

Online Appendix

Subsidies and Debt under Nonlinear Electricity Pricing

October 2026

A Administrative Data Construction

Table 1: Variable definitions and construction for administrative billing data

Variable	Description
Billed energy (kWh)	Definition: Billed energy (kWh) for the application×month as shown on the monthly bill—the electricity units consumed during that billing cycle. Zero values: Typically indicate no recorded consumption for the cycle and/or credits that fully offset usage. Negative values (examples): (a) net-metering credits where exported energy offsets consumption (often large magnitudes); (b) billing corrections/credits (e.g., prior overbilling adjustments) or advance crediting/charging of ‘free units’ for utility employees. Construction: Within application×month, KWH_TOT_UNITS is a bill-level total; when the raw extract contains multiple adjustment-amount line-item rows (TOT_ADJ_AMOUNT) for the same application×month, KWH_TOT_UNITS repeats (identically) across those rows. We set units_clean equal to KWH_TOT_UNITS and collapse to one row per application×month.
Billed amount (PKR)	Definition: Billed amount (PKR) for the application×month as shown on the monthly bill—the rupee value of the current-cycle charges (excluding arrears/previous balance). Zero values: Same interpretation as for Billed energy (kWh). Negative values (examples): Same interpretation as for Billed energy (kWh). Construction: Within application×month, ASSESSMENT_AMOUNT is a bill-level total (current-cycle charges); when the raw extract contains multiple adjustment-amount line-item rows (TOT_ADJ_AMOUNT) for the same application×month, ASSESSMENT_AMOUNT repeats (identically) across those rows. We set billed_amount_clean equal to ASSESSMENT_AMOUNT and collapse to one row per application×month.

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Variable	Description
Total billed amount (PKR)	Definition: Total billed amount (PKR) for the application×month as shown on the monthly bill—the total amount due at issuance, equal to current-cycle charges plus the arrears/previous balance carried forward. Zero values: No net amount due (e.g., zero charges and no arrears, or credits fully offset charges and arrears). Negative values (examples): Net credit balance where the utility owes the customer (e.g., refunds, overbilling corrections, relief) that exceeds current-cycle charges and any arrears. Construction: We construct <code>total_bill_clean</code> as <code>ASSESSMENT_AMOUNT + ARREAR</code>. When the raw extract contains multiple adjustment-amount line-item rows (<code>TOT_ADJ_AMOUNT</code>) for the same application×month, <code>ASSESSMENT_AMOUNT</code> and <code>ARREAR</code> repeat (identically) across those rows. We collapse to one row per application×month.
Payment amount (PKR)	Definition: Total payments (PKR) posted for the application×month. Zero values: No payment posted in the cycle. Negative values (examples): Payment reversals/corrections where a previously posted payment is netted out (e.g., reversal/chargeback, refund, or reallocation/correction across months). Construction: Posted-payment records are aggregated to the application×month level to construct <code>pay_total_new</code>. We set <code>payment_total_clean</code> equal to <code>pay_total_new</code>; application×months with no posted payment are coded as zero.
Arrears balance (PKR)	Definition: Arrears balance (PKR) for the application×month as shown on the monthly bill—the outstanding balance from prior billing cycles carried forward at the time the bill is issued. Zero values: No outstanding balance carried forward. Negative values (examples): Net credit balance where the utility owes the customer (e.g., overbilling corrections, relief, refunds). Construction: Direct copy of <code>ARREAR</code> (stored as <code>arrear_clean</code>).
Arrears age (months)	Definition: Age of arrears (months) associated with the balance carried on the bill. Zero values: No arrears pending. Negative values (examples): Net credit/advance situations where the utility/government owes the customer (e.g., refunds or relief credited in instalments; advance crediting of unused ‘free units’ for utility employees, which can generate negative values spanning many months). Construction: Direct copy of <code>ARREAR_AGE</code> (stored as <code>arrear_age_clean</code>).

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Variable	Description
Total adj. amount (PKR)	Definition: Total adjustment amount (PKR) for the application×month as shown on the monthly bill—the rupee value of billing adjustments recorded as separate line-items (e.g., overbilling corrections, litigation-related credits/refunds, disaster-relief credits). Zero values: No adjustment recorded for the application×month. Negative values (examples): Credit adjustments where the utility reduces the amount due or issues a refund/relief (e.g., overbilling correction credited back; litigation refund; flood/disaster relief). Construction: Within application×month, the raw extract may contain multiple adjustment line-items with amounts recorded in TOT_ADJ_AMOUNT. We sum TOT_ADJ_AMOUNT across all rows for the application×month to construct <code>adj_amount_clean</code>, then collapse to one row per application×month.

Notes: “Application” refers to a unique utility customer account. The unit of observation is application × month. Where the raw extract contains multiple adjustment line-items within an application-month, adjustment amounts are summed and repeated bill-level fields are retained before collapsing to one observation per application-month.

B Balance and Pre-Treatment Trends

Table 2: Balance in pre-treatment characteristics and outcomes

	Control	T1	T2	T3	T4	<i>p</i> -value
Protected customer (=1)	0.444	0.445	0.442	0.444	0.443	1.000
Household size (members)	7.79	7.81	7.63	7.84	7.48	0.598
Household-head age (years)	42.46	43.95	43.20	42.80	42.87	0.539
Household-head secondary education or above (=1)	0.319	0.338	0.328	0.353	0.307	0.765
Monthly household income (PKR)	24,268	23,085	23,946	24,809	25,112	0.227
Any baseline payment stress (=1)	0.748	0.759	0.756	0.789	0.776	0.730
Billed energy (kWh)	133.01	138.95	130.87	133.05	135.53	0.586
Billed amount (PKR)	2,810	2,957	2,744	2,864	2,952	0.658
Payment amount (PKR)	1,768	1,720	1,708	1,846	1,776	0.844
Arrears balance, Dec 2022 (PKR)	47,495	53,540	44,056	43,017	52,775	0.630
Arrears age, Dec 2022 (months)	15.89	17.38	14.77	13.97	17.54	0.570
Baseline 0–100 kWh (=1)	0.372	0.358	0.393	0.352	0.351	0.763
Baseline 101–200 kWh (=1)	0.473	0.465	0.451	0.481	0.478	0.936
Assigned applications	347	346	346	347	345	–

Notes: Baseline household characteristics are measured in the pre-treatment survey. Administrative flow outcomes are averaged over Jan–Dec 2022; arrears balance and arrears age are measured in Dec 2022. Protected customer is the randomisation stratum. Baseline tariff-position indicators use mean monthly billed energy over Jan–Dec 2022. The *p*-value reports an omnibus test of equality across experimental arms using robust standard errors.

Table 3: Pre-treatment trend tests for administrative outcomes

Outcome	<i>p</i> -value	N
Billed energy (kWh)	0.457	20,772
Billed amount (PKR)	0.761	20,772
Payment amount (PKR)	0.536	20,772
Arrears balance (PKR)	0.405	20,772

Notes: The table reports *p*-values from joint tests of differential pre-treatment trends across experimental arms over Jan–Dec 2022. Specifications include application and billing-month fixed effects and treatment-arm-by-month interactions, with Jan 2022 omitted. Standard errors are clustered by application.

C Additional Reduced-Form Results

Table 4: Average reduced-form effects by rebate-generosity period

	Energy (kWh) (1)	Bill (PKR) (2)	Payment (PKR) (3)	Arrears (PKR) (4)
Panel A. Jan–Jul 2023				
T1 × Jan–Jul	0.3 (4.1)	128 (164)	95 (217)	2,303 (1,697)
T2 × Jan–Jul	1.1 (4.3)	127 (186)	-104 (215)	342 (1,612)
T3 × Jan–Jul	2.3 (3.9)	-54 (150)	107 (209)	-160 (1,515)
T4 × Jan–Jul	-3.8 (3.9)	-134 (151)	63 (217)	1,589 (1,582)
Panel B. Aug–Dec 2023				
T1 × Aug–Dec	-5.4 (4.9)	-192 (234)	265 (359)	3,042 (2,907)
T2 × Aug–Dec	-0.4 (5.1)	-95 (236)	13 (352)	922 (3,010)
T3 × Aug–Dec	3.2 (4.6)	8 (223)	425 (368)	-1,339 (2,572)
T4 × Aug–Dec	0.9 (4.8)	-167 (226)	455 (378)	639 (2,666)
Control mean, Jan–Jul	111.6	2,591	4,129	51,600
Control mean, Aug–Dec	119.7	3,695	4,693	59,925
Application fixed effects	Yes	Yes	Yes	Yes
Billing-month fixed effects	Yes	Yes	Yes	Yes
Observations	41,544	41,544	41,544	41,544
Applications	1,731	1,731	1,731	1,731

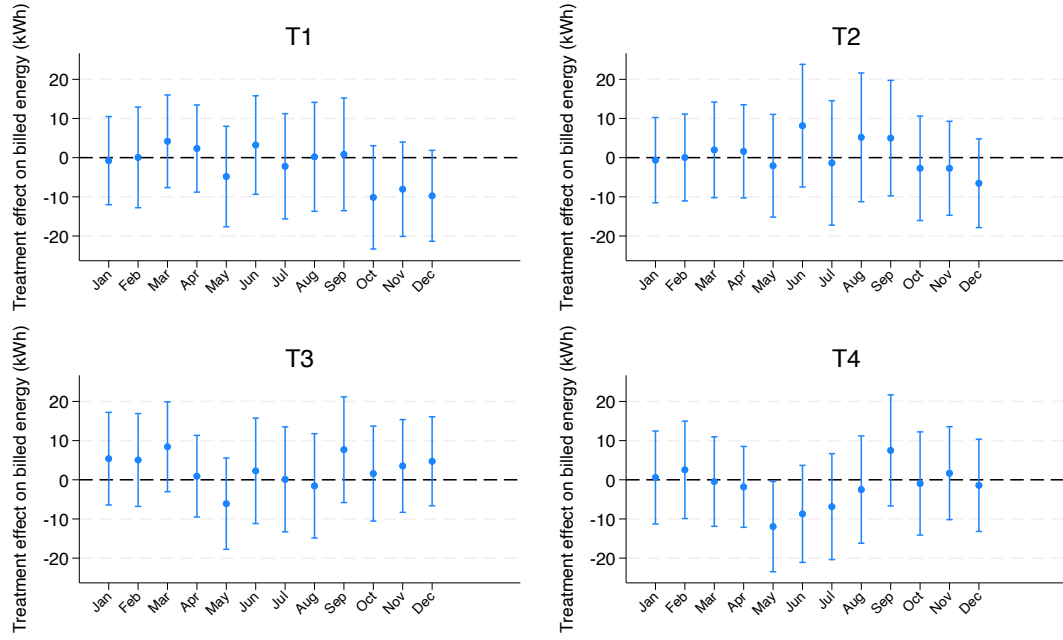
Notes: Estimates use application × month data over Jan 2022–Dec 2023. Panel A reports treatment effects for Jan–Jul 2023; Panel B reports effects for Aug–Dec 2023, when rebates became more generous. Specifications include application and billing-month fixed effects; control is the reference group and standard errors are clustered by application. Control means correspond to each treatment period. Bill excludes carried-forward arrears; arrears is the outstanding balance on the monthly bill. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Pooled effects on debt reduction and realised subsidy expenditure

	Debt reduction (PKR) (1)	Realised subsidy (PKR) (2)
Any treatment × Subsidy year	105.0* (55.4)	415.1*** (9.9)
Debt reduction per Rs 1 of subsidy	0.25	
Application fixed effects	Yes	Yes
Billing-month fixed effects	Yes	Yes
Observations	39,816	39,816
Applications	1,659	1,659

Notes: The table pools the four treatment arms and uses the common sample of applications linked to realised subsidy-payment records. Debt reduction is the gross decline in positive arrears relative to the previous consecutive billing month; realised subsidy is the research-funded rebate paid to the household. Estimates compare treatment with control over Jan 2022–Dec 2023 and include application and billing-month fixed effects; standard errors are clustered by application. The ratio of the coefficient in column (1) to that in column (2) gives the additional reduction in outstanding utility debt per rupee of realised subsidy expenditure. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 1: Monthly treatment effects on billed energy during the subsidy year



Notes: Points report arm-specific monthly treatment effects on billed energy during Jan–Dec 2023; vertical bars report 95% confidence intervals. Estimates use application and billing-month fixed effects over Jan 2022–Dec 2023, with control as the reference group. Standard errors are clustered by application.

D Additional Price-Exposure Results

Table 6: Arm-specific consumption effects by baseline consumption

Baseline consumption	Monthly billed energy (kWh)		
	(1) 0–100 kWh	(2) 101–200 kWh	(3) Above 200 kWh
T1 $\times$ Subsidy year	3.42 (3.48)	-2.23 (4.77)	-5.18 (14.83)
T2 $\times$ Subsidy year	7.42 (4.72)	-5.22 (5.24)	-2.83 (14.18)
T3 $\times$ Subsidy year	6.20 (3.90)	-1.04 (4.90)	11.83 (12.23)
T4 $\times$ Subsidy year	-1.47 (3.40)	-0.26 (5.03)	-0.05 (13.59)
Control mean, subsidy year	75.3	125.2	178.7
Application fixed effects	Yes	Yes	Yes
Billing-month fixed effects	Yes	Yes	Yes
Observations	15,168	19,512	6,864
Applications	632	813	286

Notes: Baseline-consumption groups use mean monthly billed energy over Jan–Dec 2022. Entries report arm-specific treatment effects relative to control within each group and underlie the price-exposure contrasts in the main text. Estimates use application and billing-month fixed effects over Jan 2022–Dec 2023; standard errors are clustered by application. Control means are subgroup-specific subsidy-year means. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Consumption responses by ex ante price exposure and baseline electricity supply

	Monthly billed energy (kWh)	
	(1)	(2)
Baseline consumption	0–100 kWh	101–200 kWh
<i>Panel A. Lower baseline load shedding (≤ 12 hours/day)</i>		
AP + MP versus no exposure	6.74 (6.27)	
Pooled AP + MP versus no exposure	1.71 (5.53)	
AP + MP versus AP only		-5.43 (9.01)
<i>Panel B. Higher baseline load shedding (> 12 hours/day)</i>		
AP + MP versus no exposure	-8.43 (6.65)	
Pooled AP + MP versus no exposure	-9.55 (6.50)	
AP + MP versus AP only		0.45 (4.66)
<i>Panel C. Lower minus higher baseline load shedding</i>		
AP + MP versus no exposure	15.17* (9.14)	
Pooled AP + MP versus no exposure	11.26 (8.53)	
AP + MP versus AP only		-5.89 (10.14)
Control mean, lower load shedding	84.5	122.7
Control mean, higher load shedding	72.4	122.8
Application fixed effects	Yes	Yes
Billing-month fixed effects	Yes	Yes
Observations	14,136	18,408
Applications	589	767

Notes: Baseline load shedding is measured in hours per day. Lower load shedding is defined as at most 12 hours per day; higher load shedding is more than 12 hours per day. Panels A and B report price-exposure contrasts within each supply group; Panel C reports their difference. Price-exposure contrasts follow the construction used in the main text. Estimates use application and billing-month fixed effects over Jan 2022–Dec 2023; standard errors are clustered by application. Control means are subgroup-specific subsidy-year means. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

E Survey Mechanism Evidence

Table 8: Endline survey evidence on bill-payment coping and credit demand

	(1) Borrow for summer bill	(2) Do not pay summer bill	(3) Any late bill	(4) Wants zero-interest loan
Any subsidy	0.000 (0.028)	0.001 (0.017)	0.027 (0.029)	0.062* (0.032)
Control mean	0.275	0.078	0.278	0.492
Observations	1,520	1,520	1,520	1,520

Notes: Entries report intent-to-treat effects of assignment to any subsidy arm relative to control from household-level OLS regressions controlling for the protected-customer randomisation stratum. Robust standard errors are in parentheses. Borrow for summer bill indicates borrowing as a reported strategy for paying summer electricity bills. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: Reported subsidy use among treated households at endline

	Share	Observations
Used subsidy for electricity bill	0.583	1,211
Used subsidy for other household expenses	0.543	1,211
Subsidy helped decrease expenses	0.529	1,211
Subsidy had positive livelihood effect	0.580	1,211

Notes: The table reports descriptive shares among households assigned to the four subsidy arms at endline. Outcomes are not mutually exclusive.

F Additional Financial Heterogeneity Results

Table 10: Debt repayment among applications entering the subsidy year with positive arrears

	Debt	
	(1)	(2)
	Reduced (=1)	Cleared (=1)
T1 $\times$ Subsidy year	0.042*** (0.016)	0.007 (0.009)
T2 $\times$ Subsidy year	0.033** (0.016)	0.010 (0.009)
T3 $\times$ Subsidy year	0.016 (0.017)	0.006 (0.009)
T4 $\times$ Subsidy year	0.010 (0.016)	-0.003 (0.010)
Control mean, subsidy year	0.154	0.062
Application fixed effects	Yes	Yes
Billing-month fixed effects	Yes	Yes
Observations	20,856	20,856
Applications	869	869

Notes: The unit of observation is application $\times$ month, and the sample is restricted to applications with strictly positive arrears in Dec 2022, immediately before the subsidy year. Debt reduced equals one when strictly positive arrears in the previous consecutive billing month fall in the current month; debt cleared equals one when they fall to zero or below. Estimates compare each treatment arm with control over Jan 2022–Dec 2023 and include application and billing-month fixed effects; standard errors are clustered by application. Control means are for the subsidy year. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 11: Debt-repayment effects by pre-treatment debt status

	Debt	
	(1)	(2)
	Reduced (=1)	Cleared (=1)
<i>Panel A. No positive arrears in Dec 2022</i>		
T1 $\times$ Subsidy year	0.015 (0.015)	0.021* (0.011)
T2 $\times$ Subsidy year	0.012 (0.015)	0.009 (0.011)
T3 $\times$ Subsidy year	0.017 (0.015)	0.025** (0.011)
T4 $\times$ Subsidy year	0.010 (0.015)	0.019* (0.011)
<i>Panel B. Positive arrears in Dec 2022</i>		
T1 $\times$ Subsidy year	0.042*** (0.016)	0.007 (0.009)
T2 $\times$ Subsidy year	0.033** (0.016)	0.010 (0.009)
T3 $\times$ Subsidy year	0.016 (0.017)	0.006 (0.009)
T4 $\times$ Subsidy year	0.010 (0.016)	-0.003 (0.010)
<i>Panel C. Positive arrears minus no positive arrears</i>		
T1 $\times$ Subsidy year	0.027 (0.022)	-0.014 (0.014)
T2 $\times$ Subsidy year	0.021 (0.022)	0.001 (0.015)
T3 $\times$ Subsidy year	-0.001 (0.023)	-0.018 (0.015)
T4 $\times$ Subsidy year	-0.001 (0.022)	-0.022 (0.015)
Control mean, no positive arrears	0.118	0.084
Control mean, positive arrears	0.154	0.062
Application fixed effects	Yes	Yes
Billing-month fixed effects	Yes	Yes
Observations	41,544	41,544
Applications	1,731	1,731

Notes: Pre-treatment debt status equals one if the application had strictly positive arrears in Dec 2022. Panels A and B report effects without and with positive pre-treatment arrears; Panel C reports their difference. Debt reduced equals one when previously positive arrears fall; debt cleared equals one when they fall to zero or below. Estimates include application and billing-month fixed effects; standard errors are clustered by application. Control means are subgroup-specific subsidy-year means. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.