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On India's Electricity Consumption

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On India's Electricity Consumption

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Table of Contents

List of Figures

List of Tables

List of Tables (Appendix)

List of Abbreviations

GVA	Gross Value Added
CEA	Central Electricity Authority
CAGR	Compound Annual Growth Rate
MTOE	Million Tonnes of Oil Equivalent
ICE	Internal Combustion Engine
EV	Electric Vehicle
T&D	Transmission and Distribution
CFL	Compact Fluorescent Lamp
BLY	Bachat Lamp Yojana
PAM	Partial Adjustment Model
SUR	Seemingly Unrelated Regression
EPS	Electric Power Survey
PEUM	Partial End-User Method
ARDL	Autoregressive Distributed Lag
VAR	Vector Autoregressive
FM-OLS	Fully Modified Ordinary Least Squares
Cu	Consumption from Utilities

Abstract

This paper studies growth in electricity consumption, the key factors affecting it, and its link with economic activity. To do so, the paper discusses the major characteristics of India's power sector, and the historical trends of power consumption and economic growth, by tracing the changes over the years. The study also briefly discusses the key factors that have impacted consumption measures, including captive power, deficits, enhanced efficiency, etc. It also discusses the historical role of the manufacturing sector, the growing importance of the agriculture and household sectors, and the introduction of new and more energy-efficient technologies (such as the LED bulb), in determining power-sector outcomes. In the process, the study provides an overview of the existing relationship between energy and gross domestic product (GDP) in India, using past data and extant literature. Finally, the study conducts a time-series analysis to estimate the elasticity of energy consumption with respect to overall economic activity (using gross value added (GVA) as a measure). It finds that despite ups and downs in consumption and elasticity estimates over time, the long-term elasticity has been close to unity. Therefore, given that long-term annual economic growth is expected to be in the five–seven per cent range, India should plan for capacity increases at six–seven per cent for the next five- to ten-year horizon as it is better to err on the side of excess than shortage.

At fairly conservative growth rates we find that India will need to plan for electricity consumption levels that are approximately double of those at present, and higher than other estimates like central electricity authority (CEA). This calls for significant investments in electricity-generation capacity.

However, elasticities can change over time. India is an emerging economy, moving away from its dependence on fossil fuels. This is as a consequence of the global decarbonisation process and adding more renewable capacity. This study notes that as elasticities may change in the future, the power planning horizon should be limited to ten years, appropriate investments made in electricity-generation capacity, a constant watch kept on electricity-consumption growth, and consumption closely monitored.

1. Introduction

In a world of rapidly changing technologies, shifting consumer preferences and rising incomes, how much more energy will India need? This is a question that may not have a straightforward answer. In the case of electricity, supply-side factors (including electricity deficits, distribution bottlenecks, and poor power quality) when corrected, are expected to further impact consumption and add to the inherent uncertainty in future energy demand. Moreover, there are also data issues—some of the electricity consumption may not be adequately captured by conventional data-collection and sharing mechanisms, and data on India's gross domestic product (GDP) series post-2011 has also been questioned by some.

As technologies and preferences change, it is sometimes argued that the link between electricity consumption and economic growth may not remain as strong. In other words, growth in energy consumption and economic activity may 'decouple'. Due to a combination of technological improvements, tertiarisation of economies (especially that of developed countries), and greater reliance on manufactured imports, some countries have seen a decoupling between energy consumption and economic growth (see for instance Moreau & Vuille, 2018). Given that India has a vibrant and growing services sector accounting for the bulk of its output, it could also be construed that the energy (and electricity)-to-GDP link is weaker in India. Whether that is the case or not is an empirical question that we delve into later in this paper.

There is also some evidence that the ups and downs in the growth of electricity consumption are sensitive to the rise and fall of manufacturing-sector growth. Manufacturing has traditionally been far more energy intensive than other economic activities and if government policies are any indication, the stagnating share of the manufacturing sector in the economy may soon begin to rise. How that might impact future consumption, is also a question of interest to economic policy.

Growth in electricity consumption is not just about putting up greater capacities, but also about how it may impact India's climate goals. If indeed Indian electricity-consumption growth is expected to be relatively low, it would imply significantly greater ease in meeting climate commitments. With renewable energy constrained by higher storage costs, thermal energy continues to be a lower-cost, round-the-clock energy source. Therefore, higher electricity consumption will pose a greater challenge to meeting climate commitments.

This paper explores these questions with the available evidence including data from Central Electricity Authority and received literature. Section 2 explores historical trends in electricity consumption and what they might indicate for the future. Section 3 reports results from an econometric exercise on how electricity consumption and economic activity (as measured by GVA) are linked. Finally, Section 4 concludes the study with a brief discussion on how much consumption can be expected to grow in the near future, and how much capacity increase India must plan for.

2. Trends in Electricity Consumption

This section examines observed aggregate trends in power consumption and discusses factors with historical relevance, such as economic growth and power consumption, the growing importance of captive power, and the changing role of manufacturing and other sectors. The section also reviews factors such as the impact of rainfall and temperature, falling electricity deficits, and increased use of LED bulbs and their impact on electricity consumption. The discussion helps set the stage for estimating the possible growth of electricity consumption in India, an exercise we conduct in later sections.

2a. Power Consumption and Economic Growth

The study of the relationship between power consumption and economic output/growth faces the classical correlation-causation problem. If increase in power consumption causes growth in output, then power is an explanatory factor of growth. But it is also clear that this process would lead to even higher demand for power. So, the broad correlation is evident but establishing causality and direction is more complex. Several factors need to be taken into consideration, including data reporting and timing, presence/absence of structural break, and time lags; and within this context the relative strengths and weaknesses of available statistical techniques.

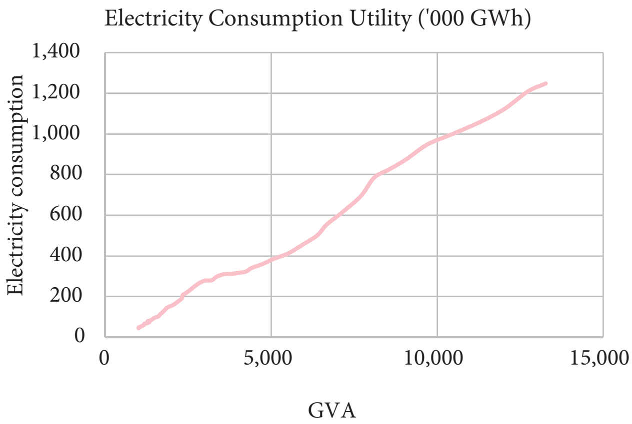
This two-way relationship has been studied extensively since Kraft and Kraft (1978). The literature summarises the relationship under four categories: Growth-led Electricity; Electricity-led Growth; Bilateral Hypothesis; and Neutrality Hypothesis. Growth-led Electricity propagates that there exists a unidirectional causality from economic growth to electricity consumption. Many empirical studies support this hypothesis including Mazumder and Marathe (2007) for India,[1] Murry and Nan (1996) for a set of developing countries, and Wolde-Rufael (2006) for Africa, among others. On the other hand, Electricity-led Growth suggests a unidirectional causality from electricity consumption to economic growth. Shiu and Lam (2004), Altinay and Karagol (2005) and, Aqeel and Butt (2001) found evidence for this hypothesis for China, Turkey, and Pakistan respectively. Studies also found that bi-directional causality between electricity consumption and economic growth existed in Malawi, Sri Lanka, Taiwan, and Korea (Awal et al., 2004; Morimoto and Hope, 2004; Yang and Jordan, 2000; Yoo, 2005). There are studies that find some evidence in sync with the Neutrality Hypothesis—that there exists no relationship between electricity consumption and economic growth (for instance, Murry & Nan, 1996).

The studies mentioned above were conducted for different countries, different periods, and using different methods. The results differ across studies not just due to the difference in the structure of the economy, location and time periods, but also due to the methodologies applied in the studies (Soytas & Sari, 2003).There is increasing evidence that in many countries, especially developed ones, there is some level of *decoupling* between electricity consumption and economic growth. The historical, strong positive association between electricity consumption and growth may thus no longer hold at higher income levels, and this may further weaken in the future (see Moreau & Vuille, 2018).

Ohlan (2018) reviewed the literature on India and posited that for India (a) there is a strong association between consumption and growth, (b) the long-run causality is from GDP to electricity consumption, (c) there is conflicting evidence on the existence of a two-way relationship (cointegration), and (d) results from such analyses are sensitive to the period under consideration (See Appendix Table A1).

Consider Figure 1, which plots the GVA (2011 prices) and electricity consumption for India (1971–2020). A strong positive relationship between the two is evident in the long run, along with some indication of a cyclicality. Whether this is merely a statistical artifact or something more real, and why that may be so, and what drives the relationship, are questions that we touch upon in later sections.

Figure 1: Plotting Electricity Consumption and GVA (1971–2000)



Source: MOSPI (2020) & CEA (2020).

Note: The electricity consumption data include data from utilities and captive generation. The data are from CMIE and sourced from Energy Statistics of India, various years, Ministry of Statistics and Program Implementation (MoSPI). Gross Value Added is for 2011 prices (also from MoSPI).

The erstwhile Planning Commission of India published a study in 2014 on electricity consumption, which provided estimated elasticities for each five-year plan (Planning Commission, 2014). It reported that elasticity estimates fell between the 3rd Plan period (5.04) and the 9th plan (0.64), but reversed direction and increased in the 10th and 11th plans (0.90 and 1.04 respectively). Note that these estimates are for a limited period of time (five-yearly plans) and use consumption data in a period of high-power deficits. These estimates are therefore susceptible to changes not only in economic activity, but also in consumption due to changes in the deficits and resultant power outages. Given that qualifier, we note that a falling long-term trend is observed till 2002, which reversed somewhat post the 9th Plan period. Though this is investigated in greater detail later, the Planning Commissions figures do not provide evidence of decoupling in India.

[1] Also Ghosh (2002) found evidence for this hypothesis for India using data from 1970–90.

Table 1: Elasticity of Electricity Consumption to GDP (1951–2021)

Period	Year	Elasticity
1st Plan	1951–56	3.14
2nd Plan	1956–61	3.38
3rd Plan	1961–66	5.04
4th Plan	1969–74	1.85
5th Plan	1974–78	1.88
6th Plan	1980–85	1.39
7th Plan	1985–90	1.50
8th Plan	1992–97	0.97
9th Plan	1997–02	0.64
10th Plan	2002–07	0.90
11th Plan	2007–12	1.04
Author Estimated*	2012–17	0.89
Author Estimated*	2017–21	1.15

Source: Planning Commission (2011).

**Note: Later values were calculated arithmetically by the authors using electricity consumption and GDP data for the years 2012–13, 2017–18, and 2021–22 from Energy Statistics of India, 2022 (MoSPI) and National Accounts Statistics. Appendix Table A2 provides the data.*

2b. Captive Power

A captive power generating plant (or CPP) is a power plant set up for generating electricity primarily (more than 51 per cent) for own use by individuals, cooperatives, companies, etc.[2] Captive power plants can be categorised into two groups—those with less than 1MW capacity and those above. There is no credible data available for the former and is believed to be quite insignificant (CEA, 2017).[3] But the share of the latter (1MW or more) in total electricity consumption has increased from around 12.1 per cent in 1973–74 to 19.1 per cent in 2001–02 and since then has fallen to 16.7 per cent in 2019–20 as seen in Table 2 below.[4] Between 2001 to 2019, the generation of power from captive power plants increased from 61,681 GWh to 1,75,000 GWh. By 2023, captive power generation is expected to increase at a compound annual growth rate (CAGR) of 5 per cent (*India Market Report*, 2020).

To understand better the role of captive power, consider three aspects. First, the electricity tariff regime applied across Indian states charges higher unit rates to industrial users to cross-subsidise retail household consumers. This high industrial/commercial-to-domestic tariff ratio is indeed peculiar to India among the developing industrial nations of Asia (Rao, 2001), as well as globally (Gokarn et al., 2022). Because of this cross-subsidy, the power supplied by utilities to commercial/industrial units is sometimes more expensive than if it was generated by a smaller, and more inefficient, captive plants.[5]

Second, the Electricity Act of 2003 had many elements that promoted the use of captive power. These included (a) the removal of CEA consent for setting up a CPP, (b) incentivising captive generation by enabling CPPs to sell excess power to third parties, providing them with the benefits of non-discriminatory open-access transmission, (c) Section 42 of the Electricity Act of 2003, which provides that surcharges and cross-subsidies levied on power from utilities shall not be levied on captive power plants generating power for self-consumption. The removal of cross-subsidy surcharges for CPPs post-2003, therefore further enhanced their viability.[6] The CPPs are thus more likely to now enhance the availability of electricity, either by limiting the reliance of their industrial customers on other grid-connected sources of power or by injecting their excess power into the grid (Mandal, 2021).

[2] The term 'own use' is for any such entity that owns 26 per cent or more of the power plant.

[3] https://cea.nic.in/wp-content/uploads/2020/04/mom_110717.pdf

[4] The data available from the CEA (Table 7, page 54, CEA 2020) is that of electricity generated by captive power plants, subtract auxiliary consumption and we obtain net generation. Net generation may then be consumed by the unit or 'exported' to the grid. Another CEA publication (Table 5.5 page 74, CEA *General Review* 2021) gives the break-up of captive power generation for the year 2020. Of the reported 239,566 GWh reported generated by captive power, 7.4 per cent is auxiliary consumption and of the remaining 92.6 per cent, 81.7 per cent is consumed by the unit and 10.9 per cent is supplied to the grid. We can safely assume that the ratio of auxiliary consumption is stable leaving greater than 90 per cent of captive power generated to be consumed in any given year. One more qualifier is that these numbers are as reported by the CPP units to the CEA and there may be some gaps in that reporting.

[5] For larger CPP, above 25 MW, the cost of electricity generation is reportedly under Rs 5/kWh, according to the type of fuel and location. State electricity tariffs on the other hand stretch to as much as Rs 8/kWh. (https://www.ceew.in/cef/masterclass/explains/captive-power-generation)

[6] Section 42 in the Electricity Act 2003, might have been an attempt to bring in more competition in the sector. The prior situation could have been that large customers putting up their captive plants might act as a disciplining mechanism on state-owned utility providers to improve their services. This, arguably, did not occur to an appreciable extent.

Table 2: Share of Captive Power (various years)

Year	Energy Generated by CPPs of 1MW & above (GWh)	Total Electricity Consumption (Utility+CPPs) (GWh)	Share of CPPs in Total Electricity Consumption (in %)
1973–74	6,067	50,246	12.1
1979–80	8,193	78,084	10.5
1984–85	12,346	1,14,068	10.8
1989–90	23,226	1,75,419	13.2
1991–92	28,602	2,07,645	13.8
1996–97	40,840	2,80,146	14.6
2000–01	59,638	3,16,600	18.8
2001–02	61,681	3,22,459	19.1
2002–03	63,850	3,39,598	18.8
2003–04	68,173	3,60,937	18.9
2004–05	71,417	3,86,134	18.5
2005–06	73,640	4,11,887	17.9
2006–07	81,800	4,55,749	18.0
2007–08	90,477	5,01,977	18.0
2008–09	99,721	5,53,995	18.0
2009–10	1,06,133	6,12,645	17.3
2010–11	1,20,917	6,94,392	17.4
2011–12	1,34,388	7,85,194	17.1
2012–13	1,44,010	8,24,301	17.5
2013–14	1,48,988	8,74,209	17.0
2014–15	1,62,257	9,48,522	17.1
2015–16	1,68,372	1,001,191	16.8
2016–17	1,72,046	1,061,183	16.2
2017–18	1,79,777	1,123,427	16.0
2018–19	2,13,074	1,209,972	17.6
2019–20(P)	2,15,000	1,291,494	16.7

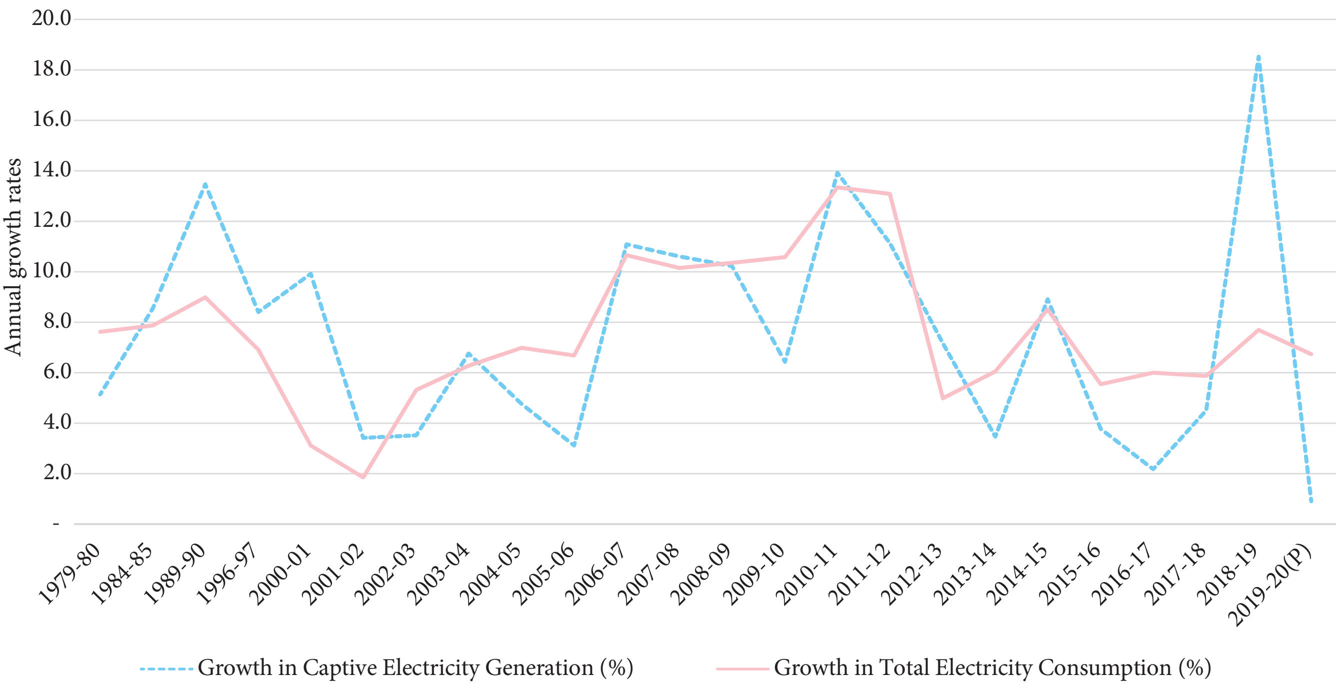
Source: CEA (2020), Table 7, p.54.

Third, there is much uncertainty in supply from the grid for many parts of India. Any discontinuity in electricity supplied by utilities contributes to production uncertainty, increases transaction costs, increases working hours and shifts for labour, and resultantly costs; consequently, reducing firm competitiveness (Nag, 2010; Ghosh & Kathuria, 2014). Such uncertainties have since reduced significantly as capacities have risen more than consumption and the power deficit has fallen in the 2000s. The large reduction in power deficits is discussed later in the text.[7]

While the first two factors discussed above provide greater incentive for large consumers to put up their own captive power plants, the third (falling deficits; discussed later in more detail) would tend to reduce the need for greater captive power. Two key insights, therefore, characterise the role of captive power. First, captive power continues to play a key role in overall electricity consumption in India and movements in captive power generation and overall electricity consumption have gone hand in hand (Table 2 and Figure 2). Second, though captive power has been growing in absolute terms, in relative terms captive as a share of total electricity consumption, stagnated in the 2000s and there is even a slight downward trend (from 19.1 per cent in 2001–02 to 16.7 per cent in 2019–20). It should also be noted that the share of captive power rose around 2000–01 before the Electricity Act, 2003 was introduced. In fact, Table 2 shows that the share of captive power didn't increase post 2003, rather it remained almost constant.

Going forward, there are three different forces that may impact the use of captive power differently (a) the differential between utility/discom prices for large customers and the cost of captive power, (b) the growth of rooftop power and micro-grids (which currently seem unlikely), and (c) the success and growth of carbon trading. While policy hurdles on the greater use of captive power are few, technological forces that will significantly determine the cost differentials are difficult to predict.

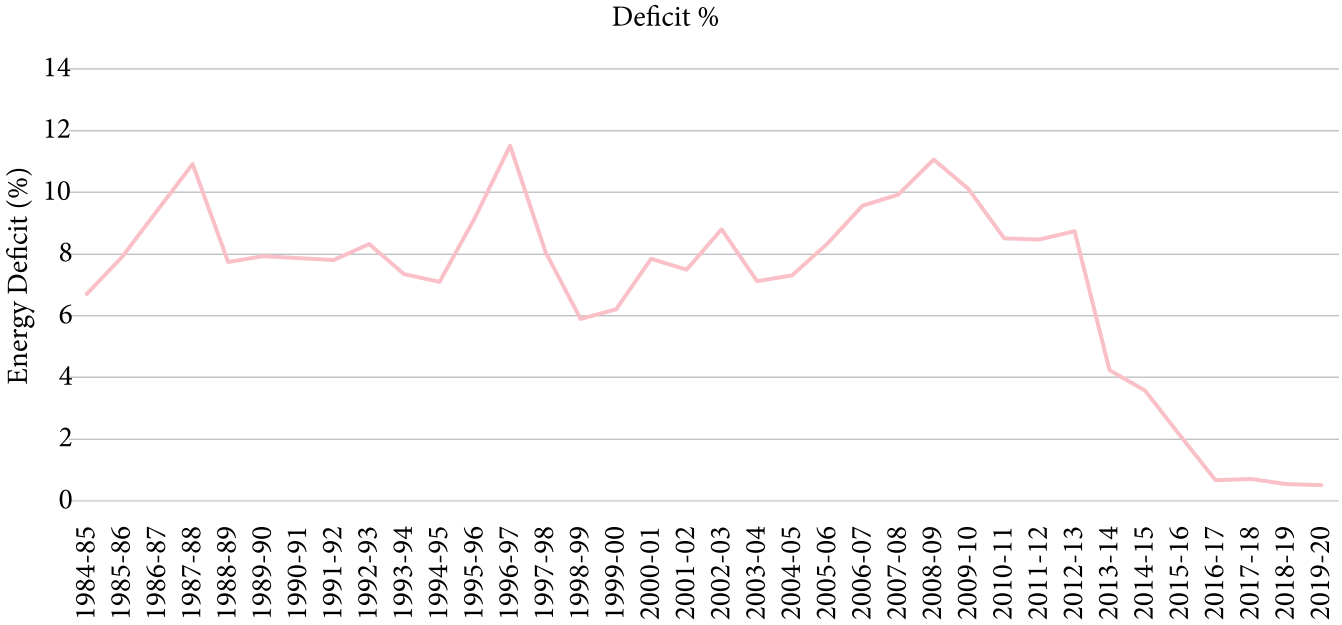
Figure 2: Annual Growth of Captive Power and Electricity Consumption in India (various years)



Source: CEA (2020).

[7] Going forward, as RE becomes more prevalent and storage becomes cheaper, it may be far more economical for large consumers of utility power to shift to cheaper captive power options. This has significant ramifications for the financial health of utilities/discoms and their ability to cross-subsidise the domestic user (Tongia & Gross, 2019).

Figure 3: All-India Energy Deficit (%)



Source: Table 8, CEA (2020).

Note: The data are estimated by CEA and draw from that reported by Discoms/utilities.

2c. Falling Deficits

As is well understood, consumption is not demand, and especially in a world of electricity shortages, data on consumption does not cover unmet demand. The CEA provides annual data on the electricity required and available, and the difference is considered to be the deficit. Power deficits have been an intrinsic part of India's economic landscape as is reflected in Figure 3 below. However, these deficits fell dramatically in the mid-2010s thanks to a significant capacity build-up in preceding years that almost completely eliminated power deficits. The decline in power deficits can be attributed to the fact that the sustained capacity addition during the 12th Plan period was much more than consumption growth during the period.

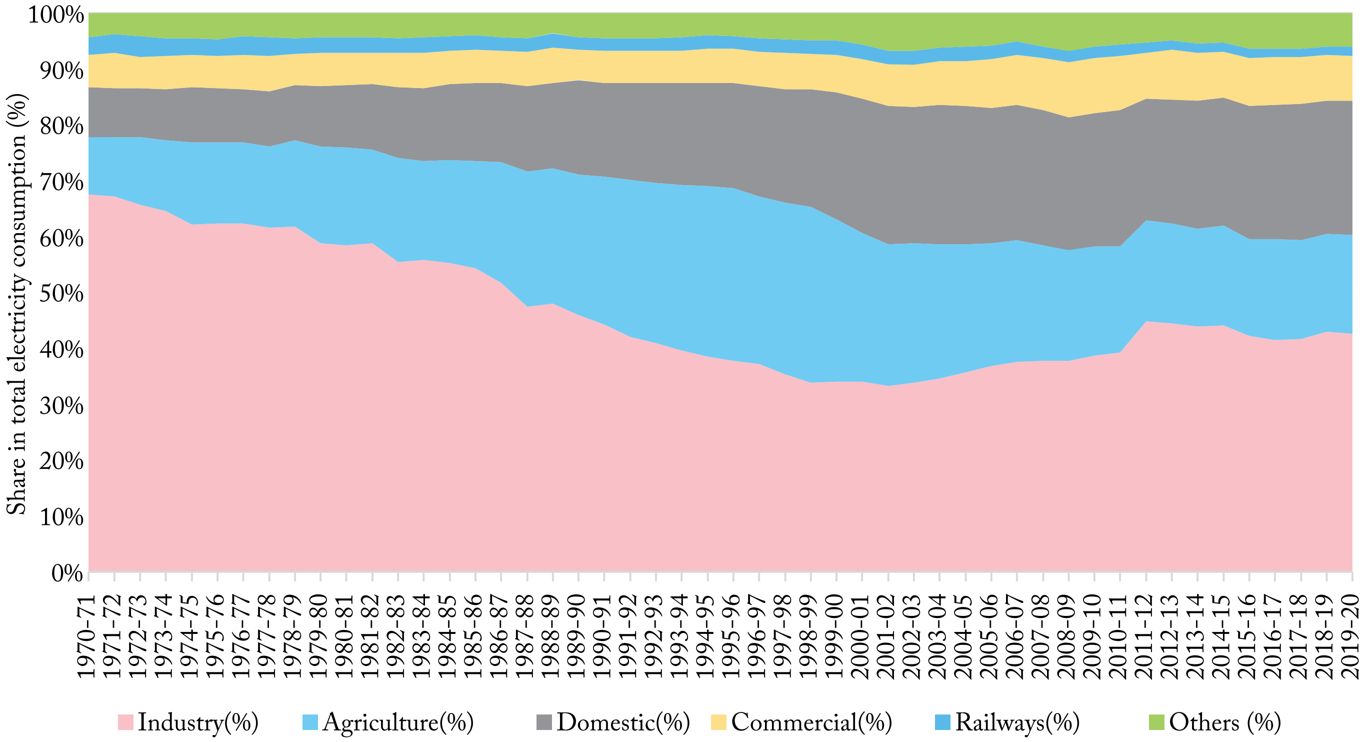
The paradigm shift in the state of power deficits in India in the 2000s has ramifications for estimates of consumption growth and its sensitivity to GDP growth. Consumption is naturally pushed downwards during times of deficits, and as deficit fell consumption would have risen up purely due to superior supply and better availability, and not because of any change in aggregate economic activity. Since many electricity consumptions studies typically do not adjust for the changes in deficits, they are susceptible to this measurement error.

There are no doubt difficulties in estimating the true deficit. Some customers may not report at all or report inadequately, others may take second-best options including using greater captive (which may also be inadequate), and yet others may change their behaviour towards non-electric options. Moreover, smaller users, who never put up captive facilities, may use diesel generators, the data for which is not captured here. Irrespective of these gaps, we believe, that deficits should be included in consumption studies that use historical data.

2d. Sectoral Shares: Role of Manufacturing

As per data from the CEA, total electricity consumption increased from 43,724 GWh in 1971 to 1,291,494 GWh in 2019–20. Throughout this period, manufacturing was the major electricity-consuming sector, though its relative share changed over time (See Figure 4 below). The share of manufacturing in total energy consumption fell steadily till 2001–02, when it was exactly a third (33.3 per cent) of the total and reversed thereafter. Compare these with Table 1, which displays elasticities as estimated by the erstwhile Planning Commission. For the 9th Plan period (1997–2002) the estimated elasticity was 0.64, and higher thereafter. A cursory evaluation, therefore, suggests that growth of the manufacturing sector may play a significant role in aggregate electricity consumption.

Figure 4: Percentage Distribution of Electricity Consumption



Source: All India Electricity Statistics (2020).

Given that manufacturing typically requires greater energy per unit output,[8] falling and rising aggregate elasticities can also therefore be explained as emanating from the relative ups and downs in manufacturing consumption. This has a significant bearing on India's future energy planning, with Make in India taking off, India may need to plan for proportionately far more energy consumption than in the past when manufacturing growth was relatively lower.

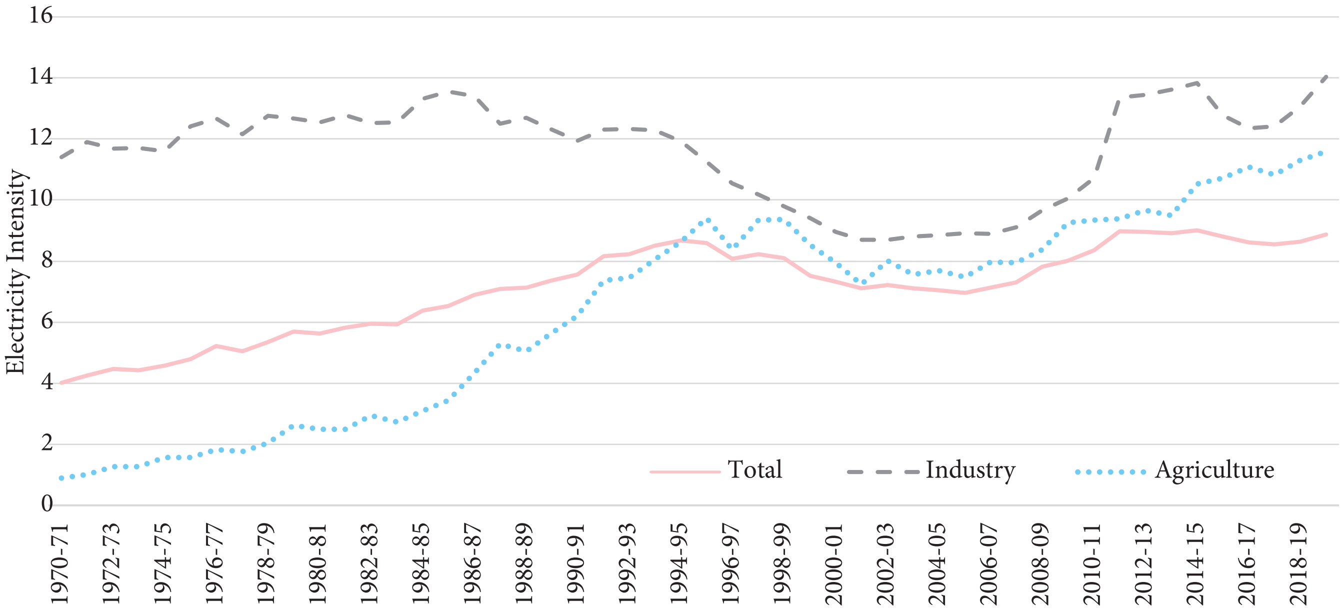
2e. Electricity Intensity in Selected Sectors

We calculate the energy intensity for the overall economy and for selected sectors, using the energy intensity definition as the total electricity consumed in that sector per unit value added. The data on energy consumed is available from the CEA and that on value-added from MoSPI. Unfortunately, the sectors of National Accounts and those from CEA's sectoral distribution don't match well, so we only look at industry and agriculture where there is some comparability (see Figure 5). The term labelled 'total' is the aggregate electricity consumption as a share of total value added for all sectors combined.

The electricity intensity of the economy as a whole more than doubled from 4.0 in 1970–71 to 8.9 by 2019–20. It increased steadily till the mid-1990s, reduced somewhat over a ten-year period between the mid-1990s and mid-2000s, and has been increasing slowly since 2011–12. The aggregate however is better understood by its components, and we find that electricity intensity has been increasing post mid-2000s for both industry and agriculture. Together these two sectors account for two-thirds of total electricity consumption, and therefore they play an important role in determining aggregate energy intensity. While the growth of electricity intensity in industry is not surprising due to the rise in capital-intensive manufacturing in recent years (see for instance Basole & Narayan, 2020; Kapoor, 2018), that of agriculture needs to be better understood. Factors, including rising aggregate temperatures, changing technologies as well as improved availability would also impact agriculture, however we leave that analysis for a later work.

[8] Of course, there exists wide variation within the manufacturing sector with basic industry typically being more energy intensive than (say) assembly-oriented units.

Figure 5: Electricity Intensity (GWh per Rs Cr Value Added 2011 Prices)



Source: Authors' calculations based on CEA(2020) and MOSPI (2020).

2f. Ongoing Structural Changes

Electricity demand in the future is likely to be very different from the current scenario due to a variety of reasons like cooling, transportation, agriculture, industry, etc; these are briefly discussed below.[9]

2f.1 Rising Manufacturing

Ali (2018) studies the attributes of expected changes in electricity-use by the manufacturing sector, including the role of several policy initiatives by the Government of India such as the National Manufacturing Policy, Make-in-India, and Perform Achieve and Trade (PAT) scheme. Biswas et al. (2020) find that the share of electricity used in the total energy need of the industrial sector will be in the range of 25–80 per cent by 2050, depending on the industry under consideration. One of the leading causes for this could be the process of decarbonisation in the industrial sector so as to achieve climate change goals (IRENA, 2018). About 220 million tonnes of oil equivalent (Mtoe) of energy was used by the manufacturing sector in 2019, which majorly came from fossil fuels that include coal, natural gas, and crude oil products (IEA, 2021). It is projected that hydrogen will eventually replace a large proportion of fossil-fuel use in industries, accounting for 15 per cent of the total energy consumed by industry by 2050. This would require the use of electricity generated from renewable energy (RE) if it is to meet environmental objectives with consequent repercussions on additional electricity demand from manufacturing (Biswas et al., 2020).

2f.2 Agriculture Mechanisation

The increasing momentum of the shift from labour-intensive to mechanised agriculture has led to greater use of both fossil fuels as well as electricity. Greater energy would be required for ploughing, planting and harvesting, irrigating, and also storage and logistics. To our knowledge, there is no study that maps each of these ongoing technology shifts with an increased need for electricity. Within these, there is significant certainty that irrigation would require greater amounts of electricity than was the case in the past. The increasing use of water pumps has been well documented by many studies and is likely to further increase in the coming decades due to mechanisation and commercialisation (TERI, 2019; Jha et al., 2012, for instance). At present, less than a third of agricultural land in India is irrigated. The bulk of the growth in irrigation has been due to the increase in water pumps. Moreover, due to the ever-increasing water requirements and groundwater use and falling water levels, the power of the irrigation pump sets used has also been increasing and will continue to do

[9] We are grateful to Rajat Verma and Monica Sharma for their contributions in this section.

so in the near future (IEA, 2021; Ali, 2018). Pumps can be powered by fossil fuels, grid power, or solar,[10] and switching to solar could reduce the drawing of power from the grid if they are stand-alone units, however total electricity requirements whether from the grid or captive, would continue to increase.

2f.3 Greater Cooling

Cooling demand is anticipated to be another key driver of electricity consumption in India in the future. As per the projections made by the India's Cooling Action Plan (MoEFCC, 2019), the number of households owning air-conditioners is expected to increase to 21 per cent in 2027–28 and 40 per cent in 2037–38. Similarly cooling requirements are also expected to increase across all productive sectors. This demand would emerge as a result of three major factors, namely, increasing average temperature due to global warming, rapid urbanisation resulting in the growing proportion of commercial and residential spaces, and increasing the purchasing power of an average Indian due to the potential increase in economic well-being (Khosla et al., 2021; Kumar et al., 2018; TERI, 2019 and IEA, 2018).

2f.4 Transport Electrification

Similarly, in the transportation sector, the Central and State governments have been incentivising the smoother transition of vehicles from traditional internal combustion engine (ICE) vehicles to electric vehicles (EVs). Moreover, public transportation is also increasingly becoming more dependent on electricity thanks to the spread of suburban and metro rail, and electrification of buses. The Indian Railways have also put in place a plan to become 100 per cent electric. All of this will increase the demand for electricity from a sector that was traditionally completely dependent on fossil fuels (see for instance, IEA, 2020).[11]

Each of the structural changes mentioned above are already underway, but most are in their early stages. Data from the past may, however, be inadequate to fully capture the potential impact of these ongoing technology-driven structural changes in the economy. Going forward using data from the past, therefore, does beg the question of whether such estimates may be lower than those operating in the future. But there is another element that is likely to have a significant impact on consumption in the future, that of climate change, which is discussed next.

2g. Impact of Changing Climate

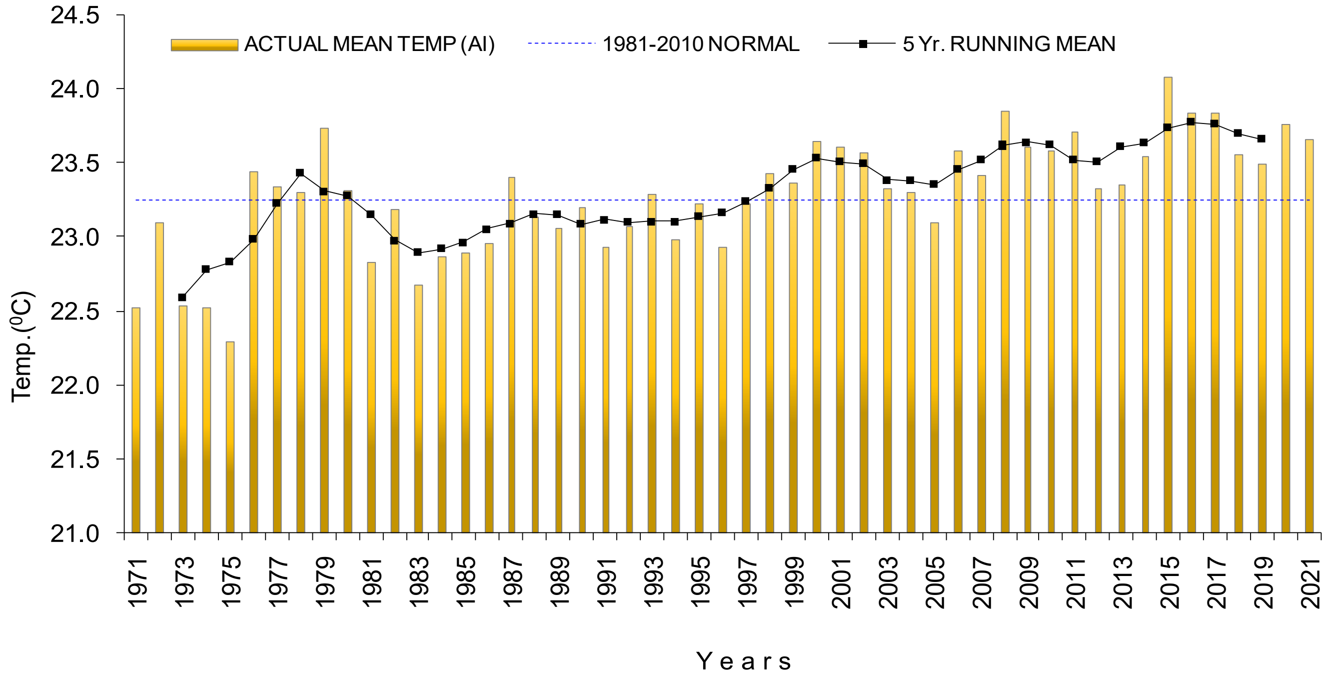
Figure 6 shows that there has been a 1-degree Celsius increase in average annual temperatures over India in the five decades spanning 1971 to 2021. Studies have attempted to establish a relationship between different weather variables—such as temperature, humidity, rainfall and, wind speed—and electricity demand (Chang et al., 2016; Kang & Reiner, 2022; Staffell & Pfenninger, 2018). The broad consensus is that the impact of temperature on electricity demand varies across geographies, depending on the role of electricity in heating or cooling and of course, the geography of the region/location being considered.

Harish, Singh and Tongia (2020) studied the change in electricity demand in response to weather shocks for India nationally, for various states, and also for a sample of Delhi households. Using aggregate India data they found that on average, aggregate electricity consumption increased by 11 per cent or more at temperatures above 30-degrees Celsius from demand at temperatures of 21–24-degrees Celsius, but with substantial heterogeneity across states. Using micro-data for Delhi household consumers, they also found that low-income consumers, especially those living in slums, showed limited incremental response to high temperatures. As the share of low-income consumers reduces over time, not only the number of total households but also the per-household sensitivity of consumption to temperature changes can, therefore, be expected to increase.

[10] It is reported that only 0.4% of the total pumps in India currently run on solar power (Agarwal & Jain, 2015, as cited by CEEW, 2018).

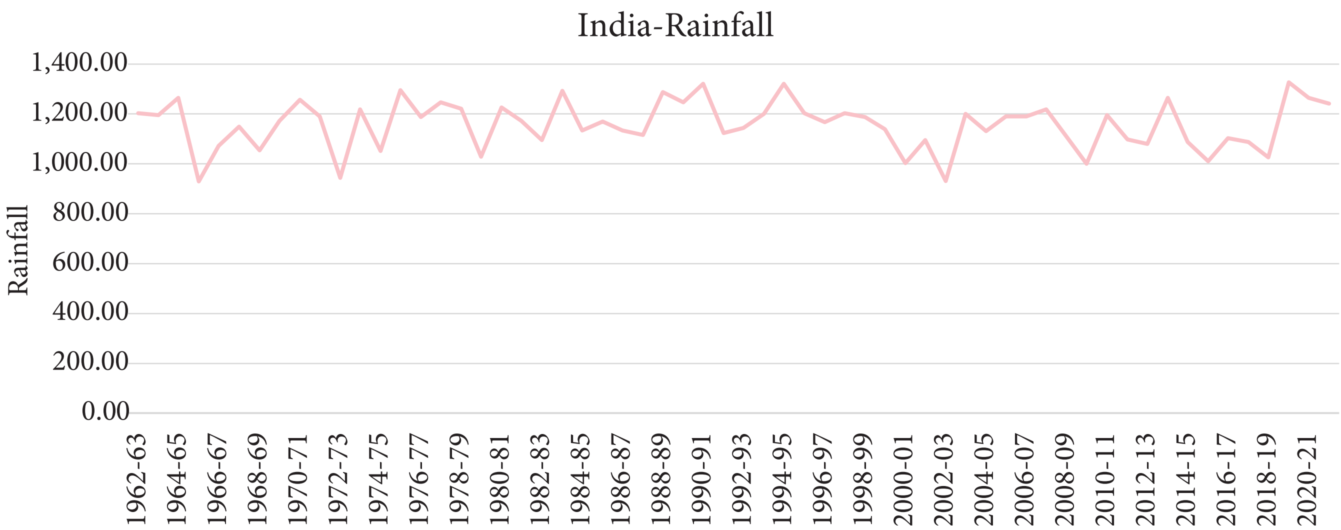
[11] Admittedly there are limits to how much such increases may be. Ali & Tongia (2018) for instance find that electricity demand from consumer EVs and city buses in 2030, cannot be more than 5 per cent of total demand even in the most optimistic case.

Figure 6: Temperature Trends for India (1970–2020)



Source: IMD (2021).

Figure 7: Rainfall (millimetre per year)



Source: CMIE (2022).

Unlike average temperatures, annual average rainfall has not seen a trending change (see Figure 7), however, there has been some increase in annual volatility. Empirical studies on the link between rainfall and electricity consumption tend to be focused on the indirect effect of rainfall on electricity consumption. This occurs via two routes, the first is the impact through lowered daytime temperatures as a result of rain, and the second is the impact of rainfall on the need for irrigation and the consequent lower use of pump sets for irrigation in agriculture. Gupta (2016), for instance, found that the higher use of agricultural pumps increases electricity demand and that greater rainfall has a significant negative impact on the use of pump sets. At the national level, however, there has been only a marginal change in aggregate annual rainfall, though volatility has no doubt increased.

2h. Efficiency Improvements

No doubt many efficiency improvements have taken place in the electricity sector. Some outcomes of these improvements, such as the fall in deficits and round-the-clock availability of power, can be expected to increase electricity consumption and have been discussed in previous sections. Some others such as the spread of LED bulbs can be expected to reduce aggregate electricity consumption. Yet others, such as the fall in transmission and distribution (T&D) losses (from 33.98 per cent in 2001–02 to 20.66 per cent in 2018–19 and expected to continue) would likely have a neutral impact, as reduced technical losses improve supply and not necessarily demand or consumption. Moreover, commercial losses, due to faulty metering, theft, etc., will lead to greater billing and not consumption per se.

2h.1 Efficiency Improvements: The Case of LED Bulbs

In 2005, the Maharashtra State Electricity Distribution Company distributed 3,00,000 energy-efficient compact fluorescent lamp (CFL) bulbs to its customers as a pilot project (see Chunekar Mulay & Kelkar, 2017). In 2009, the Central government launched the Bachat Lamp Yojana (BLY) and CFL bulbs were distributed on a national scale; about 26 million bulbs had been distributed across India by April 2012.[12] In May 2015 the Central government launched the UJALA scheme, which subsumed the BLY and switched from CFL to LED bulbs, the costs of which had fallen globally. Rapid scale-up followed and 230 million LED bulbs were sold by 2017.

As per Chunekar, Mulay and Kelkar (2017), peak electricity demand of 6 GW was saved, which was equivalent to all of the solar capacity addition in 2016. This reportedly further increased to 7.7GW of peak demand saved or about 5 per cent of the total peak demand.[13] In other words, there has been significant efficiency improvement (including for instance star ratings) that has been steadily growing in momentum throughout the mid-2010s.

Improvements in efficiency on the consumption side would no doubt tend to reduce the need for greater electricity, this arguably is likely to be overwhelmed by the need for greater power across the whole economic spectrum—both for activities currently using electricity, and those currently dependent on other sources of energy (including fossil, manual or draught animals).

3. Estimating Electricity Consumption Elasticity

3a. Other Estimates

The CEA along with consulting firm KPMG, has forecast electricity demand projection up to 2036–37 (CEA, 2019). Using a variety of methods that included a Partial Adjustment Model (PAM) and Seemingly Unrelated Regression (SUR), they estimated the elasticity of electricity consumption growth to growth in GDP. The forecasting itself required the use of these elasticities along with varying GDP growth assumptions. The data used was at the state level (for 2002/03–2015/16), and included electricity requirement (as estimated by CEA), GDP, and weather data. Among the various elasticity estimates reported, key was a long-run elasticity estimate of 0.74 using PAM. The study also compared its results with CEA's 19th Electric Power Survey (EPS) which used the Partial End-User Method (PEUM) to estimate the same. This is also a fairly detailed study that estimated electricity consumption elasticity to be in the range of 0.6 to 0.7 per year.

Given that these are CEA estimates coming out of two highly quoted studies, the relatively low elasticities need to be better understood. Since CEA studies can naturally be expected to be a key input in policy, a low estimate may translate into low build-up of capacity over the next few years. A key concern with CEA estimates is the short time period under consideration. Tongia et al. (forthcoming), for instance, rightly point to the use of data spread over a mere 14-year period, and where start and stop years matter. They argue that this makes the estimates susceptible to natural random fluctuations.

Though the CEA estimates are based on a panel of state-level data, it is not a matter of a few data points, but that of a few national-level events inordinately impacting the estimates. They show, at the all-India level, that the use of different (longer) time periods with more cognisance of outliers will lead to significantly higher elasticities. In other words, they argue that CEA elasticity—and therefore projections for India—may be too conservative.

We take the same argument further. During the period under consideration (2002/03–2015/16), there

[12] https://pib.gov.in/newsite/PrintRelease.aspx?relid=82711
[13] https://powerline.net.in/2018/04/29/affordable-lighting/

were fairly large economic fluctuations, a slowdown in manufacturing, a large increase in LED bulbs, a fall in electricity deficits contributing to an increase in consumption etc. These issues, discussed in previous sections, could lead to a downward bias in the elasticity estimates for that period. Since each of these played across India, state-level data would also be susceptible. Moreover, there is also the possibility of a two-way relationship between electricity consumption and GDP impacting elasticity estimates.

Mohanty and Chaturvedi (2015) for instance studied the causal relationship between electricity and energy consumption with economic growth for the period 1970/71–2011/12 in the Indian context. Further, they estimated the elasticity of electricity consumption on economic growth to be 0.86 via the Dynamic OLS method. Using the same, they projected the energy requirement at the end of 2016–17.

This study focuses on the same question asked by the above studies i.e., to inform India's electricity capacity addition plans, as discussed in the sections below.

3b. Data

At the risk of repetition, historical data available from the CEA on electricity consumption is impacted by a few factors that need consideration. The first is that electricity consumption data is captured by utilities and shared with the CEA, which then aggregates it. Data on captive power generation above 1MW capacity units is provided by CEA (based on self-reporting by captive power producers) and this needs to be added to the power consumed from utility (discom) supply. The resultant aggregate can then be expected to be closer to total consumption.[14]

A second aspect is related to the power deficit. Though the aggregate power deficit is fairly low in the post-2015 period, it was quite high in the pre-2010 period and, therefore, may also have impacted consumption. If the objective is to assess the electricity requirement for India, as it is in this study, we may also need to adjust for the historical power deficit. The CEA assesses the deficit through an annual exercise for which data are available from 1984–85 onwards. It does so by taking data on electricity requirements of utilities/discoms, and subtracting from it the power that was made available by them to consumers. The difference between the requirement, and the amount of electricity made available is taken to be the deficit. Note that the deficit figure does not correct for the transmission or distribution losses and may not be a perfect measure for the deficit at the consumption stage.

Data on GVA are available from MoSPI and are a part of India's National Accounts Statistics. The data used are in constant 2011 prices. It is important to note that we are using GVA instead of GDP. In the latest series, taking international practices into account, MoSPI has begun to provide GVA data as well. The difference between GDP and GVA can be accounted to the treatment of taxes and subsidy. Some taxes and subsidies have been excluded from GVA, to represent the real production side of the economy. The difference between GDP and GVA varies year to year, but in most cases remains small. We also obtained data on average daily temperature and annual rainfall from the Indian Meteorological Department.

Another issue, also mentioned above, is related to the period under consideration in that there are many ongoing deep structural changes in the economy that could have a bearing on future electricity consumption. A time period that is too short is susceptible to fluctuations, as discussed earlier, and there is also the issue of adequate data points. A time period that has a longer span solves this issue, however availability of different kinds of data for a longer duration is always an issue. Given data availability constraints, we use data from 1985 to 2020. Though annual data for consumption are available from 1970 onwards, data on deficits are available only from 1985 onwards. Moreover, given that the nature of Indian economy altered post 1991, the chosen period is apt for estimating elasticity.

3c. Methodology

In line with the Indian and global literature, we take a model where $C(Y(C), X)$ where C is electricity consumption, Y is *GVA*, and X stands for a set of exogenous factors, including weather (temperature and rainfall), economic structure (share of manufacturing in total consumption), and changing technology regimes (a dummy variable for later years taking the value 1 for 2011 and after, and 0 before). We initially

[14] Note that for a proper consumption estimate of captive power we would also require a deduction of auxiliary consumption and technical losses from the captive generation figure. Historical data for these are not available, however, they can be expected to be less than 10 per cent of the total, and remain fairly stable.

use three measures of electricity consumption, namely *Cu* (consumption from utilities), *Cup* (consumption from utility plus captive generation), and *Cupd* (consumption from utility plus captive generation plus deficit), but later focus on Cupd from 1985–2020.

Our model, with electricity consumption as a dependent as well as the independent variable, may also suffer from simultaneity bias and/or a cointegrating relationship between electricity consumption and growth. This in turn may amplify endogeneity bias using the standard OLS estimations.

Some of the literature relies on Autoregressive Distributed Lag (ARDL) models and Vector Autoregressive (VAR) models (see Ohlan, 2018, for instance). Both methodologies are useful for estimating long-term relationships allowing for structural break specifications involving longer time series. However, in the case of shorter time series, a meaningful statistical inference for models with a combination of stationary I(0) and non-stationary I(d) series is quite challenging.

We, therefore, relied on dynamic OLS (DOLS) as suggested by Stock and Watson (1993) which has enabled us to address not only the small sample challenge but also the issues related to omitted variables, simultaneity, and therefore address endogeneity issues (for instance, see Mohanty & Chaturvedi, 2014, for India; and Masih & Masih, 1996, for China). We have also applied fully modified least squares (FM-OLS) regressions as in Phillips and Hansen (1990), which enables adjustment in OLS for serial correlation and endogeneity bias in the regressors. Both set (DOLS and FM-OLS) of results are similar and are reported below.

3d. Results

As previous sections have discussed, there is no perfect measure of electricity consumption and each measure has some flaws. And therefore, we first study the elasticities using three measures of consumption *Cu* (Consumption from Utilities), *Cup* (*Cu* plus captive power generation), and *Cupd* (*Cup* plus deficit). The model used is univariate and takes the form C(Y(C)) where both the variables (C and Y) are log-transformed, the estimated coefficients, therefore, are those referred to in the discussion on elasticity below.

The appendix reports the detailed results, and Table 3 below summarises them. Overall, we find that electricity-consumption elasticity is close to unity, irrespective of the measure of consumption used. We believe this is an important result in itself. First, it puts to rest the notion that there may have been a decoupling in India. As discussed above, there are many plausible reasons why elasticities were seen to be falling, as illustrated by Planning Commission figures, and also the low CEA estimates using data for 2003–16. These ranged from the sustained fall in the share of manufacturing, to a period of economic volatility, and a fall in electricity deficits, not to mention growth in new efficiency-enhancing technologies such as the LED bulb in the 2000s. Over a longer term, however, these events aggregated out. Second, we use three plausible measures of consumption, but the elasticity is close to unity for all, this further enhances the robustness of the estimate beyond simply the econometric aspects.

Next consider the issue of whether elasticities are changing over time. Table 4 below provides summary results of different regressions where we use a dummy variable that takes the value 1 for the year 2011–12 and later, and 0 for all preceding years. We find that there is no statistical significance for this time dummy across any of the consumption measures used. In other words, while technologies are changing and greater avenues for electricity consumption are opening up, they are incorporated in the GVA measure. Moreover, elasticity estimates continue to be stable at around the unity value. In other words, there is significant stability in the estimate using data for the last three-and-a-half decades.

Table 3: Elasticity Estimates for Different Consumption Variables (1985–2020)

	DOLS			FMOLS		
	Ln Cu	**Ln Cup**	**Ln Cupd**	**Ln Cu**	**Ln Cup**	**Ln Cupd**
Ln GVA	0.99*	1.03*	0.99*	1.00*	1.03*	0.99*
Constant	-2.40*	-2.80*	-2.14*	-2.52*	-2.94*	-2.27*
N	33	33	33	35	35	35
Adj R2	0.98	0.98	0.98	0.98	0.98	0.98

*Note: *Significant at 1 per cent.*

Given that we are interested in gauging the total requirement of electricity as incomes rise in the future, using the measure *Cupd* (Consumption from utility-generated electricity, plus generation of captive power, plus deficit), we also tested whether the introduction of other variables such as temperature, rainfall, and the share of manufacturing impact elasticity estimates significantly (see Appendix Tables A3 and A4 for details). We find that none of these factors matter whether tested with a logarithmic or a linear specification (not reported). Regressions reported there also show that not only are all other independent variables statistically insignificant, but under different specifications, the elasticity coefficients also remain close to unity. In other words, the income measure (GVA) captures other developments well enough and its impact overwhelms other forces acting upon electricity consumption.

For all policy purposes, an elasticity of unity should be taken as the best measure to assess expected electricity consumption growth. Given that estimates of long-term annual economic growth range between 5–7 per cent in the foreseeable future, a similar growth can be expected in electricity consumption as well. Moreover, given that lack of electricity should not impact the process of growth itself, we would err on the side of caution, and plan for growth in electricity consumption at 7 per cent annually. Given the provisional figures for 2020, we can have a better grip on the electricity requirement for the rest of this decade.

Table 5 provides a comparison of electricity consumption projections under different growth and elasticity assumptions. We have argued above that for the next decade, given a 5–7 per cent expected growth, India should plan for a 6–7 per cent annual growth in electricity power consumption. In other words, from 1,255 TWh in 2019–20, electricity consumption is by our estimate expected to be between 2,250–2,500 TWh by 2029–30. This is a doubling of expected consumption and higher than other estimates. Spencer and Awasthy (2019) for instance using a 6.8 per cent growth rate estimate the total consumption to range between 2,040 and 2,307 TWh for the year 2030.

As per CEA (2022) estimates, a lower consumption figure for the year 2031–32 stands at 2,041 TWh. This is largely due to a methodological characteristic of the CEA's estimation process. It tends to use what it refers to as the 'Partial End User Methodology' which 'is a combination of time series analysis and End Use Method, has been used for earlier Electric Power Surveys by CEA. … Under this method, time series analysis has been done to derive growth indicators giving higher weightage to the recent trends so as to consider the benefits of energy conservation initiatives and technological changes.' (CEA, 2022)

Table 4: Elasticity Estimates for Different Consumption Measures and Time Dummy

	DOLS			FMOLS		
	Ln Cu	**Ln Cup**	**Ln Cupd**	**Ln Cu**	**Ln Cup**	**Ln Cupd**
Ln GVA	**0.93***	**0.98***	**0.99***	**0.97***	**1.02***	**1.02***
D_2011_2020	0.07	0.05	-0.03	0.04	0.01	-0.06
Constant	-1.54	-2.17	**-2.15***	**-2.06***	**-2.68***	**-2.61***
N	33	33	33	35	35	35
Adj R2	0.98	0.98	0.98	0.98	0.98	0.98

Note: Coefficients in bold are significant at 1 per cent.

Table 5: Electricity Consumption (Cupd) Projections Under Different Elasticity and Growth Assumptions (TWh)

	Elasticity = 1			Elasticity = 0.8		
GVA Growth->	**5%**	**6%**	**7%**	**5%**	**6%**	**7%**
2019–20	1,255	1,255	1,255	1,255	1,255	1,255
2024–25 (estimated)	1,601	1,679	1,760	1,526	1,586	1,648
2029–30 (estimated)	2,044	**2,247**	**2,468**	1,857	2,005	2,164
2034–35 (estimated)	2,608	3,007	3,462	2,260	2,535	2,841

Note: Consumption measure used is Cupd and includes power deficit and captive power consumption. Unit is TWh (1 TWh = 1000 GWH).

Arguably as a consequence of this methodological characteristic the CEA estimates tend to be pushed more by shorter-term momentum than by longer-term forces. Further, measures of economic activity play a lesser role in such projections as they are driven more by trends. Therefore, short- and medium-term economic factors are not feeding as well in the future estimation process. As a consequence, estimates in the past have tended to diverge from actuals as economic cycles could not be accounted for well enough.

Adding T&D losses to the consumption figure, CEA (2022) estimates electricity requirement at 2,377 TWh for 2031–32. But our estimates, after adding 10–15 per cent for T&D losses, would be significantly higher. Our moderate growth estimate at 6 per cent GVA growth, would lead to predicted consumption estimate of 2,247 TWh which would translate to a electricity requirement of about 2500 TWh after adding T&D losses.

There are two qualifiers, however. First growth in consumption does not translate linearly to comparable growth in capacity creation. This is for many reasons, (a) plant load factors for thermal power for instance have varied substantially in the past, and could be enhanced, (b) greater reliance on RE will require far greater capacity addition, as utilisation levels tend to be in the 20–25 per cent range as opposed to 50–70 per cent for thermal power and, therefore, capacity enhancement will depend significantly on the portfolio of power sources going forward, and (c) peak load power requirements if too high, may require far more capacity to service adequately.

Second, as we have argued above, given the range of economic and technology transitions underway, the link between electricity consumption and economic growth could change dramatically. But given that new power units, whether renewable or thermal (and arguably even nuclear and hydel) can be set up within that period, a ten-year planning horizon is more than adequate.

4. Concluding Note

India's electricity consumption has been growing steadily and its elasticity has been reflecting that growth. Due to the falling share of manufacturing and also other economic and technological developments, it has elsewhere been argued that electricity consumption may no longer be as sensitive to the growth process as it was in the past. We find that is indeed not the case, and the long-term elasticity to economic growth across different electricity consumption measures is close to unity.

However, other work has shown that elasticities have not remained stagnant over time. Economic and technological changes do impact consumption, and this may play out differently in the future. Indeed, agriculture is seeing a large increase in electricity consumption, manufacturing will be moving away from fossil fuel towards electricity, both through the hydrogen route and directly, and so will transport. The share of the domestic sector has also increased over the years and can be expected to increase in the future as well. Moreover, climate change-induced rise in temperature may also be expected with greater usage of air cooling. The role of captive power also increased in the past which not only reflects unreliable power supply, the impact of differential pricing, but also the changing policy stance. We also investigate the impact of the significant reduction of the electricity deficit. However, as the case of LED shows, technology changes go both ways, greater efficiencies will also dampen growth in consumption.

It is therefore quite possible that as these structural changes play out, elasticities may very well change over time. Given that it takes approximately between two to five years to put up new electricity units (barring nuclear and hydropower which tend to have a greater span of five to ten years), a planning horizon of five to ten years is all that is required. Keeping that horizon in the centre, we find that unit elasticity is an appropriate measure for electricity consumption growth. And planning for the upper end of the 5–7 per cent economic growth range, a 7 per cent growth and unit elasticity translates to approximately 2,500 TWh of electricity consumption in India by the year 2029–30.

Finally, we find that there are some data challenges emanating from the complexity of the electricity sector itself, and while the CEA data has been instrumental in enabling studies such as ours, further improvements would help in superior electricity planning. Given the deep structural changes occurring in a range of economic sectors, close monitoring of fast-emerging developments is critical for the future.

Appendix

Table A1: Review of Literature on Growth and Electricity Consumption in India

Author	Variables	Period	Cointe-gration	Long Run
Murray and Nan (1996)	EL, GDP	1970–99	No	No
Ghosh (2002)	EL, GDP	1950–97	No	GDP to Electricity
Chang et al. (2009)	EL, GDP	1971–2000	No	No
Abbas and Choudhary (2013)	EL, GDP, CO2	1972–2008	Yes	No
Bildirici (2013)	EL, GDP	1970–2010	No	GDP to Electricity
Ahmad et al. (2016)	EL, GDP	1970–2010	Yes	GDP to Electricity
Srivastava (2016)	EL, GDP	2000–13	No	GDP to Electricity
Kumari and Sharma (2016)	EL, GDP	1974–2014	No	GDP to Electricity

Source: Ohlan (2018). Note: EL=Electricity consumption.

Table A2: Electricity Consumption and Economic Activity in Recent Years (2011 Prices)

YEAR	GVA (Rs. Crore)	GDP (Rs.crore)	Electricity Consumption (GWh)
2012–13	85,46,275	92,13,017	7,08,843
2013–14	90,63,649	98,01,370	7,51,908
2014–15	97,12,133	1,05,27,674	8,14,250
2015–16	1,04,91,870	1,13,69,493	8,63,364
2016–17	1,13,28,285	1,23,08,193	9,14,093
2017–18	1,20,34,171	1,31,44,582	9,73,131
2018–19	1,27,44,203	1,39,92,914	10,37,518
2019–20	1,32,71,471	1,45,15,958	10,52,346
2020–21	1,26,81,482	1,36,87,118	10,41,656
2021–22*	1,37,98,025	1,49,25,840	11,26,030

**Provisional Figures. Source: GVA and GDP figures from NAS; and Electricity Consumption from Central Electrity Authority (CEA).*

Table A3: Elasticity Estimates and Other Factors Impacting Consumption

	DOLS				FMOLS			
	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd
Ln GVA	**0.98**	**0.99**	**1.03**	**1.01**	**1.00**	**0.97**	**1.01**	**0.99**
Share Manuf. Elect. Consumptn.	-0.37			-0.37	-0.75			-0.72
Av. Daily Temp		0.01		0.06		0.12		0.10
Annual Rainfall			0.0005	0.0008			0.0002	0.0003
Constant	**-1.81**	-2.48	**-3.41**	**-4.71**	**-2.03**	**-4.87**	**-2.77**	**-4.67**
N	33	33	33	33	35	35	35	35
Adj R2	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Source: Authors' calculation Note: LnGVA is significant at 1 per cent in all regressions. Other variables are highly insignificant.

Table A4: Elasticity Estimates and Other Factors Impacting Consumption

	DOLS				FMOLS			
	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd	Ln Cupd
Ln GVA	**0.99**	**0.99**	**1.03**	**1.02**	**1.00**	**0.97**	**1.01**	**1.00**
Ln Share of Manuf. Elect. Consumption	-0.17			-0.19	-0.29			-0.28
Ln Av. Daily Temp		0.30		1.02		2.94		2.45
Ln Annual Rainfall			0.63	0.96			0.23	0.37
Constant	**-2.30**	-3.12	-7.25	**-12.76**	**-2.69**	-11.20	-4.21	-12.90
N	33	33	33	33	35	35	35	35
Adj R2	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Source: Authors' calculation Note: LnGVA is significant at 1 per cent in all regressions. Other variables are highly insignificant.

Table A5: Correlation

	CU	CUCA	CUCAD	GVA	ELE_CON_IND	TEMP	RAINFALL
CU	1.0	1.0	1.0	1.0	0.1	0.5	-0.2
CUCA	1.0	1.0	1.0	1.0	0.1	0.5	-0.2
CUCAD	1.0	1.0	1.0	1.0	0.0	0.6	-0.2
GVA	1.0	1.0	1.0	1.0	0.0	0.5	-0.2
ELE_CON_IND	0.1	0.1	0.0	0.0	1.0	-0.2	0.1
TEMP	0.5	0.5	0.6	0.5	-0.2	1.0	-0.4
RAINFALL	-0.2	-0.2	-0.2	-0.2	0.1	-0.4	1.0

Source: Authors' calculation Note: CU= Electricity Consumption (Utility), CUCA= Electricity Consumption (Utility+Captive), CUCAD= CUCA+Deficit, GVA= Gross Value Added at 2011 base and ELE_CON_IND= Share of electricity consumed by industries.

Table A6: Electricity Required – Forecast

Requirement ('000 GWh)	6% GDP Growth	7% GDP Growth	8% GDP Growth
2022–23	1,659.98	1,675.64	1,691.30
2023–24	1,759.58	1,792.94	1,826.60
2024–25	1,865.15	1,918.44	1,972.73
2025–26	1,977.06	2,052.73	2,130.55
2026–27	2,095.69	2,196.42	2,301.00
2027–28	2,221.43	2,350.17	2,485.08
2028-29	2,354.72	2,514.69	2,683.88
2029–30	2,496.00	2,690.71	2,898.59

Source: Authors' calculation.

Table A7: Elasticity and Manufacturing

Period	Year	Elasticity	Average Manufacturing Growth
1st Plan	1951–56	3.14	5.80
2nd Plan	1956–61	3.38	6.28
3rd Plan	1961–66	5.04	6.62
4th Plan	1969–74	1.85	4.94
5th Plan	1974–78	1.88	6.47
6th Plan	1980–85	1.39	5.22
7th Plan	1985–90	1.50	6.32
8th Plan	1992–97	0.97	9.49
9th Plan	1997–2002	0.64	3.63
10th Plan	2002–07	0.90	9.54
11th Plan	2007–12	1.04	6.69
Estimated*	2012–20	1.01	6.21

Source: Planning Commission (2014).

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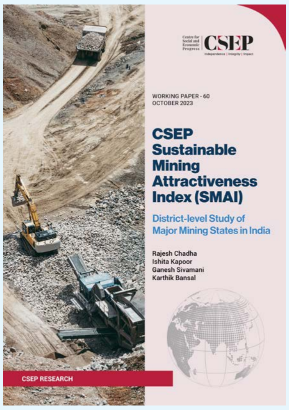

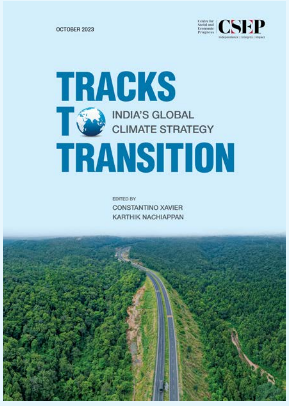

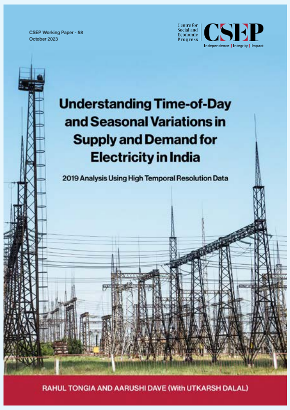

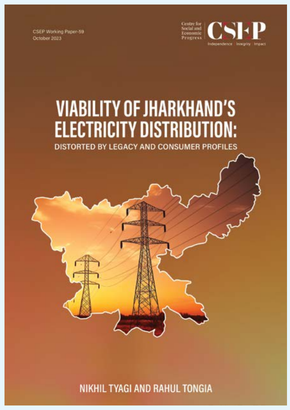

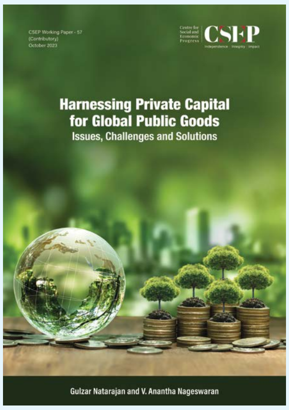

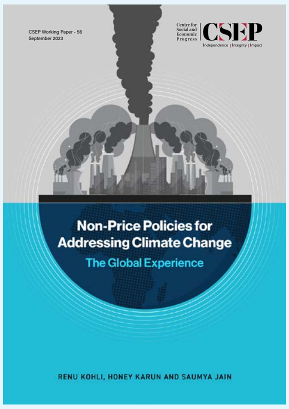

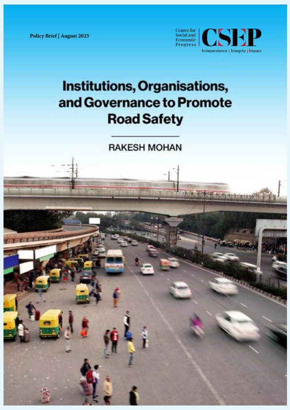

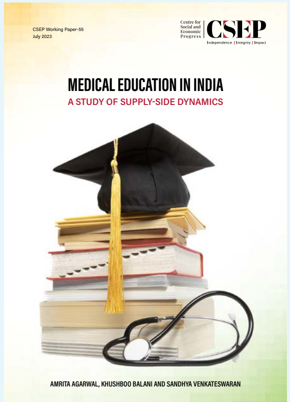

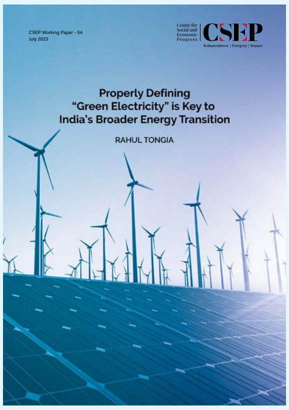

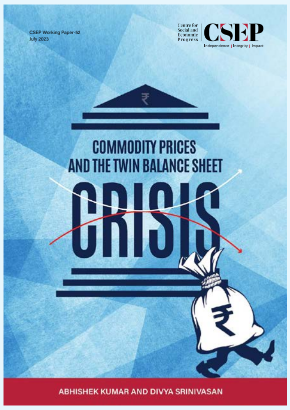

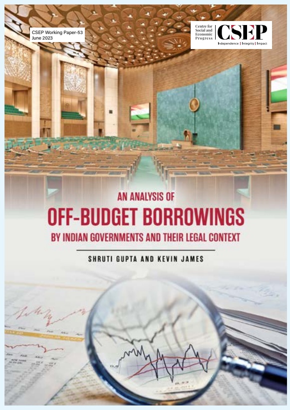

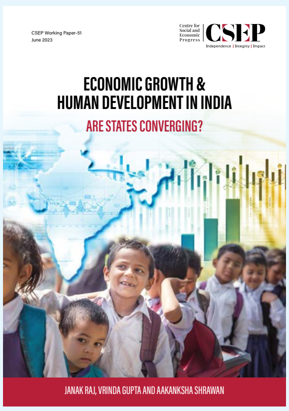

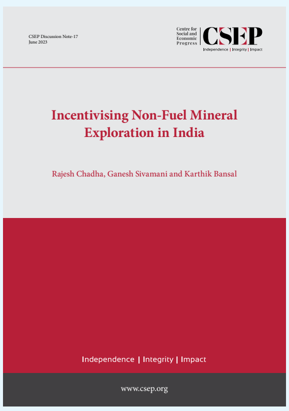

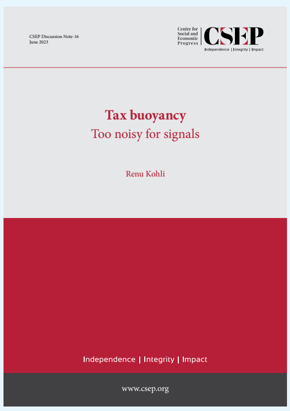

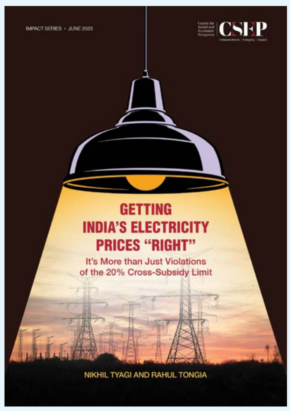

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