Contract Enforcement and Productive Efficiency
Evidence from the Bidding and Renegotiation of Power Contracts in India
Replication Exhibits

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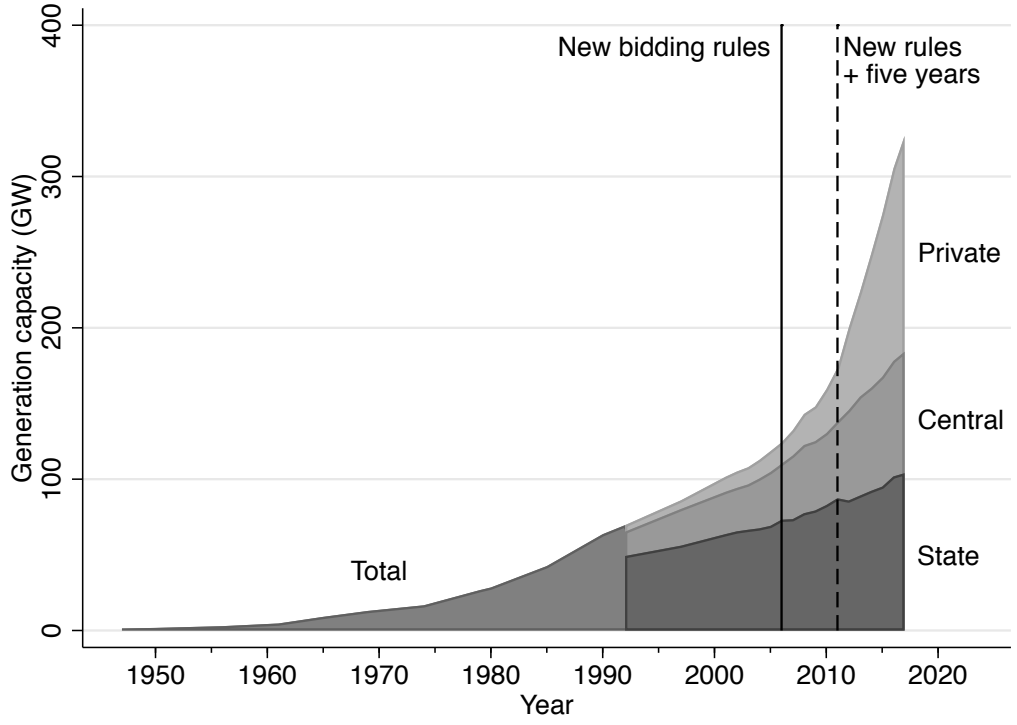
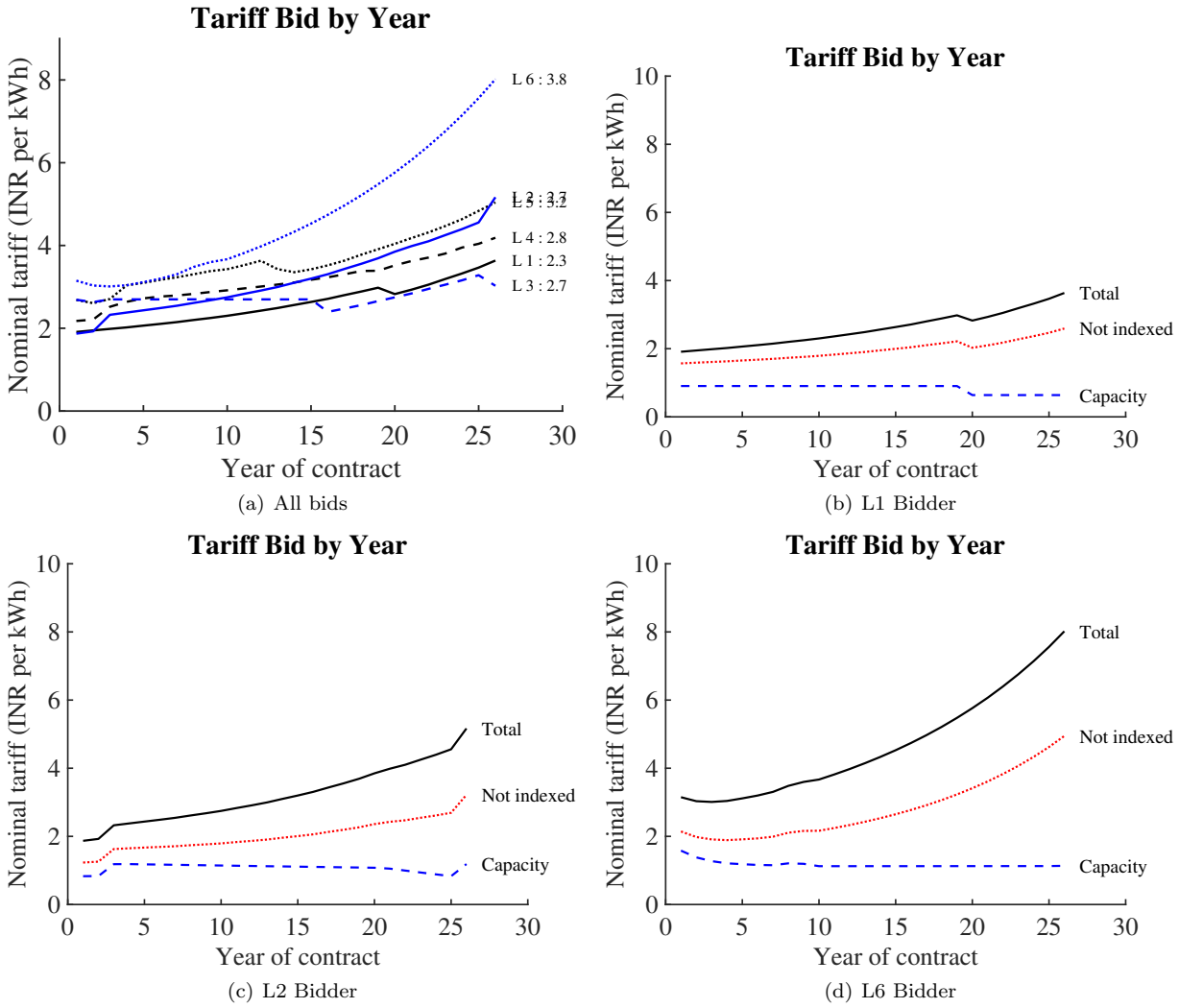
Figure 1: Division of Generation Capacity Across Sectors



The figure displays the division of generation capacity between the state, central, and private sectors in India from 1947 to 2017. The Tariff Policy under the Electricity Act are issued in 2006 (indicated by the vertical line), which introduced new competitive bidding guidelines. Only the combined generation capacity is available prior to 1992. The data from 1947 to 1992 and from 2001 to 2017 is from report "Growth of Electricity Sector in India from 1947-2017" from the Central Electricity Authority of the Government of India. The data from 1992 to 2001 is from the Ninth Plan and Tenth Plan reports by the Planning Commission of the Government of India. Since the reports only provided additional capacity to each of the sectors during each plan (each plan is five years), the generation capacity for 1992 and 1997 were calculated by subtracting the additional capacity from the known capacity for each sector.

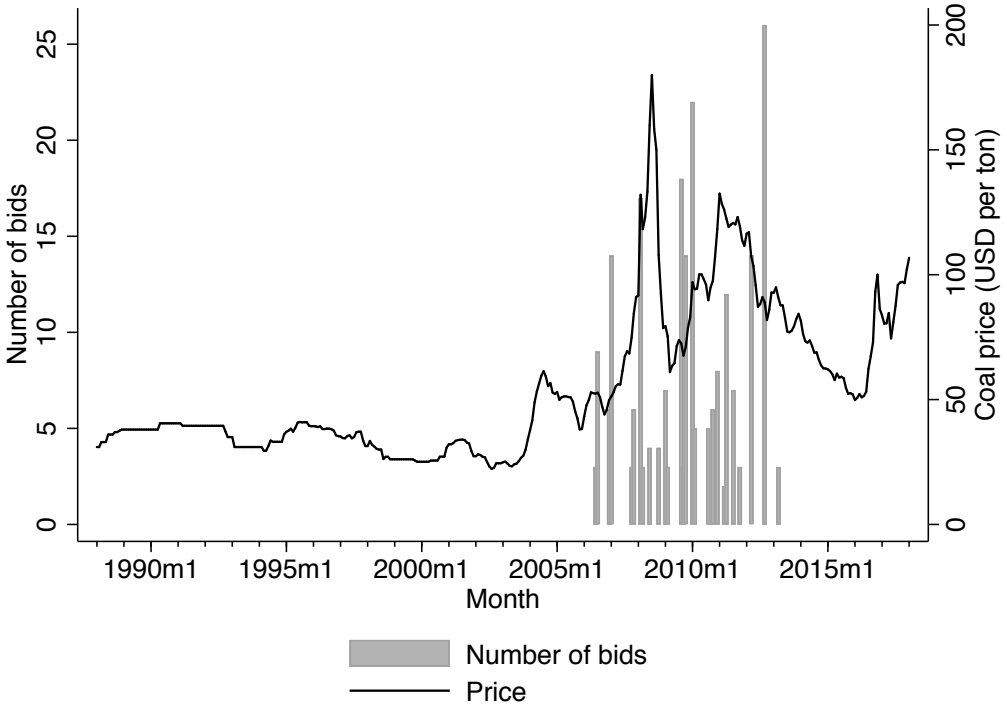


(a) All bids (b) L1 Bidder (c) L2 Bidder (d) L6 Bidder

Figure 2: Bidding for the Mundra Ultra-Mega Power Project

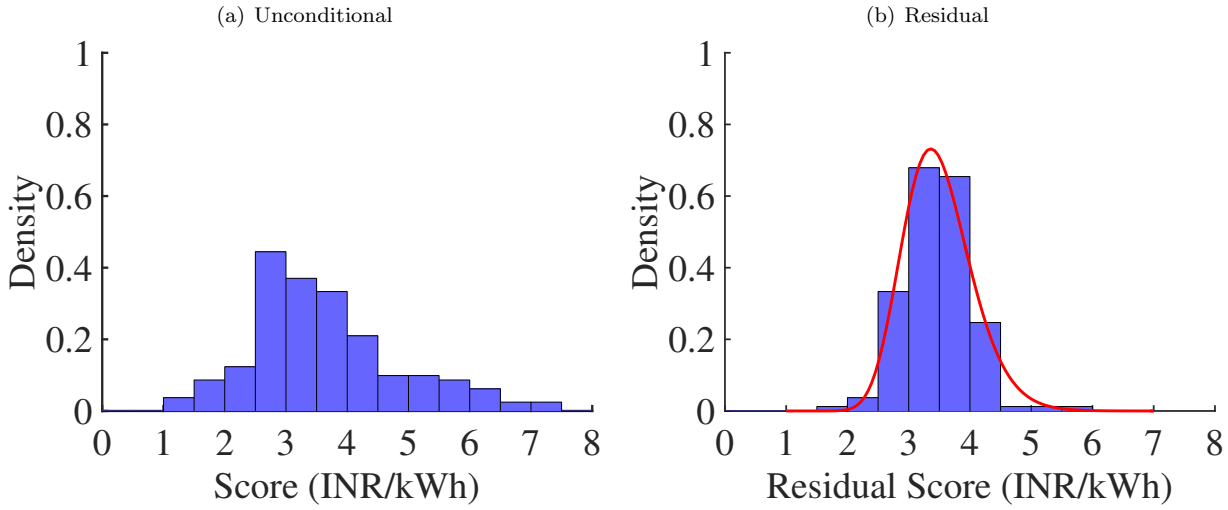
The figure shows bids from the Mundra Ultra-Mega Power Project, which was bid in 2006 for delivery starting in 2012. Panel A shows the time path of all the bids in the Mundra UMPP auction, ranked from L1 (the winning bidder) to L6 (the highest bidder) in terms of their expected discounted nominal tariff (the *score* of the auction). Each curve shows the tariff offered by each bidder in each year of the contract from one to twenty-six (contracts are 25 years long but often span 26 calendar years). These future offered tariffs are expectations, because, for bids indexed to future prices, like the price of coal, the realized value of future tariffs will depend on the realizations of those prices. Panels B, C and D then break down the overall tariffs for the L1, L2 and L6 bidders into their component parts. In each of these three panels, there are three curves. The bottom, dashed (blue) curve shows the nominal tariff for capacity (i.e., fixed) charges. The middle, dotted (red) curve shows the tariff for all parts of the bid not indexed to coal prices. It is therefore the sum of the dashed curve and other charges like energy charges not indexed to coal prices and transportation charges. The topmost, solid (black) curve shows the total tariff in a year. The gap between the solid (black) and dotted (red) curves is therefore the part of the bid indexed to coal prices.

Figure 3: Timing of Power Procurement and Coal Price Shocks



The figure shows the number of bids in sample power procurement auctions (gray bars, against left axis) and the time series of coal prices (solid black line, against right axis). The coal price is the Newcastle coal index, formerly the Barlow-Jonkers index, which gives the price of one ton of coal with gross calorific value of XXXX kcal per kg. This benchmark price, out of Australia, is used as a reference price for international coal for the indexation of Indian power purchase auctions.

Figure 4: Distribution of Equilibrium Scores



The figure shows the marginal distribution of equilibrium bid scores. The score of a bid is the expected present discounted tariff (i.e., "levelised tariff") of a bid over the life of a contract in INR per kWh. The left panel shows the unconditional distribution of scores. The right panel shows the distribution of residual scores. Let $\hat{\mu}_{jt}$ be the estimated mean of the log score distribution in auction j in year t and likewise $\hat{\sigma}_{jt}$ the estimated standard deviation. The residual score is then defined as $\epsilon_{ijt} = (\log S_i - \hat{\mu}_{jt})/\hat{\sigma}_{jt}$. The residuals plotted are scaled up as $\tilde{\epsilon}_{ijt} = \exp(\overline{\hat{\sigma}}_{jt}\epsilon_{ijt} + \overline{\hat{\mu}}_{jt})$ to represent the residual variance in an average auction. The red curve overlaid on the histogram is the log-normal fit for such an auction.

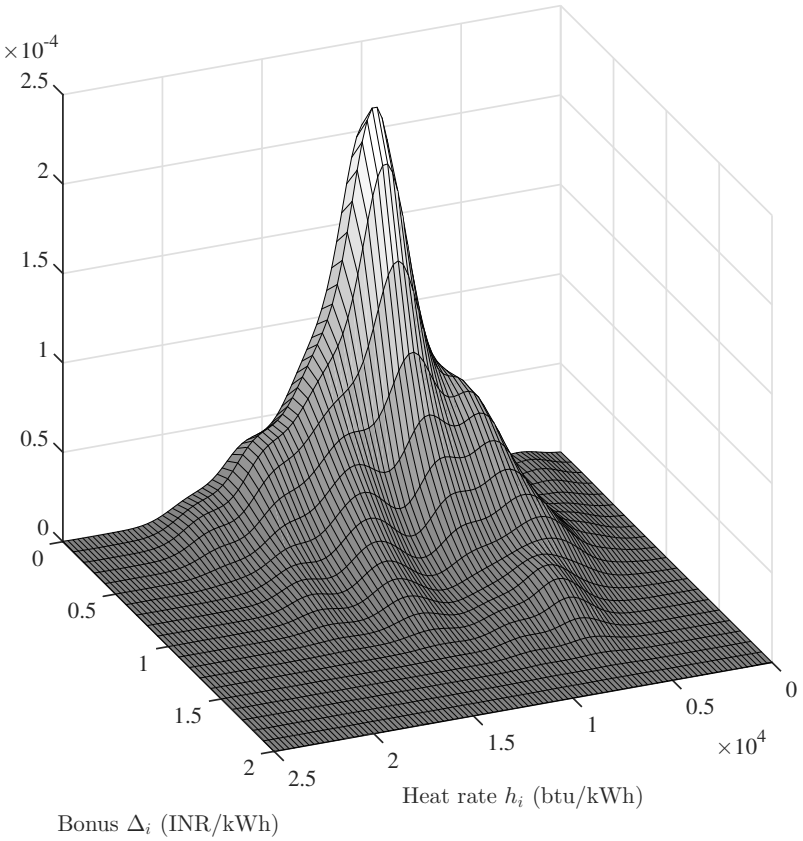
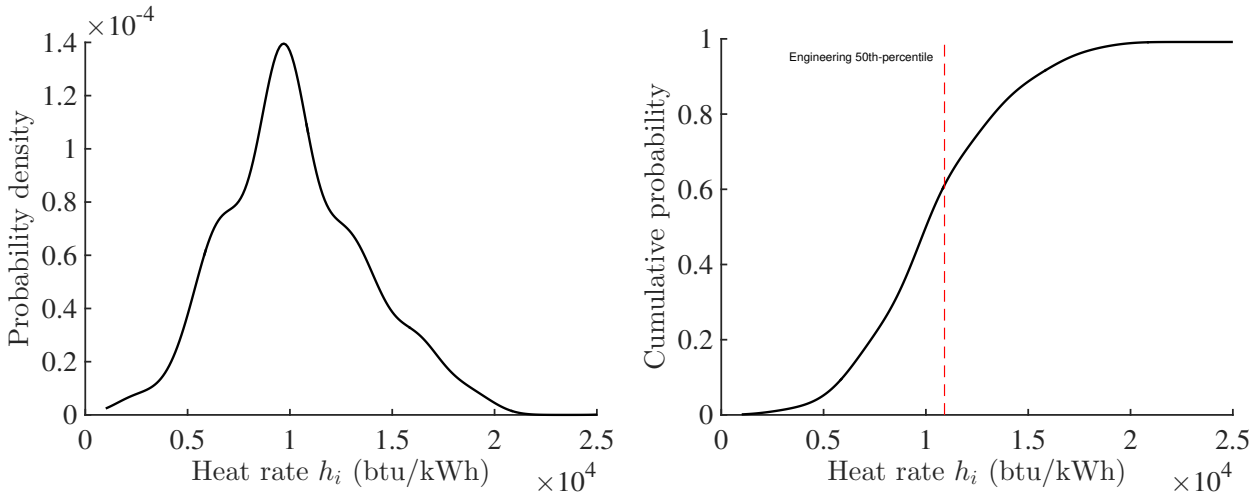


Figure 5: Joint Distribution of Types

The figure shows the joint density of the type distribution. The density is oriented to provide a view to the relation between heat rates and bonuses. The horizontal (lower right) axis shows the heat rate h_i in btu per kWh, decreasing from left (high heat rate, inefficient plants) to right (low heat rate, efficient plants). The horizontal (lower left) axis shows the bonus Δ_i, increasing from upper left (low bonus plants) to lower right (high bonus plants, that expect to received high payments in renegotiation). The density is kernel-smoothed in both dimensions using a normal kernel and bandwidths of 1,000 btu per kWh in the heat rate dimension and INR 0.2 per kWh in the bonus dimension.



(a) Probability density function

(b) Cumulative distribution function

Figure 6: Marginal Distribution of Heat Rates

The figure plots the marginal distribution of heat rates estimated in the model and used for counterfactual simulations of optimal bidding. Panel A shows the probability density function and panel B the cumulative distribution function. The PDF and CDF are kernel-smoothed using a normal kernel and a bandwidth of 1000 btu per kWh.

2 Paper Tables

Table 1: Summary of Bids and Renegotiation

Year	Bids	Winners	Petition			Mean	
			Known	Filed	Granted	Tariff	Capacity
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2006	18	3	3	3	2	2.1	3465
2007	23	10	8	4	0	2.9	1043
2008	26	6	4	3	1	3.1	350
2009	42	14	8	7	3	3.6	782
2010	36	5	4	0	0	3.8	365
2011	22	7	3	1	1	4.7	259
2012	40	12	9	2	0	5.7	340
Total	207	57	39	20	7	3.9	816

Table 2: Cost Shocks and Renegotiation

	(1)	(2)	(3)	(4)
Coal price shock (5 years after − before)	0.242**	0.205*		0.120
	(0.0991)	(0.109)		(0.124)
Coal imported (=1) × coal price shock				0.452***
				(0.159)
Ultra-mega power plant (=1)		0.335**	0.526***	0.197
		(0.142)	(0.177)	(0.215)
Capacity missing (=1)				
Coal imported (=1)			0.474**	0.228
			(0.177)	(0.205)
Coal domestic (=1)			0.282*	0.178
			(0.166)	(0.202)
Constant	0.513***	0.487***	0.158	0.278
	(0.0762)	(0.0839)	(0.129)	(0.175)
Observations	39	39	39	39

The table shows linear probability models for whether an auction winner filed a petition for renegotiation of tariffs. The explanatory variables are the shock to coal prices around the time of bidding, a dummy for whether a plant is an ultra-mega power plant (the largest projects) and dummies for the source of fuel used by the plant. The coal price shock is measured as the difference in coal prices in a five-year moving period after the auction date relative to a five-year moving period before the auction. The units for the coal price shock are converted from USD per ton, the original price of the coal price index, to INR per kWh, by assuming a calorific value of coal of 6300 kcal per kg and a plant heat rate of 11615 btu. Hence a one unit change in coal prices is the change in coal prices that would cause a plant with this efficiency and using this grade of coal to experience a one INR per kWh increase in the marginal cost of power generation. The coal price shock has been demeaned. Robust standard errors in parentheses with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Connectedness and Renegotiation

	(1) Filed	(2) Filed	(3) Granted	(4) Granted
Connected firm (=1)	0.292*	0.331*	0.183	0.251*
	(0.161)	(0.166)	(0.112)	(0.124)
Firm controls		Yes		Yes
Mean dep. var.	0.51	0.51	0.18	0.18
Mean dep. var.: unconnected	0.33	0.33	0.07	0.07
Observations	39	39	39	39

The table shows linear probability models for whether an auction winner filed a petition for renegotiation of tariffs. The explanatory variables are a dummy for whether a firm is connected (received coal below market rates in the coalgate scandal) and controls for firm age and whether a firm is publicly traded. Robust standard errors in parentheses with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Firm Connectedness and Bidding Strategies

	(1)	(2)	(3)	(4)	(5)
Connected firm (=1)	-0.0694**	-0.0775**	-0.0789**	-0.0750**	-0.0776**
	(0.0297)	(0.0297)	(0.0306)	(0.0347)	(0.0317)
Bid price (Rs/kWh)	0.0589***	0.0268	0.0558**	0.0543**	0.0552**
	(0.0108)	(0.0295)	(0.0258)	(0.0267)	(0.0259)
Connected firm (=1) × coal tied to auction (=1)				-0.0216	
				(0.0645)	
Connected firm (=1) × bid before getting coal (=1)					-0.00854
					(0.0698)
Firm controls		Yes	Yes	Yes	Yes
Auction controls		Yes			
Auction fixed effects			Yes	Yes	Yes
Mean dep. var.			0.24	0.24	0.24
Observations	121	121	121	121	121

The table shows estimates of linear regressions of bidding strategies on firm connectedness. The dependent variable is the fraction of the expected present discounted value of bids that a firm indexed to the price of coal in their bid. The main independent variable of interest is , which is a dummy variable equal to one if the firm bidding was allocated a coal block during the Coalgate scandal. All regressions control for the present discounted value of the bid, denoted as the bid price here. Firm-level controls are the firm age at bidding and whether the firm is publicly owned. Auction controls include a set of dummies for the source of fuel and the price of coal at the time of bidding. See the text for a description of the interaction variables. Robust standard errors in parentheses with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

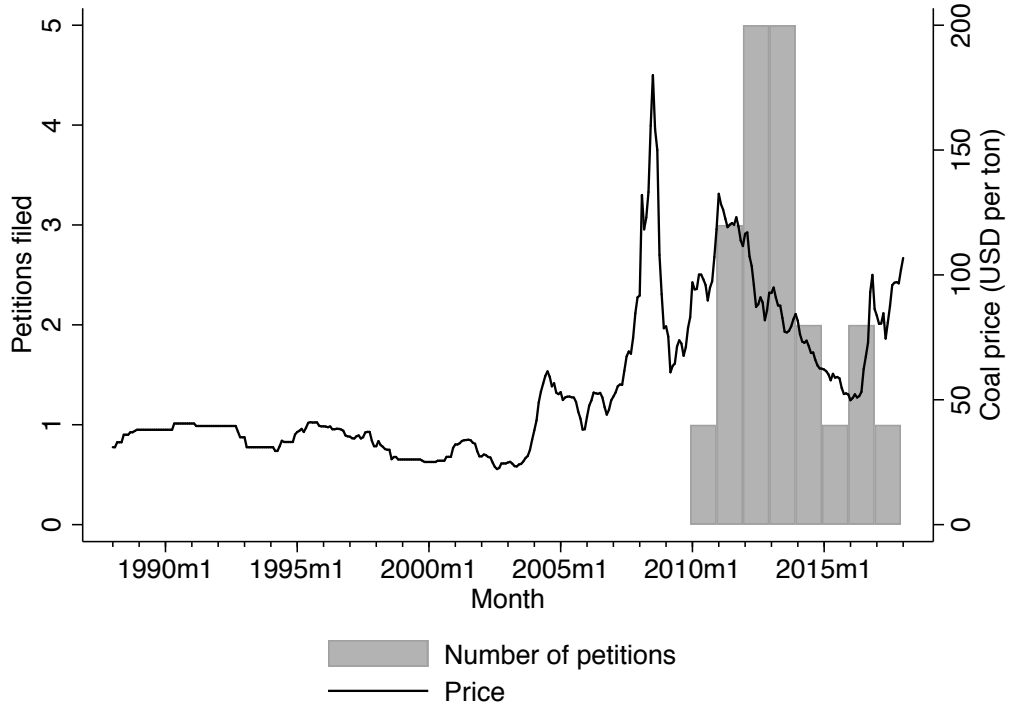
Table 5: Equilibrium and Counterfactual Bids, Costs and Mark-ups

	Equilibrium				Counterfactual	
Sample:	With bid		With type		With type	
Bids:	All	Winning	All	Winning	All	Winning
	(1)	(2)	(3)	(4)	(5)	(6)
Bid (INR/kWh)	3.68	3.41	3.62	3.39	4.20	3.70
	(0.05)	(0.05)	(0.05)	(0.05)	(0.10)	(0.09)
Pseudo-type (INR/kWh)	3.46	3.03	3.38	2.98	3.38	3.27
	(0.06)	(0.08)	(0.07)	(0.10)	(0.07)	(0.11)
Margin over pseudotype (%)	9.16	16.61	10.07	18.36	29.07	21.87
	(1.01)	(2.19)	(1.28)	(2.75)	(2.95)	(4.87)
Cost of supply (INR/kWh)	NaN	NaN	3.97	3.72	3.97	3.36
	(NaN)	(NaN)	(0.10)	(0.11)	(0.10)	(0.10)
Margin over cost (%)	NaN	NaN	-3.88	-2.81	7.73	12.81
	(NaN)	(NaN)	(1.76)	(2.94)	(0.95)	(1.91)
Bonus Δ (INR/kWh)	NaN	NaN	0.29	0.31	0.29	0.33
	(NaN)	(NaN)	(0.02)	(0.05)	(0.02)	(0.05)
Value of renegotiation (INR/kWh)	NaN	NaN	0.22	0.24	0.22	0.27
	(NaN)	(NaN)	(0.02)	(0.04)	(0.02)	(0.04)

The table presents both the equilibrium estimates and the counterfactual results in parallel. The first four columns show estimates describing the current equilibrium bidding. The last two columns show counterfactual simulations. The statistics in the table are reported for two samples. The first pair of columns applies to the entire sample with bids, i.e. equilibrium scores. The second and third pairs of columns, columns three through six, apply to only bids that have their component parts, such as the indexed energy charge, in the data set. Within each pair of columns, the first column reports the mean for all bids and the second the mean for winning bids only. Each column of the table then reports the means of several bidder-level variables. These are the equilibrium or counter-factual bid; the pseudo-type; the margin of the bid over the pseudo-type; the cost of supply, using the estimated heat rate and the coal price applicable to each auction; the margin over cost; the estimated bidder bonus Δ_i; and finally the value of renegotiation, which is equal to the bonus times the expected discounted number of times renegotiation will occur evaluated at the time of bidding. I block bootstrap equilibrium outcomes and counterfactual outcomes by redrawing bidders within clusters of bidding year, fuel source, and data availability (i.e., whether a bid as component parts or not). Standard errors across 200 bootstrap samples are reported in parentheses.

3 Appendix Figures

Figure 7: Timing of Petition Filing and Coal Price Shocks



The figure shows the number of petition filings each year (grey bars, against left axis) and the time series of coal prices (solid black line, against right axis). The petitions are petitions to the appropriate Central or State Electricity Regulatory Commission for a change in the tariff discovered at auction. The coal price is the Newcastle coal index, formerly the Barlow-Jonkers index. This benchmark price, out of Australia, is used as a reference price for international coal for the indexation of Indian power purchase auctions.

4 Appendix Tables

Table 6: Estimates of equilibrium score distribution

	μ_{jt} (1)	$\log \sigma_{jt}$ (2)
Constant	0.314	-1.703
	(0.1099)	(0.4656)
Number of bidders	-0.000	-0.016
	(0.0034)	(0.0158)
Ultra-mega power plant (=1)	0.297	0.438
	(0.0862)	(0.4281)
Coal imported (=1)	0.677	-0.383
	(0.0946)	(0.3122)
Coal domestic (=1)	0.995	-0.050
	(0.1132)	(0.4832)
Coal price (USD/ton)	0.028	-0.005
	(0.0017)	(0.0083)
N	162	
$\log \mathcal{L}$	-130.78	

The table provides estimates of the parameters of the marginal distribution of equilibrium bid scores. The first column gives coefficients on variables affecting the mean score for auction j in time t and the second column coefficients on variables changing the variance. Number of bidders is the maximum of the number of bidders in an auction and six. An asset-specific project is a project where land or coal is given to the winning bidder. Ultra-mega power plant is a large projects of nearly 4,000 MW capacity for which the Central government ran procurement. Coal source not captive refers to projects using domestic or imported sources of coal and therefore exposed to coal price fluctuations. The coal price is the 5-year trailing average of the Newcastle (imported) coal price as of the year prior to bidding in the auction. Estimates are by maximum likelihood with standard errors in parentheses.

Table 7: Cost Shocks and Renegotiation, Hazard Model

	(1)	(2)	(3)	(4)
Coal price shock (INR per kWh)	2.228*	2.119*		1.232
	(0.058)	(0.089)		(0.66)
Coal imported (=1) × coal price shock				7.379**
				(0.011)
Ultra-mega power plant (=1)		1.376	2.094	1.110
		(0.41)	(0.15)	(0.84)
Coal imported (=1)			4.682**	1.982
			(0.011)	(0.43)
Coal domestic (=1)			2.641	1.911
			(0.14)	(0.40)
Observations	2699	2699	2699	2699

The table shows hazard ratios from Cox proportional hazard models for whether an auction winner filed a petition for renegotiation of tariffs. In hazard model terms, filing a petition represents failure. The sample is monthly data from the first year of auctions, 2006, to the end of 2017. Contracts are at risk of failure from the time of the auction until failure is observed or until the end of the sample. The explanatory variables include a time-varying shock to coal prices from the month of bidding to the observation month. Explanatory variables that do not vary in time include: a dummy for whether a plant is an ultra-mega power plant (the largest projects) and dummies for the source of fuel used by the plant. The coal price shock is measured as the difference in coal prices in a five-year moving average in the observation month minus the same five-year moving average in the auction month. The units for the coal price shock are converted from USD per ton, the original price of the coal price index, to INR per kWh, by assuming a calorific value of coal of 6300 kcal per kg and a plant heat rate of 11615 btu. Hence a one unit change in coal prices is the change in coal prices that would cause a plant with this efficiency and using this grade of coal to experience a one INR per kWh increase in the marginal cost of power generation. The coal price shock has been demeaned. Table entries are hazard ratios, not coefficients. Inference is done with robust standard errors clustered at the bid level (across years); p-values from a test of the null that the hazard ratio is equal to one are in parentheses, with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: Summary statistics for determinants of renegotiation

	mean	sd
Bidder petitioned for new tariff (=1)	0.51	0.51
Bidder petition granted (=1)	0.18	0.39
Coal price shock (5 years after − before)	0.00	0.78
Coal imported (=1) × coal price shock	0.09	0.34
Ultra-mega power plant (=1)	0.08	0.27
Coal imported (=1)	0.28	0.46
Coal domestic (=1)	0.64	0.49
Connected firm (=1)	0.62	0.49
Age of bidder (years)	27.41	24.22
Publicly-owned firm (=1)	0.69	0.47
Observations	39	

The table shows summary statistics for the dependent and indepenent variables in the regressions of Tables 2 and 3. The variables are: whether a bidder filed a petition for a revision to their tariff; whether the bidder filed a petition for a new tariff that was granted; the (de-meaned) shock to coal prices from the five years before a project was bid to the five years after; the interaction of the coal price shock with a dummy for the use of imported coal; dummies for imported and domestic coal use; a dummy for a firm being connected, as measured by having received coal during the coalgate scandal, the age of the firm and a dummy for whether the firm is publicly owned.

Table 9: Summary statistics for bidding strategies

	mean	sd
Share of bid value indexed	0.24	0.18
Connected firm (=1)	0.54	0.50
Bid price (Rs/kWh)	3.61	1.33
Connected firm (=1) × coal tied to auction (=1)	0.12	0.33
Connected firm (=1) × bid before getting coal (=1)	0.15	0.36
Age of bidder (years)	30.69	26.82
Publicly-owned firm (=1)	0.69	0.47
Coal source captive (=1)	0.11	0.31
Coal source imported (=1)	0.07	0.26
Coal price (INR/ton)	1759.37	581.43
Observations	121	

The table shows summary statistics for the dependent and indepenent variables in the regressions of Table 4. The variables are: the fraction of the present value of a bid indexed to the price of coal; a dummy for a firm being connected, as measured by having received coal during the coalgate scandal; the present discounted value of the bid; an interaction between being connected and the source of coal for a project being bundled with the auction; an interaction between being connected and the auction being bid out before a connected firm was awarded a coal block in coalgate; the age of the firm; a dummy for whether the firm is publicly owned and controls for the source of coal for a project and the coal price at the time of an auction.

Table 10: Tariff bid by renegotiation status

	(1) None	Filed	Granted	Filed - None	Granted - None
Levelised tariff (Rs/kWh)	3.61	3.26	2.97	-0.36	-0.56
	[1.08]	[1.21]	[1.28]	(0.37)	(0.50)
	19	20	7	39	39
Bidders per winner	3.35	3.74	4.00	0.40	0.55
	[1.49]	[1.82]	[2.69]	(0.53)	(1.00)
	19	20	7	39	39
Bidders per winner					
					39

* p lt 0.10, ** p lt 0.05, *** p lt 0.01

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Table 11: Firm Connectedness and Bidding Strategies

	(1)	(2)	(3)	(4)	(5)
Connected firm (=1)	-0.102***	-0.0788***	-0.0801**	-0.0702**	-0.0764**
	(0.0320)	(0.0295)	(0.0308)	(0.0351)	(0.0322)
Connected firm (=1) × coal tied to auction (=1)				-0.0541	
				(0.0625)	
Connected firm (=1) × bid before getting coal (=1)					-0.0250
					(0.0695)
Firm controls		Yes	Yes	Yes	Yes
Auction controls		Yes			
Auction fixed effects			Yes	Yes	Yes
Mean dep. var.	0.24	0.24	0.24	0.24	0.24
Observations	121	121	121	121	121

The table shows estimates of linear regressions of bidding strategies on firm connectedness. The dependent variable is the fraction of the expected present discounted value of bids that a firm indexed to the price of coal in their bid. The main independent variable of interest is , which is a dummy variable equal to one if the firm bidding was allocated a coal block during the Coalgate scandal. Firm-level controls are the firm age at bidding and whether the firm is publicly owned. Auction controls include a set of dummies for the source of fuel and the price of coal at the time of bidding. See the text for a description of the interaction variables. Robust standard errors in parentheses with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 12: Robustness of Type Distribution Estimates to Calibrated Parameters

	Calibrated parameter values				
	$\eta = 1.0$ $V_0 = 0.30$ (1)	$\eta = 0.5$ $V_0 = 0.30$ (2)	$\eta = 1.5$ $V_0 = 0.30$ (3)	$\eta = 1.0$ $V_0 = 0.15$ (4)	$\eta = 1.0$ $V_0 = 0.45$ (5)
Mean h (btu/kWh)	10433	10602	10199	10263	10500
	(306)	(307)	(316)	(304)	(316)
Median h (btu/kWh)	9876	10046	9787	9926	9974
	(159)	(180)	(201)	(192)	(187)
Standard deviation of Δ (btu/kWh)	3635	3674	3706	3767	3702
	(373)	(365)	(374)	(381)	(378)
Mean Δ (INR/kWh)	0.29	0.26	0.31	0.25	0.31
	(0.023)	(0.021)	(0.027)	(0.021)	(0.026)
Median Δ (INR/kWh)	0.15	0.14	0.15	0.12	0.17
	(0.021)	(0.015)	(0.022)	(0.014)	(0.024)
Standard deviation of Δ (INR/kWh)	0.33	0.29	0.36	0.29	0.35
	(0.024)	(0.023)	(0.030)	(0.024)	(0.026)
Correlation of h and Δ	-0.20	-0.15	-0.20	-0.19	-0.15
	(0.076)	(0.079)	(0.074)	(0.073)	(0.077)

The table shows summary statistics on the estimated type distribution under different assumptions on the calibrated parameters in the model. The calibrated parameters are the bidder risk aversion η and the regulatory threshold V_0 for granting a contract revision. Column 1 shows the baseline estimates and the other columns vary the values of η and V_0. The standard errors are bootstrapped over $B = 200$ iterations. In each column the row statistic is calculated on each iteration and the standard error is the standard deviation of the statistic across iterations.