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SOCIAL ACCOUNTING MATRIX CONSTRUCTION AND MULTIPLIER ANALYSIS

Social Accounting Matrix Construction and Multiplier Analysis

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1. An Introduction to Social Accounting Matrix

A social accounting matrix (SAM) is for a given period of time, and is a 'comprehensive representation of economic transactions between all agents in the economy' (Breisinger et al., 2009). The agents may be broadly classified into four groups, namely, productive activities, factors of production, institutions, and the rest of the world (Figure 1). The single-entry style of accounting in SAM allows for documentation of transactions made between these agents in the form of a square matrix (Hayden & Round, 1982). Each column represents the various components of expenditure of the account to which the column belongs, and each row represents the related components of income. The value in each cell of a SAM depicts the payment made by the column account and received by the row account.

Figure 1: A Social Accounting Matrix

	Production Activities	Factors	Institutions	Capital Account	Rest of the World	Total
Production activities	I-o table		Institutions' consumption	Gross fixed capital formation	Exports	Aggregate demand
Factors	Value added				Net factor income from abroad	Factor income
Institutions	Taxes on intermediary goods		Taxes, transfer payments and interest on public debt	Taxes on investment goods	Net current & capital transfer from abroad, taxes on exports	Institutions' total income
Capital account		Depreciation	Institutions' savings	Foreign savings	Gross savings of the economy	
Rest of the world						Foreign exchange payments
Total	Total cost of production	Total factor endowments	Institutions' total expenditure	Aggregate investment	Foreign exchange receipts	

Source: Pradhan et al., 2013

SAMs can be used to estimate key macroeconomic indicators such as gross domestic product (GDP), gross value added (GVA), material input intensity, labour and capital intensity, average savings rate, per capita income of households, etc. They can also serve as a database for more complex models like the multiplier and computable general equilibrium (CGE) models.

A multiplier analysis allows for the estimation of direct and induced indirect impacts of exogenous shocks on economic output. Unlike input-output tables, SAM considers the entire circular flow of income in the economy by accounting for household earnings from various sources and expenditures. So, a multiplier analysis using SAM helps in understanding the impact of changes in economic activity on household income and income inequality. The multiplier model is based on assumptions of fixed coefficients of technology and price neutrality. While the model is useful in understanding the structural set-up of an economy and short-term policy implications, the assumptions restrict long-term policy analysis.

CGE models, which also use SAMs as the primary database, allow relaxation of these assumptions and determine price endogenously. They are, therefore, able to analyse the behavioural changes in economic agents, in response to changes in economic activity, thus facilitating long-run macroeconomic policy analysis.

This note details the construction of SAM for base year 2017-18 and explains how it can be used for analysing low-carbon development scenarios in India through a simple multiplier model. The note outlines the development of SAM literature in India over time and discusses how the SAM proposed by CSTEP adds to it. It then describes the process of constructing the proposed CSTEP SAM and introduces low-carbon scenarios for analysis. It also puts forth the limitations of the exercise and the way forward.

1.1. Need for extension of SAM

A growing economy faces continuous structural changes (such as those brought about in India by the green revolution and economic liberalisation), bringing along social and economic variations that morph over time. Therefore, it is necessary to update SAMs regularly to reflect these changes for facilitating a more accurate policy analysis. For instance, if the aim is to observe distributional issues across households, then a detailed segregation of the household accounts by different socioeconomic characteristics would be useful. Further, using a SAM that places emphasis on the sectors or economic agents that are most likely to be affected by the research area, may be beneficial.

The Indian economy is likely to undergo considerable structural changes, owing to rapid increases in per capita energy use and the resulting emissions, as well as due to the international climate commitments like the nationally determined contributions (NDCs). Considering this, CSTEP has chosen the energy sector for the SAM extension exercise. It focusses on energy-policy analysis, which would require disaggregating key energy-related sectors, such as fossil-fuel production and energy generation.

2. An Overview of SAMs in India

Several SAMs are available for India. The earliest one recorded was constructed by Hiren Sarkar and S V Subbarao in 1981, who then used it as a database for a CGE model (Venkatesh & Pal, 2018). Table 1 provides an overview of the SAMs published for India, and also indicates the extent of their suitability for policy analysis.

Table 1: Published SAMs for India

S. No.	Reference	Salient features of SAM	Suitability for energy policy analysis
1.	Sarkar & Subbarao (1981)	**Base year:** 1979-80 **Sectors (3):** agriculture (1); industry (1); and services (1). **Agents:** non-agricultural-wage income class, non-agricultural non-wage income class, agricultural income class, and the government. **Factors of Production:** Labour and Capital	Limited suitability due to lack of a disaggregated energy/electricity sector.
2.	Sarkar & Panda (1986)	**Base year:** 1983-84 **Sectors (6):** agriculture (2); industry (2); infrastructure (1); and services (1). **Agents:** non-agricultural-wage income class, non-agricultural non-wage income class, agricultural income class, and the government. **Factors of Production:** Labour and Capital	Limited suitability due to the absence of a disaggregated energy/electricity sector.
3.	Bhide & Pohit (1993)	**Base year:** 1985-86 **Sectors (6):** agriculture (2); livestock & forestry (1); industry (2); infrastructure and services (1) **Agents:** non-agricultural-wage income earners, non-agricultural-profit income earners, agricultural income earners, and the government. **Factors of Production:** Labour and Capital	Limited suitability due to the absence of a disaggregated energy/electricity sector.
4.	Pradhan & Sahoo (1996)	**Base year:** 1989-90 **Sectors (8):** agriculture (2); mining and quarrying (1); industry (2); construction electricity combined with water and gas distribution and services (3). **Agents:** government, agricultural self-employed, agricultural labour, and non-agricultural self-employed and other labour.	Limited suitability due to the absence of a disaggregated energy/electricity sector.

S. No.	Reference	Salient features of SAM	Suitability for energy policy analysis
		Factors of Production: Labour and Capital	
5.	Pradhan, Sahoo, & Saluja (1999)	**Base year:** 1994-95 **Sectors (60):** agriculture (4); livestock products (2); forestry (1); mining (4); manufacturing (27); machinery and equipment (6); construction (1); electricity (1); transport (2); gas and water supply (1), other services (11). **Agents:** government, agricultural self-employed (rural and urban), non-agricultural self-employed (rural and urban), agricultural wage earners (rural and urban), other households (rural and urban), private corporate, and public non-departmental enterprises. **Factors of Production:** Labour and Capital	Limited suitability since the base year needs to be updated.
6.	Pradhan, Saluja, & Singh (2006)	**Base year:** 1997-98 **Sectors (57):** agriculture (4); livestock products (2); forestry (1); mining (1); manufacturing (27); machinery and equipment (6); construction (1); electricity (1); transport (2); gas and water supply (1); other services (11). **Agents:** the government, agricultural self-employed (rural & urban), non-agricultural self -employed (rural & urban), agricultural wage earners (rural & urban), other households (rural & urban), private corporate, and public non-departmental enterprises. **Factors of Production:** Labour and Capital	Limited suitability, since base year needs to be updated.
7.	Sinha, Siddiqui, & Munjal (2007)	**Base year:** 1999-2000 **Sectors (13):** agriculture (informal) (1); formal manufacturing (9); construction (informal) (1); other services (formal & informal) (1); and government services (1). **Agents:** rural occupations class (1), urban occupations class (4), government, and private corporations. **Factors of Production:** Labour and Capital	Limited suitability because there is no disaggregated energy/electricity sector, and the base year also needs to be updated.
8.	Saluja & Yadav (2006)	**Base year:** 2003-04 **Sectors (73):** agriculture (12); livestock products (4); forestry (1); mining (4); manufacturing (28); machinery and equipment (7); construction (1); energy (1); gas	Limited suitability due to the absence of a disaggregated energy generation sector.

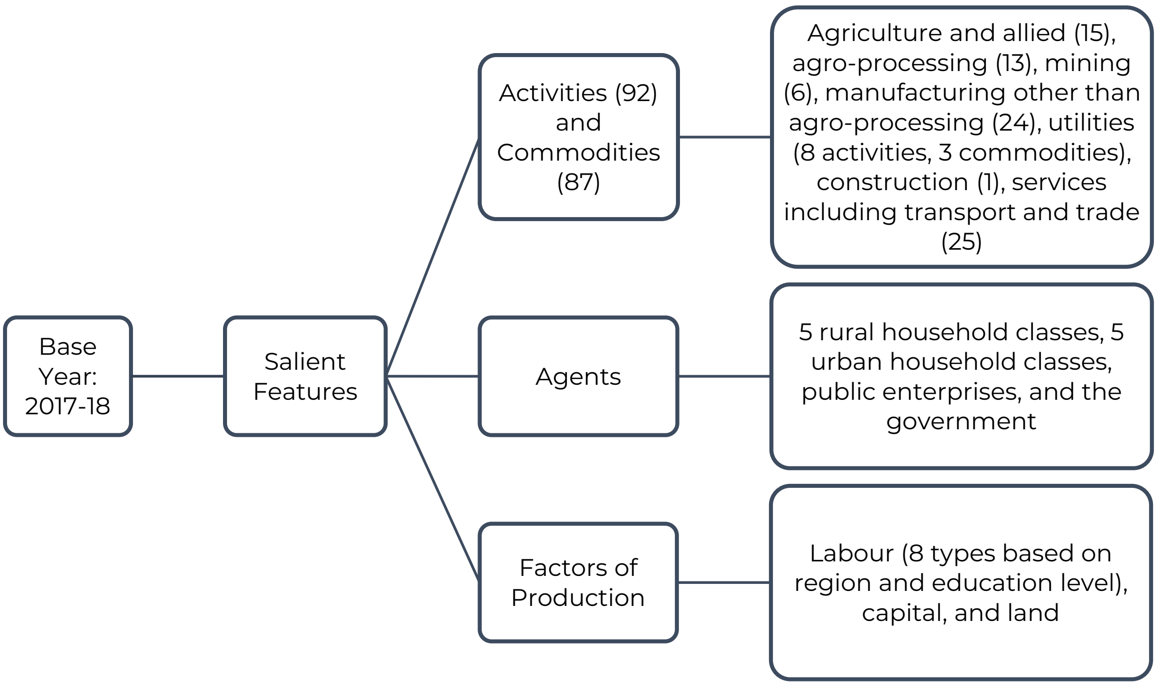
S. No.	Reference	Salient features of SAM	Suitability for energy policy analysis
		distribution (1); water supply (1); transport (2); other services (10). **Agents:** rural household expenditure class (5), urban household expenditure class (5), private corporation, public enterprises, and the government **Factors of Production:** Labour and Capital	
10	Pradhan, Saluja, & Sharma (2014)	**Base year:** 2007-08 **Sectors (85):** agriculture and allied sectors (22); mining (9); manufacturing (29); machinery and equipment (3); construction (1); electricity (1); water supply (1); transport (4); other services (18). **Agents:** 5 rural households' occupation classes, 4 urban households' occupation classes, private corporation, public enterprises and government **Factors of Production:** Labour, Capital and Land	Limited suitability, since the base year needs to be more recent
11	Pal, Pohit, & Roy (2012)	**Base year:** 2003-04 **Sectors (85):** agriculture and allied (21); mining (9); manufacturing (32); construction (1); electricity and water supply (5); transport (5); services (12). **Agents:** 5 rural household classes, 4 urban household classes, private corporate, public non-departmental enterprises, government, rest of the world. **Factors of Production:** Labour, Capital, and Land	Has energy sector disaggregation but an updated version for a more recent base year is required.
12	Pal, Pradesha, and Thurlow (2020)	**Base year:** 2017-18 **Sectors (112):** agriculture and allied (39); agriculture-based processing (18); mining (4); manufacturing other than agro-processing (24); utilities (3); construction (1); services including transport and trade (23). **Agents:** 5 rural farm household classes, 5 rural non-farm household classes, 5 urban household classes, public enterprises, rest of the world, and government. **Factors of Production:** Labour (8 types based on region and education level), 4 types of Capital, and Land	A more detailed energy sector disaggregation is useful in the case of manufacturing and utilities.

Source: Pal et al., 2012

3. The SAM Proposed by CSTEP: Approach and Process

CSTEP has attempted to construct a SAM for energy-policy analysis and simulation of low-carbon development pathways (Figure 2). Here, we discuss the SAM built by CSTEP on the basis of the SAM presented by Pal et al. (2020)—referred to henceforth as the IFPRI (International Food Policy Research Institute) SAM. The IFPRI SAM brings together data from the National Accounts Statistics, Supply-Use Table 2015-16, UN Comtrade Database 2017, and National Sample Survey 68th Round, among other sources. Although recent, it prioritises agricultural sector development, and thus, has limited relevance for the energy sector.

Figure 2: Proposed SAM (by CSTEP)



CSTEP's SAM further disaggregates the key energy-related sectors presented in the IFPRI SAM, using data from the Central Statistics Office (2020). The CSTEP SAM, therefore, emphasises disaggregation in energy generation, transmission, distribution, and energy-intensive manufacturing activities to enable a better understanding of the macroeconomic impacts of energy-related policy in India, and hence a better targeting of investment. The representation of sectoral interlinkages facilitates estimation of the spillover effects of energy-related policies arising from the interdependence of productive activities, factors, and institutions.

3.1. Data source: Annual Survey of Industries 2017-18

The key data source used by CSTEP to facilitate disaggregation of energy-related sectors is the Annual Survey of Industries (ASI) 2017-18.

The ASI is an annual country-wide sample survey of activities in the area of manufacturing, repair services, gas and water supply, and cold storage. It aims to collect data on assets and liabilities, employment and labour costs, receipts, expenses, indigenous and imported input items, products and by-products manufactured, taxes, distributive expenses, etc. It covers all factories registered under Sections 2(m)(i) and 2(m)(ii) of the Factories Act, 1948, where the manufacturing process is defined under Section 2(k) of the Act (ASI Manual 2019-20). The survey also includes electricity generation, transmission, and distribution undertakings that are not registered with the Central Electricity Authority (CEA).

3.2. Key disaggregated accounts

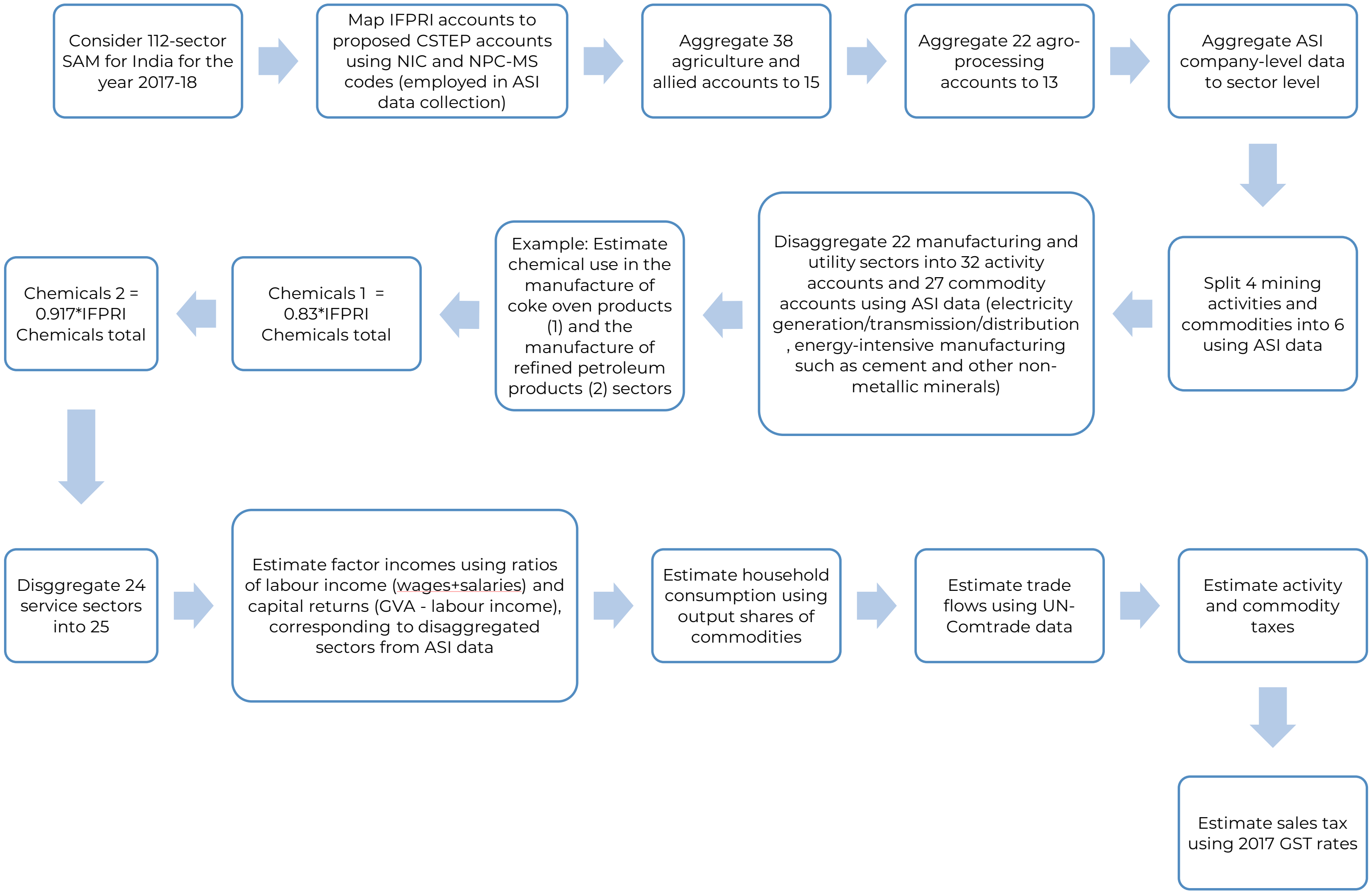
Given that the aim of the CSTEP-SAM extension was to disaggregate the energy-generation and energy-end-use sectors, it is important to understand how the energy-related sectors in IFPRI SAM were split and what each disaggregated account contains. The disaggregated accounts fall mainly within the activities related to the manufacturing sector. Ideally, those activity and commodity accounts that meet the following criteria would be split:

- it (any activity or commodity) has a high energy (thermal/electrical) footprint.
- it (any activity or commodity) has a high natural-resource footprint.
- it (any activity or commodity) has an imported-material footprint.
- it (any activity or commodity) has a high pollution externality.
- it (any sub-activity or sub-commodity) is likely to grow differently.

The IFPRI SAM contains 112 activities and 112 commodities with a one-to-one correspondence between them. The activities and commodities in the CSTEP SAM, however, do not have one-to-one correspondence due to differences in the National Product Classification (NPC) and the National Industrial Classification (NIC) code correspondence and the ASI data that was used to split the existing IFPRI accounts.

The flowchart in Figure 3 shows how the ASI (2017-18) data was used to build the CSTEP SAM.

Figure 3: SAM-extension process



4. Multiplier Analysis Using CSTEP SAM

SAMs, as constructed using the methodology outlined above, form a comprehensive dataset exhibiting the structure of the economy in the year of survey. They represent all the different sources of demand for the various commodity accounts (export, investment demand, government consumption expenditure, household consumption expenditure), as well as the complete supply chain for each. As a result, the production and consumption linkages are clearly detailed for the entire economy. A SAM forms a good basis for setting up many kinds of macroeconomic models: linear multi-sectoral ones like multipliers or complex ones like CGE models (Mainar et al., 2018). Here we outline the principles of a multiplier model that analyses various low-carbon energy policies and scenarios, using the SAM constructed (as described above).

4.1. Understanding the multiplier

A multiplier is a quantification of the entire range of economic impacts that occur due to an exogenous change in any particular variable/factor. The change will have an immediate impact on the sector that is directly affected by it. However, due to the presence of economic interlinkages, many other sectors (activities, factors, etc.) are also impacted indirectly by the initial exogenous shock. These cause spillover effects across all accounts, including those that are linked to the indirectly affected accounts. At each stage of linkage-induced impacts, the magnitude of the resulting change gets smaller and smaller. In the end, when the spillover effects become negligible, there is a total economy-wide impact that may be calculated. This is known as the multiplier effect.

For example, if demand for cement from the government rises to enable more infrastructure construction, then the cement manufacturing sector will have to step up production (for meeting this rise in demand). But to raise production, more raw material (which comes from production through other activities) is needed and this is determined by factors of production (labour and capital owned by households). This means that the supply of limestone and coal (two major inputs for cement production) must also be raised to meet the rising demand from the cement-manufacturing sector (leading to a further increase in demand for raw materials and labour). This increases household income, which, in turn, raises the demand for other commodities that are included in the household consumption mix. These effects are brought out by SAM through the representation of consumption linkages (Breisinger et al., 2009). The consumption linkages prompt the associated activities to accelerate production, which will encourage those down the supply chain to raise production as well. As a result, there is an overall rise in economic activity (and therefore in the GDP) that is greater than the initial stimulus created by the rise in cement demand from the government.

4.1.1. Size and distribution of the multiplier effect

The final size of impacts is determined by the structure of the economy (as illustrated in the SAM). The key determinants include:

1. **Household consumption-expenditure mix:** If incomes accruing to households change, household expenditure changes, and the commodities demanded are determined by the mix of commodities purchased by households.
2. **Shares of domestically produced and imported commodities in demand:** If imported goods form the larger share of total demand, then an increase in demand may not be beneficial to the domestic economy and the multiplier will be smaller.
3. **Tax on factor incomes:** This reduces a households' purchasing power and consequently the demand for commodities, reducing the size of the multiplier.

The multiplier analysis allows us to examine how these effects are distributed across the economy due to linkages of varying strengths between different sections of the economy (Round, 2003). The stronger the linkage, the bigger the resulting multiplier effect in that sector (Breisinger et al., 2009). Consumption linkage representation is an important feature that distinguishes SAMs from input-output tables and helps to improve analysis and quantification of economic impacts. Breisinger et al. (2009) found that consumption linkages account for 50-60% of total multiplier effects in Asia.

4.1.2. Key assumptions of multiplier models

The most widely used multiplier models assume Leontief production functions and allow for the estimation of what are called 'fixed-price multipliers' (Mainar et al., 2020). This means they assume that prices are fixed and there is no elasticity of substitution between factors of production. The implication is that changes in demand are met automatically by changes in output, rather than being reflected in price changes (Breisinger et al., 2009). These models also assume that factors of production are unlimited—always available to meet an increase in demand. Such models are known as unconstrained multiplier models and face the criticism of overstating the multiplier effect. CGE models allow these issues to be overcome, by relaxing the assumptions.

4.1.3. Calculating the multiplier

The multiplier is calculated using a simple matrix algebra:

$$Z = I - M^{-1}\mathrm{E}$$

where Z is total demand, I is the identity matrix, M is the coefficient matrix, and E is the vector of exogenous demand.

The coefficient matrix M is obtained by deriving the column ratios (cell value divided by column total) for each cell. For different types of accounts (activity-commodity, commodity-household, labour-activity, etc.), these reveal different kinds of information about the structure of the economy, such as the share of domestic output in total demand, the household consumption mix, and the share of labour value added in gross output. As the entire circular flow of income is represented, the multiplier (using matrices) captures all direct and indirect effects of exogenous policy shocks.

Different types of multipliers are computed for different purposes. Predominantly, output multipliers are calculated to show the final change in total output due to an initial policy shock. Employment multipliers show sector-wise change in total employment, and income multipliers show changes in total household income. For a more detailed explanation of the computation of the multiplier, please refer to '*Social accounting matrices and multiplier analysis: An introduction with exercises*' (Breisinger et al., 2009)

5. Introducing Low-Carbon Development Scenarios for Analysis

Scenarios for low-carbon development pathways can be introduced into the multiplier model by initiating a change in one or more of the exogenous demand accounts. The literature available on multiplier models indicates that there is more or less a consensus that government, investment, and export demand can be considered as exogenous variables (Bell et al., 1982; Defourny & Thorbecke, 1984; Pyatt & Round, 1985), while household demand is an endogenous variable.

5.1. India's climate goals and the energy sector

Even though its current per capita energy use and emissions is far below the global average, India is likely to see rapid increases in per capita energy use and the resultant emissions in the coming decade—driven by rising population and urbanisation.

Under the Paris Agreement, India's Nationally Determined Contributions (NDCs) consist of three key components (last updated at the 2021 UN Climate Change Conference [COP26]):

- To reduce the emissions intensity of its GDP by 45% by 2030 (from 2005 levels).
- To achieve about 50% cumulative electric power installed capacity from non-fossil-fuel-based energy resources by 2030, with financial support from developed countries and international bodies.
- To create an additional carbon sink of 2.5 to 3 billion tonnes of carbon-dioxide equivalent by 2030 through additional forest and tree cover.

India's mitigation strategies mainly include a push for cleaner energy systems. This implies a rising investment in renewable energy (RE) generation in the coming years and an increased demand for energy-efficient technologies. For example, a significant increase in investment demand from solar-, wind-, and hydro-based electricity generation sectors is expected. The SAM may be employed to assess the total economic impact of the increased RE generation on the economic activity of directly and indirectly related sectors, as well as on the distribution of factor incomes across households.

In the Intended Nationally Determined Contributions Report (MoEFCC, 2015, 2022), India laid out the key strategies planned to achieve the NDC targets. These include, among other things, a cess on coal and increased direct benefit transfer to households to encourage the uptake of cooking gas.

While India is certainly on track to achieve its NDCs (International Energy Agency, 2021), the NDCs themselves are not Paris-compliant, implying that the proposed emissions reduction does not align with the goal to keep the increase in the global average temperature at or below 1.5 degrees above pre-industrial levels. India still invests in coal, primarily to ensure reliable and adequate energy access, while developing its RE and storage potential, and reducing import dependence (Boehm, et al., 2023). These investments would have significant economic impacts. An analysis of the effects of subsidy withdrawal from fossil fuels and/or shifting of subsidies to RE (which currently receives lower subsidies) would provide crucial insights for devising policies that can aid the achievement of Paris goals.

5.2. Scenarios proposed for analysis

The scenarios proposed in this note can be broadly classified into the following four themes:

1. **Increasing fossil-fuel taxes:** Taxing the carbon content of various products is a way to discourage the production and use of emissions-intensive products, as well as to generate revenue for low-carbon development projects and schemes. The multiplier model can help in evaluating the impacts of increasing taxes on some of the most widely used emissions-intensive commodities such as fossil fuels.
2. **Increasing demand for RE:** One of the components of India's NDCs involves increasing the RE generation capacity. The multiplier model that uses the CSTEP SAM allows us to simulate the change in energy mix, where renewables account for a larger share of total electricity generated.
3. **Increasing subsidies to electricity generators/utilities:** Raising the share of renewables in electricity generation is one part of emissions reduction efforts. The distribution system must be efficient as well. Encouraging structural reforms and getting rid of inefficiencies can help electricity utilities to overcome losses incurred. In August 2021, the central government approved the Revamped Distribution Sector Scheme (RDSS), which provides the necessary financial support to utilities. On the other hand, there are numerous government schemes and subsidies that encourage solar power generation. The Jawaharlal Nehru National Solar Mission, which includes viability gap funding, as well as initiatives by central public sector undertakings, schemes to develop solar parks, the Grid-Connected Solar Photovoltaic (PV) Rooftop, and the Small Solar Power Programme are a few examples.

4. **Employing constrained multiplier model to analyse the ongoing energy crisis:** Shortage of coal can be modelled as an increase in demand. A constrained multiplier model relaxes the assumption that there are unlimited factors of production/material resources available to meet the increased demand for coal and petroleum.

Analysing the proposed scenarios can enable an assessment of the economy-wide impacts and their distribution across sectors under different low-carbon policies, which is crucial for achieving the goals of the Paris Agreement, beyond the voluntary commitments made thus far. It would help in identifying the 'winners' and 'losers' created by climate action (Mani et al., 2018) , thus facilitating appropriate allocation of policy support to ensure inclusive development alongside emissions reduction.

6. Limitations

The current CSTEP SAM disaggregates important activities that find representation in the ASI data. Ideally, there should be more disaggregation in accounts such as mining. While the disaggregation of energy-related sectors in the CSTEP SAM is significant and facilitates better policy analysis, there are some limitations to the study.

The ASI data covers only a section of all economic activities. However, for a better analysis of the impacts of energy-policy changes, the disaggregation of transport into passenger and freight; mining into coal and lignite mining; mining of metal ores into iron, aluminium, and others; and so on, is required. These can be undertaken when the relevant data becomes available.

The limitations of the multiplier model also come in here, but those can be dealt with by using non-linear modelling techniques (like CGE) that allow for relaxation in the assumptions of fixed prices and unlimited availability of factors of production.

7. Way Forward

A pertinent topic for further research could be the consideration of state-wise disaggregation of data available from the ASI to observe the inter-regional disparities that arise from various low-carbon policies. Given that the distribution of natural resources across the country is not uniform, significant insights can be obtained from the assessment of state-level dynamics that could direct both central and state climate policies more fruitfully. It would also add an extra dimension to the identification of 'winners' and 'losers' of climate action, as discussed above.

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