CLEAN DEVELOPMENT PATHWAYS FOR INDIA: EVALUATING FEASIBILITY AND MODELING IMPACT OF POLICY OPTIONS

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Overview

Sustaining rapid economic growth and satisfying increasing energy demand while limiting greenhouse gas emissions is a central challenge in India. Nearly 240 million individuals still lack access to electricity (IEA 2015) and 76% of rural households depend upon traditional biomass for their cooking needs (Saptarsh 2012). Proposed policy solutions should be evaluated according to their impacts on the energy system and the economy to identify efficient policies. We have developed an energy-economic model for India that provides a comprehensive foundation for analyzing energy technologies and policies. This novel model based on general equilibrium approach simulates the Indian economy, with detailed inter-sectoral linkages, and facilitates an understanding of economy-wide impacts of policies. The model allows for analysis of tradeoffs among different technology choices in terms of their costs and efficiency in emissions reduction.

While comprehensive carbon pricing is arguably the most economically efficient emissions reduction measure, political considerations often favor technology-specific solutions (Jenkins & Karplus 2016). To study the impact of policies that promote renewable energy, our model represents renewable electricity in great detail. Impact of incentives and scale factors are also incorporated in projecting renewables expansion. We model India's Nationally Determined Contributions (NDCs) to the Paris Agreement and compare their effectiveness, benchmarking them against the theoretical least-cost alternative of broad-based carbon pricing. Specifically, India's NDCs include targets on non-fossil capacity expansion and CO_2 emissions intensity of GDP (GoI 2015). Our model provides valuable quantitative insights on the impact of these policy measures, and fills a critical knowledge gap in the design and implementation of effective climate policies in India.

Methods

The Indian economy is represented in a general equilibrium framework through interactions between eighteen production sectors (including seven electricity types), one representative consumer, and the government. Production is described through nested constant elasticity of substitution functions, representing constant returns to scale and trading through perfectly competitive markets. The model is parametrized using GTAP Power database (Peters 2016) based on the GTAP-9 dataset (Aguiar et al. 2016). Data for India in the GTAP database is derived from the input-output tables prepared by India's Ministry of Statistics and Program Implementation.

The model is formulated as a mixed complementarity problem (MCP) (Mathiesen 1985; Rutherford 1995) in the Mathematical Programming System for General Equilibrium Modeling (MPSGE) (Rutherford 1998) and the General Algebraic Modeling System (GAMS) modeling language. The system of equations is solved using the PATH solver (Dirkse & Ferris 1995) to determine prices and quantities for all factors of production as well as goods and services produced by respective economic sectors. Solving the model for different policy scenarios involves adjustment of relative prices as economic activities adjust to reach new equilibrium that meets the policy constraints at least cost.

Results

We simulate three policy scenarios for India in 2030 compared to reference case with no policy contraints. The policy scenarios include (1) introducing an economy wide emissions intensity constraint, (2) introducing a non-fossil electricity target in India's electricity mix in 2030, and (3) combining both emissions intensity and non-fossil capacity targets. Compared to reference, the cost of reducing a tonne of CO_2 is lowest in the emissions intensity scenario, and higher by a factor of four in the pure non-fossil electricity target scenario (Figure 1). This resonates with economic theory's support for economy-wide emission reduction policies as being least expensive.

Emissions intensity targets result in an 18% drop in total electricity demand. As CO_2 emitting electricity sources become more expensive, non-fossil sources - particularly solar and wind - increase in the mix (Figure 2). Introducing non-fossil capacity targets leads to an additional 16% drop in total electricity demand as electricity prices increase to account for a higher share of more expensive non-fossil electricity.

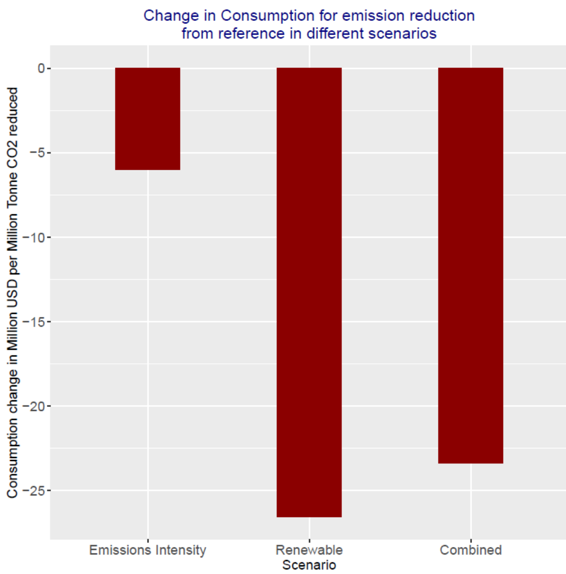

Figure 1*: Change in consumption per unit emission reduction under different scenarios in 2030*

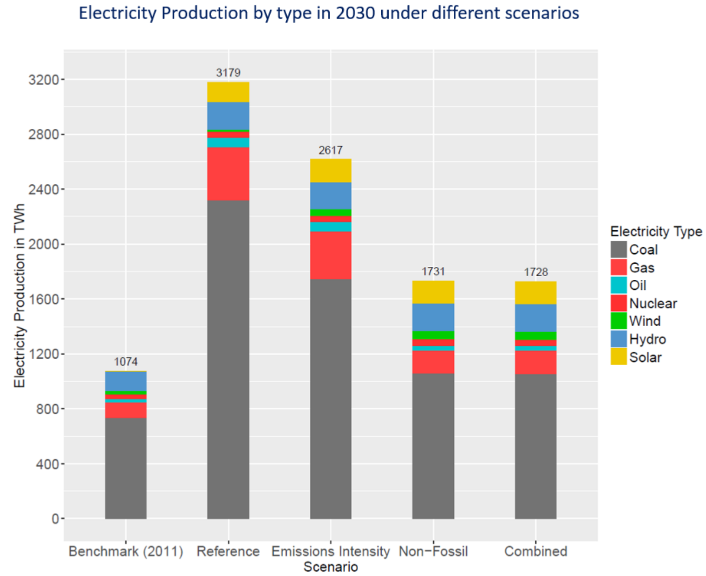

Figure 2*: Electricity Mix in India under different scenarios in 2030*

As expected, total emissions as well as emissions intensity decrease relative to the reference case in all policy scenarios (Figure 3). However, non-fossil electricity targets result in 5% higher emissions than under the emissions intensity target. As non-fossil targets directly impact the electricity price, but have little impact on other energy prices, energy intensive industries substitute expensive electricity with other energy sources (Figure 4). This further underscores the advantage of economy-wide emission policies relative to sector specific policies – which may lead to leakage of emissions.

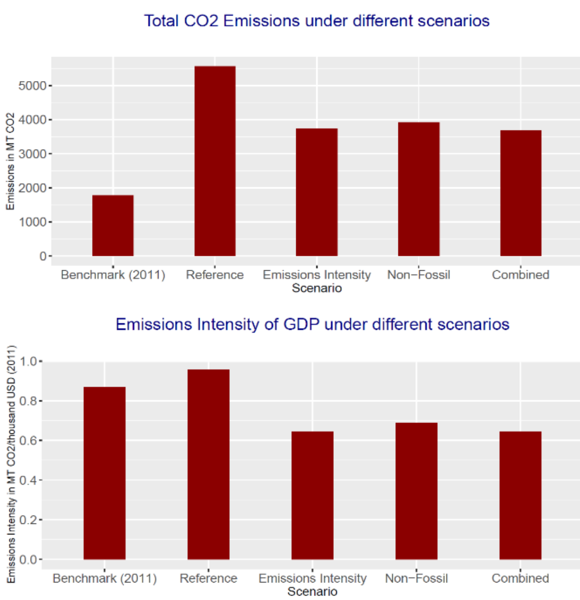

Figure 3*: Total emissions and emissions intensity in 2030 under different scenarios*

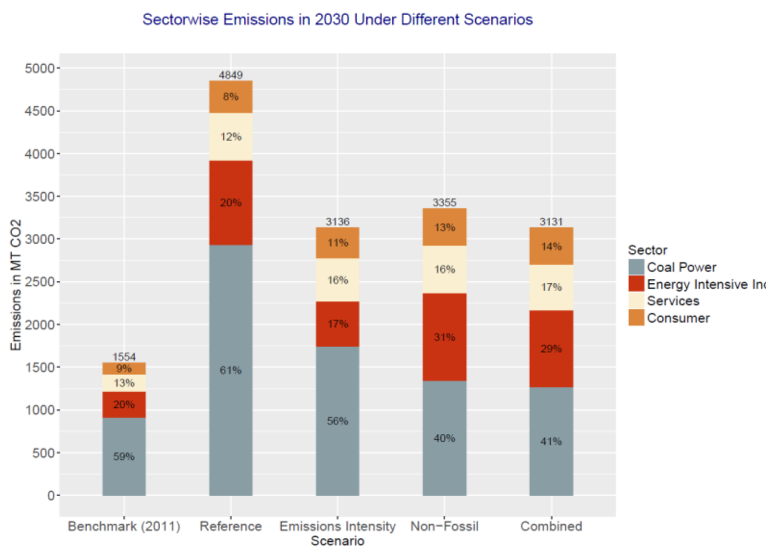

Figure 4*: Emissions by sector in 2030 under different scenarios*

Conclusion

Our results for India align with the therotical argument that economy wide targets are more efficient in achieving similar levels of emission reduction. However, in absence of political support for economy wide carbon tax, technology specific targets are favoured. Ensuring desired electricity expansion while discouraging leakage of emissions to non-electricity energy sources would require availability of cheaper non-fossil electricity.