Electricity reforms in the economic strategy of Tamil Nadu

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Abstract

Discussions about the electricity sector have traditionally taken place within a specialised community of experts on electricity. In this paper, we broaden the discussion to look at the problems of the electricity sector in Tamil Nadu from the viewpoint of the economic growth strategy of Tamil Nadu.

Electricity investment in Tamil Nadu has faltered. Electricity availability could potentially hamper growth in coming years. Renewable electricity will become particularly important for exporting, and directly connects into the success of Tamil Nadu in exporting. There are a group of feedback loops which are playing upon the difficulties of the status quo, which are intensifying the problems of the electricity sector.

When we think of the path to a decarbonised electricity sector, a great wave of investment and risk-taking is required. This can only come from the private sector, which commensurately requires 'investibility': a trusted environment of the rules of the game which elicit their confidence. To get to this, policy makers need to grapple with the problems of under-pricing of electricity.

While there are many problems in the Tamil Nadu economy, the electricity sector looms large in making a material difference to the outcomes. We sketch a seven part feasible path to reform.

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How is the process of investments in electricity generation faring in Tamil Nadu? In order to obtain evidence on this, we turn to the CMIE Capex database. This database tracks all large projects which leave a footprint of information in the public domain, and has been in operation from 1995. It has been widely used in the research literature, e.g. in Lall, Wang and Deichmann (2010), Patnaik and Pundit (2015), Jadhav (2016), Bahal, Raissi and Tulin (2018) and Hasnat (2021). Aggregates made from this database can be traced down to micro data on a per-project level, which enhances their credibility, as opposed to the black box nature of some aggregative estimates.

While the dataset represents a sample and not a census, it is a fairly complete dataset. In the field of electricity generation, CMIE does not observe small projects such as rooftop solar. If a firm sets up a captive facility without announcing it into the public domain, this would go unobserved. We should view the CMIE data as a large subset of the underlying reality. The methods of database construction have been stable from 1995, hence the *changes* seen in summary statistics from the database are fairly reliable.

CMIE watches a project through its life cycle, from announcement, to a category called 'under implementation', to completion. Many projects may never make it up to 'under implementation'. Some projects make it up to the 'under implementation' classification and then get abandoned; the classification in the database is updated through time to reflect these developments. In order to observe growth in generation, we focus on the list of all *completed* projects in electricity generation.[1] For each of these completed projects, we observe the physical capacity (measured in watts) and the stated project cost. These two are cumulated up through time to obtain the time-series of the cumulated capacity and cumulated expenditure. To improve comparability, all rupee values are converted into constant 2024 prices. There will, of course, be changing real project costs per watt over time, e.g. as induced by the declining prices of solar panels.

Figure 1 juxtaposes the cumulated generation capacity and the cumulated cost, for Tamil Nadu vs. the total for India. In the period under examination, from 1999 to 2024, this dataset covers 300 GW of generation capacity completed on an all-India scale, which is a good subset of the overall electricity generation capacity in the country.

For India, we see a period of strong growth from about 2009 to 2017, followed by a reduced pace of growth. In the case of Tamil Nadu, there was a strong jump to about 32 GW in 2019. Within this dataset, the total project cost of all the completed projects seen was about Rs.4.2 trillion. After 2019, there has been a stagnation in generation capacity. While it is true that electricity generation investment in India has also been weak in this period, there is a greater faltering in Tamil Nadu in the post-2019 period.

There is enormous heterogeneity within India, and it is more useful to compare Tamil

[1] Many times, CMIE observes completed projects with a certain time delay. To this extent, there is a downward bias for the most recent year in these graphs.

Figure 1 Generation capacity, vs. India

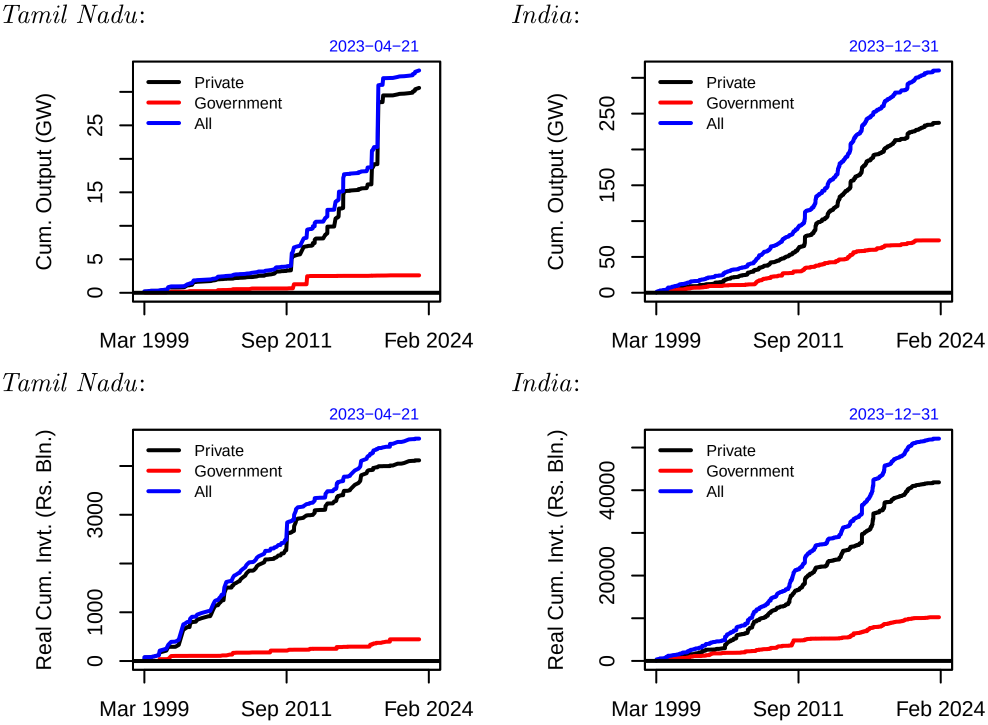


Figure 2 Generation capacity, vs. similar states

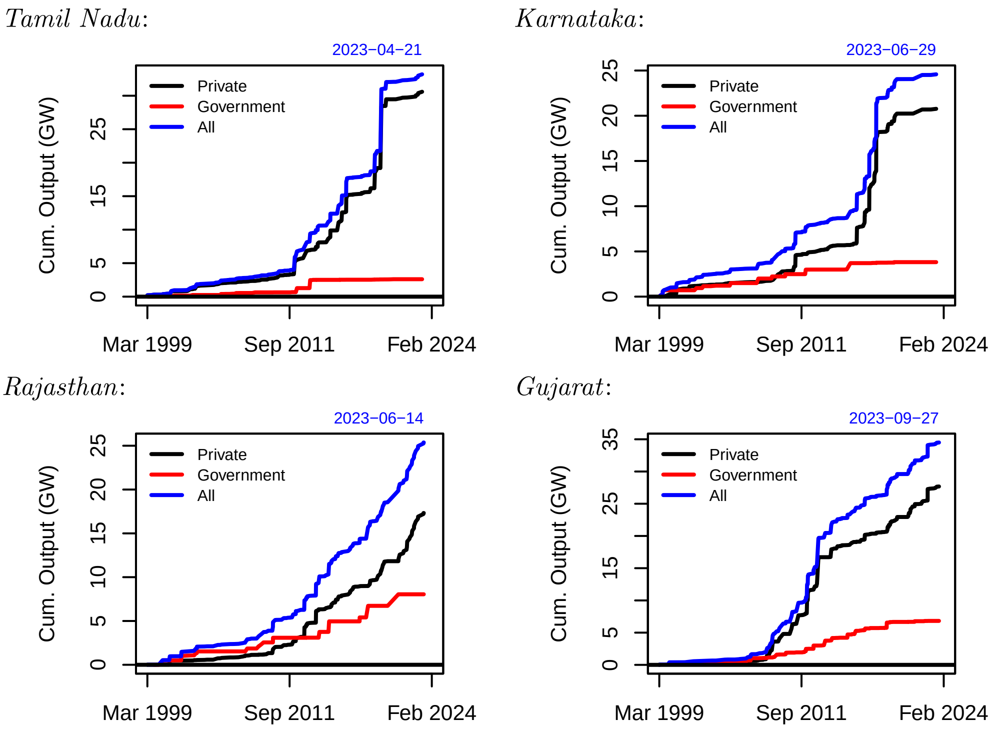
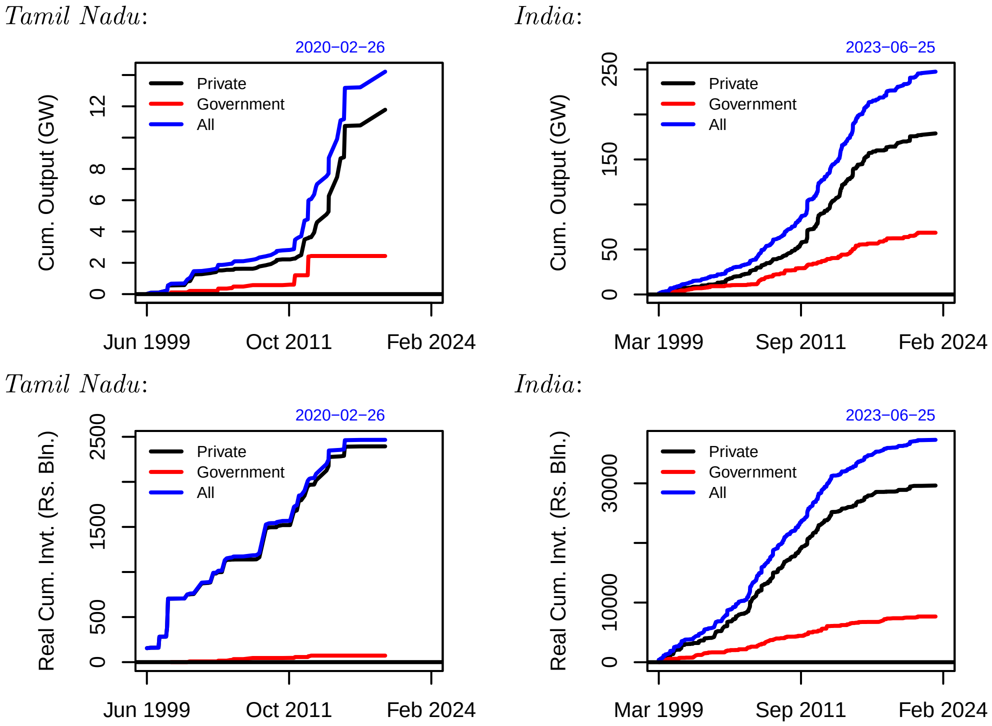


Figure 3 Fossil fuel generation, vs. India



Nadu against three relatively prosperous states: Karnataka, Rajasthan and Gujarat. This comparison is placed in Figure 2. In the case of Karnataka, the story is strikingly similar to that of Tamil Nadu, with a sharp surge in capacity going up to about 2018, followed by a stall. But there is a clear contrast with Rajasthan and Gujarat, where generation capacity has been steadily added in a linear trend.

We turn to an examination of fossil fuel generation in Figure 3. The red lines – government projects – have a bigger role here when compared with the overall. Tamil Nadu is faring relatively well on the clean energy transition, in that the last fossil fuel project was completed in February 2020. For most practical purposes, by 2016, the addition of fossil fuel capacity in Tamil Nadu had ended. At the level of the full country, there has been a greater scale of fossil fuel capacity addition, but there also, a distinct tapering of fossil fuel capacity addition is visible, reflecting a successful process of energy transition that is underway.

The four states are all faring similarly on the tapering off of the addition of fossil fuel capacity. This is seen in Figure 4, where the last plant commissioned was in 2017 (Karnataka), 2020 (Tamil Nadu) and 2021 (Rajasthan and Gujarat).

We now turn to renewable generation capacity, in Figure 5. There was a big gain in 2019 in Tamil Nadu, followed by a stall. This is different from the pattern seen on an all-India

Figure 4 Fossil fuel generation, vs. similar states

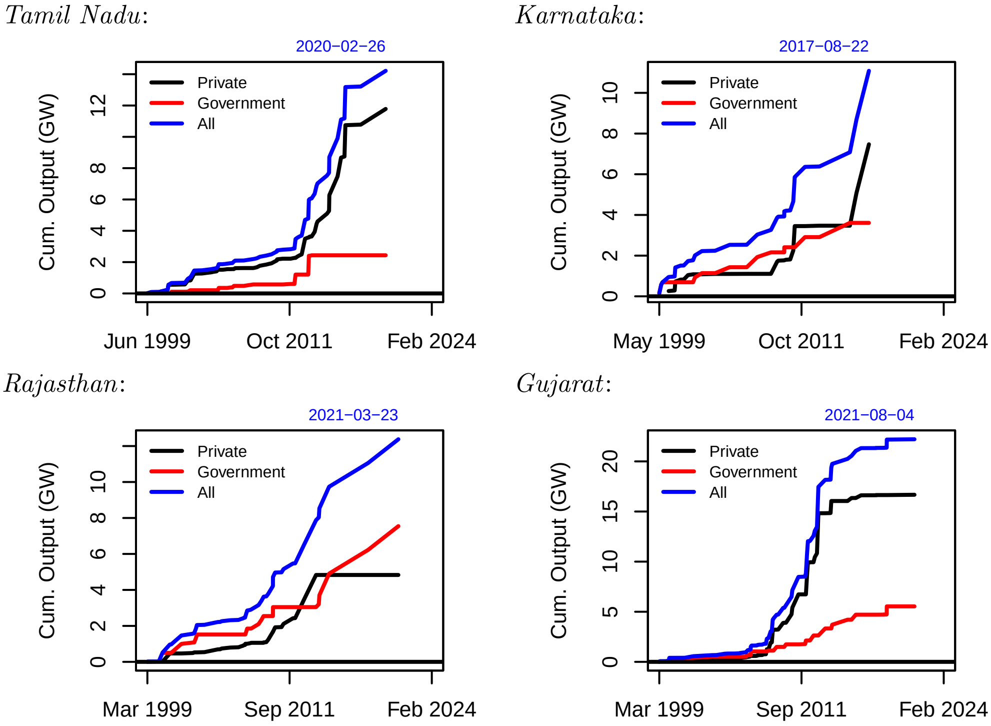


Figure 5 Renewable generation, vs. India

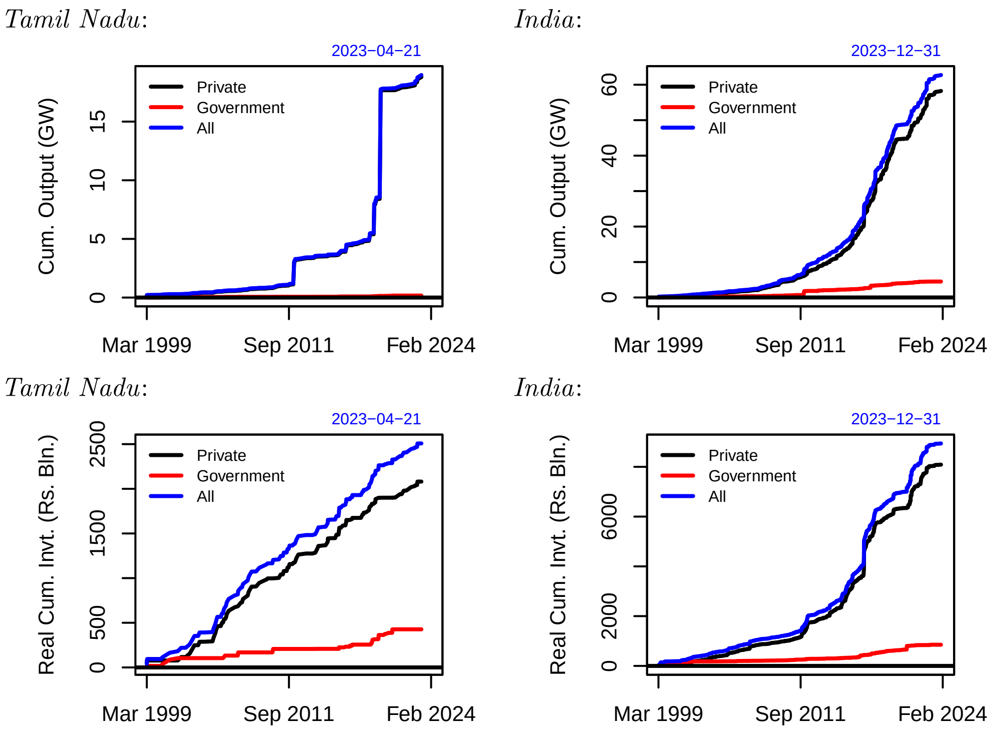
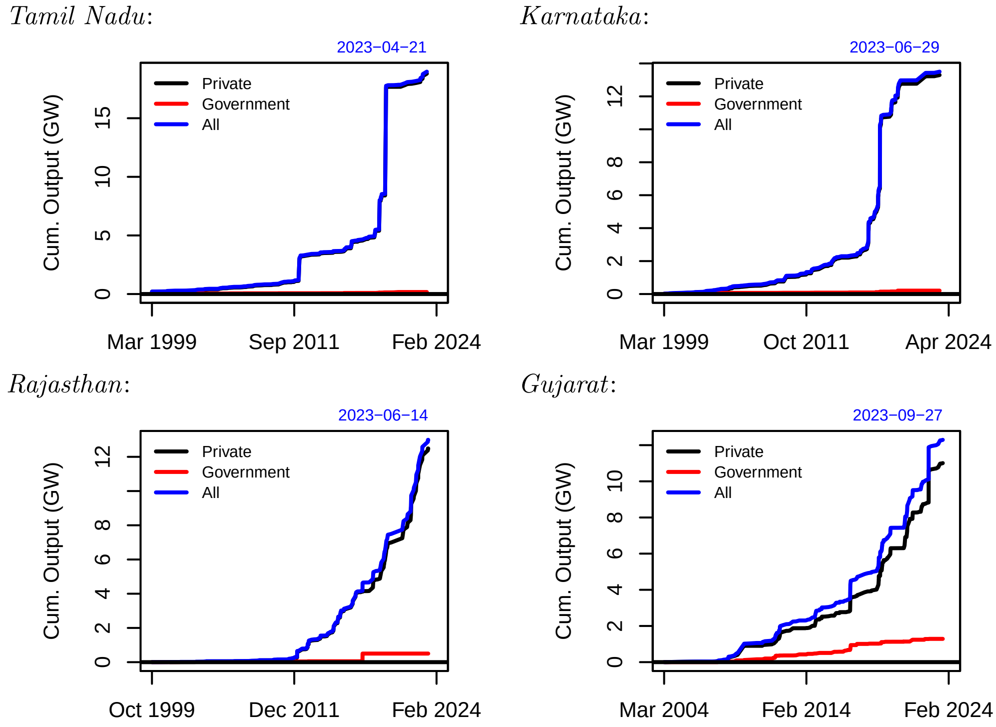


Figure 6 Renewable generation, vs. similar states



scale, where about 20 GW has been added after 2019.[2]

Finally, we compare Tamil Nadu against three states, in Figure 6. With Karnataka, there was a stall in about 2020, that is similar to what was seen in Tamil Nadu in 2019. But in Rajasthan and Gujarat, strong growth was visible.

To summarise, this evidence suggests that:

1. Tamil Nadu is at the leading edge of the clean energy transition, with no fossil fuel generation added after 2020,
2. Tamil Nadu is faring poorly on renewables capacity addition after 2019, while some peer states (e.g. Gujarat and Rajasthan) have got strong growth in this period.
3. Overall, electricity generation capacity in Tamil Nadu has not grown materially after 2019.

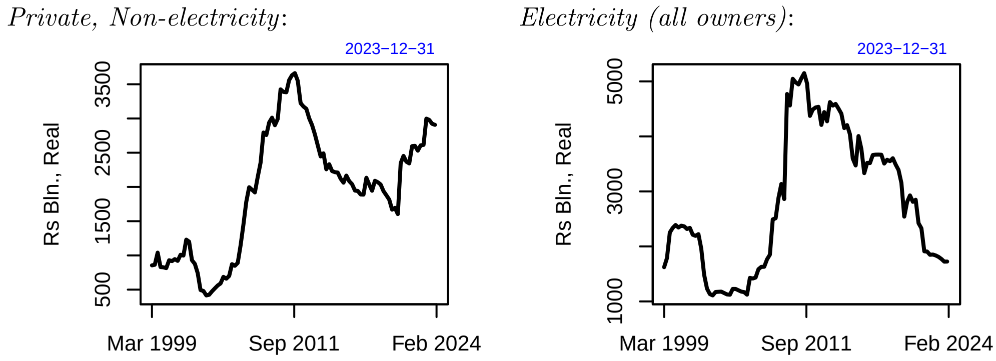
2 Electricity availability could hamper growth

A thumb rule in development economics suggests that each percentage point of economic growth in a developing country requires slightly more than a percentage point of electricity

[2]It is useful to locate these numbers in the international comparison. Using IEA data, the renewables capacity addition worldwide in calendar 2023 was 507 GW.

Figure 7 The investment underway for makers and takers of electricity in Tamil Nadu

At each point in time, we show the stock of 'under implementation' projects, expressed in 2024 rupees. The left pane shows the end-users of electricity: private non-electricity projects. The right pane shows all projects generating electricity.



consumption. Every private investment in the modern sector – factories, services firms – requires electricity. Stagnation in electricity generation in Tamil Nadu is inconsistent with the growing electricity demand that goes with economic growth (Jaitly and Shah, 2023b). In the face of difficulties in growth of electricity generation, we should examine the extent to which the growth process may outstrip the investment pipeline in the electricity sector.

So far, our analysis of the CMIE Capex database has utilised the history of project *completion* as seen there. We now turn to an examination of the stock of projects that are classified as '*under implementation*' at a point in time. While we show the history, these facts are particularly revealing when they concern the *present*. The projects that are 'under implementation' *today* will come to fruition in the coming few years. This data thus helps us understand the working of the economy in coming years. The projects that are 'under implementation' today will be completed in coming days, and demand electricity, which calls for a commensurate pipeline of electricity generation projects that are also 'under implementation'.

We think of the users of electricity, the 'takers' as private projects that are under implementation in all fields other than electricity. Alongside this, we look at the 'makers' of electricity, all projects that are under implementation in the field of electricity generation. Figure 7 shows the numbers in these two pipelines, expressed in constant rupees. The users of electricity had a sharp downturn starting in 2011, which was reversed in recent years. However, the pipeline with investment in electricity generation has declined from 2010 onwards. Some of these projects have completed, thus giving gains in the completed data (as shown in Figure 1 for example), but the pipeline has not been refilled with new 'under implementation' electricity projects. This raises concerns about the future; perhaps the investment pipeline for the takers of electricity could outstrip the addition to electricity generation capacity by the makers of electricity.

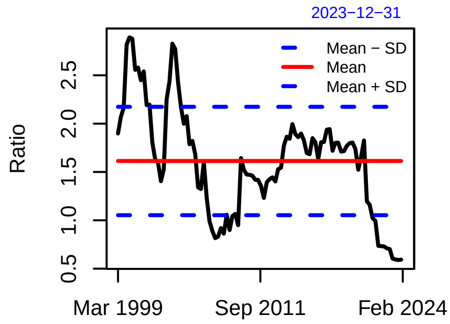
Figure 8 The Electricity Investment Intensity Ratio

At each point in time, we compute the 'Electricity Investment Intensity Ratio', which is defined at each point in time as:

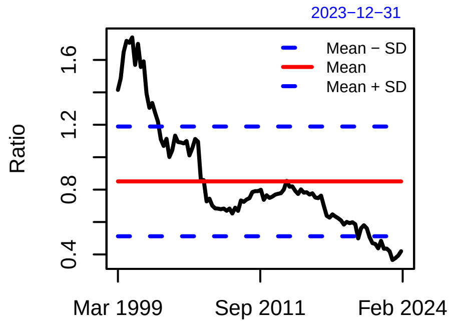
$$\frac{\text{Under implementation investment in electricity (all owners)}}{\text{Under implementation private investment in non-electricity}}$$

The time series (the black line) is superposed with the global mean and with dashed lines that are one standard deviation above and below.

Tamil Nadu:



India:



To expore this phenomenon further, we construct an 'Electricity Investment Intensity Ratio', where at each point in time, we divide the under-implementation electricity projects upon the under-implementation non-electricity projects. These two time-series are shown in Figure 8, where the global mean is superposed with bands of one standard deviation.

Based on these graph we may cautiously make a normative claim. In the Indian data, a reasonable location estimator is about 0.8. In order words, a normal configuration is one where for each Rs.1 of projects 'under implementation' in the non-electricity private sector, there should be Rs.0.8 of projects 'under implementation' in electricity generation. The comparable location estimator for Tamil Nadu is about 1.6. On one hand, the all-India evidence draws on a larger database and is more trustworthy. The development pattern of Tamil Nadu is more manufacturing-oriented, and may commensurately require more electricity; on the other hand, the declining prices of solar generation may help get the job done at a lower unit cost. Drawing on this information, we may then cautiously hold a normative estimate for the required value of the Electricity Investment Intensity Ratio for Tamil Nadu as being about 1 to 1.5.

In Tamil Nadu, the ratio has long been above the this normative range from 1–1.5. But in recent years it has dropped sharply to a value of 0.5. This suggests that the present state of non-electricity private projects under implementation may be out of sync with the present state of electricity projects under implementation.[3]

[3]We note that difficulties in the electricity are present all over the Indian landscape, and not just in Tamil Nadu. The most recent values for the Electricity Investment Intensity Ratio for India are at about 0.4, and are below the normative estimate of about 0.8. In this paper, however, we are focused on the

2.1 Electricity generation within Tamil Nadu is desirable

When electricity demand grows in Tamil Nadu, but generation within Tamil Nadu is not forthcoming, could purchases of electricity from elsewhere in India suffice? Perhaps the right organisation of the Indian electricity industry is to generate solar power in Rajasthan, or hydel power in the Himalayas, and transport this to the consumption centres like Tamil Nadu. Alternately, perhaps renewable generation could happen in Andhra Pradesh or Telangana, with transmission lines to Tamil Nadu. This is undoubtedly a sensible approach to India as a unified market and to international trade within South Asia. There are three concerns with this thought process:

1. A central problem in Tamil Nadu's electricity system is the difficulties faced by the distribution company in paying for electricity. Generation companies outside of Tamil Nadu will need to be paid. Relying on out-of-state generators will require addressing the financial difficulties within Tamil Nadu. If those financial difficulties can be solved, then it is preferable if the economic activity of electricity generation also takes place in Tamil Nadu which helps reduce losses in transmission.

2. There are capacity constraints in the transmission system which could possibly interfere with the requisite transportation of energy. Policy makers in Tamil Nadu would have to navigate the policy making process of the union government in enabling some of these investments.

3. Some state governments could sometimes use state power to interfere with the sale of electricity outside the state. As an example, Sane (2023a) examines an episode where the Karnataka government blocked the sale of electricity by generators within Karnataka to buyers outside Karnataka, even when there were contractual obligations to that effect. Jaitly, Mehta, Ranga et al. (2025) find episodes where similar events took place in Tamil Nadu also. Given the correlations of demand and supply shocks within the country, we can envision situations when other state governments exert such influences upon generation companies located in their state, at a time when there are energy shortages in Tamil Nadu.

We obtain further insights into these questions by comparing the Electricity Investment Intensity Ratio across the four successful states. These time-series are shown in Figure 9. As before, we think of location estimator for the Electricity Investment Intensity Ratio for India over long periods of time, of 0.8, as the required normative value.

There are very high values for Rajasthan, with an overall average of about 3 and sharp growth in recent years. This is consistent with the idea that Rajasthan is a strong centre of the electricity generation industry. Rajasthan does not have commensurate levels of non-electricity private investment: the generators there expect to sell electricity to neighbouring states such as Gujarat. Gujarat, on the other hand, has historically had relatively poor values of this ratio, and now stands at below 0.2. Users in Gujarat require sustained purchase of electricity from out-of-state, e.g. from nearby Rajasthan.

economic strategy of Tamil Nadu.

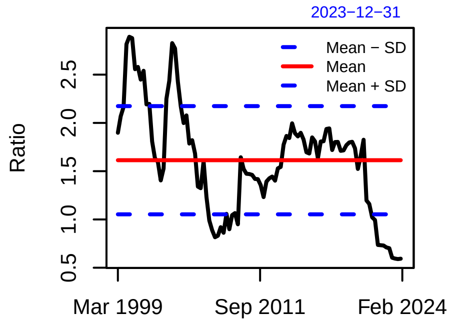
Figure 9 The Electricity Investment Intensity Ratio, compared across four states

At each point in time, we compute the Electricity Investment Intensity Ratio, which is defined at each point in time as:

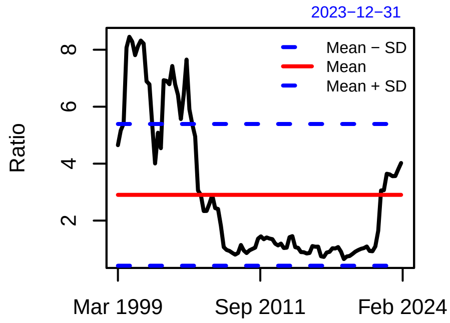
$$\frac{\text{Under implementation investment in electricity (all owners)}}{\text{Under implementation private investment in non-electricity}}$$

The time series (the black line) is superposed with the global mean and with dashed lines that are one standard deviation above and below. Also see Figure 8.

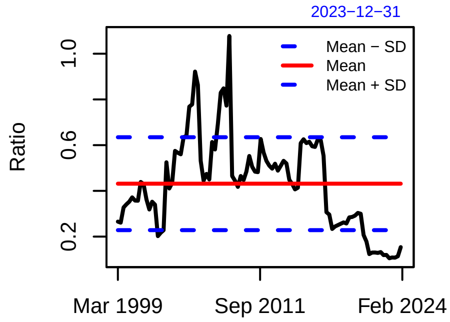
Tamil Nadu:



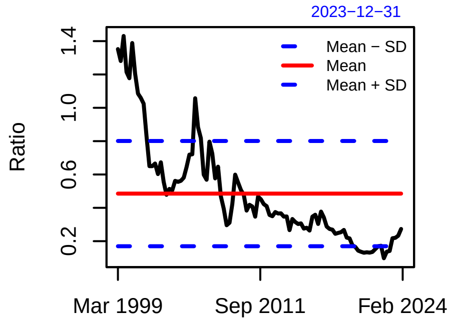
Rajasthan:



Gujarat:



Karnataka:



This may well be a sound strategy for economic policy makers in Gujarat. Gujarat is a financially sound electricity system, and faces no problems in paying for electricity from out-of-state where generators expect to be paid. Gujarat is physically close to Rajasthan, which reduces the capital cost of building transmission links. Gujarat and Rajasthan are likely to coordinate well with policy initiatives of the union government in the field of transmission. These factors suggest that it is a reasonable policy strategy for Gujarat to live with sustained low values of the Electricity Investment Intensity Ratio. But the situation in Tamil Nadu is different.

To summarise, there are signs of a shortfall in electricity generation in Tamil Nadu. This should encourage a reorientation of the economic policy strategy in Tamil Nadu in favour of creating conditions where there are buoyant investments in the electricity sector in Tamil Nadu.

3 Renewable electricity matters for exporting

The Tamil Nadu economy has a greater reliance on exporting when compared with many other states. There are important clusters in the fields of electronics, garments, autmobiles and services exports where Tamil Nadu possesses the network effect, where it is unusually efficient to work within the state. These network effects are exerting an influence upon investment decisions of firms and are central to the economic possibilities of the future for the state of Tamil Nadu. An export orientation in Tamil Nadu, however, impinges upon the strategy taken in the electricity sector.

3.1 Carbon border taxes

The global process of the clean energy transition has emphasised the combination of regulatory measures and carbon taxes alongside a market for carbon. These measures are valuable in terms of reigning in carbon emissions, but carry the associated problem of trade diversion.

A good organising principle for economic policy everywhere is to protect neutrality in international trade, to make all markets for goods and services competitive outside of the national border, and impose the domestic taxation regime symmetrically upon goods and services consumed within each country (whether they are produced locally or abroad).

This principle motivated the design of the Value Added Tax ("VAT") which is termed the GST in India. Each country is free to set its own internal VAT rate. The full embedded burden of VAT is refunded to the exporter at the point of export and the full burden of VAT is imposed upon imported goods at the point of import. This creates a competitive environment between imported vs. locally produced goods within each country, while leaving each country free to choose a different VAT rate.

These principles are relevant to the question of decarbonisation. Each country will choose a different pace of proscribing carbon emissions. This can have a trade diversionary impact. Investments and jobs would tend to go to countries that have a more lax regime (Shah, 2023). This is solved through carbon border taxes. There is a high consensus among economists that the most efficient way to decarbonise – i.e. the way to get decarbonisation done at the lowest cost to society – lies in a combination of carbon taxation and carbon border taxes (Economists, 2019).

As with the VAT, the implementation of carbon border taxes is a time consuming process. Carbon border taxes are set to kick in for the European Union in 2026 and the UK for 2027. It is likely that many countries will move in this direction.

When an Indian exporter has to pay a carbon border tax at the shore of a foreign country, this seems like a customs duty to many. However, the correct analogy is with the VAT on imports. The political system in a country such as the UK chooses a certain level of taxation of carbon. Buyers in the UK are layering a higher tax upon their purchases, in proportion to the carbon intensity of the product. The tax is ultimately paid by consumers in the UK who face higher prices. The carbon border tax achieves neutrality between production in the UK vs. production in India.

3.2 Implications for the Tamil Nadu economic strategy

These developments have important consequences for the strategy of Indian exporting firms (Jaitly and Shah, 2023a). Exporting firms will face the choice of buying carbon-intensive electricity in India, and paying carbon border taxes, or of buying renewables in India which are immune to this tax. This will create incentives for exporting firms to buy renewables.

Given the cross-subsidy system operated by the public grid, Commercial and Industrial ("C&I") buyers in any case have had an incentive to exit the public grid. They have been escalating the extent of direct purchase either from an arms length generator (with or without ISTS) or by setting up captive units. The desire for C&I to exit the public grid will be accentuated through the increasing presence of carbon border taxes in export destinations. This will further diminish the financial viability of the public grid.

Direct contracting by C&I is appealing when compared with being overcharged on the public grid. However, it is not costless. Exiting the grid comes with costs of greater grid-like operations within the consuming firm. Every consuming firm that sources electricity privately has to establish operations for procurement and operations, deal with outages on its own, etc. At present, C&I buyers of renewables are able to solve outages by falling back on the public grid and temporarily paying higher prices for electricity. The economic reasoning will change when use of the public grid involves not just more expensive electricity but also a carbon border tax in the export destination.

Not all electricity systems suffer from these problems. In a country which does not engage in the complexities of electricity policy in India, the exporting firm merely gets an electricity connection, and its electricity operations problem is solved by the public grid that is rapidly decarbonising. If an electricity reforms program in Tamil Nadu were to give auditably renewable electricity to C&I consumers, at the (fluctuating) market price, through the economies of scale and reliability of a well functioning grid, this would improve the attraction of Tamil Nadu as a platform for exporting.

4 The status quo is coming under increasing stress

There is a certain human instinct where it is felt that if something has worked out for many years, this will continue indefinitely into the future with a flow of practical problem solving every few months, as was the case in the past decade. It is often felt that while the electricity policy framework in Tamil Nadu is regrettable, it is survivable. In this section, we turn to questions of sustainability of the status quo.

We start by reviewing the causal links in the electricity system nationwide (i.e. not narrowly in Tamil Nadu). These are summarised in Figure 10. There is one external stimulus and three feedback loops.

Some Commercial and Industrial ("C&I") users have de-carbonisation goals, owing to ESG investors, and are exiting the grid in their pursuit of auditably renewable sourcing, which the grid does not offer. C&I exit harms the finances of the SEB, which gives payment failures to private generators, which hampers investibility, and creates shortages which exacerbate C&I exit. C&I exit hampers SEB finances, which has often given higher prices charged to C&I users, which encourages C&I exit. Finally, high C&I prices create greater incentives for theft, which harms SEB finances, and generally exacerbates high C&I prices.

These four causal pathways are prevalent in many parts of India. When distribution works well, e.g. in Bombay, we see these components peel away. Feedback loop 2 (unreliable grid owing to poor investibility) is absent: the electricity supply in Bombay is reliable. Feedback loop 3 (excessive prices for C&I) is a relatively limited problem in Bombay. And Feedback loop 4 (through theft) is absent in Bombay. There are examples of a well functioning grid in the public sector also, such as Gujarat. But in many parts of India, the causal links shown in the figure are in play.

In this paper, we take a Tamil Nadu centric view of the sources of stress in the electricity system. There is no free lunch: all electricity sold below cost is paid for by a combination of taxpayers, financial lenders and overcharged C&I. Four concerns about sustainability can be identified.

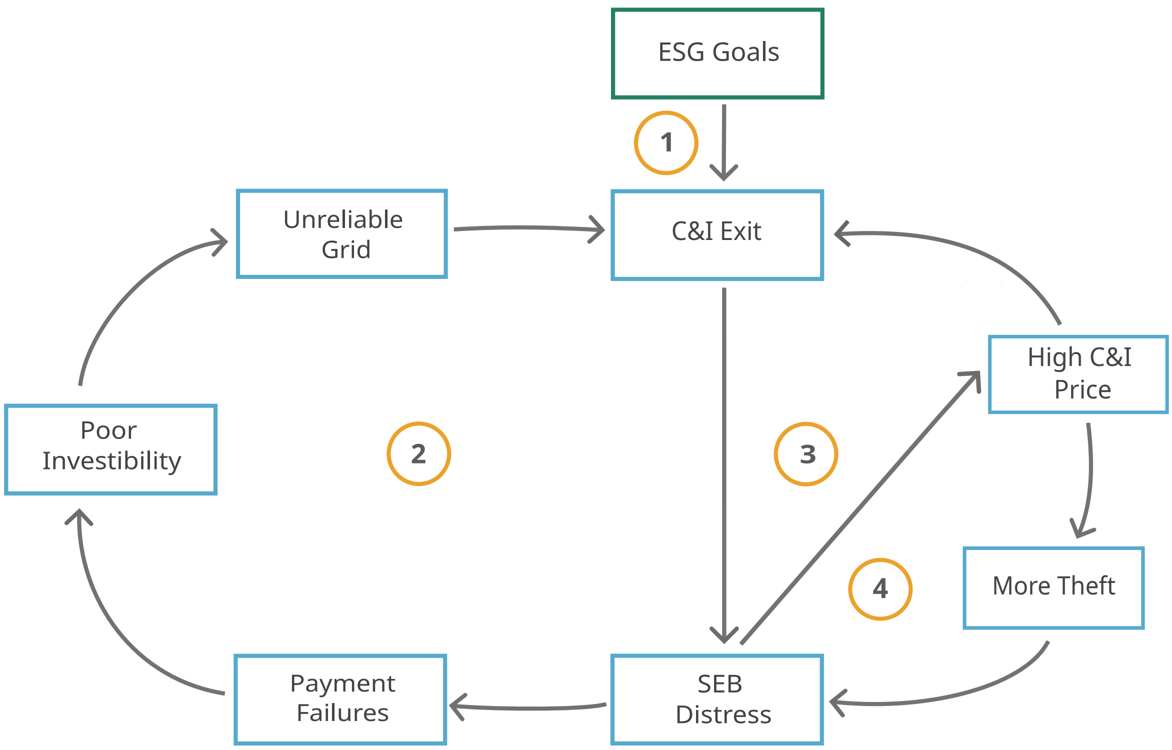
Sustainability of the cashflow from taxpayers to the electricity system The revenue shortfall of the electricity system has been partly paid for by the exchequer. The ability of the exchequer to bear this burden has been declining, owing to the deteriorating fiscal situation. Mehta et al. (2024) apply the standard tools of Debt Sustainability Analysis to Tamil Nadu. The results show significant threats to Tamil Nadu's public finance. Over the last decade, Tamil Nadu has gone from being a median Indian state to being at the 90th percentile of fiscal stress.

Figure 10 Causal links in the Indian electricity system

Four causal links are at work in the Indian electricity system of which three are feedback loops.

1. There is a desire for exit from the public grid, on the part of firms who desire low carbon emissions as part of their ESG strategy. As the public grid is not able to give auditable guarantees about carbon-free electricity, they have an incentive to exit.
2. There is a feedback loop of Commercial and Industrial ("C&I") exit, which increases the financial difficulties of the public grid, which undermines investibility and thus accentuates C&I exit.
3. There is a feedback loop where the pressure upon the public grid to raise prices, to uphold the cross-subsidy system, when C&I exit takes place. High prices heighten C&I exit.
4. There is a feedback loop high prices give increased incentives for theft of electricity, which undermines the revenues of the public grid and drives higher prices.

In the future, there will be one more external impetus in favour of C&I exit, the incentives of exporters who are influenced by carbon border taxes in export destinations (Section 3). This will become an additional factor feeding into C&I exit in this diagram.



State governments in India have choices on how default take place. There are choices between defaulting on bonds, failing to pay private vendors, failing to pay pensions or failing to pay wages. While relatively little is known about the late stages of fiscal distress, Mehta et al. (2024) have estimates of the numerical values associated with these extremes of fiscal stress. The present projections suggest that Tamil Nadu is partially headed towards these values in a few years. Policy makers will then face dilemmas in allocating scarce resources for the electricity sector vs. other high priority applications. The political choices made when interest payments were 15% of revenue receipts will diverge from those made when interest payments reach 25% of revenue receipts.

Sustainability of the cashflow from financial lenders to the electricity system The electricity system also requires a substantial annual flow of additional borrowing (at TANGEDCO, TANTRANSCO and at Tamil Nadu Power Finance Corporation. As Mehta et al. (2024) argue, the full range of mechanisms through which borrowing is presently being done might experience frictions and attentuation in future scenarios.

Sustainability of revenues from C&I to the electricity system The status quo requires a sustained resource flow by overcharging C&I users. As emphasised in Figure 10, there is one external stimulus (the desire of some C&I users to obtain auditably renewable supply in order to meet ESG requirements) and three feedback loops, all encouraging C&I exit. The Inter-state Transmission System (ISTS) will increase the ability of C&I consumers to access renewables producers outside Tamil Nadu, and thus exit the public grid (Jaitly and Shah, 2022b).

An additional external stimulus will appear on the scene from 2025 onwards, the emergence of carbon border taxes in 2026 (European Union) and 2027 (UK) (Section 3). Many exporting firms will find a greater impetus to exit the grid and lock down auditably renewable supply. This will layer on top of the existing forces of Figure 10 and accelerate C&I exit.

C&I presence is essential for upholding the status quo, and heightened C&I exit will undermine the feasibility of the status quo.

The possibility of shortages If high economic growth takes place for a few years, it will trigger increases in electricity demand. The evidence presented in Section 1 shows that investment in electricity generation in Tamil Nadu has faltered, and the argument presented in Section 2.1 suggests that buying electricity from elsewhere in India has its problems. If shortages emerge, they will constitute one more impetus for changing the status quo.

Even though a certain policy paradigm has been in place for over a decade, the fire fighting is increasingly difficult, and there is now a possibility that these four forces may induce a bigger re-examination of that policy paradigm.

5 A great wave of investment and risk-taking is required

Sustained economic growth in Tamil Nadu calls for a great wave of investment in the field of electricity, from three points of view:

- The grid of a fossil fuel electricity system involves a few high capacity lines to large generation plants. This needs to change considerably when we come to the post-carbon environment, which is characterised by a large number of small generation facilities. The grid architecture for a clean energy system involves a modified architecture of transmission, distribution, smart metering, and it requires prices that fluctuate. The grid of the future will have mechanisms for electric vehicles and rooftop solar to sell energy back to the discom in the evening peak. The intermittency of renewables can cause shortfalls at any one location which require transportation from other locations, through price-based mechanisms. Substantial investments are required to achieve a new kind of grid for the net zero world.
- Substantial investments are required in storage, through which the price fluctuations of the evening peak are more subdued.
- Substantial investments in renewables are required to support the removal of carbon intensive generation. The aggregate energy generated will increase as fossil fuel applications like transport will switch to electric.

In the early years, it was relatively easy adding RE into the incumbent grid. Grid-connected RE generators have a 'must-run' status : when they have electricity, the grid is obliged to take that electricity. This was not a problem for the unreconstructed electricity system in the early days of RE in India. Tamil Nadu was successful at an early stage in having high growth of grid-connected RE capacity in the early years. But once the magnitude of RE capacity becomes larger, this presents difficulties to the legacy electricity system. Kapur (2021) has a valuable detailed analysis of the difficulties of reconciling an increasing scale of RE into the Tamil Nadu grid. It is not possible for grid managers to cope with the consequences of adding a large magnitude of 'must-run' RE on top of a traditional electricity system. Once the possibilities for easy early gains are exhausted, there is a need of a deeper transformation of the electricity system, on questions of economics (of the role for prices) and on changing the engineering of the grid.

These three groups of investment problems require capital and management capabilities. The resource limitations of the Tamil Nadu electricity system, and the limitations of public sector management, come in the way.

Further, there is considerable uncertainty about the future. Nobody knows how different RE and storage technologies will work out. Nobody knows how the net zero grid will work. It is not as if a central planner can design the electricity system of the future and then tender it out. A process of exploration and risk-taking will be required to find the answers in the future. It is, however, difficult for officials in government organisations to undertake speculative bets, and to countenance business failure.

What is required is a process of discovery, and not design, where profit-motivated private persons peer into the future, speculate about what might work, and take risks in building businesses that constitute bets about certain technologies and business models. When the state-controlled electricity system brings in private generators with long-term PPAs, this harnesses private sector competence in construction and O&M, but it does not fully harness what the private sector can do. Private firms in a market economy are able to do four additional things (over and beyond competence in construction and O&M):

- Undertake risky choices on technology, placing large speculative bets about what technology might work in the future;
- Continuously innovate and solve technical problems based on ground reality and shifting market conditions;
- Place capital at risk in a world with unpredictable demand and prices; and
- Suffer losses with many business plans that fail (and earn large profits in many business plans that succeed).

The private sector can bring in the resources and management capability required to build and operate the grid, to generate RE and to construct a largely new storage industry. There is an essentially limitless capability in the private sector for raising finances and for building management teams. However, this calls for investibility in the Tamil Nadu electricity system.

In the market economy, the private sector does not need targets or tenders from the government in order to initiate investments; it forms its own investment plans based on the likelihood of earning a profit. All these capabilities need to be harnessed for the Tamil Nadu electricity system (Jaitly and Shah, 2021). What the private sector requires is investibility. This is about the incentives of a market-oriented policy framework that emphasises competition and the price system, a sound mechanism for electricity regulation, reduced policy risk and safety from expropriation.

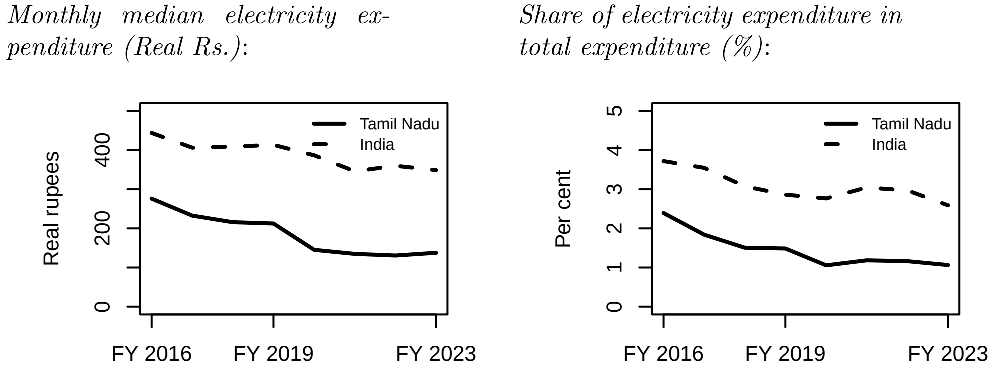
The present electricity system is a centrally planned system where some tasks are contracted out to private persons. This process has run into an investibility problem through difficulties in contract enforcement and timely payment. A narrow focus upon solving the problems of the present (of contract enforcement and timely payment) would suffice to bring private investment back into the present system. However, the puzzles of the future are much larger, and require a bigger role for the private sector: that of creatively imagining business plans and risk taking in a technologically uncertain future.

6 Tamil Nadu policymakers need to grapple with the under-pricing of electricity

Many locations in India feature pricing distortions in electricity where agricultural and domestic users get cheap or sometimes even free electricity. The theft of electricity also takes place, with varying intensity all across the country. These pricing distortions are paid for through a combination of on-budget subsidies paid for by the exchequer, and

Figure 11 Electricity expenditure in Tamil Nadu is unusually low by Indian standards

The left pane reports the median household expenditure on electricity, comparing Tamil Nadu against India, expressed in real rupees. The right pane reports the median value of the share of electricity in household expenditure, also comparing Tamil Nadu against India. These summary statistics are based on the CMIE CPHS database.



unfunded subsidies which are financed through borrowing by the distribution company. The presence of these subsidies is an important problem for electricity policy. While there is a fair amount of information about the state of prices and the quantity of electricity sold, from the viewpoint of the distribution company, relatively little is known about how this plays out at the level of the household.

An important data source with household survey data is now available, the CMIE CPHS dataset. This is a household survey dataset which measures about 170,000 households in India, three times a year. It has started to be applied into the field of electricity. Martinez Arranz et al., 2021 study the expansion of access to 24 hours supply over 2014-2019 period. Kulkarni, Sahasrabudhe and Chunekar, 2022 used it analyse appliance ownership. In the Tamil Nadu setting, Das, Sane and Shah (2024b) examine this data around four natural experiments of tariff or subsidy changes in Tamil Nadu, and find that the picture is broadly consistent with what would be expected across each of these events.

This database offers novel facts and insights into electricity expenditure at the household level. Figure 11 shows the time-series of the median electricity expenditure, and the share of electricity in total expenditure, for Tamil Nadu and for India. The expenditure values are expressed in constant 2024 rupees. Tamil Nadu is a relatively prosperous state, and we would expect both the level and the share of electricity expenditure to be higher than the Indian median. However, the evidence shows that the level and the share in household expenditure are about half those seen in the overall country.

Pressures to underprice electricity, either directly through tariffs or indirectly through the lack of metering or outright theft, are present everywhere in the country. The evidence here suggests that Tamil Nadu is relatively unusual in the extent to which households are paying little for electricity. The political leadership of Tamil Nadu needs to grapple with this problem.

One element of this problem is the use of electricity in agriculture. There has been much interest in the possibility for solar pumps that would simultaneously do two things. First, solar pumps would remove the need for farmers to take electricity from the grid. Second, farmers would have the option to sell electricity back to the grid, which implicitly puts a price on extracting groundwater, and helps address the tragedy of the commons in groundwater extraction.

Das, Sane and Shah (2024a) undertake a detailed analysis within Tamil Nadu, for the district of Erode, with a first principles calculation of the economics of solar pumps. They test whether it is efficient for the distribution company to pay a 100% subsidy to farmers for the purpose of solarisation of pumps. They find this is the case under certain assumptions about the internal price of electricity at the distribution company. This approach can be applied in the future in each district of Tamil Nadu, to obtain estimates grounded in local conditions, that can guide political economy bargains in the journey out of free power for agriculture.

7 The electricity sector is important on the scale of Tamil Nadu's economic strategy

Electricity policy has traditionally been the specialised domain of experts in the field of electricity. There are four aspects through which the problems of this field have risen to prominence, and now matter for the overall economic policy strategy of Tamil Nadu.

1. *Linkages with the fiscal problem.* Mehta et al. (2024) show the fiscal calculations for the standalone Tamil Nadu exchequer, and then the modified calcualations where TANGEDCO and TANTRANSCO are consolidated into the exchequer. Under business-as-usual, the forecasted value for 2028 of the Debt/GSDP ratio and the interest / revenue receipts ("IP/RR") ratio are 43.5% and 26.1%. If the electricity problem is fully solved, these forecasted values become 32.47% and 19.71%. Under business-as-usual, the Tamil Nadu fiscal situation would likely switch over to significant fiscal distress, and if only one reform is implemented – completely solving the electricity problem – then it would be out of this zone. This demonstrates that this one problem is an important one, on the scale of medium term fiscal planning.

2. *Electricity availability for economic growth* As demonstrated in Section 2, the current pace of non-electricity investment is out of line with the current pace of electricity investment.

3. *Exporting demands RE* A great strength of the Tamil Nadu economy is its unusual export orientation and success in exporting. The combination of ESG investors and carbon border taxes implies that exporters require an auditably RE supply mechanism.

4. *The natural resource of offshore wind* A remarkable fact about Tamil Nadu is that off the coast of Tamil Nadu there are vast opportunities for offshore wind, both near the coast and

then further out in Sri Lanka. Once a strong electricity reform is undertaken, and conditions of investibility are in place, a big private industry with perhaps 70 GW of capacity can arise which installs and runs offshore wind generation. RE capacity of 70 GW is perahps three times bigger than all the RE installed from 1999 to 2024 (a subset of which is shown in Figure 5). Very rough estimates suggest this is an investment of $175 billion or about Rs.14 trillion. Such a capital expenditure which would have a positive impact upon the economy including strengthening the engineering capabilities of the Tamil Nadu economy.

Large scale offshore wind supply would create tremendous low cost RE availability in Tamil Nadu, which would attract investment. It can also create revenues through the sale of energy into other states, as is done by Rajasthan.

There is an attractive possibility here which is large in the overall context of the economic strategy of Tamil Nadu. It is one more benefit from a thorough electricity reform (Jaitly, Mehta, Sane et al., 2024; Subramanian, 2023).

8 Summary of the present state of Tamil Nadu electricity

In previous sections, we have sketched an argument of eight elements:

1. Electricity investment in Tamil Nadu has faltered
2. Electricity availability in the future may hamper growth
3. Electricity generation within Tamil Nadu is desirable
4. RE is linked to export orientation
5. The status quo is coming under increasing stress
6. A great wave of investment and risk taking is required
7. Tamil Nadu policy makers need to grapple with its de facto under-pricing of electricity
8. The electricity sector is important on the scale of the Tamil Nadu economic strategy.

We now turn to solutions.

9 A feasible path to reform

9.1 Element: Regulatory reform

One part of the investibility problem is that of regulation. Achieving a high state of investibility requires establishing sound regulatory arrangements. The private sector should have the expectation that the regulator will behave in predictable and correct ways at future dates. The presence of a strong public sector and government sector makes private persons uncomfortable; regulators are required that will create a fair environment. Sound institutional design for regulation is a necessary (but not sufficient) condition for investibility.

The Electricity Act, 2003 governs the regulation of electricity in India. Much has been written about the difficulties of electricity regulation in India. Experts in electricity policy got to the Electricity Act in 2003, and now have 20 years of experience with the weaknesses of electricity regulation that was created by this law. In parallel, over these years, there have been remarkable improvements in the field of 'regulatory theory' in India. Across numerous domains (such as finance, telecom, airports, etc.), new knowledge and experience has been created in India, on why regulation fails and how regulation can be done better.

This new body of knowledge is brought to bear upon electricity regulatory reform for Tamil Nadu in Jaitly, Mehta, Ranga et al. (2025). They identify the proximate difficulties as viewed through electricity domain knowledge; bring the toolkit of regulatory theory to obtain a root cause analysis of these difficulties and develop a regulatory reform strategy that is feasible for the leadership of Tamil Nadu.

Indian regulatory theory is organised as nine fields: (a) Clarity of purpose, (b) Composition and role of the board, (c) Separation of powers, (d) Legislative functions, (e) Executive functions, (f) Judicial functions, (g) Principles for penalties, (h) Transparency and accountability, and (i) The interface between the government and regulator. In each of these nine fields, there are difficulties in the present working of electricity regulation, and possibilities for progress.

Many features of electricity regulation in any state including Tamil Nadu are coded into the Electricity Act, 2003, which is not under the control of the policy makers in the state. The paper identifies a set of mechanisms where there are levers through which Tamil Nadu can make partial progress. The comprehensive problem of regulatory reform cannot be solved by Tamil Nadu (or any state) alone. But there are many avenues for progress that will materially make a difference. When the leadership of the state embarks on these policy initiatives, this will improve electricity regulation (while some problems remain), and it will will signal the commitment of policy makers to the private sector.

In terms of the objectives of regulation, the Electricy Act has a 2003 vintage notion of what electricity regulation has to do, and Jaitly and Shah (2021) has first principles reasoning about market failure in electricity that calls for regulatory intervention. Two additional concepts need to be brought into the regulatory strategy for the future:

- Market-based pricing will require a modified paradigm of regulation intended to address the market failure of market power, that is primarily in *distribution*, which establishes a regulated rate of return on equity for distribution companies. When the distribution company buys from a wholesale market where prices fluctuate, and sells to buyers at a price which fluctuates, the purpose of electricity regulation lies only on the *margin* of the distribution company where consumer protection is required for unsophisticated consumers.

Similarly, the field of transmission requires fresh thinking where there are situations with market power, with a high market share by one firm.

- Traditional thinking about electricity utilities views them as dull, stable, predictable businesses, where a physical facility is put up and generates a stable return on equity year after year. The coming years, in the run up to net zero, are anything but dull, stable or predictable (e.g. see Section 5). The private sector is required to take risk, and many a private project will go bankrupt. Hence, the regulatory strategy needs to shift to permitting a higher regulated rate of return for the distribution company.

9.2 Element: Distribution reform

The state of Tamil Nadu is a large and heterogeneous distribution system. The problems seen in different districts are diverse, and there is a considerable distinction between serving urban areas vs. serving rural areas. Tamil Nadu is perhaps too big to solve all at once, but one by one, we can envision small geographical areas of the state rising to a well functioning electricity sector. There would be gains in restructuring distribution to have multiple firms which focus on smaller geographies, e.g. as is the case with Surat or Calcutta.

Privatisation of distribution is an important question. Many policy initiatives have not worked, but many have worked. It is striking to see how many top cities of India (Bombay, Surat, Ahmedabad, Delhi and Calcutta) now have a successful private distribution company. This suggests an analogy with important cities of Tamil Nadu. The history of numerous successful and failed attempts at such reforms offers valuable knowledge on how this can be done better (Rossow and Singh, 2024).

9.3 Element: Pricing reform

Pricing reform is best approached as an exercise in quantitative political economy, where households are classified into coherent subsets and each sub-component is addressed separately.

A striking feature of Tamil Nadu is low prices for electricity for a wide range of households. There are natural opportunities to achieve parity with the pricing faced by affluent households e.g. in Bombay, Surat, Ahmedabad, etc.

The problem of free electricity for farmers may require detailed work where there is estimation of the adverse impact upon farming households, and offsetting policy initiatives are designed, such as the detailed analysis for the district of Erode in Das, Sane and Shah (2024a). Similar careful work is needed within each district, reflecting local conditions, to identify useful policy designs.

Many successful reforms in Indian history have been compensated through high economic growth and not narrow solutions at the level of the population. As an example, when customs duties declined sharply 1991-2007, many firms, industries and workers were adversely affected and were not directly compensated. The compensation took place through the acceleration of economic growth, a rising tide that lifted all boats. Policy makers should see the larger gains from an improved electricity sector, and not look to fully compensate every loser from the reforms.

9.4 Element: The price system

The conventional system achieves a balancing between supply and demand through the following steps:

1. Reasonably accurate forecasts are known for the demand in each 15 minute slot of the coming week.
2. The grid managers look at the various choices through which electricity can be obtained, and choose the least cost choices.
3. At the last minute, there are surprises. For example, it suddenly becomes cloudy, and air conditioners are switched off, giving a dip in demand, and solar output also goes down, and grid managers do the last minute fire-fighting of juggling sources in order to ensure equality of supply and demand.

It is possible to carry such a process forward into the RE-intensive world e.g. as is analysed in (USAID and Ministry of Power, 2017). But it is particularly hard once RE dominates. Solar output declines in the evening at the precise point at which demand rises. Fluctuations in the wind can give a sudden decline (or increase) in the power generated. Coal-fired plants are not good at rapidly changing course. Indeed, after accomodating a certain amount of RE in the early years, it has become increasingly difficult for grid managers to continue to accept more RE (Kapur, 2021).

An alternative strategy involves placing the burden of adjustment upon the market economy with a spot price that fluctuates. As with most goods and services, the price of electricity can be determined in a spot market. This has three important implications:

1. When consumers see the high price in the evening, they will pull back from using electricity, which will reduce the evening peak (Sane, 2023c). It is not unreasonable to think that moment to moment, consumers will be aware of the price of electricity and modify their decisions on switching on air conditioners dynamically. We can envision mobile phones giving out a notification when the price of electricity goes above a certain threshold. More long-term adjustments will also arise: firms will redesign their working hours so as to avoid the evening peak price.
2. Profit-seeking generators will be attracted by high prices in the evening peak and take greater effort to supply at that time.
3. The storage industry is, at heart, the business of buying electricity when it is cheap (in the afternoon) in the hope that it will be expensive in the evening. The intra-day variation of prices sends out incentives to private firms to build storage firms (Jaitly and Shah,

2023c). Every electric vehicle is a small storage facility; we can imagine consumers at home setting rules where they allow their vehicle to sell electricity when the price crosses a certain threshold.

Each of these mechanisms of adjustments leans towards closing the gap between supply and demand. These three mechanisms should take up the brunt of supply/demand adjustment, leaving small technical fixes for the grid manager to bring in.

In an age with predictable demand and predictable supply, the concept of a fixed price was feasible for the grid managers of that age. When generation must change over entirely into RE, with the intermittency problem, the fixed price induces an unreasonable burden upon the electrical engineers manning the grid. The price system is the tool for solving precisely this problem.

Prices that fluctuate can be introduced in phases, with C&I and affluent households coming first. Of great importance to many C&I buyers is the need to have auditable RE sourcing. Once this is achieved by the public grid without a cross-subsidy price distortion, many C&I buyers would dial back their internal grid-like energy sourcing and management operations, and come back to being price takers in the grid. Far reaching adjustments on the demand side will arise over long periods of time. For this reason, it is important to pre-announce the steps in this journey.[4]

9.5 Element: Offshore wind

The Tamil Nadu government must achieve a leadership role in harnessing the remarkable natural resource that is present on its coast. This will involve complex coordination with union government agencies and the Government of Sri Lanka. However, this field should be seen primarily as a part of the economic strategy of Tamil Nadu.

9.6 Element: Transition financing

The main pool of resources required for a better electricity system in Tamil Nadu is summarised in Section 5, and comprises investments in the grid, in RE generation and in storage. It is useful to think of a batch of reforms (and associated costs), after which investibility would be achieved, and the private sector would then supply that main pool of resources. The resourcing required for actually building the electricity system does not need to come from the government.

Policy makers need to focus on the costs incurred on this finite journey, of the project of getting up to investibility. These include elements such as a variety of political economy

[4]For an analogy, customs tariff reductions demand large-scale changes in the domestic industry, and many changes play out over multiple years through the investment process of firms. Hence, Yashwant Sinha pre-announced that the peak rate would drop by five percentage points every year. This gave firms the planning horizon to execute far-reaching changes. It took two of these 5% cuts taking place, as predicted, for the program of tariff reform to achieve full credibility in the eyes of private persons.

bargains that enable reforms, the liquidated damages that have to be paid to generators when closing down PPAs in favour of market-based operations, and the R&R costs for closing coal thermal plants. There is a full congruence between the goals of Tamil Nadu economic strategy, and Tamil Nadu electricity policy, and the global goal of achieving net zero. Hence, there may be a possibility of attracting external resources to pay for these one-time transition costs (Jaitly and Shah, 2022a; Sane, 2023b).

9.7 Element: Monitoring the reform

Measuring inputs The electricity reform would have many internal components that need to be monitored, such as distribution reform, pricing reform, and the extent to which the price fluctuates within the day. One measure of the extent of the pricing reform is the gap between electricity payments of the median household in Tamil Nadu vs. that seen in the overall India (e.g. Figure 11), and more sophisticated versions of this that compare households with similar characteristics.

Measuring outputs The outputs demanded from the electricity system are measures such as:

1. Electricity generation investments 'under implementation' (e.g. Figure 7, right pane).
2. The Electricity Investment Intensity Ratio (e.g. Figure 8).
3. The cumulated sum of completed RE (e.g. Figure 5).

Measuring outcomes The electricity system is an output that is intended to ultimately shape the outcome, which is private non-electricity investment in Tamil Nadu(e.g. as seen in the left pane of Figure 7).

10 Conclusions

The Indian electricity sector started out from a backdrop of government control. Officials controlled the methods of production and the price. There was a small role for private persons where a contract was given out under completely determined terms and conditions. These private persons were just vendors of government, who were expected to competently build and operate certain engineering systems, and then got regulated, low, fixed rates of return. While this superficially appeared to be the emergence of a private sector, the fundamental energy of private persons – of taking risks, sometimes making mistakes and large losses, sometimes making large profits – was absent.

This approach was suited for a relatively stable environment where the government took coal out of the ground and the government turned it into electricity. There were difficulties of the electricity sector in that world, to be sure, but they could be papered over. Private firms often opted out to build captive generation, but this was not much superior to living with an inadequate grid.

The picture changed with the emergence of the problem of decarbonisation. Decarbonisation requires a break with the coal-intensive ways. In addition, the global work on climate change unleashed technological revolutions in renewables generation and storage, which brought new economic forces to bear on the Indian electricity system. For the first time in the history of energy, there were straight lines in semi-log graphs, and the status quo faced new kinds of stress.

The best policy pathway for dealing with uncertainty is a process of private risk-taking and innovation. Nobody knows what the future will look like. Firms in all aspects of the energy system are now required to peer into the future and place bets about the technologies and business models which will work. Some of these bets will go wrong, some of these bets will generate high profits. In this world, electricity is once again a *business*, not a quiet government controlled sector.

Jaitly and Shah (2021) examined the problems of the Indian electricity sector and envisioned how the price system would work well in solving these problems. The essential feature required is one in which electricity prices fluctuate, and work as the coordinating point for private persons making decisions about distribution, generation, transmission and storage. The arguments of this paper were relatively abstract.

The Republic of India is a vast landmass of 3.3 million square kilometres, and the economic conditions vary dramatically by location. There was much merit in the Constitutional scheme, where electricity is primarily a state subject. The economic difficulties of the status quo, the possibilities for progress, the costs and benefits of rapid decarbonisation, all these vary by state. In this paper, we have undertaken a deep dive into the problems of one state, Tamil Nadu. For the purpose of this paper, we care only about the problems of Tamil Nadu and on useful policy pathways for the leadership of Tamil Nadu. It is also an illustration of how economic reasoning based on the price system can yield fresh insights and solutions at the level of one state of India at a time.

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