

Sectoral Performance and Institutions: Electricity Distribution in Indian States

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Overview

❖ Background

❖ Method

❖ Data

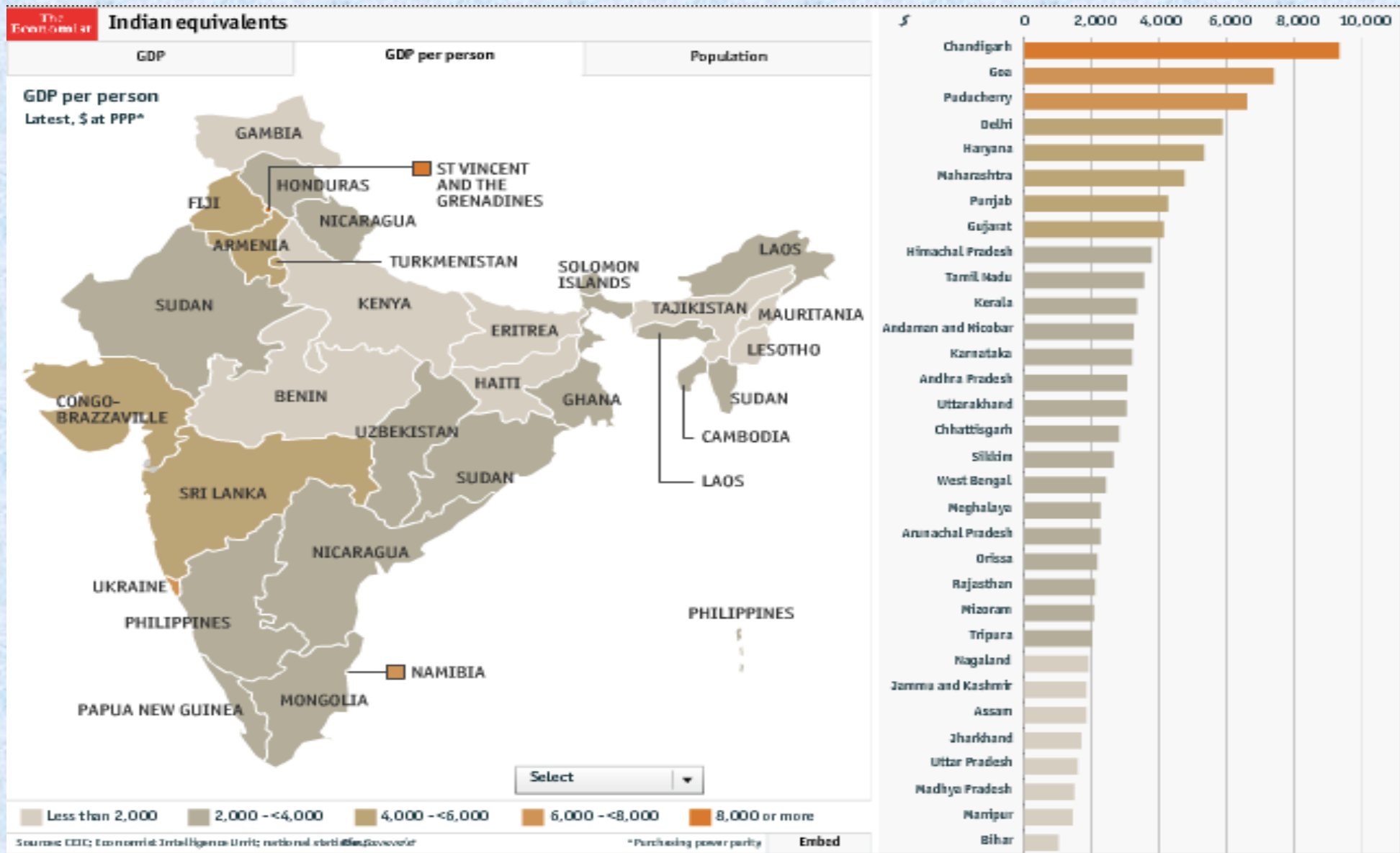
❖ Results

❖ Conclusions

Electricity Distribution Networks in India



Different States Different Economies



Electricity DNOs in India

- ❖ 1.4 bill. people in the world without electricity, India accounts for over 300 mill. (IEA, 2015)
- ❖ Ineffective electricity sector bottleneck to economic growth and social equity (Bella and Grigoli, 2016, Balza et al., 2013)
- ❖ Barriers to improvement: Capacity and technical; Economic and financial; policy and institutional (Sovacool, 2012, Watson et al., 2012, Nepal and Jamasb, 2012)
- ❖ Despite sector reforms the distribution sector are characterised as having: large financial losses, inefficiency, low productivity, interruptions (Shunglu, 2011)
- ❖ Thus, important to explore the linkage between performance of DNOs and quality of institutions, though all under public ownership

Literature shows institutions affect economic growth.

Does this also hold even within the regions of a country in a given sector?

Methodology

- ❖ Identify determinants of firms' cost inefficiency of electricity DNOs
- ❖ Stochastic Frontier Analysis (SFA)
- ❖ Estimate a set of cost functions
- ❖ Model determinants of inefficiency

- ❖ Include state-level:
 - GDP
 - GDP growth
 - Institutional, political, infrastructure quality
 - Human Development Index (HDI)
 - President's Rule (PRESI)
 - Coalition Government (COALI)
 - Surfaced Road Length to Total Road Length (ROAD)
 - Share of Expenditure in GDP (EXP)
 - Share of Secondary Sector in GDP (SESEC)

Models estimated

- ❖ Three cost functions – Cobb-Douglas, Translog (ALS), Translog w. Modelled inefficiency term (RCSFG)

- ❖ ALS - Aigner et al. (1977)

$$\ln C_{it} = \ln C(y_{it}, w_{it}, x_{it}, \beta) + v_{it} + u_{it}$$

- ❖ RSCFG - Reifschneider & Stevenson (1991), Caudill & Ford (1993), Caudill *et al.* (1995)

$$\ln C_{it} = \ln C(y_{it}, w_{it}, x_{it}, \beta) + v_{it} + \exp(z'_{it}\delta) u_{it}^*$$

- ❖ Where 'C' is total utility cost, 'y' is a set of outputs, 'w' prices of labour and capital inputs, 'x' are control variables, 'β' are parameters to be estimated, 'z_{it}' is a set of environmental variables, 'δ' is a set of parameters to be estimated, and 'u_{it}^{*}' is a measure of "raw" inefficiency that does not depend on z_{it}.

Data

- ❖ Unique data set
- ❖ 52 electricity distribution companies
- ❖ 24 different states
- ❖ Period 2006/07 to 2011/12
- ❖ Panel data set, balanced, 312 Observations
- ❖ Sources: Various company annual reports, state and central government publications, international sources

Summary Statistics

Variable	Unit	Mean	Std. Dev.	Min.	Max.
Total Distribution Cost	Crore rupees (2011)	1,388	1,993	123	22,506
Energy Sold (ENE)	MU's	10,370	11,725	395	80,132
Customers (CUS)	Number of people	3,261,180	3,866,851	230,580	23,180,000
Energy Losses (LOS)	MU's	4,166	4,474	163	33,785
Distribution Capacity (DCA)	MVA	7,895	8,206	492	62,194
Labour Price (LPR)	Crore rupees (2011)	0.04	0.02	0.01	0.14
Capital Price (KPR)	Index	117.68	4.80	110.12	125.08
Private Utility (PRIV)	-	0.19	0.39	0	1
Average Technical and Commercial Losses (ATCL)	%	29.69	14.48	6.12	83.68
Gross Domestic Product (GDP)	Crore rupees (2011)	336,369	227,767	11,759	1,112,220
Growth of GDP (GRW)	%	8.51	4.44	-5.98	22.47
Human Development Index (HDI)	Index in 2008	0.50	0.11	0.36	0.79
President's Rule (PRESI)	Number of times	0.04	0.21	0	1
Coalition Government (COALI)	Number of times	0.08	0.35	0	2
Surfaced Road Length to Total Road Length (ROAD)	%	64.10	21.03	11.55	93.55
Share of Expenditure in GDP (EXP)	%	6.06	2.07	1.31	16.55
Share of Secondary Sector in GDP (SESEC)	%	29.87	7.59	10.67	48.16

Correlation Table

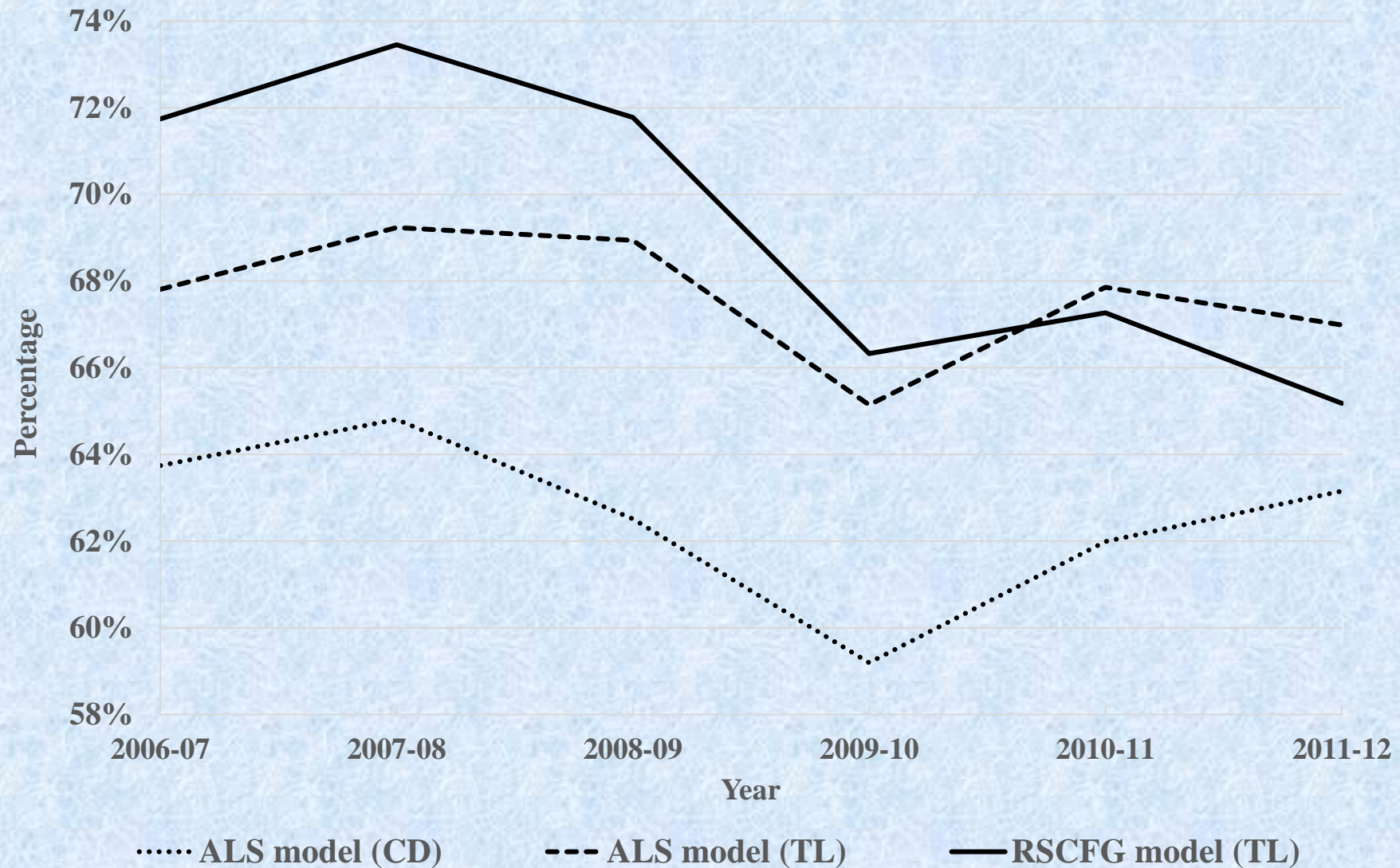
	<i>D_COST</i>	<i>ENE</i>	<i>CUS</i>	<i>LOS</i>	<i>DCA</i>	<i>LPR</i>	<i>KPR</i>	<i>PRIV</i>	<i>ATCL</i>	<i>GDP</i>	<i>GRW</i>	<i>HDI</i>	<i>PRESI</i>	<i>COALI</i>	<i>ROAD</i>	<i>EXP</i>	<i>SESEC</i>
<i>D_COST</i>	1	0.73116	0.73206	0.48136	0.57504	0.1303	0.11284	-0.16316	-0.15259	0.21487	0.07576	0.13102	-0.0852	-0.06178	0.20013	-0.29951	-0.0685
<i>ENE</i>	0.73116	1	0.9297	0.68673	0.88053	0.03753	0.11326	-0.20703	-0.23613	0.42676	-0.01158	0.15896	-0.08947	-0.07149	0.31478	-0.35818	-0.01259
<i>CUS</i>	0.73206	0.9297	1	0.60185	0.81602	0.0517	0.08494	-0.24044	-0.24294	0.40533	-0.02605	0.19222	-0.04108	-0.05077	0.19493	-0.33231	-0.0908
<i>LOS</i>	0.48136	0.68673	0.60185	1	0.68447	0.13933	0.04665	-0.25804	0.38626	0.25333	0.00841	-0.13777	-0.07114	0.01426	0.15468	-0.10274	-0.04628
<i>DCA</i>	0.57504	0.88053	0.81602	0.68447	1	0.09428	0.1298	-0.22496	-0.14917	0.42478	0.00354	0.11298	-0.09855	-0.11309	0.25334	-0.27363	-0.13664
<i>LPR</i>	0.1303	0.03753	0.0517	0.13933	0.09428	1	0.27307	0.03844	0.20711	-0.14034	-0.03486	0.06288	-0.00506	-0.02401	-0.04995	0.09212	-0.22061
<i>KPR</i>	0.11284	0.11326	0.08494	0.04665	0.1298	0.27307	1	0	-0.10038	0.16999	-0.34245	0	-0.0606	-0.14793	0.1265	0.08884	-0.07229
<i>PRIV</i>	-0.16316	-0.20703	-0.24044	-0.25804	-0.22496	0.03844	0	1	-0.03561	-0.08354	0.02301	0.13711	-0.10576	-0.10733	-0.34339	-0.26916	-0.14295
<i>ATCL</i>	-0.15259	-0.23613	-0.24294	0.38626	-0.14917	0.20711	-0.10038	-0.03561	1	-0.34815	-0.00571	-0.47484	0.06914	0.12488	-0.36206	0.42365	-0.07742
<i>GDP</i>	0.21487	0.42676	0.40533	0.25333	0.42478	-0.14034	0.16999	-0.08354	-0.34815	1	-0.07032	-0.05856	-0.06122	-0.08608	0.42157	-0.39264	-0.06906
<i>GRW</i>	0.07576	-0.01158	-0.02605	0.00841	0.00354	-0.03486	-0.34245	0.02301	-0.00571	-0.07032	1	-0.03551	-0.06601	0.03913	0.00849	-0.10957	0.05748
<i>HDI</i>	0.13102	0.15896	0.19222	-0.13777	0.11298	0.06288	0	0.13711	-0.47484	-0.05856	-0.03551	1	0.01017	-0.06518	0.33031	-0.20154	-0.24482
<i>PRESI</i>	-0.0852	-0.08947	-0.04108	-0.07114	-0.09855	-0.00506	-0.0606	-0.10576	0.06914	-0.06122	-0.06601	0.01017	1	0.52787	-0.03695	0.14587	0.06572
<i>COALI</i>	-0.06178	-0.07149	-0.05077	0.01426	-0.11309	-0.02401	-0.14793	-0.10733	0.12488	-0.08608	0.03913	-0.06518	0.52787	1	-0.03212	0.08982	0.14894
<i>ROAD</i>	0.20013	0.31478	0.19493	0.15468	0.25334	-0.04995	0.1265	-0.34339	-0.36206	0.42157	0.00849	0.33031	-0.03695	-0.03212	1	-0.09249	0.16839
<i>EXP</i>	-0.29951	-0.35818	-0.33231	-0.10274	-0.27363	0.09212	0.08884	-0.26916	0.42365	-0.39264	-0.10957	-0.20154	0.14587	0.08982	-0.09249	1	-0.02291
<i>SESEC</i>	-0.0685	-0.01259	-0.0908	-0.04628	-0.13664	-0.22061	-0.07229	-0.14295	-0.07742	-0.06906	0.05748	-0.24482	0.06572	0.14894	0.16839	-0.02291	1

<i>Variable</i>	ALS (Cobb-Douglas)			ALS (translog)			RSCFG (translog)		
	<i>Est.</i>		<i>Est./s.e.</i>	<i>Est.</i>		<i>Est./s.e.</i>	<i>Est.</i>		<i>Est./s.e.</i>
<i>Frontier</i>									
Intercept	1.359	***	51.720	1.361	***	27.820	1.402	***	21.720
ln ENE _{it}	0.343	***	4.730	0.295	***	4.150	0.220	*	1.930
ln CUS _{it}	0.265	***	4.260	0.188	***	2.750	0.199	**	2.230
ln LOS _{it}	0.090	***	2.640	0.105	***	3.130	0.135	**	1.970
ln DCA _{it}	0.142	**	2.280	0.214	***	3.780	0.228	**	2.500
ln (LPR _{it} /KPR _{it})	0.318	***	4.970	0.317	***	4.810	0.290	***	2.960
T	-0.048	***	-3.750	-0.035	***	-2.860	-0.058	***	-2.780
½ (ln ENE _{it}) ²				0.019		0.060	-0.114		-0.260
½ (ln CUS _{it}) ²				0.108		0.450	0.075		0.290
½ (ln LOS _{it}) ²				-0.011		-0.140	0.012		0.100
½ (ln DCA _{it}) ²				0.747	***	3.560	0.644	**	2.100
½ [ln (LPR _{it} /KPR _{it})] ²				0.221		1.260	0.141		0.460
½ t ²				-0.031	*	-1.880	-0.034		-1.550
ln ENE _{it} · ln CUS _{it}				0.380	*	1.760	0.441		1.630
ln ENE _{it} · ln LOS _{it}				0.217	**	1.980	0.175		0.940
ln ENE _{it} · ln DCA _{it}				-0.463	**	-2.400	-0.414		-1.640
ln ENE _{it} · ln (LPR _{it} /KPR _{it})				0.333	*	1.650	0.301		0.970
ln ENE _{it} · t				-0.028		-0.740	-0.048		-0.710
ln CUS _{it} · ln LOS _{it}				0.052		0.610	0.064		0.480
ln CUS _{it} · ln DCA _{it}				-0.433	**	-2.540	-0.405	*	-1.810
ln CUS _{it} · ln (LPR _{it} /KPR _{it})				0.342	*	1.840	0.391		1.550
ln CUS _{it} · t				-0.085	**	-2.500	-0.073		-1.410
ln LOS _{it} · ln DCA _{it}				-0.082		-1.000	-0.063		-0.530
ln LOS _{it} · ln (LPR _{it} /KPR _{it})				0.113		1.250	0.138		0.860
ln LOS _{it} · t				-0.049	**	-2.400	-0.044		-1.460
ln DCA _{it} · ln (LPR _{it} /KPR _{it})				-0.622	***	-4.720	-0.680	***	-3.430
ln DCA _{it} · t				0.111	***	3.640	0.116	**	2.340
ln (LPR _{it} /KPR _{it}) · t				0.036		1.070	0.011		0.200
PRIV _i	0.229	***	3.380	0.219	***	2.810	0.216	**	2.420

<i>Noise term</i>									
$\ln(\sigma_v^2)$	-3.586	***	-12.730	-4.066	***	-13.530	-4.140	***	-12.690
<i>Inefficiency term (variance)</i>									
Intercept	-0.571	***	-5.220	-0.757	***	-7.320	-1.022	***	-8.690
ATCL _{it}							-0.031	*	-1.920
$\ln \text{GDP}_{st}$							-0.711	***	-4.270
GRW _{st}							0.069	***	3.140
HDI _s							-2.844	**	-2.210
PRESI _{st}							-0.542		-0.840
COALI _{st}							0.768	**	2.020
ROAD _{st}							0.011	*	1.810
EXP _{st}							-0.178	***	-2.860
SESEC _{st}							-0.054	***	-3.360
t							0.303	***	3.710
Obs.	312			312			312		
Log-likelihood	-192.774			-154.652			-127.656		
Chi-squared LR test	76.245 ***			53.991 ***			-		
	(21)			(10)			-		

Significance code: *p<0.1, **p<0.05, ***p<0.01

Average efficiency score over time



Conclusions

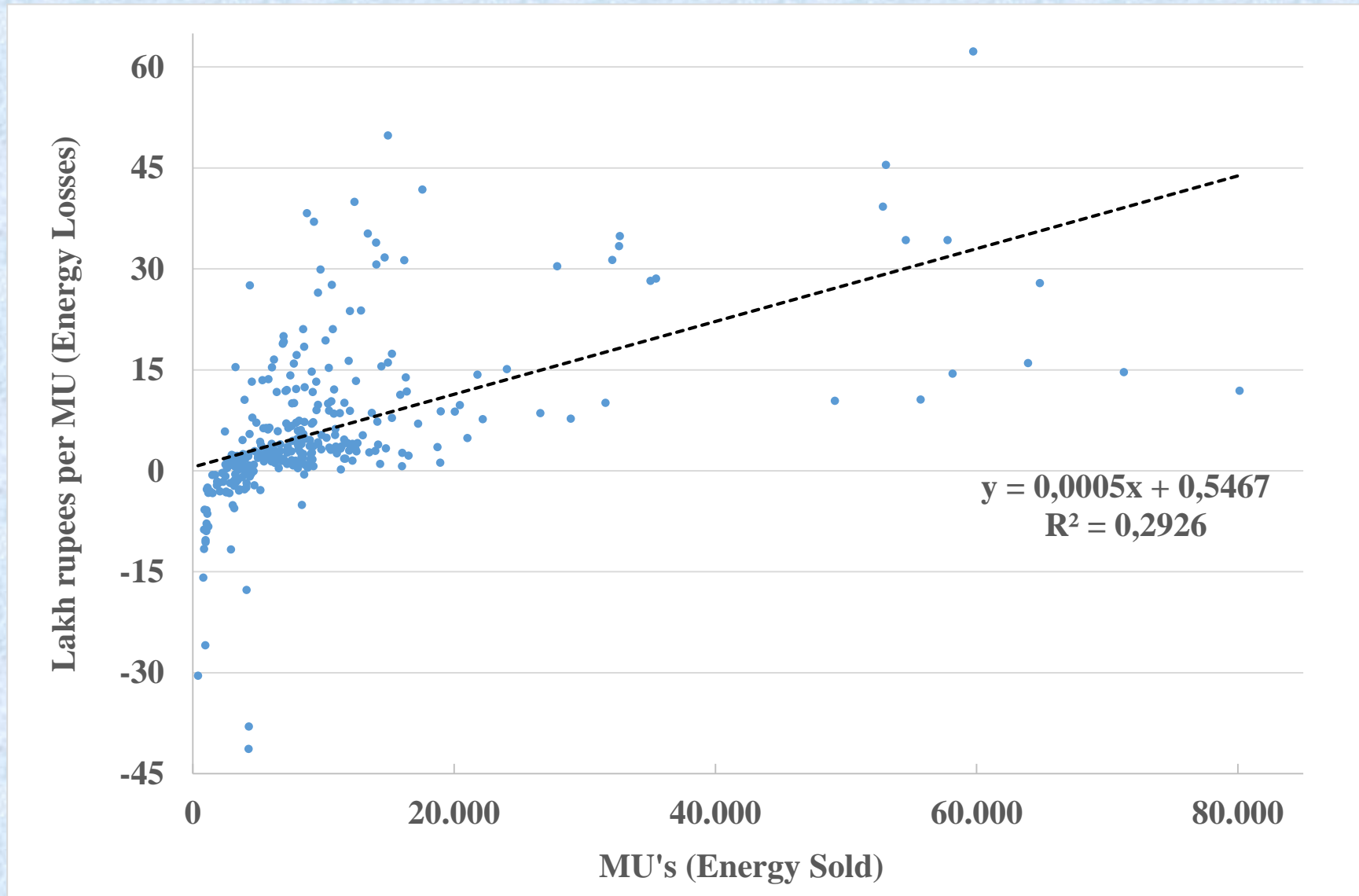
- ❖ India has made efforts to improve the efficiency of sector since 1990s
 - Difficult political economy environment
 - Some experimentation with privatisation
 - Generation shortage has improved
 - Incentive-based regulation of loss-making DNOs difficult

- ❖ We find:
 - Average cost efficiency of 69%, but this has declined over time
 - Network energy losses have increased – more intensive use of the networks

- ❖ We also show that institutions matter for efficiency,
 - Even within the states of the same country, in a given sector

Appendix

Marginal Cost of Energy Losses vs. Energy Sold



Data Appendix. Variables, definitions and sources

<i>Variable</i>	<i>Data Source</i>	<i>Definition</i>
Total Distribution Cost	<p>1. PFC (Power Finance Corporation). 2010. The Performance of State Power Utilities for the Years 2006–07 to 2008–09. New Delhi.</p> <p>2. PFC (Power Finance Corporation). 2011. The Performance of State Power Utilities for the Years 2007–08 to 2009–10. New Delhi.</p> <p>3. PFC (Power Finance Corporation). 2012. The Performance of State Power Utilities for the Years 2008–09 to 2010–11. New Delhi.</p> <p>4. PFC (Power Finance Corporation). 2015. The Performance of State Power Utilities for the Years 2011-12 to 2013-14. New Delhi.</p>	<p>Cost incurred in distributing / selling the electrical energy to end consumers. It is calculated as:</p> <p>(TOTEX – (Power Purchased Cost + Generation Cost))</p> <p>TOTEX is made up of the following components:</p> <p>(Power Purchased Cost + Generation Cost + Employee Cost + O&M Cost + Total Interest Cost + Depreciation + Admin & Gen Expenditure + Other Expenditure)</p>
Energy Sold	<p>1. PFC (Power Finance Corporation). 2010. The Performance of State Power Utilities for the Years 2006–07 to 2008–09. New Delhi.</p> <p>2. PFC (Power Finance Corporation). 2011. The Performance of State Power Utilities for the Years 2007–08 to 2009–10. New Delhi.</p> <p>3. PFC (Power Finance Corporation). 2012. The Performance of State Power Utilities for the Years 2008–09 to 2010–11. New Delhi.</p> <p>4. PFC (Power Finance Corporation). 2015. The Performance of State Power Utilities for the Years 2011-12 to 2013-14. New Delhi.</p>	Total energy delivered to the end consumers in MU.
Customers	<p>1. Annual Reports of the corresponding / individual distribution utilities published yearly.</p> <p>2. Annual Revenue Requirement and Tariff Petition filed by the distribution utilities to their respective State Electricity Regulatory Commission.</p>	Number of end consumers served.
Energy Losses	1. Annual Revenue Requirement and Tariff Petition filed by the distribution utilities to their respective State Electricity Regulatory Commission.	Net Energy Input (MU) – Energy Realized (MU)

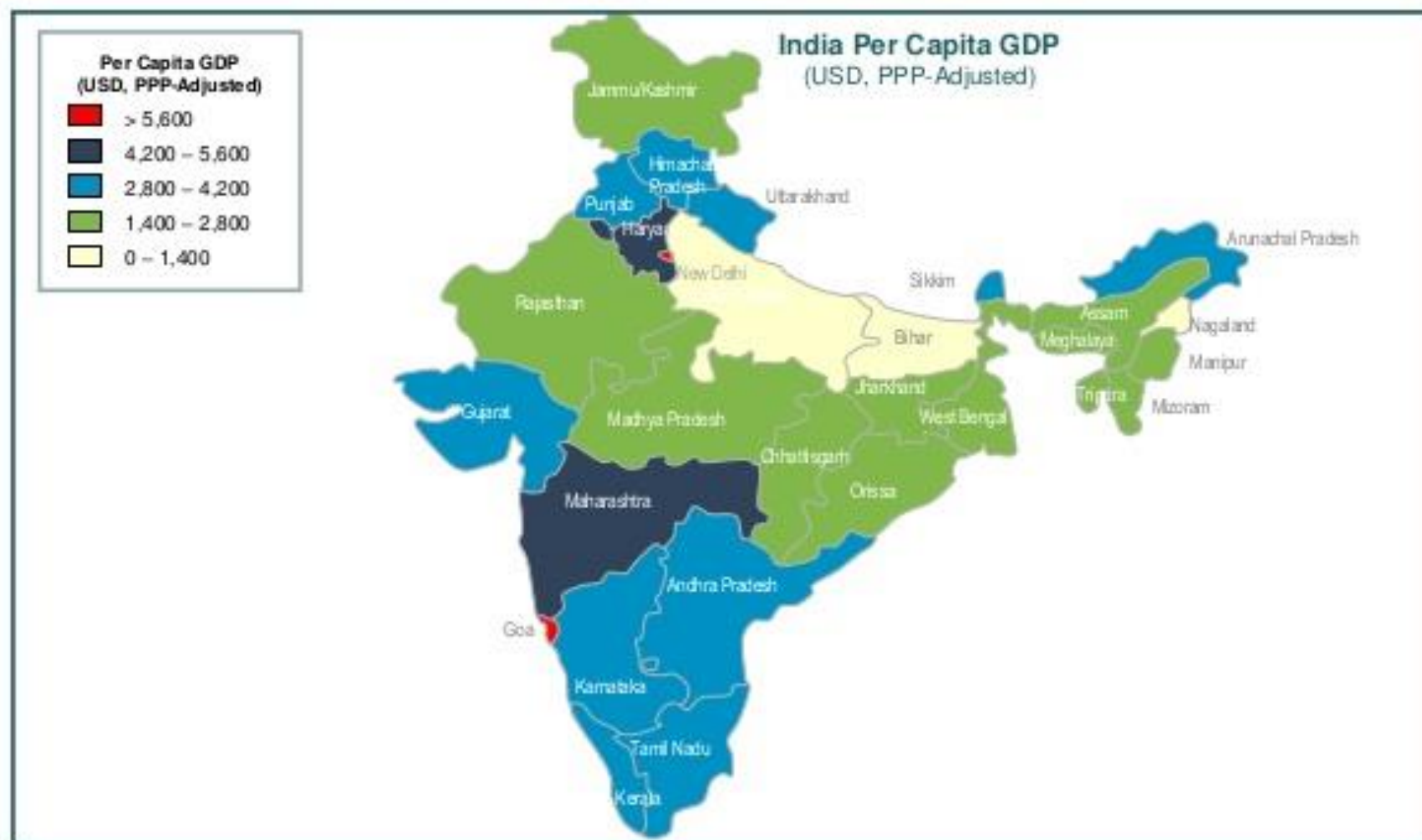
Distribution Capacity	<ol style="list-style-type: none"> 1. Annual Reports of the corresponding / individual distribution utilities published yearly. 2. Annual Revenue Requirement and Tariff Petition filed by the distribution utilities to their respective State Electricity Regulatory Commission. 3. http://www.cag.gov.in/ 	Distribution Transformer Capacity in MVA.
Labour Price	<ol style="list-style-type: none"> 1. PFC (Power Finance Corporation). 2010. The Performance of State Power Utilities for the Years 2006–07 to 2008–09. New Delhi. 2. PFC (Power Finance Corporation). 2011. The Performance of State Power Utilities for the Years 2007–08 to 2009–10. New Delhi. 3. PFC (Power Finance Corporation). 2012. The Performance of State Power Utilities for the Years 2008–09 to 2010–11. New Delhi. 4. PFC (Power Finance Corporation). 2015. The Performance of State Power Utilities for the Years 2011-12 to 2013-14. New Delhi. 4. Annual Revenue Requirement and Tariff Petition filed by the distribution utilities to their respective State Electricity Regulatory Commission. 5. http://www.cag.gov.in/ 	It is calculated as: (Employees Expenditure / Number of Employees)
Capital Price	Office of the Economic Adviser, Government of India, Ministry of Commerce & Industry, Department of Industrial Policy & Promotion (DIPP).	Wholesale Price Index (K, Machinery & machine tools).
Private Utility	http://cercind.gov.in/sebs.html	Distribution utility that is not under the control of State government.
Average Technical and Commercial Losses	<ol style="list-style-type: none"> 1. PFC (Power Finance Corporation). 2010. The Performance of State Power Utilities for the Years 2006–07 to 2008–09. New Delhi. 2. PFC (Power Finance Corporation). 2011. The Performance of State Power Utilities for the Years 2007–08 to 2009–10. New Delhi. 	$((\text{Net Energy Input (MU)} - \text{Energy Realized (MU)}) / (\text{Net Energy Input (MU)})) \times 100$

Gross Domestic Product	For Sl. No. 1-32 - Directorate of Economics Statistics of respective State Governments, and for All-India - Central Statistical Organisation; Released on 1 st March, 2014.	Gross State Domestic Product (GSDP) at Current Prices (as on 31-05-2014) (Rupee in Crores).
Human Development Index	Planning Commission (2011), <i>India human development report 2011: Towards social inclusion</i> , Government of India, New Delhi: Oxford University Press.	It is a composite index of outcome indicators that comprises three dimensions: life expectancy, acquisition of education and knowledge, and the standard of living and command over resources (Planning Commission, 2011). It is computed as follows: HDI = 1/3 (Health index + Education Index + Income index)
Number of Times the President's Rule Was Imposed	http://www.worldstatesmen.org/India_states.html	In the Republic of India, the phrase "President's rule" refers to the imposition of Article 356 of the Constitution of India on a State whose constitutional machinery has failed. In the event that a State government is not able to function as per the Constitution, the State comes under the direct control of the central government; in other words, it is "under President's rule". Subsequently, executive authority is exercised through the centrally appointed Governor, who has the authority to appoint retired civil servants or other administrators to assist him.
Number of Times the Chief Minister Headed the Coalition Government	http://www.worldstatesmen.org/India_states.html	A coalition government is a cabinet of a parliamentary government in which several political parties cooperate, reducing the dominance of any one party within that coalition. The Chief Minister of a coalition is not supreme in the Parliamentary sense that he does not have a free hand in the choice of his own team.

Ratio of Surfaced Road Length to Total Road Length	Infrastructure Statistics -2014 (Third issue, VOL. II) published by Central Statistics Office Ministry of Statistics and Programme Implementation Government of India, New Delhi. www.mospi.nic.in	Surfaced Road - A road with a hard smooth surface of bitumen or tar.
Ratio of Total Expenditure as a Percentage of Total State Gross Domestic Product	India, State Finances: A Study of State Budgets (Mumbai, Reserve Bank of India, 2011-12).	It measures the degree of Government intervention in various economic activities. A higher ratio indicates more State intervention in the economy and there is a greater scope for corruption and other kinds of rent-seeking activities. Hence, unnecessary State interventions preclude productive activities and encroach upon the freedom of private individuals, subsequently creating stumbling blocks for economic prosperity.
Percentage Share of Secondary Sector in State Gross Domestic Product Growth	Percentage Share of Secondary Sector in SGDP Growth, Central Statistical Organisation (CSO) & Ministry of Industry, Government of India, 2013.	Percentage contribution of Industry Sector in State Gross Domestic Product Growth. This variable basically tells about the Level of Industrialisation.

3. Market Seekers: Significant Income Stratification across India

Wealth Bands Emerging across Country



GDP per capita of Indian States (2013-14)

