Econometrica Supplementary Material

SUPPLEMENT TO "CONTRACT ENFORCEMENT AND PRODUCTIVE EFFICIENCY: EVIDENCE FROM THE BIDDING AND RENEGOTIATION OF POWER CONTRACTS IN INDIA"

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NICHOLAS RYAN
Department of Economics, Yale University

APPENDIX D: ADDITIONAL RESULTS

THIS ONLINE APPENDIX D gives additional results to supplement the findings in the main text. This Appendix includes summary statistics on the bidding data; an alternative, hazard model for the response of renegotiation to cost shocks; the estimated parameters of the score distribution; alternative specifications of the bidding strategy regressions without controls for bid price; and checks for the robustness of the counterfactual results to different values of the calibrated parameters in the model.

D.1. *Hazard Model for Effect of Cost Shocks on Renegotiation*

An assumption of the model, tested in Paper Table II, is that large input cost shocks induce renegotiation. Paper Table II provides evidence on this point, but, given the cross-sectional specification, only considered whether renegotiation occurred, and not its timing. This subsection provides further evidence that cost shocks affect renegotiation from the timing of renegotiation.

Figure D.1 show the timing of renegotiation against the time series of coal prices. Renegotiation is dated with the year in which a petition was filed for the revision of the tariff discovered at auction. The very large, but brief price spike in 2008 is not accompanied by renegotiation, but few projects had been bid out by that point, and those that had were not yet generating. The climb in prices in 2010 and 2011 is followed by a large number of renegotiations in 2012 and 2013. Renegotiations then taper off. This wave of renegotiation therefore shows a slightly delayed response to price shocks.

The regression in Paper Table II simplifies the description of cost shocks by (a) using whether a petition for a change in tariff was filed to indicate renegotiation, rather than accounting for when a petition was filed (b) measuring cost shocks around the time an auction was bid out, when in fact coal prices vary month by month after a project is awarded.

Table D.I presents a Cox proportional hazard model that relaxes both of these assumptions, but is otherwise analogous to the cross-sectional specification of Paper Table II. In this hazard model, an observation is a winning bid-by-month, and each winning bid is observed from the time of the auction until the time of failure (filing a petition to revise the tariff) or the end of the sample (at the end of 2017). The coal price shock is measured as the change in a 5-year moving average of coal prices from the time of an auction to the time of observation.

The main findings of the hazard model are the same as for the cross-sectional model of Paper Table II. The entries in Table D.I are hazard ratios. Column 1 shows that the hazard for renegotiation of a project is roughly twice as high for a project that has experienced

Nicholas Ryan: nicholas.ryan@yale.edu

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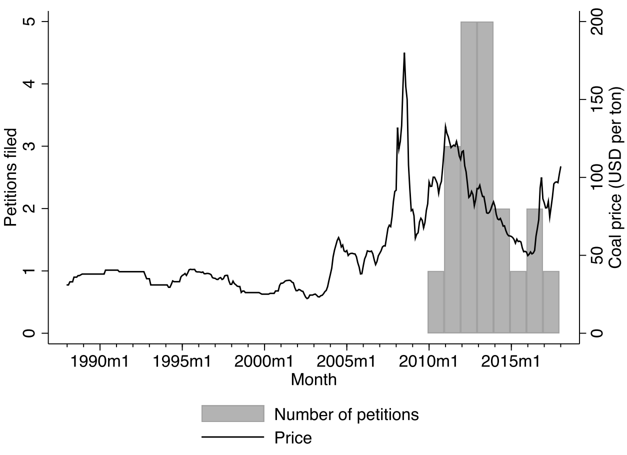

FIGURE D.1.—Timing of petition filing and coal price shocks. The figure shows the number of petition filings each year (grey bars, against left axis) and the time series of coal prices (solid black line, against right axis). The petitions are petitions to the appropriate Central or State Electricity 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.

TABLE D.I

COST SHOCKS AND RENEGOTIATION, HAZARD MODEL[a]

	Failure: Dummy for Renegotiation			
	(1)	(2)	(3)	(4)
Coal price shock (Rs/kWh)	2.228	2.119		1.232
	(0.058)	(0.089)		(0.66)
Coal imported (=1) × coal price shock (Rs/kWh)				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 (winning bid)	39	39	39	39
Observations (year-month)	2699	2699	2699	2699

[a]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 11,615 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.

a coal-price shock that would change the output price by Rs. 1 per kWh (about a third of the mean price bid). This estimate has a p-value of 0.058 against the null hypothesis that the hazard ratio is one. The elevated hazard estimate is unaffected by controlling for UMPP status (column 2); the coefficient on ultra-mega power plant is itself greater than, but not statistically different from, one. Column 3, removing the control for price shocks, shows that imported coal projects face the greatest hazard, nearly five times higher than projects based on captive coal. Column 4 shows that this elevated hazard is due to the greater exposure of imported coal projects to coal price shocks. An imported coal project exposed to a one unit coal price shock has a hazard seven times higher than baseline, with a p-value of 0.011 against the null of a hazard ratio of one.

The hazard model, which accounts for the timing of coal price shocks and the differential length of exposure of different projects, therefore supports the main finding of Table II that input cost shocks drive renegotiation.

D.2. *Summary Statistics for Renegotiation and Bidding Strategy Regressions*

This subsection reports summary statistics for the variables used in the regressions of Paper Tables II, III, and IV.

Paper Tables II and III use a sample of auction outcomes from winning bids. The main outcome is whether a winning bidder filed a petition to renegotiate their tariff (or, alternately, whether they filed a successful petition). Summary statistics for this sample are given in Table D.II below. Table D.III compares the tariffs of winning bids based upon whether or not the winner would go on to file a petition to revise the tariff.

The statistics in Table D.III suggest that bidders who go on to file petitions have meaningfully lower bids, although the differences with other winning bidders are not statistically different from zero, due to the small sample of auction winners. The table compares auction characteristics by whether or not the winning bidder filed a petition to renegotiate the tariff set at auction. The auction characteristics are the winning bid price and the number of bidders per auction winner. The first three columns show the means [standard

TABLE D.II

SUMMARY STATISTICS FOR DETERMINANTS OF RENEGOTIATION[a]

	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	

[a]The table shows summary statistics for the dependent and indepenent variables in the regressions of Tables II and III. 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 D.III

TARIFF BID BY RENEGOTIATION STATUS[a]

	Petition Status				
	None (1)	Filed (2)	Granted (3)	Filed–None (4)	Granted–Not (5)
Bid price (Rs/kWh)	3.61	3.26	2.97	−0.36	−0.56
	[1.08]	[1.21]	[1.28]	(0.37)	(0.50)
Bidders per winner	3.35	3.74	4.00	0.40	0.55
	[1.49]	[1.82]	[2.69]	(0.53)	(1.00)
Observations	19	20	7	39	39

[a]The table compares auction characteristics by whether or not the winning bidder filed a petition to renegotiate the tariff set at auction. The auction characteristics are the winning bid price and the number of bidders per auction winner. The first three columns show the means [standard deviations] of these variables for three different groups: auction winners who did not file a petition to revise tariffs (column 1), auction winners who filed a petition to revise tariffs (column 2) and auction winners who filed a petition and had that petition granted (column 3). Since a petition has to be filed to be granted, the column 3 cases are a subset of column 2. Column 4 gives the difference between columns 2 and 1 and column 5 the difference between column 3 and all cases where a petition was either not filed or not granted (therefore, the weighted mean of columns 1 and 2). In columns 4 and 5, the number in parentheses is the standard error of the estimated difference in means.

deviations] of these variables for three different groups: auction winners who did not file a petition to revise tariffs (column 1), auction winners who filed a petition to revise tariffs (column 2) and auction winners who filed a petition and had that petition granted (column 3).

The mean tariffs among winners filing petitions are INR 0.36 per kWh lower (standard error INR 0.37 per kWh, column 4) than those who do not file (INR 3.61 per kWh, column 1). The mean tariffs among winners granted petitions are INR 0.56 per kWh (standard error INR 0.50 per kWh, column 5) lower than for those not granted a petition and INR 0.64 per kWh (standard error 0.53) lower than for those who did not file. These differences, while not statistically significant, are economically meaningful relative to estimated bid markups and the value of renegotiation. Lower bids among winners who petition are consistent with the idea that having underbid in the initial auction contributes to renegotiation.

Paper Table IV uses a sample of auction bids, regardless of whether a bidder won or not. The outcome is the share of a bid that a bidder indexed to coal prices. Summary statistics for this sample are given in Table D.IV below.

D.3. *Effect of Connectedness on Indexation, Without Bid Price Controls*

Paper Table IV showed that connected firms index their bids less to the price of coal, conditional on firm and auction characteristics and the level of prices bid. In the context of the model, the specification properly includes the bid price as a control, since the prediction of the model is that given a level of efficiency, a connected bidder will index less. However, it may be objected that, since the bid price and level of bid indexation are determined simultaneously, it is unorthodox to control for bid price when indexation is the dependent variable.

Table D.V therefore reproduces Paper Table IV without the control for the bid price. The estimated effect of connectedness on indexation in these specifications is very similar to the estimated effect with the control for bid price. The point estimate in column 1, without controls, shows a slightly larger (more negative) effect of connectedness on

TABLE D.IV

SUMMARY STATISTICS FOR BIDDING STRATEGIES[a]

	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	

[a]The table shows summary statistics for the dependent and independent variables in the regressions of Table IV. 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.

indexation, though I could not reject that the estimated coefficient is equal to that in Paper Table IV, column 1. The coefficients in columns 2 through 5, which include firm and auction level controls, are even more similar. Thus the finding that connected firms index less of their bids does not depend on whether the test is conditional on the level of those bids.

TABLE D.V

FIRM CONNECTEDNESS AND BIDDING STRATEGIES[a]

	Dependent Variable: Fraction of Bid Indexed to Coal				
	(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)				−0.0541	
× coal tied to auction (=1)				(0.0625)	
Connected firm (=1)					−0.0250
× auction before coal awarded (=1)					(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

[a]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 a bid that is indexed to the price of coal. The main independent variable of interest is "Connected firm (=1)", 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.

D.4. *Auctions With Multiple Winners*

Power procurement auctions may select a single winner or multiple winners. I assume that the number of bidders N and the number of winners W in an auction are both known *ex ante*. The number of bidders is likely to be known *ex ante*, since financial bids are preceded by a request for qualification (RFQ), or screening stage. The number of winners is not known *ex ante*, but the quantity of capacity to be procured is known, and bidders are likely able to infer how many winning bids will be needed to meet that capacity. All UMPP projects have only one winner. For non-UMPP projects, the correlation between the number of winners and capacity is 0.81, suggesting that bidders are well informed about the number of winners in an auction.

There is no significant difference in the average offered bid in auctions with multiple winners versus auctions with a single winner, with the mean bid in auctions with multiple winners INR 0.57 per kWh (standard error INR 0.37 per kWh) higher than in auctions with a single winner. However, auctions with multiple winners have about two fewer bidders per winner, and consistent with this difference in participation reducing competitiveness, winning bids are INR 0.80 per kWh (stndard error INR 0.33 per kWh) higher in auctions with multiple winners. The model accounts for these differences in competitiveness by using the number of bidders and winners in each auction in both estimation and counterfactuals (see equations (5) and (8), resp.).

D.5. *Score Distribution Parameter Estimates*

Table D.VI reports the maximum likelihood estimates of the parameters of the distribution of equilibrium scores. Since the distribution is assumed log-normal the parameters μ_{it} and σ_{it} are the mean and standard deviation of the distribution of log scores; the two columns of the table report the coefficients on observables from linear specifications for μ_{it} and $\log \sigma_{it}$.

The parameters of the distribution are precisely estimated and marginal effects on the mean of the distribution have the expected signs. Since the same variables change both the mean and dispersion of the distribution I use the coefficients in the table to calculate marginal effects (or the discrete effects of switching indicator variables from zero to one). The mean of the score distribution is higher for projects reliant on imported or domestic coal than for captive coal projects. For example, applying the estimated parameters to a project with four bidders and the mean coal price, if we change a project from a captive Ultra-Mega Power Plant to a plant using domestic coal, this raises the mean of the score distribution by INR 1.82 per kWh (the mean of the score distribution in the data is INR 3.68 per kWh, so this is a large effect). This jump in prices is to be expected since a captive UMPP has the lowest cost structure of any type of plant. The mean of the score distribution is also increasing in the coal price. The price effect is large and precisely estimated. A one standard deviation (INR 519 per ton) increase in coal price raises the mean score by INR 0.55 per kWh. A two standard deviation price change therefore has the same effect as moving a project from using domestic to imported coal.

D.6. *Robustness of Type Distribution Estimates*

Table D.VII studies the robustness of the estimated type distribution to alternative assumptions on the calibrated parameters. The baseline values of the calibrated parameters are $\eta = 1.0$, for firm risk aversion, and $V_0 = 0.30$ (INR per kWh), for the regulator's tolerance for a firm's loss in variable profits before permitting renegotiation. Column 1 shows

TABLE D.VI

ESTIMATES OF EQUILIBRIUM SCORE DISTRIBUTION[a]

	μ_{jt} (1)		$\log \sigma_{jt}$ (2)
Coal price (USD/ton)	0.028		−0.005
	(0.0017)		(0.0083)
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)
Number of bidders	−0.000		−0.016
	(0.0034)		(0.0158)
Constant	0.314		−1.703
	(0.1099)		(0.4656)
N		162	
$\log \mathcal{L}$		−130.78	

[a]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 4000 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.

statistics on the type distribution under the baseline values of these parameters and the other columns show the same statistics on the estimated type distribution under different values of the calibrated parameters, as indicated by the column headers.

The estimates of the type distribution are not sensitive to reasonable changes in the values of the calibrated parameters. For example, the mean heat rate in the baseline case with $\eta = 1.0$ is 10,433 btu per kWh (standard error 306 btu per kWh) and the median is 9,876 btu per kWh (standard error 159 btu per kWh). If we cut risk aversion by half, to $\eta = 0.50$, the mean heat rate rises to 10,602 btu per kWh (standard error 307 btu per kWh) and the median to 10,046 btu per kWh (standard error 180 btu per kWh). These are small changes both economically and statistically. Cutting risk aversion in the same way decreases the estimated mean bonus Δ from 0.29 INR per kWh to INR 0.26. There are similarly small changes in the moments of the estimated heat rate and bonus distributions from changing the regulatory tolerance for firm losses (columns 4 and 5). Nor does varying the calibrated parameters change the conclusion that there is a negative and significant correlation of around −0.20 between the two dimensions of the type (final row, comparing across columns).

The robustness checks illustrate the logic of the trade-off in the model between risk and renegotiation. In particular, when firms are more risk averse, we estimate a combination of lower heat rates and higher bonuses. This result can be understood via how the model rationalizes bidding patterns. Given the data that shows the firm's bid and its indexation choice, if the same firm is supposed to be more risk averse, then to have chosen the observed bid it must have had either lower heat rates or a higher bonus. Lower heat rates, ceteris paribus, since a more risk averse firm faces lesser risk from fuel prices if it is more efficient and therefore uses less coal per unit output. A higher bonus, ceteris

TABLE D.VII

ROBUSTNESS OF TYPE DISTRIBUTION ESTIMATES TO CALIBRATED PARAMETERS[a]

	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)	10,433	10,602	10,199	10,263	10,500
	(306)	(307)	(316)	(304)	(316)
Median h (btu/kWh)	9876	10,046	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)

[a]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.

paribus, since a more risk averse firm is willing to bear risk only if it expects a greater payoff to renegotiation.

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