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Can India grow and live within a 1.5 degree CO_2 emissions budget?

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ABSTRACT

The world of 1.5 degree C requires a global compact and action. Assuming that a fair allocation of global emissions space is made, the question arises can India live within that space? What kind of technological innovations are needed to make it possible? What would be the consequences of such a path for human welfare in India? The model has 25 goods and services and 38 alternative production activities reflecting different technologies to produce these goods or services. The model provides for social welfare measures by the government. The paper explores the consequences of different technological futures and policy regimes using a multi-sectoral inter temporal dynamic optimizing model with endogenous demand. With endogenous income distribution and 20 different consumer classes effects of heterogeneity are accounted. Reductions in costs of renewable power and batteries are stipulated based on projections by various researchers. Also targets for energy efficiency are based on past experience. The scenarios show the importance of technical progress for India can meet its human development goals within a fair emission limit.

1. Objective

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 °C. (http://unfccc.int/paris_agreement/items/9485.php). The agreement has been ratified by most of the parties to the convention. Though the INDCs pledged by the countries are not adequate to reach the target of 2 °C (Rogelj et al., 2016), the hope is that countries will make more ambitious contributions in the coming years. Even more ambitious pledges would be needed to reach the goal of 1.5 °C. In this context we explore what this implies for India.

India's INDC pledges (MoEF, 2015) http://www4.unfccc.int/Submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf) are:

- To reduce the emissions intensity of its GDP by 33–35% by 2030 from 2005 level.
- To achieve about 40% cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).
- To create an additional carbon sink of 2.5–3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.

Our earlier modeling studies have shown that these contributions are achievable (Parikh et al., 2010, 2012, 2016a) albeit with some costs using the figures for technology costs prevalent then and assuming cost reduction trends to continue. Since the renewable costs have dropped more than earlier, it is important to assess if India can grow and live within a 1.5 °C budget.

The dramatic progress that is being made in the world to increase energy efficiency and reduce costs of renewable power opens up possibilities to do so. Here we explore the following:

- What are some achievable levels of technical change by 2050. E.g. reduction ion costs of solar PV plants and batteries and increase in energy efficiency in households, buildings and transport?
- With such developments what will be the levels of emissions?
- What is a fair share of India in global carbon budget till 2050 for a 1.5 °C world? Could India live within this budget while meeting its human development goals?
- What are the implications for India's power sector, economic development and policies?

2. Review of modeling studies for climate change for India

A few modeling studies have explored India's technology options. Technology assessment using MARKAL (Fishbone and Abilock, 1981) type linear programming (LP) models have been done by many (Loulou et al., 1997; Rana and Shukla, 2001, 2003; TERI, 2006; Parikh et al.,

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2009). TERI (in MoEF, 2009) also used it for exploring emission reduction scenarios. As pointed out by Daly et al. (2015), technology explicit energy system optimization model do not correctly account for emissions from infrastructure, manufacturing, construction, transport etc.

The importance of using top-down-bottom-up model has been demonstrated by a number of studies in different countries. Decomposition of emission reduction due to low carbon technologies, change in GDP and structural shift of the economy have been explored by Nag and Parikh (2005), Fisher-Vanden et al. (1997); Mishra et al. (2014); and Fabian and Gabrial (2011). These also show that it is important to examine economic feedback effects, also called rebound effects, which can be significant. Our model accounts for such effects.

Hartwig et al. (2017) have used a bottom up- top down model to explore macroeconomic impacts of ambitious energy efficiency policy in Germany. Mundaca et al. (2015) have explored Sweden's sharp decarbonization and emissions intensity reduction using on multi-regional input-output (I/O) model.

Hienuki et al. (2015) have used I/O table to evaluate environment and socio-economic impacts of power generation technology. Chun et al. (2014) use an I/O based analysis to explore role of hydrogen in the Korean economy over a long term perspective. Mi et al. (2017) have assessed the socio-economic impact of China's CO2 emission peak prior to 2030 using an integrated optimization model of economy and climate using I/O framework. For India also Shukla and Dhar (2016) have used a soft linkage between ANSWER-MARKAL model and a CGE model to get consistency along supply, demand and resource constraints to explore India's GHG reduction and sustainable development.

3. Approach and model description

We use IRADe's multi-sectoral inter-temporal optimizing model for negotiations up to 2050 called IRADe-Neg50. It is in activity analysis framework to explore long term scenarios. The model is similar to the multi-sectoral inter-temporal optimizing model MARKAL-TIMES widely used for electricity planning, but with a number of extensions, critical for assessing the macro-economic impact and accounting for the rebound impacts. While MARKAL (Fishbone and Abilock, 1981) balances the demand and supply of electricity for each time period, IRADE-Neg50 model balances demand and supply of all goods and services for each period including electricity and energy commodities. It was developed in 2014 to provide decision support for Conference of Parties (COP) meeting held in Paris in 2015, using certain energy and resource futures acceptable to then government departments' perspectives. Even then, India promised 35–40% reduction in carbon intensity and 40% of power generation from non- fossil fuels. Merely 4 years later, renewable energy and energy efficiency have made dramatic progress and a different scenario seems within reach.

The model covers the whole economy, has endogenous income distribution with 10 income classes each in rural and urban areas and demand for all goods in the economy including electricity and energy goods based on an empirically estimated demand system (Parikh et al., 2016b) and is solved for each year simultaneously for 45 years. Demand in the model is the sum of demand by 20 different consumer classes to account for the impact of heterogeneity of consumers, the importance of which has been emphasised by a number of studies, (see Chen and Ma, 2017 and KC et al., 2017). The model permits alternative technologies to produce different goods and services as well as consumption modes to permit exploration of demand side measures. It is thus a top-down, bottom-up model in the sense that it covers the whole economy and has specific technological options in both supply and demand. The model has 25 goods and services and 38 different production activities. Of these 13 activities are for power generation including and two activities for 'other services' sector. These are listed in Annexure C. Since it covers the whole economy it is used for policies in different sectors e.g. Parikh et al. (2016a), shows its use for agricultural policy. The IRADe-Neg50 model (similar to Parikh and Ghosh, 2009) captures the characteristics considered essential by Urban et al. (2007) for models of developing countries. The model is solved as a linear programming problem using the GAMS programme (Brooke et al., 1998).

The model uses the Social Accounting Matrix (SAM) for the year 2007–08 (estimated by Pradhan et al., 2013) to represent the whole economy and the sectoral inter linkages. The SAM used in the model is aggregated to 25 commodities. Besides balancing demand and supply for each commodity, it ensures investment and savings balance and foreign exchange balance. Also production in any activity cannot exceed the created capacity, which requires investment ahead of time. Adequate balancing power for renewables from hydro or natural gas plants is also ensured. The coefficients for non-energy inputs in all production technologies change as per energy efficiency assumptions. In some technologies for example in transport the changes reflect the rate at which petroleum products get substituted by electricity and natural gas. We have not considered substitution of coal by electricity or natural gas and it is a limitation of our analysis. However, it will project higher consumption of coal than otherwise.

A mathematical description of the model is given in the Annexure A.

Our model has hard linkage between the economy and technological options for low carbon development as they are integrated in one model. Also, the feedback and demand structure changes are endogenous. Moreover, the various human development policies for housing, health, education, water and sanitation are prescribed and the resources and investments for them are given the highest priority, as most of them pertain to Sustainable Development Goals (SDG),

Whatever India does, the requirement to meet its human development goals have the first priority as these goals are non-negotiable. To achieve the targets of development thresholds, cross-country regressions of over 100 countries using UNDP and World Bank data are used to identify needed measures. Better education reduces chances of infant mortality and so on. This study (similar to Parikh et al., 2014) has assessed additional expenditures and/or the reallocation of expenditure required for various development actions and incorporated the following interventions in the scenarios.

1. To achieve the development thresholds in health (life expectancy, infant mortality), government expenditures on health and education is increased from 4% to 7% of the GDP in 2015 and, thereafter, it grows in that proportion at 7% per year. This is to ensure better outcomes in health and education.
2. The governments programmes target access to clean drinking water and sanitation to all by 2022 and provide adequate resources for them and the programmes are on track. Thus no new mechanism is added in the model.
3. The government of India has launched schemes to provide monetary support for constructing houses in rural and urban areas. The total durable housing backlog in the country has been assessed and government expenditure on these schemes has been stepped up accordingly, to provide durable housing to all by 2030. This is modelled as increased government consumption for construction.
4. India faces major shortage of electricity, with regular power cuts and lack of grid connectivity in rural areas. The model identifies the population that consumes less than one kWh of electricity per household per day (73 kWh per person per annum) and provides it with subsidized electricity to step up electricity consumption to the threshold level from 2015 onwards. Government's consumption of electricity is correspondingly increased.
5. To reduce the dependence of rural population on cow dung and fuelwood for cooking, there is a provision for 90 kg of LPG or six cylinders per year to every household, and the government buys these and provides them free of cost to poor households.
6. Direct cash transfer is identified as the best way to provide all other forms of subsidies and income transfers to the poor. Cash transfers of INR 3000 per person or roughly INR15,000 per household per year,