. CS (2.50 BT)**	**12. (3+6+8) NDC plus**

*PLEASE REFER TO SUPPLEMENT 1 FOR FURTHER DETAILS ON SCENARIO CREATION

IV. SCENARIO RESULTS

The analysis reveals that all three policy elements of climate change mitigation actions articulated under NDC (and NDC plus) target lead to positive impacts on economic indicators like GDP, employment, income and consumption expenditure at national level along with reduction in emissions and energy demand due to efficiency measures. Although economic growth potential associated with only renewable energy capacity addition is much less then combined scenario of incremental renewable and energy efficiency. The modelling framework captures both the impacts of increased investment in renewables along with impacts of reduction in overall capacity of power generation due to reduction in energy demand. The results are summarized in (**Table 2**) as cumulative impacts of capacity addition, efficiency improvement and carbon sink creation investments in the year 2030.

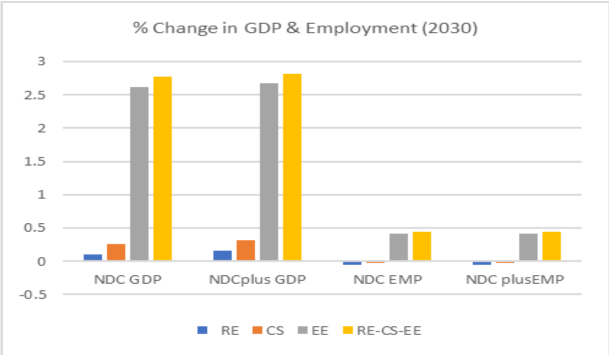
TABLE II IMPACTS OF INTEGRATED POLICY (2030)

Variable	NDC (%)	NDC plus(%)
GDP	(+) 2.77	(+) 2.81
Consumption Exp.	(+)1.74	(+)1.8
Employment	(+)0.44	(+)0.442
Income	(+)0.87	(+)0.92
CO2 Emissions	(-)6.6	(-)9.2
Electricity Use	(-)10.29	(-)10.26

* Percent change in NDC and NDC plus scenario w.r.t. BAU

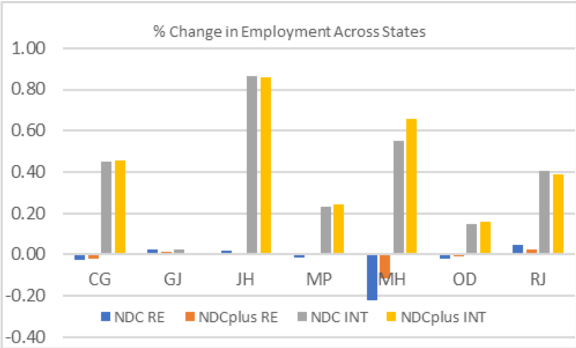
Renewable energy capacity addition and carbon sink creation will lead to an increase in overall GDP by only 0.26%-0.32 % percent whereas the efficiency integrated scenario leads to an increase in GDP of 2.7-2.8 % in the NDC & NDC plus scenario respectively as compared to BAU. The employment impacts associated with only the renewable energy and carbon sink mechanism are also marginally negative [(-0.03) to (-0.02)] when compared to the integrated scenarios which leads to 0.44% increase in employment.

FIGURE I: IMPACTS ON GDP & EMPLOYMENT



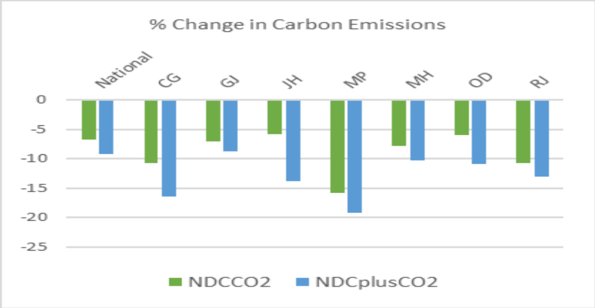
The employment trend is positive for all the states in the integrated scenarios but in case where increased renewable is not augmented by efficiency measures, we find a decrease in employments in the states of Chhattisgarh, Madhya Pradesh and Maharashtra indicating a strong need of integrated policy design for transition management.

FIGURE II: IMPACTS ON EMPLOYMENT ACROSS STATES



The analysis also reveals that most effective integrated scenarios for NDC and NDC plus scenario brings reduction in carbon emissions in the range of 7-9 %. However, potential for carbon reduction varies a lot across individual states ranging from 6-7 % for Jharkhand and Odisha to as high as 19% in 2030 for Madhya Pradesh.

FIGURE III: REDUCTION IN CARBON EMISSION



V. Conclusions

Considering the complex techno-economic and energy-economy- geographic interactions of the transition trajectory our analysis involves two frames of analysis for greater granularity and comprehensiveness

A. Socio-economic impacts of NDC and NDC plus action targets at national level

The benefits of shifting to new and more efficient and clean technologies go beyond just meeting the urgency of climate change, pollution and energy security concerns for India. Studies have already established that the existing policy targets and programs of India are well aligned to meet the Paris commitments [11,12]. Our analysis demonstrates that progressive investments for 2^0C and beyond through 2030 will also bring in greater economic benefits in terms of cumulative percent increase in GDP (2.77 & 2.81), employment (0.44) and income (0.87 & 0.92) for India under NDC and NDC plus targets. However, the three NDC action targets for India i.e. Increase in RE capacity, reduction in energy intensity & creation of carbon sinks have characteristically different economic drivers and associated socio –economic impacts. Energy efficiency scenarios with a concomitant inter-sectoral investment for efficiency improvement brings in maximum positive economic benefits. The addition of renewable capacities although an important element of the transition discourse brings in only marginal positive impacts due to greater import inputs in the economy. Aggressive NDC plus scenarios has greater implicit positive impacts for the economy so India can aim for higher commitments for climate mitigation, however aggressive commitment should include a comprehensive energy efficiency portfolio for effectively leveraging transition benefits in NDC & NDC plus scenarios.

B. Regional economic impacts associated with NDC and NDC plus targets

There exists a unique energy-economy-geography interlinkage which will define the distributional impacts of energy transitions across Indian states. The renewable capacities are located in bigger Western and Southern states while coal bearing states are smaller and less developed Eastern and central states. Many of the coal bearing states are also identified as climate hotspots. Although transition will create economic opportunities for states due to investments in renewables, efficiency and agroforestry but it will also create stranded fossil fuel assets in form of idled capacity of coal-based power generation and coal mining. An overall positive socio -economic trajectory revealed at national level thus do not translate into equal growth and development opportunity across states. We studied impacts of transition trajectory on a seven identified climate hotspot states (Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, Gujarat, Rajasthan, Gujarat, Maharashtra) including both coal bearing and high renewable capacity states. The results revealed a positive GDP impacts across all the states will not translate into similar growth in employment and income. Further, Coal Bearing states like Jharkhand, Chhattisgarh and Orissa will need to alleviate adverse impacts of transition trajectory. A balanced and just energy transition portfolio for both 2^0C and 1.5^0C targets will therefore need policy interventions at both central and state levels for reskilling and employment generation along with focus on integrated policies including renewable scale up, energy efficiency and carbon sink creation

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