

# Hardening the Grid: Technology versus Enforcement\*

Robin Burgess<sup>†</sup>   Tim Dobermann<sup>‡</sup>   Michael Greenstone<sup>§</sup>   Faraz Hayat<sup>¶</sup>  
Muhammad Usman Naeem<sup>||</sup>

Working Paper — October 2026

## Abstract

Can infrastructure succeed where enforcement struggles to curb electricity theft? We study this question in a field experiment with 120 distribution transformers in high-theft neighbourhoods of Lahore, Pakistan. Working with a public electricity utility, we randomly assign transformers to theft-resistant aerial bundled cables, intensified monthly inspections, or control. Using transformer-level electricity accounts, we find that assignment to theft-resistant infrastructure reduces recorded electricity losses by 10 percentage points (SE 3.2), nearly one-quarter of the pre-treatment mean. The result is robust to alternative estimators and measurement specifications, while intensified inspections produce no detectable reduction over their first three months. The findings highlight the potential of infrastructure to reshape the opportunity to steal, rather than relying solely on the threat of detection. Because administrative measurement remains imperfect and billed consumption does not increase detectably, the evidence establishes a reduction in recorded losses, not an equivalent reduction in theft or increase in revenue.

**JEL codes:** C93, D73, L94, Q41, Q48.

**Keywords:** electricity theft; distribution losses; aerial bundled cables; enforcement; infrastructure; randomised experiment; Pakistan.

---

\*We are grateful to the Lahore Electric Supply Company (LESCO) and Pakistan’s Ministry of Energy (Power Division) for their collaboration. We thank LESCO’s Market Implementation and Regulatory Affairs Department and Management Information System office for coordination and access to administrative records, the implementation teams, and the independent field survey team. We gratefully acknowledge financial support from the International Growth Centre (IGC) and the Weiss Fund for Research in Development Economics. The experiment was registered in the AEA RCT Registry as AEARCTR-0015084. All errors are our own.

<sup>†</sup>Department of Economics, London School of Economics and Political Science. Email: r.burgess@lse.ac.uk.

<sup>‡</sup>International Growth Centre. Email: t.dobermann@lse.ac.uk.

<sup>§</sup>Department of Economics, University of Chicago. Email: mgreenst@uchicago.edu.

<sup>¶</sup>International Growth Centre. Email: shayat1@uchicago.edu.

<sup>||</sup>The Fletcher School and Department of Economics, Tufts University. Email: usman.naeem@tufts.edu.

# 1 Introduction

Electricity theft is a persistent challenge for utilities in many developing countries. Electricity delivered through the distribution network can exceed electricity billed to customers because of illegal connections, meter tampering, and technical losses. The resulting revenue shortfalls undermine utility finances and can contribute to higher tariffs and unreliable supply for paying customers. In Pakistan, distribution companies lost 18.3 percent of electricity delivered in fiscal year 2023–24, against an allowed 11.8 percent, and recovered 92.4 percent of amounts billed. Losses above the allowed level and unpaid bills contributed approximately PKR 591 billion to the sector’s circular debt in that year (NEPRA, 2024).

This raises an economic choice between prevention and deterrence. Utilities can raise the physical cost of stealing electricity, or increase the probability that theft is detected and penalised. The distinction matters for both the cost and durability of compliance. Insulated aerial bundled cable (ABC) makes illegal hook connections more difficult but requires up-front capital investment. Inspection campaigns, known locally as “combing”, can identify illegal connections and meter irregularities, but must be implemented repeatedly and depend on enforcement capacity. These approaches change different margins of the decision to steal: the feasibility of illegal access versus the expected cost of getting caught. Yet we have limited experimental evidence on either approach, or on how their effects compare within the same utility.

We study this question in partnership with the Lahore Electric Supply Company (LESCO) and Pakistan’s Ministry of Energy (Power Division). We randomised 120 distribution transformers in Lahore’s Eastern and Southern circles, stratifying by circle, into three equally sized groups: replacement of conventional low-voltage lines with ABC, monthly intensified anti-theft inspections, and control. ABC installation proceeded in five waves between July and November 2025; enhanced inspections began in May 2026. Our primary outcome is the monthly transformer-level *recorded loss rate*: electricity received but not billed, divided by electricity received. We construct a panel from January 2024 to July 2026 using the utility’s administrative records. The analysis sample contains 117 distinct transformers after three duplicated administrative entries were removed.

Assignment to ABC reduces the recorded loss rate by 10.0 percentage points (SE 3.2) in a specification with transformer and month fixed effects, equivalent to roughly one-quarter of the 43 percent pre-treatment mean. The extended two-way fixed-effects estimator, which accommodates treatment-effect heterogeneity across installation cohorts and months, estimates a 9.7-point reduction (SE 3.4). The Callaway–Sant’Anna estimate is a 7.5-point reduction (SE 4.9;  $p = 0.13$ ). Thus the negative result also appears under staggered-adoption-robust approaches, although the precision of the estimated effect depends on the estimator. The decline in recorded losses is visible around installation and over the first six months of exposure; estimates at longer horizons are imprecise. Enhanced monthly inspections have no detectable effect during their first three months, but this short observation window cannot exclude economically meaningful effects.

The reduction in recorded losses is robust to several measurement choices. It remains negative and statistically significant using observed readings only (TWFE:  $-9.9$  points, SE 3.2), and when

restricting the analysis to the original scanning-meter regime without interpolation (TWFE:  $-11.2$  points, SE 4.0; extended TWFE:  $-9.9$  points, SE 4.2). Retaining negative measured losses with a bounded outcome likewise yields a negative estimate (TWFE:  $-10.6$  points, SE 4.9). These findings show that neither interpolation nor the later switch in metering records alone explains the estimated decline. Utility accounting nevertheless presents a separate limitation: billed units sometimes exceed recorded supply, and usable observations are less frequent among ABC-assigned transformers after installation. Such inconsistencies require further reconciliation and leave possible selection in the measured outcome unresolved. Consumer billing data show no detectable increase in billed consumption, so we interpret the experiment as evidence of lower *recorded* losses, without treating the full estimated decline as proven theft prevention or additional revenue.

Implementation further informs interpretation. ABC was installed at 37 of 40 assigned transformers, but LESCO also installed ABC at 24 transformers assigned to other arms. Results from these non-random additional installations do not reproduce the experimental pattern; that contrast may reflect differences in site selection, timing, installation or measurement. We retain the original assignment for our main estimates and treat comparisons conditioned on realised installation as descriptive. The paper documents treatment delivery through utility records and independent field verification.

Our contribution is to distinguish two ways of raising the cost of electricity theft: changing the physical opportunity to steal and increasing the risk of detection. The closest evidence on ABC comes from a quasi-experimental study of K-Electric’s installations in Karachi (Ahmad et al., 2025); our transformer-level randomisation adds experimental evidence from a state-owned utility with a separately assigned enforcement arm. The analysis distinguishes changes in recorded energy losses from reductions in illegal consumption and improvements in cost recovery. Linking transformer accounts with consumer billing, implementation records and alternative measurement samples allows us to test the stability of the experimental result while identifying which economic channels remain open.

Section 2 discusses related research, Section 3 describes the setting, and Section 4 the pilot. Section 5 presents the experiment and data; Sections 6 and 7 report the empirical approach and findings. Sections 8–10 discuss policy implications, limitations and conclusions.

## 2 Related Literature

Our study connects research on the economic incentives behind electricity theft to evidence on technologies of compliance and public-sector enforcement. One strand of the literature on non-payment for public services concerns social norms. Burgess et al. (2020) argue that electricity in South Asia is treated as a right rather than a product, and that in the resulting equilibrium the binding constraint on cost recovery is the norm rather than the metering technology.

Appeals to moral or religious values can move payment behaviour. Bursztyn et al. (2019) sent late-paying credit-card customers of an Indonesian Islamic bank a text message quoting the Islamic

teaching that non-repayment of a debt by someone able to repay is an injustice. The message reduced delinquency by 4.4 percentage points, comparable to a substantial cash rebate, and a version without the religious attribution had a similar effect. Bryan et al. (2021) randomised an evangelical Protestant values program across poor households in the Philippines and find higher religiosity and about 9 percent higher income, with no change in consumption or labor supply. Neither study concerns electricity, and this trial has no values-based arm, but both suggest that norms operate alongside the physical and enforcement barriers tested here.

Technological responses to theft have only recently been evaluated. Ahmad et al. (2025) study K-Electric’s conversion of bare low-voltage lines to ABC in Karachi using the staggered roll-out across feeders in a difference-in-differences design. Feeders with converted transformers show losses 6 to 8 percentage points lower, roughly a quarter to a third of the mean, with higher revenue recovery, more registered customers and higher billed consumption per customer, and the effects persist for at least 30 months. Consumers report fewer outages, and billing complaints rise. Roll-out timing was chosen by the utility, so identification rests on parallel trends; our consumer billing data test the same channels (Section 7.2).

Enforcement is rarely evaluated rigorously, because campaigns are rolled out area by area rather than assigned. In India, detection drives and penalties have produced short-lived reductions in losses (Forum of Regulators, 2021). To our knowledge no randomised trial has tested whether more frequent inspection alone decreases losses.

Enforcement also depends on the agents who deliver it. Callen et al. (2020) equipped government health inspectors in Punjab with a smartphone system that reported their inspections to senior officials: inspection rates doubled in the first six months and fell back within a year, and staff attendance rose only where under-performing facilities were flagged to supervisors. Monitoring changes the behaviour of enforcing agents only when someone acts on the information. This matters for combing, which is delivered by the same sub-divisional staff who conduct routine inspections.

## 3 Institutional Background

### 3.1 Challenges of Electricity Distribution in Lahore

LESCO is one of Pakistan’s largest distribution companies, serving Lahore and neighbouring districts. Its network is organised into circles, divisions and sub-divisions, and sub-divisional offices run field operations such as meter reading and inspections. Like the other state-owned distribution companies it is required by the regulator, the National Electric Power Regulatory Authority (NEPRA), to reduce losses and improve recovery. In 2023–24 LESCO’s losses were 15.9 percent against an allowed 10.0 percent, a shortfall the regulator values at PKR 47.6 billion, while it collected 99 percent of what it billed (NEPRA, 2024). Losses are concentrated in informal settlements (*katchi abadis*) and peri-urban villages; the Eastern and Southern circles, the study area, contain both, and the study transformers have loss rates of about 43 percent.

A *kunda* connection, a hook thrown over a bare conductor, bypasses the meter and appears at

the transformer as units received but not billed; meter tampering (slowing, bypassing or damaging the meter) appears as implausibly low bills. The transformer loss rate can reflect both practices, alongside technical losses and errors in energy accounting.

Routine enforcement relies on linemen, who take monthly readings and follow up unusual drops in consumption, and on the Metering and Testing (M&T) department, which checks meters for tampering. Detected theft is charged through a detection bill, an estimate of the electricity taken based on past usage or area averages under NEPRA guidelines, plus the cost of damaged equipment. Serious cases are reported to the police through a First Information Report (FIR), although most are settled once the consumer pays. Inspection teams face resistance and sometimes need police escort, and disconnected consumers commonly reconnect after the team leaves.

### 3.2 Institutional Response and Collaboration

One infrastructure response is aerial bundled cable: insulated phase and neutral conductors are twisted into a bundle designed to make illegal hook connections more difficult. The intervention is intended to raise the physical cost of bypassing metering. With the support of the Ministry of Energy, LESCO agreed in late 2024 to test this investment against more intensive inspection in a randomised trial. LESCO implemented both treatments; we designed the randomised study. LESCO’s Market Implementation and Regulatory Affairs Department (MIRAD) coordinated the collaboration, and its Management Information System (MIS) office supplied the administrative data.

## 4 The Kasur Pilot

Before committing to a trial at scale, we piloted both interventions with LESCO in 2024–25 at the request of the Ministry of Energy. The pilot covered 20 distribution transformers in Kasur district, one of LESCO’s highest-loss areas. LESCO selected the transformers for operational feasibility and staff safety; we then assigned them at random: ten to ABC, five to two months of intensified inspections without ABC, and five to control. Because installation crews are required to remove the illegal connections they find, the ABC transformers were also inspected while the cable was being strung, so the pilot could not separate the cable from the enforcement that accompanied it. The contractor that later worked in Lahore installed the cable between 4 November and 20 December 2024, completing six transformers in November and four in December; the combing-only transformers were combed in January and February 2025. Loss rates are computed as in Section 5.2 from the scanning-meter registers of the three sub-divisions, December 2023 to May 2026, which gives 11 months before installation and about 18 after it.

Figure 1 plots the mean loss rate by group. Before installation the three groups fluctuate without a common trend. The ABC group falls from 51 percent in October 2024 to 11 percent in January 2025 and averages 14 percent from the sixth month after installation onward, while the control group stays near its pre-period level (42 percent before installation, 39 percent from February 2025).

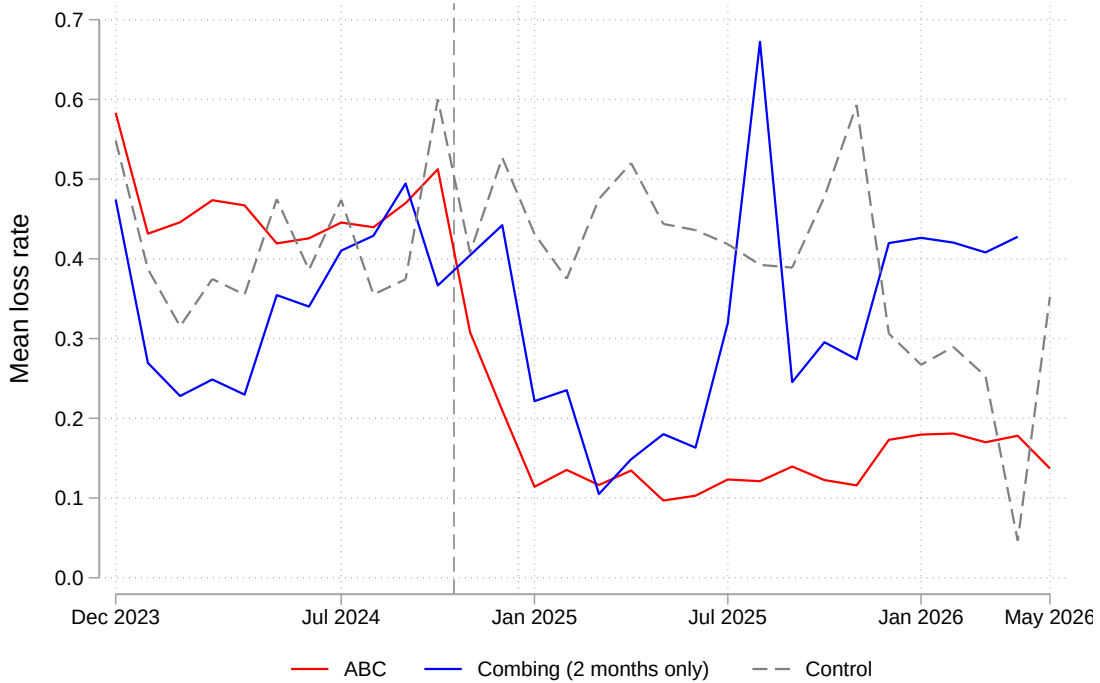


Figure 1: Kasur pilot: mean transformer loss rate by group, December 2023–May 2026

*Notes:* Monthly mean of the transformer loss rate over the 20 pilot transformers (10 ABC, 5 combing only, 5 control), cleaned as in Section 5.2: transformer-months with received units below billed units are set to missing (16 of 541 transformer-months, 14 of them in April–May 2026). The dashed line marks November 2024, the first ABC installation month; the dotted line marks January 2025, the first of the two combing months in the combing-only group.

The combing-only group falls during its two combing months and returns to its pre-period level within six months of the last visit.

We prefer the Callaway and Sant’Anna (2021) estimator because installation was staggered. Over the full window to May 2026, that estimator gives  $-21.9$  percentage points for ABC (SE 15.5), and a two-way fixed-effects regression of the loss rate on treatment  $\times$  post against the controls gives  $-29.8$  points (SE 6.8); the reduction from the sixth month after installation onward is as large as in the first months. Combing without ABC lowered losses only while the visits lasted:  $-8.5$  points (SE 6.8) through February 2025, and  $+1.1$  points (SE 13.8) over the full window. With 15 and 10 clusters, the standard errors are indicative only.

The pilot shaped the study in Lahore in three ways. The size of the ABC reduction and the variance of monthly loss rates set the sample at 40 transformers per arm. The return of losses in the combing-only group once combing stopped led to a sustained monthly inspection schedule rather than a two-month drive. The pilot also established the data-sharing and field protocols with LESCO’s MIRAD, MIS and sub-divisional offices that the study relies on.

## 5 Experimental Design and Data

### 5.1 Design and Randomisation

The trial is randomised at the transformer level. The sampling frame contained the 142 distribution transformers in the two circles with complete loss data and verified scanning-meter records (68 Eastern, 74 Southern); we randomly dropped 22 Southern transformers to reach 120. Within each circle we assigned transformers to the three arms by random ordering (23, 23 and 22 in Eastern and 17, 17 and 18 in Southern, giving 40 per arm), so that each arm has a similar number of transformers in each circle. A transformer serves about 85 metered connections on average.

**ABC:** bare low-voltage conductors replaced with ABC; routine inspections continued unchanged. Installation ran in five monthly waves from July to November 2025.

**Combing:** one anti-theft inspection visit a month to each transformer by LESCO teams, who check connections and meters; routine inspections can be months apart. Combing began in May 2026; its first three months fall within the data.

**Control:** no ABC and routine inspections only.

New smart transformer meters (advanced metering infrastructure, AMI) were installed in all three arms between mid-December 2025 and mid-January 2026, replacing the older scanning meters (Section 5.2).

Three Combing-arm transformers were duplicates of transformers already in the sample, listed twice in LESCO’s records, and were dropped before the intervention, leaving 117 transformers in the analysis panel (40 ABC, 37 Combing, 40 Control). Implementation departed from assignment in further respects, documented in Section 5.5; the main estimates compare transformers by assigned arm (intent-to-treat), and per-protocol estimates on the transformers that received their assigned treatment complement them. Figure 2 summarizes the design and Figure 3 the timeline.

### 5.2 Data Sources and Measurement

The primary outcome is the monthly recorded transformer loss rate,

$$\text{Loss rate} = (\text{units received} - \text{units billed}) / \text{units received},$$

from LESCO’s administrative accounts. The recorded loss rate encompasses technical losses, unmetered use and measurement discrepancies; its changes cannot, by themselves, distinguish these components. Billed units, the units billed to the consumers mapped to each transformer, come from LESCO’s monthly CP22-T transformer energy accounts throughout the panel. Received units are the monthly reads of each transformer’s scanning meter through January 2026, and the CP22-T transformer accounts from February to July 2026, which draw on the new transformer meters. A CP22-T transformer account exists for 116 of the 117 transformers in each month from February

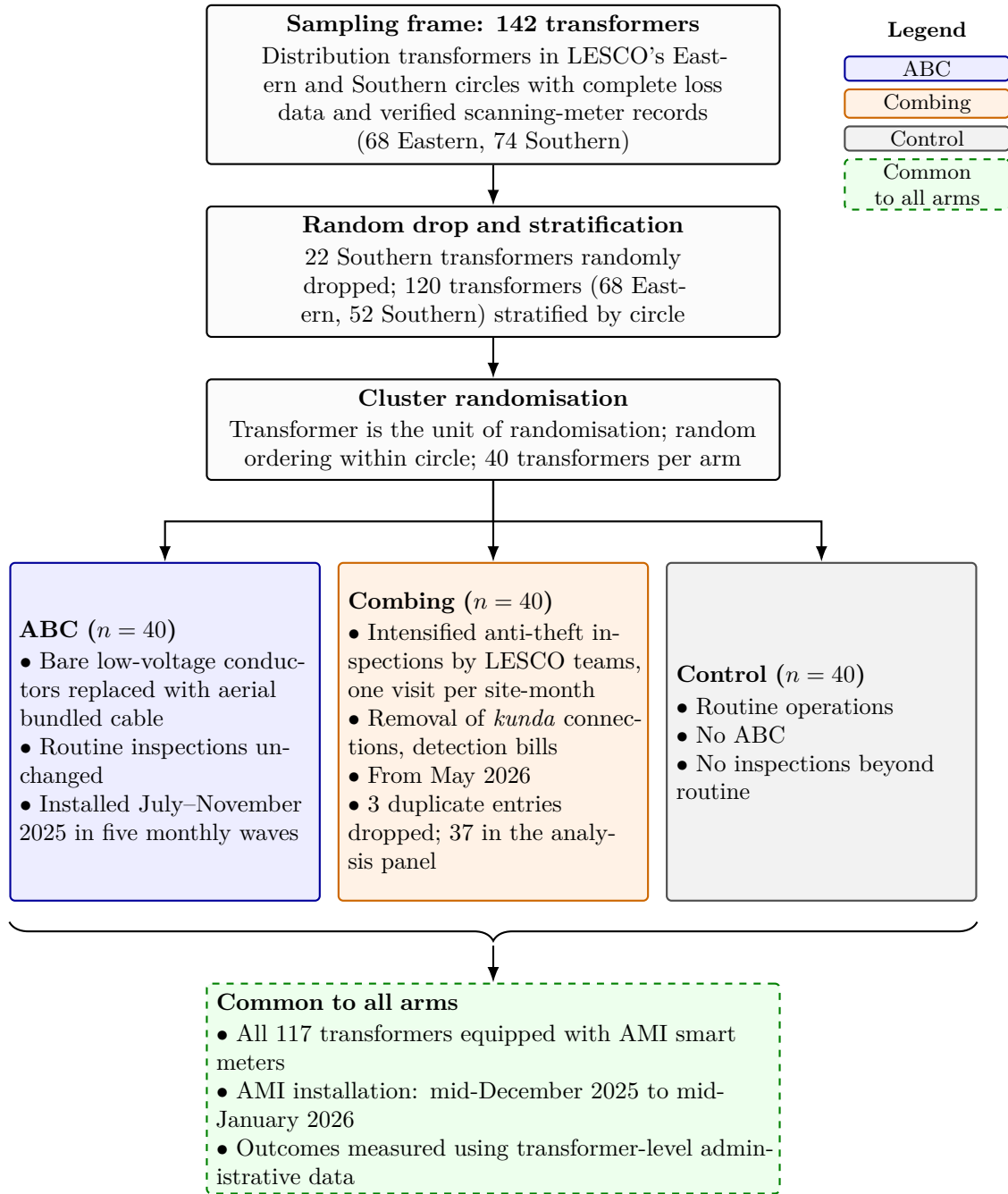


Figure 2: Experimental design and sampling frame

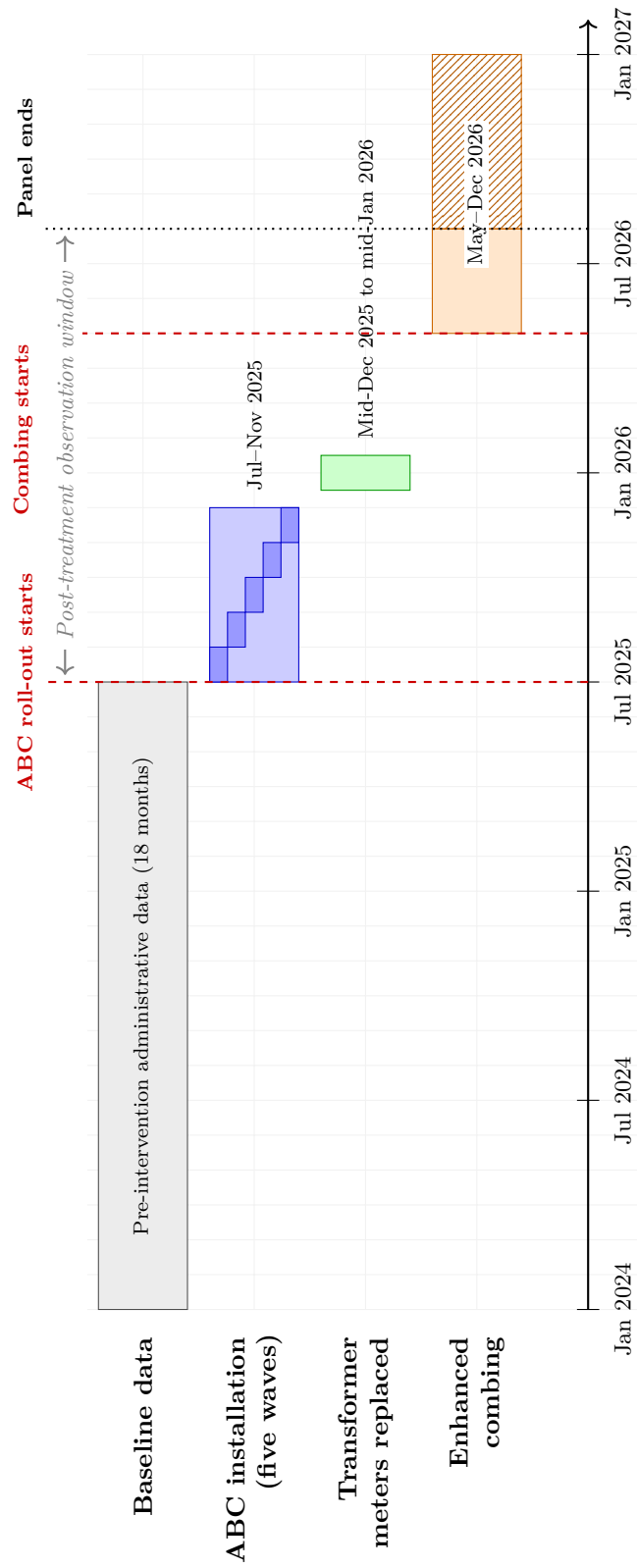


Figure 3: Timeline of intervention and data collection

Notes: Month scale from January 2024. The analysis panel runs from January 2024 to July 2026; enhanced combing runs from May to December 2026 and is hatched beyond the panel. ABC installation waves are one month each; the transformer meters were replaced in all three arms between mid-December 2025 and mid-January 2026.

to June 2026 and for 114 in July. Of these transformer accounts, 61 percent carry a usable loss rate; the rest are set aside because the transformer’s received units are below its billed units (29 percent) or because received units are zero or billed units are zero or negative (10 percent). The August 2026 CP22-T accounts are not used because they omit several sub-divisions that LESCO reorganised that month. The panel therefore runs from January 2024 to July 2026 (31 months), with an 18-month pre-intervention window. The *analysis series* applies LESCO’s accounting conventions (transformer-months with zero received units, zero or negative billed units, or received below billed units set to missing; loss rate bounded to  $[0, 1]$ ) and fills interior gaps by linear interpolation within transformer for months through January 2026; the CP22-T months are not interpolated. Because the source of received units changes in February 2026, Section 7.3 reports coverage by arm, estimates on observed months only, and estimates within each measurement regime.

Negative measured losses can arise from mismatches between billing and transformer-meter reading cycles, as well as errors in account mapping. Consumer meters are read in batches on fixed dates, and a transformer’s consumers should fall in one or two batches. In the June 2026 billing extract, however, 42 of the 117 study transformers carry consumers from three or more batches (up to 17), because LESCO’s consumer-to-transformer mapping has not been updated as connections were moved. The transformer meter is also read on its own date, a median of 5 days after the consumer readings. Billed and received units for a month then cover different days, and where consumption in the unmatched days is large enough, billed units exceed received units and the measured loss is negative.

A feeder panel and consumer billing records complement the transformer panel. The feeder panel, from LESCO’s CP22 feeder accounts, covers the 667 11kV feeders in the two circles from January 2024 to April 2026; 21 carry at least one ABC-arm transformer. Feeder treatment is inherited from the transformer randomisation, so the feeder analysis is exploratory (Appendix E). Consumer billing records from LESCO’s MIS cover every consumer in the study sub-divisions from July 2025 to July 2026 (200,539 consumer-months on 115 study transformers; one ABC and one Control transformer are missing from the extract), with units billed, bill, payment, arrears, tariff status, detection bills and the consumer’s transformer code (summary statistics in Appendix Table D.2). The extract maps about 160 accounts to each transformer, more than the 85 connections in LESCO’s transformer register. Because the extract begins in July 2025, the consumer-level estimates rest on a short pre-treatment window (Section 6).

Implementation is documented by the monthly reporting forms (proformas) that LESCO’s sub-divisional offices submit for each Combing-arm transformer, available for May to July 2026, and by an independent field check in July and August 2026 (Section 5.5). Variable definitions are in Appendix A.

### 5.3 Outcome Measures

Besides the transformer loss rate in the analysis series, the outcomes are the feeder loss rate and, at the consumer level, billed consumption, bill and payment amounts, an indicator for any payment,

collection loss, arrears, and protected and lifeline tariff status, the subsidised residential tariffs for consumers with low monthly consumption (Section 6). Detection bills from the consumer billing records document enforcement (Section 5.5).

## 5.4 Balance, Attrition and Power

The three duplicate Combing entries have no loss data and are the only attrition from the randomised sample. Table 1 compares the arms on pre-period administrative data. The ABC–Control difference in the pre-period loss rate is 3.8 percentage points (SE 2.3,  $p = 0.11$ ) and the Combing–Control difference 0.6 points (SE 2.2); a joint three-arm test does not reject equality ( $p = 0.27$ ), nor does a test of differential linear pre-trends within transformer ( $p = 0.67$ ). The ABC arm nonetheless starts with the highest loss rate, and the estimates below condition on transformer fixed effects. Consumer-level outcomes are balanced in July 2025, the last untreated month in the consumer sample (Appendix Table D.1; none of the 44 differences is significant at the 10 percent level).

The ABC estimate has a 95 percent confidence interval of about 4 to 16 percentage points. For combing, three months of data give a confidence interval from about  $-11$  to  $+12$  points, so the design detects only large combing effects.

Table 1: Baseline balance by arm, transformer level, January 2024–June 2025

|                              | Control<br>(1)     | ABC<br>(2)         | ABC–Control<br>(3) | Combing<br>(4)     | Combing–Control<br>(5) |
|------------------------------|--------------------|--------------------|--------------------|--------------------|------------------------|
| Transformer loss rate        | 0.414<br>[0.096]   | 0.452<br>[0.113]   | 0.038<br>(0.023)   | 0.420<br>[0.095]   | 0.006<br>(0.022)       |
| Monthly units lost (kWh)     | 11,443<br>[9,022]  | 12,848<br>[12,531] | 1,404<br>(2,441)   | 11,156<br>[14,944] | $-287$<br>(2,789)      |
| Monthly units received (kWh) | 26,580<br>[19,326] | 28,207<br>[22,840] | 1,627<br>(4,731)   | 24,349<br>[28,421] | $-2,231$<br>(5,502)    |
| Active connections (count)   | 87.9<br>[77.8]     | 82.9<br>[71.2]     | $-5.0$<br>(16.7)   | 84.0<br>[93.5]     | $-3.9$<br>(19.5)       |
| Transformers                 | 40                 | 40                 |                    | 37                 |                        |

*Notes:* Transformer-level means over the pre-period, standard deviations in brackets. Columns (3) and (5): difference in means, standard error in parentheses, from two-sample  $t$ -tests across transformers. Loss rate = (received – billed)/received and units lost = received – billed, analysis series; units received and active connections from LESCO’s transformer register, connections cross-sectional. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

## 5.5 Implementation and Compliance

**ABC installation and contamination.** ABC was installed at 37 of the 40 ABC-arm transformers; at three it was never installed, and two of these make up the entire November 2025 wave. LESCO’s installation records also show ABC at 24 transformers outside the ABC arm (11 Combing, 13 Control), installed in November–December 2025 (16), March 2026 (three) and April 2026 (five) as LESCO extended ABC under its own program to neighbouring transformers; we refer to these as contaminated transformers. Per-protocol estimates keep only transformers that received their

assigned treatment and no other. They exclude the 24 contaminated transformers, the three ABC transformers without ABC and, in the Combing arm, the six transformers (none of them contaminated) without combing recorded in at least two of the three reported months, leaving 84 transformers (37 ABC, 20 Combing, 27 Control). Because non-compliance is not random, the per-protocol estimates are descriptive complements to the intent-to-treat estimates.

**Enhanced combing.** Sub-divisional offices submitted reports for 102 of the 111 site-months (a Combing transformer in a given month) in May–July 2026, and a combing visit is recorded in 86 of them; each report documents one visit, so delivery was one inspection per site-month, with 20 sites combed in all three months and 2 never. Table 2 summarizes activity by month. Recorded discrepancies, the suspected theft cases that teams log in the reports (hook connections and meter irregularities such as tampering), fell from 62 in May to 6 in July, and detection bills charged to consumers’ accounts from 54 to 13. Over the three months consumers on Combing transformers received 96 detection bills (7.6 per 1,000 consumer-months) against 87 at Control transformers (4.9 per 1,000), so enforcement as delivered raised detection billing modestly and mainly in the first month. Meter replacement was the larger enforcement output: the billing records show 968 consumer meters replaced at Combing transformers over the three months (77 per 1,000 consumer-months, against 19 at Control transformers), 448 of them in June. The reports of one sub-division repeat the same meter counts in each month, so we treat the reports as an upper bound on enforcement intensity.

Table 2: Enhanced combing: activity at the 37 Combing-arm transformers, May–July 2026

|                                               | May 2026  | June 2026 | July 2026 | Total      |
|-----------------------------------------------|-----------|-----------|-----------|------------|
| Transformers with a recorded inspection visit | 30        | 26        | 30        | 86         |
| Discrepancies found                           | 62        | 17        | 6         | 85         |
| Detection bills issued                        | 54        | 29        | 13        | 96         |
| Units charged (kWh)                           | 75,892    | 46,932    | 36,887    | 159,711    |
| Amount charged (PKR)                          | 4,714,384 | 3,091,517 | 2,477,883 | 10,283,784 |
| Consumer meters replaced                      | 178       | 448       | 342       | 968        |

*Notes:* Rows 1–2: monthly reports submitted by LESCO’s sub-divisional offices; a visit is recorded when the report shows meters checked  $> 0$ , and the total in row 1 counts site-months; a discrepancy is a suspected theft case logged in the report. Rows 3–6: consumer billing records; a detection bill is a consumer-month on a Combing-arm transformer with a positive detection-units or detection-amount entry, and a meter replacement a consumer-month whose meter status reads **REPLACED**.

**Independent field verification.** An independent survey team visited 116 of the 117 transformers in two rounds (6–9 July and 5–12 August 2026; 152 visits), recording whether ABC was installed and, at Combing sites, whether LESCO staff were present and inspecting meters. ABC was observed at 37 of the 40 ABC sites, the exceptions being the three transformers at which it was never installed, and at all 11 Combing and 13 Control sites that LESCO’s installation record lists as equipped. In the round timed to LESCO’s schedule, staff were present at all 37 Combing sites and combing was under way at 35. In the earlier unannounced round, teams were found at 9 of 33 sites, which is weak evidence on delivery because a monthly inspection lasts a few hours. Figure C.1 in Appendix C shows three field photographs.

## 6 Empirical Strategy

We estimate two-way fixed-effects (TWFE) regressions on the monthly panel,

$$Y_{it} = \alpha_i + \gamma_t + \beta \text{Treat}_i \times \text{Post}_{it} + \varepsilon_{it}, \quad (1)$$

where  $Y_{it}$  is the loss rate of transformer  $i$  in month  $t$ ,  $\alpha_i$  and  $\gamma_t$  are transformer and month effects, and  $\text{Treat}_i \times \text{Post}_{it}$  equals one from the installation month onward for ABC transformers and from May 2026 onward for Combing transformers. We compare each treated arm with the Control arm on the corresponding two-arm sample, so that the comparison group is the same across arms and estimators. The transformer effects absorb baseline differences and the month effects absorb common shocks; standard errors are clustered by transformer, the unit of randomisation (80 clusters for ABC versus Control, 77 for Combing versus Control), and we report randomisation inference as a check on the cluster count.

Because ABC installation is staggered, the conventional two-way fixed-effects coefficient need not identify a transparent weighted average of heterogeneous cohort-specific effects (Goodman-Bacon, 2021; de Chaisemartin and D’Haultfoeulle, 2020). We therefore give particular weight to the extended two-way fixed-effects (ETWFE) estimator of Wooldridge (2021), which allows cohort-by-time treatment effects and aggregates them using the never-treated Control group as the comparison. We also report the Callaway and Sant’Anna (2021) estimator, which compares installation cohorts with never-treated Control transformers using a pre-installation base period. The different estimators and missing-data patterns can change aggregation weights and precision; we report their results together rather than treating conventional TWFE as definitive.

For consumer-level outcomes we use the Callaway and Sant’Anna (2021) doubly robust estimator with the consumer as the panel unit, ABC cohorts by installation month, Combing treated from May 2026, the Control arm as comparison, and standard errors clustered by transformer. Because the billing extract begins in July 2025, the nine ABC transformers installed that month have no pre-treatment observation and are excluded; the other cohorts have one to four pre-treatment months. Level outcomes are winsorized at the 1st and 99th percentiles of the Control arm, and protected and lifeline status are defined on residential (tariff A-1a) consumers, the only category in which they exist (Appendix Table A.2). The feeder-level specification is in Appendix E.

## 7 Results

### 7.1 Main Effects

Figure 4 plots monthly mean loss rates by arm. The three series track each other closely before July 2025; after installation the ABC series lies at or below the other two in most months. All three arms move together in February–March 2026, when received units switch to the transformer accounts; the movement is larger and less completely measured in the ABC arm (Section 7.3).

Table 3 reports the conventional TWFE and Callaway–Sant’Anna estimates; Table 7 also reports

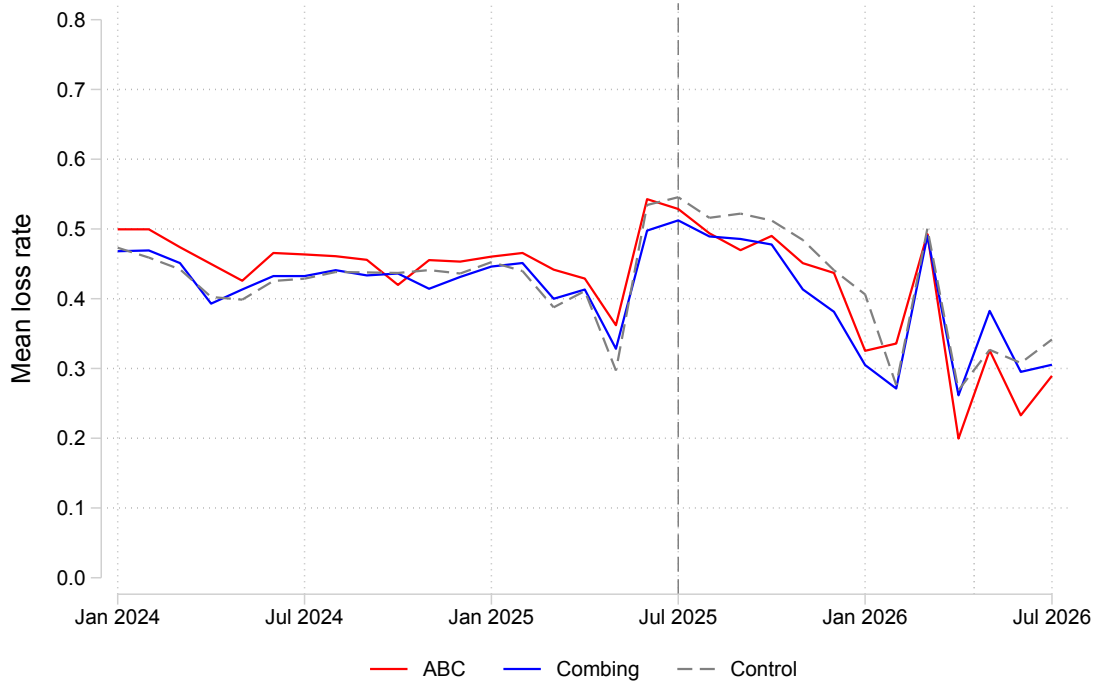


Figure 4: Mean transformer loss rate by arm, January 2024–July 2026

*Notes:* Monthly mean of the transformer loss rate, analysis series, over the 117 transformers of the analysis panel. The dashed line marks July 2025, the first ABC installation month; the dotted line marks May 2026, the start of combing. Received units for February–July 2026 come from the CP22-T transformer accounts and are not interpolated.

ETWFE. ABC assignment reduces the recorded loss rate by 10.0 percentage points (SE 3.2) under conventional TWFE, about a quarter of the 43 percent pre-period mean. The heterogeneity-robust ETWFE estimate is 9.7 points (SE 3.4), and the Callaway and Sant’Anna (2021) estimate is 7.5 points (SE 4.9,  $p = 0.13$ ). The latter has the same sign but is less precisely estimated; its failure to reject zero should not be interpreted as evidence of no effect. The per-protocol estimates are 10.9 and 8.3 points. Randomisation inference gives  $p = 0.005$  (Table 7). Combing, dated from its May 2026 start, has no detectable effect: +0.6 points (SE 5.9), with  $-2.3$  under Callaway and Sant’Anna (2021) and  $-2.7$  in the per-protocol sample; alternative specifications in Appendix Table B.2 give the same answer. The estimate describes combing as LESCO delivered it over three months (Section 5.5), and monthly loss rates, which average the weeks before and after each visit, would also dilute any deterrence that fades between visits.

Figure 5 plots the binned TWFE event study. The estimated reduction is 7.3 percentage points (SE 3.0) in the installation month and averages 10.6 points (SE 4.6) over the first six months of exposure. The five leads average  $-0.3$  points. A joint test of the leads gives  $p = 0.08$ , driven by the two months before installation, which are slightly above the base month. Measured against the average of the leads, the early effect is 10.3 points (SE 3.8). After six months the estimates rest on one or two cohorts and are imprecise (5.7 points, SE 7.3); beyond nine months the point

Table 3: Effect of ABC and enhanced combing on the transformer loss rate

|                                   | Intent-to-treat      |                   | Per-protocol         |                   |
|-----------------------------------|----------------------|-------------------|----------------------|-------------------|
|                                   | TWFE<br>(1)          | CS<br>(2)         | TWFE<br>(3)          | CS<br>(4)         |
| ABC $\times$ post-installation    | −0.100***<br>(0.032) | −0.075<br>(0.049) | −0.109***<br>(0.038) | −0.083<br>(0.059) |
| Combing $\times$ post-May 2026    | 0.006<br>(0.059)     | −0.023<br>(0.071) | −0.027<br>(0.072)    | −0.032<br>(0.102) |
| Observations, ABC vs. Control     | 1,882                | 1,882             | 1,461                | 1,461             |
| Observations, Combing vs. Control | 1,834                | 1,834             | 1,051                | 1,051             |
| Transformers, ABC vs. Control     | 80                   | 80                | 64                   | 64                |
| Transformers, Combing vs. Control | 77                   | 77                | 47                   | 47                |

*Notes:* Dependent variable: transformer loss rate, analysis series, January 2024–July 2026; each arm vs. Control on the two-arm sample; per-protocol sample as defined in Section 5.5. TWFE: equation (1). CS: Callaway and Sant’Anna (2021) regression-adjustment estimator, overall average treatment effect on the treated with Control as the never-treated comparison, ABC cohorts by installation month, Combing a single May 2026 cohort. Standard errors clustered by transformer in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

estimates are near zero. By cohort, the effect is concentrated in the October 2025 cohort (Appendix Table B.1); cohort effects range from  $-1.6$  to  $-19.5$  points, and the data do not identify the source of the difference because cohorts coincide with sub-divisions and contractor work areas. The November cohort has two transformers, at neither of which ABC was installed, and its estimate ( $-4.5$ , SE 9.9) is uninformative.

**Feeder level.** For the 21 feeders that carry at least one ABC-arm transformer, the preferred TWFE estimate is  $-3.7$  percentage points (SE 2.1) and the ETWFE aggregate  $-2.3$  (SE 2.4). Treated feeders are larger and higher-loss than other feeders, the median ABC share of feeder capacity is 1.7 percent, and the estimates are sensitive to specification, so we treat the feeder estimates as exploratory (Appendix E).

## 7.2 Mechanisms and Heterogeneity

Whether the loss reduction comes from the billed side or the received side matters for interpretation: removing theft should raise billed units for a given supply, whereas a change in how supply is recorded at the transformer would lower received units. Table 4 reports outcomes that need no bounding and the decomposition. ABC raises the probability that a transformer-month records billed units at or above received units by 9 percentage points ( $p = 0.06$ , against a Control post-period mean of 22 percent) and raises the billed-to-received ratio by 0.19 ( $p = 0.022$ ). Regressions of log received and log billed units on observed months are imprecise (received  $-0.14$ , SE 0.12; billed  $+0.10$ , SE 0.15) and condition on a positive measured loss, an outcome that ABC itself may affect; the estimates cannot decisively separate changes in recorded supply from changes in billing. The post-period distribution of observed ABC loss rates shifts down rather than becoming bimodal (median 0.37 against 0.42 for Control). This pattern is compatible with lower unmetered consumption but does not distinguish that mechanism from differences in recorded energy flows. Substantial measured

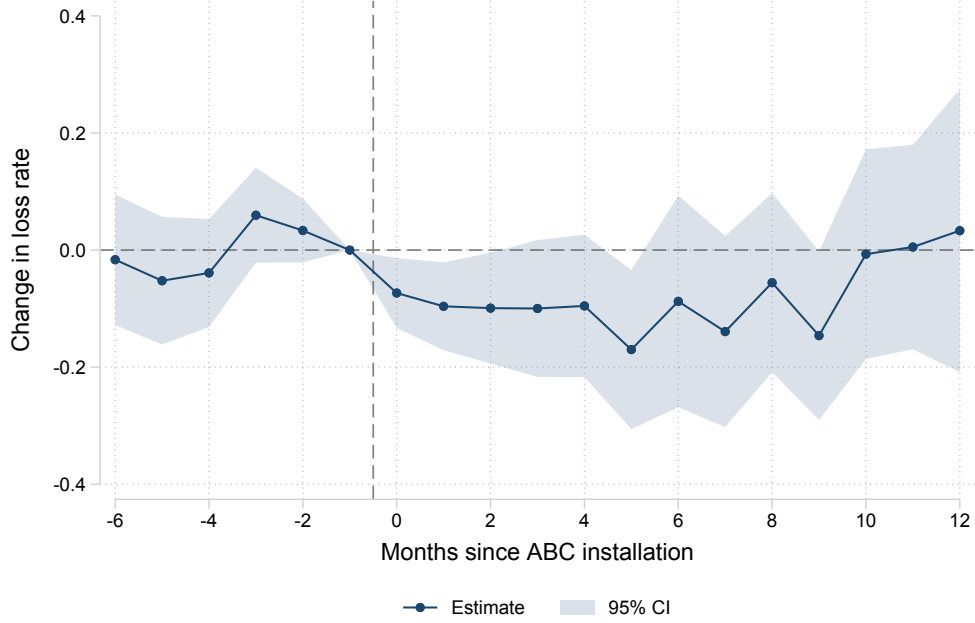


Figure 5: Event study: ABC effect on the transformer loss rate

*Notes:* TWFE coefficients on  $ABC \times 1[\text{event time} = e]$ , base  $e = -1$ , with  $e < -6$  and  $e > 12$  binned, on the transformer loss rate (analysis series) for the 40 ABC and 40 Control transformers, January 2024–July 2026; transformer and month fixed effects; shaded bands are 95 percent confidence intervals, standard errors clustered by transformer. Per-protocol version in Figure B.1.

losses remain: the post-period ABC mean is 41.1 percent. These residual losses may reflect meter tampering, under-billing, technical losses and measurement discrepancies. We cannot rule out that installation, which restrings service drops and in some cases replaces transformer meters, changed how supply is recorded at treated sites.

The consumer billing records test the same question from the demand side. Tables 5 and 6 report the aggregate effect on each outcome; transformer-level aggregates (Appendix Tables D.3 and D.4), alternative samples (Tables D.5 and D.6) and event studies (Figure D.1) are in Appendix D. ABC has no detectable effect on billed consumption, bills, payment, arrears or tariff status. The one marginal coefficient (asinh consumption,  $-0.11$ , SE 0.07) reflects the treatment of zero-consumption months rather than a shift in the distribution, and the consumption estimate is  $-4.4$  kWh per consumer-month (SE 6.2) on a Control mean of 110. Enhanced combing likewise leaves consumption, bills, payment, arrears and tariff status unchanged: the share of A-1a consumers on the protected tariff, which requires consumption at or below 200 kWh in each of the preceding six months, changes by  $-0.7$  percentage points (SE 1.8) from a Control mean of 45 percent, and the lifeline share by 0.0 (SE 0.4). Combing did replace consumer meters, at 77 per 1,000 consumer-months against 19 at Control transformers (Section 5.5); a replacement appears in the billing records as a meter-event code that displaces the tariff code for that month, so tariff status is carried through such months (Appendix Table A.2). Neither the transformer-level decomposition nor the consumer records show

Table 4: Effects on outcomes that require no bounding and on log units received and billed

| Outcome                                              | ABC ×<br>post-installation<br>(1) | Combing ×<br>post-May 2026<br>(2) | $N$<br>(ABC / Combing)<br>(3) | Control<br>post-period mean<br>(4) |
|------------------------------------------------------|-----------------------------------|-----------------------------------|-------------------------------|------------------------------------|
| 1[measured loss $\leq 0$ ], raw series               | 0.094* (0.048)                    | −0.006 (0.061)                    | 1,792 / 1,689                 | 0.219                              |
| Billed / received units (raw,<br>capped at 3)        | 0.188** (0.081)                   | −0.085 (0.086)                    | 1,792 / 1,689                 | 0.783                              |
| log(received units), observed<br>months              | −0.141 (0.123)                    | −0.375** (0.170)                  | 1,478 / 1,426                 |                                    |
| log(billed units), observed<br>months                | 0.096 (0.149)                     | −0.428* (0.222)                   | 1,478 / 1,426                 |                                    |
| log(received units),<br>scanning-meter regime        | −0.064 (0.149)                    |                                   | 1,205                         |                                    |
| log(billed units), scanning-meter<br>regime          | 0.232 (0.200)                     |                                   | 1,205                         |                                    |
| log(received units), pre-period<br>and CP22-T months | −0.207 (0.155)                    |                                   | 1,183                         |                                    |
| log(billed units), pre-period and<br>CP22-T months   | −0.057 (0.172)                    |                                   | 1,183                         |                                    |

*Notes:* TWFE with transformer and month fixed effects, each arm vs. Control on the two-arm sample as in Table 3; standard errors clustered by transformer in parentheses. Rows 1–2 use every transformer-month with positive received units (Appendix A); rows 3–8 use observed months of the analysis series with a positive loss rate; scanning-meter regime = January 2024–January 2026; CP22-T months = pre-period plus February–July 2026. Column (3) gives the observations in the ABC and the Combing comparison; rows 5–8 report the ABC coefficient only; column (4) is reported for rows 1–2 only. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

higher billing at ABC transformers, unlike in Karachi, where billed consumption rose (Ahmad et al., 2025); the data do not rule out the received-side explanation.

### 7.3 Robustness and Validity

**Specification and inference.** Table 7 collects the ABC estimate across samples, specifications and estimators. Across rows (2)–(6), which vary interpolation, the measurement regime, fixed effects and the set of Control transformers, the estimate lies between 8.0 and 11.2 percentage points. Column (4) reports the extended two-way fixed-effects estimator of Wooldridge (2021), which interacts cohort and time effects with Control as the never-treated comparison. Its main-sample estimate is 9.7 points (SE 3.4), and it gives similarly negative results in the observed-only and earlier-regime specifications. In particular, the scanning-meter-only, observed-only ETWFE estimate is −9.9 points (SE 4.2). That the negative estimate persists under heterogeneity-robust estimation, the original metering regime and observed-only data makes it unlikely to arise solely from conventional TWFE weighting, interpolation or the later metering transition. A three-arm regression that also uses the Combing arm’s months before May 2026 as untreated observations gives a 7.6-point reduction (SE 2.8), and ABC versus Combing alone through April 2026 gives −4.2 (SE 3.0). Combing-arm losses fell relative to Control before enforcement began, in part because 11 Combing transformers received ABC from November 2025, so the Combing arm is not a clean second comparison group.

Table 5: Effects on consumption and billing, consumer level

|                               | kWh<br>(1)    | log(1+kWh)<br>(2) | asinh(kWh)<br>(3)  | Bill (PKR)<br>(4) | log(1+Bill)<br>(5) |
|-------------------------------|---------------|-------------------|--------------------|-------------------|--------------------|
| <b>A. ABC vs. Control</b>     |               |                   |                    |                   |                    |
| ATT                           | −4.4<br>(6.2) | −0.100<br>(0.064) | −0.114*<br>(0.068) | −112.2<br>(275.5) | −0.065<br>(0.072)  |
| Control mean                  | 110.4         | 3.696             | 4.239              | 3,663.2           | 6.539              |
| Consumer-months               | 122,022       | 122,022           | 122,022            | 122,022           | 122,022            |
| Treated transformers          | 30            | 30                | 30                 | 30                | 30                 |
| Control transformers          | 39            | 39                | 39                 | 39                | 39                 |
| Consumers                     | 10,064        | 10,064            | 10,064             | 10,064            | 10,064             |
| <b>B. Combing vs. Control</b> |               |                   |                    |                   |                    |
| ATT                           | 1.8<br>(6.9)  | 0.006<br>(0.057)  | 0.003<br>(0.060)   | 172.6<br>(294.8)  | 0.033<br>(0.047)   |
| Control mean                  | 110.1         | 3.693             | 4.237              | 3,651.2           | 6.563              |
| Consumer-months               | 135,276       | 135,276           | 135,276            | 135,276           | 135,276            |
| Treated transformers          | 37            | 37                | 37                 | 37                | 37                 |
| Control transformers          | 39            | 39                | 39                 | 39                | 39                 |
| Consumers                     | 12,090        | 12,090            | 12,090             | 12,090            | 12,090             |

*Notes:* Consumer-month panel, July 2025–July 2026; the nine ABC transformers installed in July 2025, which have no pre-treatment month, are excluded. Callaway and Sant’Anna (2021) doubly robust average treatment effect on the treated, cohort-weighted over post-treatment months, Control as comparison; cohorts and winsorization as in Section 6. Control mean: mean of the outcome in the Control arm over the estimation sample. Standard errors clustered by transformer in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

**Contamination and displacement.** The estimate against contaminated Control transformers alone (a 10.5-point reduction) is the same as against uncontaminated ones, which does not provide evidence of attenuation in that comparison, although these subgroup contrasts are not randomly assigned. Losses at the 24 contaminated sites did not fall after their own installation: dated from each site’s recorded installation month, the contamination effect within the Combing and Control arms is +1.4 points (SE 3.5). The absence of a corresponding decline following installations outside the assigned ABC arm cautions against attributing the entire experimental effect to the cable alone. Because LESCO selected these sites, the comparison is descriptive rather than causal. The field check confirms cable at most of these sites but cannot date it, and LESCO chose the sites, plausibly where losses were rising. Treating assignment as an instrument for installation gives a first stage of 0.76 and an estimated 13.4-point reduction on installed transformers (SE 4.3), which inherits the same caveat. If theft displaces from ABC transformers to neighbouring bare-wire transformers, Control losses rise and the intent-to-treat contrast overstates the net reduction; we do not observe transformer locations and cannot test for displacement.

Table 6: Effects on payment, arrears and tariff status, consumer level

|                               | Payment<br>(PKR)<br>(1) | Paid<br>(0/1)<br>(2) | Collection<br>loss<br>(3) | Arrears<br>(PKR)<br>(4) | Protected<br>(0/1)<br>(5) | Lifeline<br>(0/1)<br>(6) |
|-------------------------------|-------------------------|----------------------|---------------------------|-------------------------|---------------------------|--------------------------|
| <b>A. ABC vs. Control</b>     |                         |                      |                           |                         |                           |                          |
| ATT                           | -138.6<br>(307.7)       | -0.009<br>(0.009)    | 0.011<br>(0.011)          | 1,373.8<br>(1,098.0)    | -0.010<br>(0.011)         | 0.002<br>(0.003)         |
| Control mean                  | 3,747.4                 | 0.652                | 0.262                     | 17,636.2                | 0.446                     | 0.039                    |
| Consumer-months               | 122,022                 | 122,022              | 106,875                   | 122,022                 | 110,602                   | 110,602                  |
| Treated transformers          | 30                      | 30                   | 30                        | 30                      | 30                        | 30                       |
| Control transformers          | 39                      | 39                   | 39                        | 39                      | 39                        | 39                       |
| Consumers                     | 10,064                  | 10,064               | 9,029                     | 10,064                  | 9,263                     | 9,263                    |
| <b>B. Combing vs. Control</b> |                         |                      |                           |                         |                           |                          |
| ATT                           | -21.0<br>(337.2)        | -0.005<br>(0.012)    | 0.006<br>(0.013)          | -327.1<br>(655.4)       | -0.007<br>(0.018)         | 0.000<br>(0.004)         |
| Control mean                  | 3,720.6                 | 0.654                | 0.263                     | 17,046.9                | 0.453                     | 0.042                    |
| Consumer-months               | 135,276                 | 135,276              | 121,437                   | 135,276                 | 124,128                   | 124,128                  |
| Treated transformers          | 37                      | 37                   | 37                        | 37                      | 37                        | 37                       |
| Control transformers          | 39                      | 39                   | 39                        | 39                      | 39                        | 39                       |
| Consumers                     | 12,090                  | 12,090               | 11,129                    | 12,090                  | 11,265                    | 11,265                   |

Notes: As Table 5. Collection loss is defined for positive bills; protected and lifeline are estimated on tariff A-1a consumers. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table 7: Robustness of the ABC estimate to sample, specification and inference

| Specification                                                      | TWFE<br>(1)   | SE<br>(2) | N<br>(3) | ETWFE (SE)<br>(4) |
|--------------------------------------------------------------------|---------------|-----------|----------|-------------------|
| (1) Main estimate: all months, ABC vs. Control                     | -0.100***     | (0.032)   | 1,882    | -0.097*** (0.034) |
| (2) Observed months only (no interpolation)                        | -0.099***     | (0.032)   | 1,507    | -0.098*** (0.034) |
| (3) Scanning-meter months only, to January 2026                    | -0.089**      | (0.036)   | 1,609    | -0.085** (0.038)  |
| (4) Scanning-meter months to January 2026, observed only           | -0.112***     | (0.040)   | 1,234    | -0.099** (0.042)  |
| (5) Circle $\times$ month fixed effects                            | -0.080**      | (0.033)   | 1,882    |                   |
| (6) Uncontaminated Control transformers only                       | -0.101***     | (0.036)   | 1,525    | -0.097** (0.040)  |
| (7) Contaminated Control transformers only                         | -0.105***     | (0.037)   | 1,288    |                   |
| (8) Three-arm regression, Combing dated May 2026                   | -0.076***     | (0.028)   | 2,765    |                   |
| (9) Negative measured losses retained, $[-1, 1]$                   | -0.106**      | (0.049)   | 1,998    | -0.103** (0.051)  |
| (10) 2SLS: ABC installed $\times$ post, instrumented by assignment | -0.134***     | (0.043)   | 1,882    |                   |
| Randomization inference $p$ -value, row (1)                        | 0.005         |           |          |                   |
| First stage, row (10)                                              | 0.762 (0.062) |           |          |                   |

Notes: Dependent variable: transformer loss rate, analysis series unless stated; ABC vs. Control two-arm samples except row (8). TWFE with transformer and month fixed effects; ETWFE (Wooldridge, 2021) with Control as the never-treated comparison, reported for the specifications with a staggered-adoption counterpart. Rows (6)–(7) split the Control arm into the 27 transformers without and the 13 with ABC in LESCO’s installation records; row (9) retains transformer-months with billed  $>$  received, bounding the loss rate to  $[-1, 1]$ ; row (10) instruments installed ABC  $\times$  post (ABC-arm transformers from their installation month, contaminated Control transformers from the month in LESCO’s installation record) with assigned ABC  $\times$  post. Randomisation inference permutes the (arm, installation cohort) assignment across transformers within circle, 2,000 permutations. Standard errors clustered by transformer in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

**Measurement coverage and interpolation.** The stability of the negative estimate across observed-only and original-regime specifications is particularly useful given differences in administrative-data coverage. Interpolation matters more after treatment: 37 percent of ABC and 38 percent of Combing post-period observations in the analysis series are interpolated, against 24 percent for Control (10–15 percent in the pre-period; Appendix Table A.3). Administrative records sometimes show billed units exceeding received units, which the analysis series treats as missing; this occurs more frequently at ABC transformers after installation. ABC transformers were also less often recorded with positive received units in the first CP22-T month. A regression of an indicator for “loss rate observed” on the balanced transformer  $\times$  month grid shows that ABC installation lowers the probability of an observed loss rate by about 15 points (SE 7.0), against a Control post-period rate of 63 percent. To test sensitivity to interpolation, we re-estimate on observed months only: the estimated reduction is 9.9 points (SE 3.2; Table 7, row (2)). The CP22-T regime also records loss rates about 15 points lower in every arm than the scanning-meter regime, so specifications spanning this change depend on the assumption that common month effects adequately absorb the shift, despite potential treatment-specific measurement differences. The estimated reduction within the scanning-meter regime alone is 8.9 points. The scanning-meter-only, observed-only specification likewise remains negative (TWFE  $-11.2$  points, SE 4.0; ETWFE  $-9.9$  points, SE 4.2). Together with the bounded-negative-loss specification (row (9)), these checks show that the estimate is not driven by a single missing-value rule or by the digital-meter transition. Because valid readings remain differentially available across treatment arms, however, they do not by themselves rule out selection in observed outcomes.

**Negative measured losses.** Setting transformer-months with billed above received units to missing, as LESCO’s convention requires (Section 5.2), excludes 32 percent of the February–July 2026 CP22-T transformer accounts with positive received units, asymmetrically by arm (43 percent for ABC transformers against 25–27 percent for Combing and Control). Retaining these transformer-months with a  $-100$  percent floor gives a 10.6-point reduction (SE 4.9; Table 7, row (9)); the unbounded series has values as low as  $-24,342$  and is uninformative (Appendix A).

## 8 Cost Effectiveness and Policy Implications

A study transformer receives about 26,400 kWh a month, so a 10.0-point reduction in the loss rate is the accounting equivalent of about 2,650 kWh a month, or 31,800 kWh a year, per transformer. Whether that is energy no longer stolen or supply no longer recorded is the open question of Section 7.2. The contractor’s quotation for installing the cable at the 40 assigned transformers was PKR 21.0 million including taxes, about PKR 524,000 per transformer. LESCO supplied the cable and fittings; its standard estimate, shared by MIRAD in September 2026, puts them at PKR 3.68 million per transformer, and the full cost with its own installation estimate at PKR 4.38 million. With the contractor’s installation price, the full cost of conversion in the trial is about PKR 4.2 million per transformer. Against the accounting equivalent of 31,800 kWh a year, that is PKR

132 per kWh of loss reduction if the reduction lasts one year and PKR 26 if it lasts five years, before discounting. We do not observe inspection costs. ABC involves an up-front capital outlay rather than recurrent inspection visits. However, the accounting-equivalent kWh reduction is not established as recovered energy or revenue, and its long-run persistence remains uncertain. The cost calculations are therefore illustrative rather than a benefit–cost estimate.

The implementation record also bears on potential scale-up. The contractor equipped 37 of the 40 assigned transformers within five months, and LESCO itself extended ABC to 24 neighbouring transformers (Section 5.5). The additional installations suggest that maintaining transformer-level treatment boundaries may be difficult when construction teams operate in contiguous areas. The combining result concerns one inspection per transformer each month over three months, not intensified enforcement in general; a scale-up of enforcement would need supervision of the inspecting teams, which the trial did not vary. A phased roll-out in high-loss areas with transformer-level monitoring would show whether the reduction persists and converts into billed sales before the full program is committed.

## 9 Limitations

Several limitations govern interpretation. First, our outcome is an administrative accounting ratio rather than a direct measure of illegal consumption. The negative ABC estimate survives observed-only, original-meter and bounded-negative-loss specifications, but the administrative records contain inconsistent readings and the availability of a valid loss rate differs by assigned arm after installation. The transition to CP22-T accounts also shifts recorded loss rates across all arms. These robustness checks narrow the role of particular cleaning and metering choices without fully excluding selection in measured outcomes. Second, the consumer billing panel begins only in July 2025 and therefore offers limited pre-installation comparisons; we cannot attribute the recorded loss reduction to additional billed electricity or improved utility collections. Third, installation outside the assigned ABC arm complicates treatment contrasts. Per-protocol and as-treated comparisons are not experimentally assigned, and we lack transformer coordinates needed to assess spatial displacement. Fourth, evidence on persistence after six months is limited, and the three-month observation window for enhanced inspections has wide confidence intervals. Finally, the cost analysis uses estimated material and installation costs and cannot value the observed accounting change as additional revenue without establishing its mechanism. Without comparable inspection costs, the analysis cannot establish a definitive cost-effectiveness ranking of the two approaches.

## 10 Conclusion

Preventing illegal electricity connections and detecting them after the fact are distinct ways to change the incentives for theft. In a randomised evaluation with a public distribution company in Pakistan, assignment to theft-resistant aerial bundled cable reduces recorded transformer-level

losses by approximately 10 percentage points from a 43 percent pre-treatment mean. The extended two-way fixed-effects estimate, which accommodates staggered installation, is similarly negative and statistically significant; the Callaway–Sant’Anna estimate is negative but less precise. We detect no effect of intensified monthly inspections in the first three months of implementation, but that short and imprecisely estimated comparison does not establish that enforcement is ineffective.

The estimated reduction in recorded losses is stable across modern staggered-adoption estimators and key measurement checks, including observed-only readings, the original metering regime and a bounded measure that retains inconsistent readings. This strengthens confidence that the finding is not an artefact of any one estimator or data-cleaning rule. It does not establish the full reduction as theft prevented: consumer billing shows no detectable increase, and differential availability of usable administrative readings remains to be reconciled. Additional cable installations outside the assigned arm also complicate interpretation. Further work will clarify how infrastructure changes recorded energy flows, whether these changes translate into collections and revenue, and whether benefits persist long enough to justify the capital investment. A key lesson for electricity-sector reform is that the credibility of administrative outcome measures matters as much as the assignment mechanism used to evaluate the intervention.

# Online Appendix

## A Data Construction and Cleaning

**Variable definitions.** Tables A.1 and A.2 define the outcomes and their construction.

Table A.1: Variable definitions: feeder and transformer outcomes

| Variable                                  | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Transformer loss rate</b>              | (Units received – units billed)/units received, per transformer-month. Received units: scanning-meter reads through January 2026; CP22-T transformer accounts February–July 2026. Billed units: CP22-T consumer billing aggregated to the transformer. Zero received units, zero or negative billed units, or received below billed units set to missing (billing and reading cycles do not coincide); loss rate bounded to $[0, 1]$ ; interior gaps through January 2026 interpolated within transformer. |
| <b>Feeder loss rate</b>                   | (Units dispatched – units billed)/units dispatched, per feeder-month, from the CP22 feeder accounts (grid-station metering against total billing on the feeder). Negative values and values above 100 percent set to missing in the estimation series.                                                                                                                                                                                                                                                     |
| <b>Units received, active connections</b> | Monthly units received (cleaned series) and the cross-sectional count of connections, from LESCO’s transformer register.                                                                                                                                                                                                                                                                                                                                                                                   |

**Coverage and interpolation.** Table A.3 reports interpolation shares, CP22-T measurement coverage and the observed-loss regression by arm.

**Loss with no bounding.** The analysis series follows LESCO’s convention: transformer-months with received below billed units, and those with zero or negative billed units, are set to missing, and the loss rate is bounded to  $[0, 1]$ . Table A.4 describes the raw loss rate,  $(\text{received} - \text{billed})/\text{received}$  for every transformer-month with positive received units, with no bounds and no interpolation. In the pre-period its median is 0.44, as in the analysis series, but 4.8 percent of transformer-months are negative and 2.8 percent are below  $-1$ , with a minimum of  $-473$ ; in the post-period 27 percent are negative and the minimum is  $-24,342$ . These extreme values are bookkeeping artifacts, typically a received-units entry of a few units against thousands billed. The share of negative months is highest in the ABC arm (35 percent post-period against 26–22 percent), consistent with ABC pushing billed units toward received units. Figure A.1 shows that the monthly medians keep the ordering of the analysis series. Regressions on the raw series (Table A.5) are uninformative because a few values of order  $-10^2$  to  $-10^4$  dominate the variance (ABC coefficient  $-76.7$ , SE 85.4); winsorizing at the pooled 1st and 99th percentiles still leaves the regression dominated by the negative tail. Some treatment of negative values is therefore unavoidable; Table 7, row (9), retains them within  $[-1, 1]$ .

Table A.2: Variable definitions: consumer-level outcomes and enforcement

| Variable                                   | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Billed consumption (kWh)</b>            | Units billed in the month ( <b>TOTAL_IMPORT_UNITS</b> ) for every account on the transformer, including disconnected accounts, which are billed zero; also as $\log(1 + \text{kWh})$ and $\text{asinh}(\text{kWh})$ .                                                                                                                                                                                                                                                                  |
| <b>Bill and payment (PKR)</b>              | Current month's bill before payments ( <b>CURRENT_BILL</b> ); payment received, including arrears paid ( <b>PAYMENT</b> ). Paid = $\mathbf{1}[\text{payment} > 0]$ ; collection loss = $1 - \min\{\text{payment}/\text{bill}, 1\}$ for bills above zero.                                                                                                                                                                                                                               |
| <b>Arrears (PKR)</b>                       | Outstanding amount carried into the month (amount component of <b>ARREAR_AGE</b> ), floored at zero; a blank entry, which marks a paid-up account, is treated as zero.                                                                                                                                                                                                                                                                                                                 |
| <b>Protected, lifeline (0/1)</b>           | Tariff status from <b>METER_STATUS</b> : <b>PROTECTED</b> (consumption at or below 200 kWh in each of the preceding six months), <b>LIFE LINE</b> , or blank for the normal tariff. In months in which the field carries a meter-event code instead ( <b>REPLACED</b> , <b>DEF-EST</b> , <b>RECONN</b> , <b>LOCKED</b> ) the last recorded tariff status is carried forward; permanently disconnected accounts ( <b>P-DISC</b> ) are set to missing. Defined on tariff A-1a consumers. |
| <b>New connections</b>                     | Consumers on the transformer whose <b>CONNECTION_DATE</b> falls in the month; transformer $\times$ month.                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Detection bills, meter replacements</b> | Consumer-months with a positive <b>DET_UNITS</b> or <b>DET_AMOUNT</b> entry; units and amounts are the sums of those fields. Meter replacements: consumer-months with <b>METER_STATUS</b> equal to <b>REPLACED</b> (Table 2).                                                                                                                                                                                                                                                          |

Notes: Monthly consumer billing extract (LESCO MIS), July 2025–July 2026; variable names in typewriter font are its column headers. Level outcomes are winsorized at the 1st and 99th percentiles of the Control arm.

Table A.3: Interpolation, measurement coverage and observed loss rates by arm

|                                                                                     | ABC   | Combing          | Control |
|-------------------------------------------------------------------------------------|-------|------------------|---------|
| <b>A. Share of analysis-series transformer-months interpolated</b>                  |       |                  |         |
| Pre-period, January 2024–June 2025                                                  | 13.9% | 14.8%            | 10.4%   |
| Post-period, July 2025–July 2026                                                    | 36.8% | 37.9%            | 24.2%   |
| <b>B. Share of transformers with positive received units in the CP22-T accounts</b> |       |                  |         |
| February 2026                                                                       | 77.5% | 91.9%            | 87.5%   |
| March 2026                                                                          | 87.5% | 91.9%            | 90.0%   |
| April 2026                                                                          | 87.5% | 91.9%            | 97.5%   |
| May 2026                                                                            | 92.5% | 97.3%            | 95.0%   |
| June 2026                                                                           | 90.0% | 89.2%            | 90.0%   |
| July 2026                                                                           | 85.0% | 89.2%            | 80.0%   |
| <b>C. Probability that a loss rate is observed</b>                                  |       |                  |         |
| ABC $\times$ post-installation                                                      |       | −0.153** (0.070) |         |
| Combing $\times$ post-May 2026                                                      |       | 0.100 (0.079)    |         |
| Control post-period mean of the indicator                                           |       | 0.627            |         |

Notes: Panel C: TWFE with transformer and month fixed effects on an indicator equal to one when the analysis series has an observed loss rate, on the balanced  $117 \times 31$  transformer-month grid; standard errors clustered by transformer in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table A.4: Distribution of the raw (unbounded) monthly loss rate

| Arm / period   | <i>N</i> | Mean   | SD      | P1     | P5    | Median | P95  | P99  | Min     | Max  | % < 0 | % < -1 |
|----------------|----------|--------|---------|--------|-------|--------|------|------|---------|------|-------|--------|
| ABC, pre       | 496      | -3.06  | 29.8    | -175.3 | 0.00  | 0.44   | 0.69 | 0.93 | -473    | 1.01 | 4.4   | 2.4    |
| ABC, post      | 385      | -64.49 | 1,240.5 | -49.3  | -5.10 | 0.17   | 0.93 | 1.00 | -24,342 | 2.00 | 34.5  | 12.7   |
| Combing, pre   | 431      | -3.09  | 23.6    | -174.2 | -0.01 | 0.44   | 0.65 | 0.97 | -226    | 1.00 | 5.1   | 2.8    |
| Combing, post  | 347      | -0.41  | 4.7     | -11.7  | -2.17 | 0.21   | 0.97 | 1.00 | -74     | 2.78 | 25.6  | 10.4   |
| Control, pre   | 491      | -3.08  | 26.5    | -122.5 | 0.00  | 0.43   | 0.65 | 0.92 | -375    | 1.00 | 4.9   | 3.3    |
| Control, post  | 420      | -5.24  | 99.9    | -7.1   | -0.93 | 0.28   | 0.95 | 1.00 | -2,038  | 1.00 | 21.9  | 4.3    |
| All arms, pre  | 1,418    | -3.07  | 26.9    | -144.0 | 0.00  | 0.44   | 0.66 | 0.93 | -473    | 1.01 | 4.8   | 2.8    |
| All arms, post | 1,152    | -23.58 | 719.7   | -29.5  | -2.17 | 0.22   | 0.95 | 1.00 | -24,342 | 2.78 | 27.3  | 8.9    |

*Notes:* Transformer-months with positive received units; no cleaning, bounding or interpolation. Pre = January 2024–June 2025; post = July 2025–July 2026.

Table A.5: Treatment effects on the raw (unbounded) loss rate

|                                                                            | Intent-to-treat   |                   | Per-protocol      |                   |
|----------------------------------------------------------------------------|-------------------|-------------------|-------------------|-------------------|
|                                                                            | TWFE<br>(1)       | ETWFE<br>(2)      | TWFE<br>(3)       | ETWFE<br>(4)      |
| <b>A. Raw, unbounded loss rate</b>                                         |                   |                   |                   |                   |
| ABC                                                                        | -76.72<br>(85.42) | -76.39<br>(87.46) | -73.20<br>(89.04) | -76.86<br>(96.31) |
| Observations                                                               | 1,792             | 1,792             | 1,415             | 1,415             |
| Combing                                                                    | 0.98<br>(1.31)    | 0.98<br>(1.31)    | 2.62<br>(2.00)    | 2.59<br>(2.00)    |
| Observations                                                               | 1,689             | 1,689             | 1,003             | 1,003             |
| <b>B. Winsorized at the pooled 1st and 99th percentiles (-103.6, 1.00)</b> |                   |                   |                   |                   |
| ABC                                                                        | -0.08<br>(1.30)   | -0.44<br>(1.41)   | 1.75<br>(1.61)    | 1.51<br>(1.78)    |
| Observations                                                               | 1,792             | 1,792             | 1,415             | 1,415             |
| Combing                                                                    | 1.43<br>(1.23)    | 1.42<br>(1.22)    | 2.49<br>(1.64)    | 2.46<br>(1.61)    |
| Observations                                                               | 1,689             | 1,689             | 1,003             | 1,003             |

*Notes:* Dependent variable: raw loss rate of Table A.4; each arm vs. Control on the two-arm sample, observed transformer-months only. TWFE: transformer and month fixed effects (ABC  $\times$  post-installation; Combing  $\times$  post-May 2026). ETWFE: Control as never-treated; Combing as a single May 2026 cohort. Standard errors clustered by transformer in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

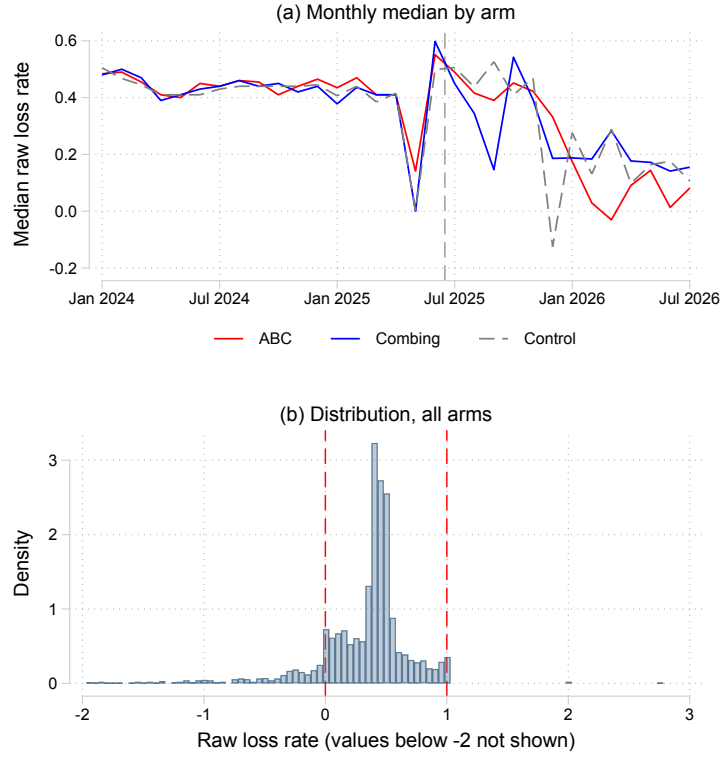


Figure A.1: Raw (unbounded) transformer loss rate

*Notes:* Transformer-months with positive received units, January 2024–July 2026. (a) Monthly median of the raw loss rate by arm; the dashed line marks July 2025, the first ABC installation month. (b) Histogram of the raw loss rate over all transformer-months in the range  $-2$  to  $3$ ; the dashed lines mark the bounds  $0$  and  $1$  of the analysis series, and 101 transformer-months below  $-2$  are not displayed.

## B Additional Estimates

Table B.1: Callaway–Sant’Anna estimates by ABC installation cohort

| Installation cohort | Intent-to-treat |          |         | Per-protocol |           |         |
|---------------------|-----------------|----------|---------|--------------|-----------|---------|
|                     | $n$             | ATT      | SE      | $n$          | ATT       | SE      |
| July 2025           | 9               | −0.074   | (0.107) | 9            | −0.075    | (0.112) |
| August 2025         | 12              | −0.016   | (0.064) | 12           | −0.021    | (0.071) |
| September 2025      | 9               | −0.075   | (0.084) | 8            | −0.077    | (0.098) |
| October 2025        | 8               | −0.195** | (0.076) | 8            | −0.215*** | (0.083) |
| November 2025       | 2               | −0.045   | (0.099) | 0            |           |         |
| Observations        |                 | 1,882    |         |              | 1,461     |         |

*Notes:* Cohort-level average treatment effects on the treated underlying the overall Callaway–Sant’Anna estimates in Table 3, aggregated over post-installation months through July 2026; Control as the never-treated comparison;  $n$  is the number of transformers in the cohort, and the per-protocol sample contains no November 2025 transformer. Standard errors clustered by transformer in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table B.2: Effect of enhanced combing on the transformer loss rate: alternative specifications

|                                                                  | Intent-to-treat  |            | Per-protocol      |            |
|------------------------------------------------------------------|------------------|------------|-------------------|------------|
|                                                                  | Estimate<br>(1)  | $N$<br>(2) | Estimate<br>(3)   | $N$<br>(4) |
| (1) TWFE, Combing vs. Control, full panel                        | 0.006<br>(0.059) | 1,834      | −0.027<br>(0.072) | 1,051      |
| (2) ETWFE, May 2026 cohort vs. Control                           | 0.003<br>(0.059) | 1,834      | −0.035<br>(0.072) | 1,051      |
| (3) TWFE, three arms                                             | 0.022<br>(0.055) | 2,765      | −0.029<br>(0.064) | 1,918      |
| (4) TWFE, Combing vs. Control, January 2025–July 2026            | 0.017<br>(0.060) | 1,282      | −0.022<br>(0.072) | 787        |
| Joint test of pre-May 2026 differentials, row (4) window: $F(p)$ | 0.39 (0.98)      |            | 1.07 (0.41)       |            |
| Combing / Control transformers                                   | 37 / 40          |            | 20 / 27           |            |

*Notes:* Dependent variable: transformer loss rate, analysis series; Combing dated from May 2026 throughout. Row (1) as in Table 3; row (2) is the ETWFE estimate (Wooldridge, 2021) with Control as the never-treated comparison; row (3) is a three-arm regression that also includes  $ABC \times \text{post-installation}$ ; the joint test in the row (4) window is on the 15 monthly Combing–Control differentials before May 2026. Standard errors clustered by transformer in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

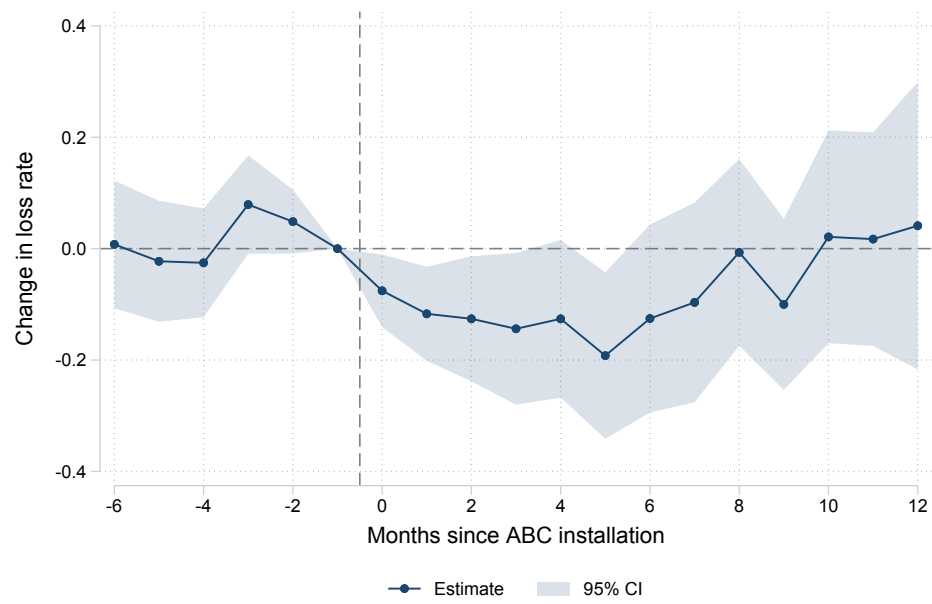
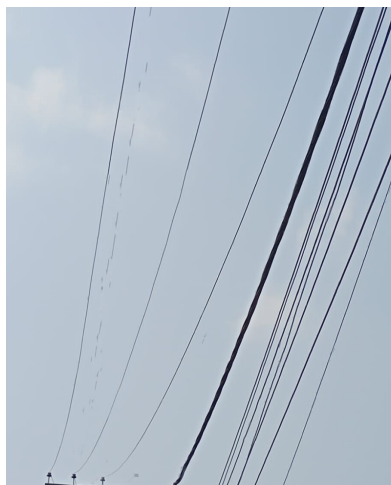


Figure B.1: Event study: ABC effect on the transformer loss rate, per-protocol sample

*Notes:* As Figure 5, on the per-protocol sample of 37 ABC and 27 Control transformers.

## C Field Photographs



(a) ABC bundle on the low-voltage line at an ABC-arm transformer, July 2026.



(b) LESCO staff testing consumer meters during a combing visit, Combing arm, August 2026.



(c) Burnt, empty transformer meter box, August 2026.

Figure C.1: Field photographs

*Notes:* Photographs by the independent survey team during the verification rounds.

## D Consumer-Level Analysis: Additional Results

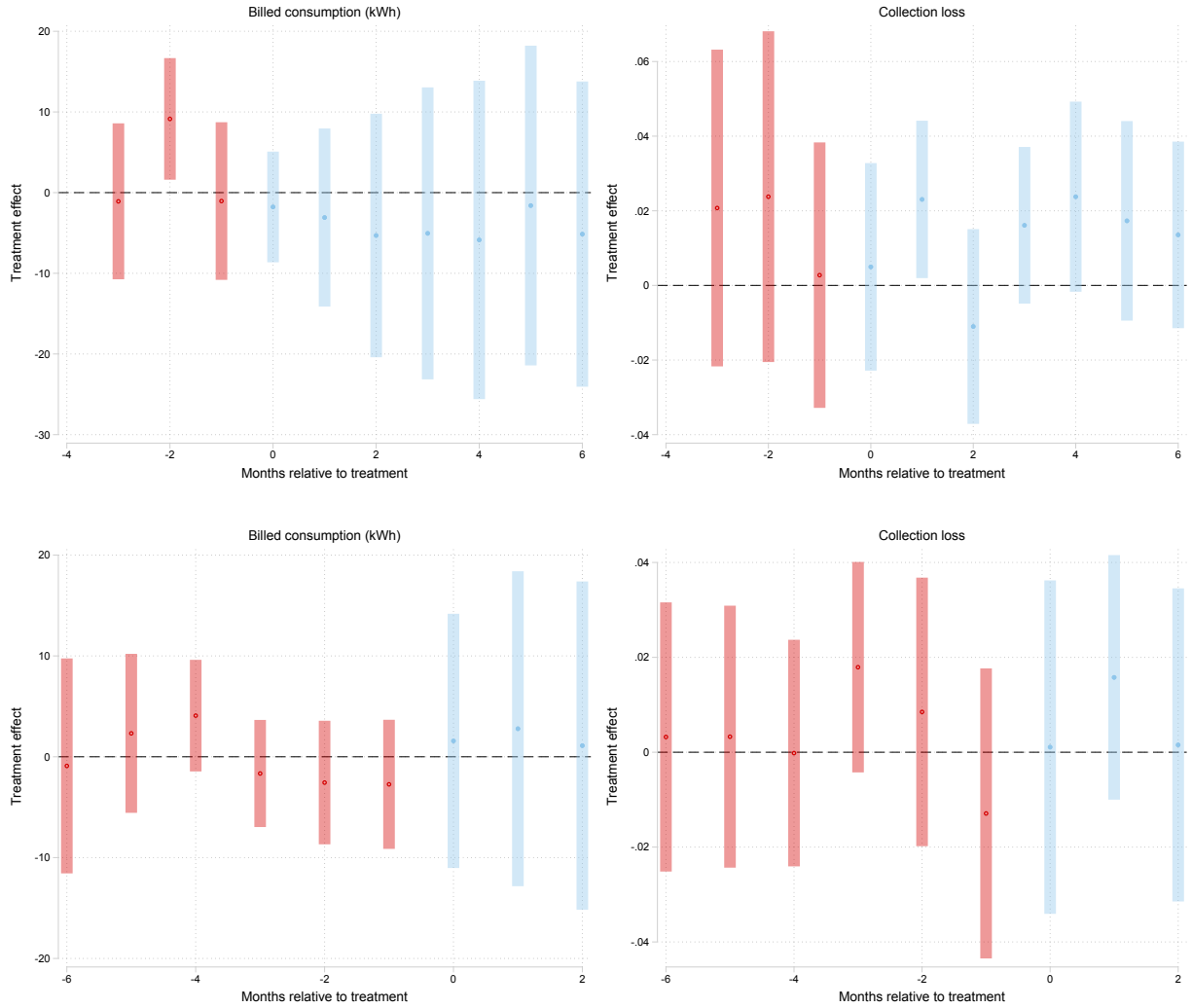


Figure D.1: Event-study estimates for billed consumption and collection loss, consumer level

*Notes:* Left panels: billed consumption (kWh); right panels: collection loss. Callaway and Sant'Anna (2021) average treatment effects by months relative to treatment (pre-treatment months in red, post-treatment in blue), base period the month before treatment, with 95 percent confidence intervals, standard errors clustered by transformer; sample and cohorts as in Table 5. Top: ABC vs. Control, three months before and six after installation. Bottom: Combing vs. Control, six months before May 2026 and the three months from May 2026.

Table D.1: Balance of consumer outcomes at baseline, July 2025

|                             | Control<br>(1)     | ABC<br>(2)         | ABC – Control<br>(3) | Combing<br>(4)     | Combing – Control<br>(5) |
|-----------------------------|--------------------|--------------------|----------------------|--------------------|--------------------------|
| <b>A. Transformer level</b> |                    |                    |                      |                    |                          |
| kWh                         | 144.61<br>[74.79]  | 153.33<br>[67.21]  | 8.73<br>(17.14)      | 142.19<br>[60.80]  | –2.42<br>(15.60)         |
| log(1+kWh)                  | 3.88<br>[1.37]     | 4.02<br>[1.15]     | 0.14<br>(0.30)       | 3.89<br>[1.18]     | 0.00<br>(0.29)           |
| asinh(kWh)                  | 4.42<br>[1.54]     | 4.57<br>[1.30]     | 0.15<br>(0.34)       | 4.43<br>[1.33]     | 0.01<br>(0.33)           |
| Bill (PKR)                  | 4,502<br>[2,824]   | 5,277<br>[3,638]   | 775.16<br>(802.64)   | 5,035<br>[3,167]   | 533.41<br>(689.51)       |
| log(1+Bill)                 | 6.55<br>[2.05]     | 6.87<br>[1.79]     | 0.32<br>(0.46)       | 6.85<br>[1.71]     | 0.29<br>(0.43)           |
| Payment (PKR)               | 4,279<br>[2,953]   | 5,136<br>[4,092]   | 856.17<br>(883.24)   | 4,838<br>[3,472]   | 558.30<br>(741.15)       |
| Paid (0/1)                  | 0.60<br>[0.22]     | 0.64<br>[0.20]     | 0.05<br>(0.05)       | 0.65<br>[0.21]     | 0.05<br>(0.05)           |
| Collection loss             | 0.34<br>[0.14]     | 0.31<br>[0.13]     | –0.03<br>(0.03)      | 0.32<br>[0.16]     | –0.02<br>(0.03)          |
| Arrears (PKR)               | 17,299<br>[19,890] | 19,216<br>[20,912] | 1,917<br>(4,969)     | 17,639<br>[16,109] | 340.80<br>(4,142)        |
| Protected, A-1a             | 0.38<br>[0.17]     | 0.36<br>[0.15]     | –0.02<br>(0.04)      | 0.38<br>[0.13]     | 0.00<br>(0.03)           |
| Lifeline, A-1a              | 0.05<br>[0.06]     | 0.03<br>[0.05]     | –0.02<br>(0.01)      | 0.05<br>[0.06]     | 0.00<br>(0.01)           |
| Transformers                | 39                 | 30                 |                      | 37                 |                          |
| <b>B. Consumer level</b>    |                    |                    |                      |                    |                          |
| kWh                         | 147.43<br>[141.25] | 154.89<br>[156.55] | 7.46<br>(19.76)      | 141.64<br>[130.99] | –5.79<br>(16.48)         |
| log(1+kWh)                  | 3.95<br>[2.12]     | 3.91<br>[2.20]     | –0.04<br>(0.41)      | 3.96<br>[2.08]     | 0.01<br>(0.35)           |
| asinh(kWh)                  | 4.50<br>[2.38]     | 4.44<br>[2.47]     | –0.05<br>(0.46)      | 4.50<br>[2.34]     | 0.01<br>(0.40)           |
| Bill (PKR)                  | 4,824<br>[7,187]   | 6,860<br>[10,199]  | 2,036<br>(1,614)     | 5,487<br>[8,333]   | 663.06<br>(1,016)        |
| log(1+Bill)                 | 6.66<br>[2.97]     | 7.14<br>[2.78]     | 0.48<br>(0.57)       | 7.11<br>[2.50]     | 0.45<br>(0.49)           |
| Payment (PKR)               | 4,853<br>[8,824]   | 7,114<br>[12,456]  | 2,261<br>(1,818)     | 5,540<br>[9,970]   | 687.21<br>(1,168)        |
| Paid (0/1)                  | 0.63<br>[0.48]     | 0.68<br>[0.46]     | 0.05<br>(0.06)       | 0.70<br>[0.46]     | 0.06<br>(0.06)           |
| Collection loss             | 0.28<br>[0.45]     | 0.25<br>[0.43]     | –0.03<br>(0.04)      | 0.26<br>[0.44]     | –0.02<br>(0.04)          |
| Arrears (PKR)               | 16,065<br>[49,701] | 15,483<br>[50,010] | –582.28<br>(5,353)   | 12,447<br>[45,468] | –3,618<br>(4,470)        |
| Protected, A-1a             | 0.38<br>[0.49]     | 0.38<br>[0.48]     | –0.01<br>(0.04)      | 0.42<br>[0.49]     | 0.03<br>(0.04)           |
| Lifeline, A-1a              | 0.04<br>[0.18]     | 0.03<br>[0.16]     | –0.01<br>(0.01)      | 0.04<br>[0.20]     | 0.01<br>(0.01)           |
| Consumers                   | 5,815              | 3,849              |                      | 4,788              |                          |

Notes: July 2025 billing month; the nine ABC transformers installed that month are excluded, as in the estimation sample. Means with standard deviations in brackets; columns (3) and (5): differences from a regression on the arm indicator, standard errors in parentheses (heteroskedasticity-robust in Panel A, where the transformer is the unit; clustered by transformer in Panel B). Levels winsorized at the Control 1st and 99th percentiles; protected and lifeline on tariff A-1a consumers. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table D.2: Summary statistics, consumer-month data, by assigned arm

|                 | Mean   | SD      | Median | P25    | P75    | <i>N</i> |
|-----------------|--------|---------|--------|--------|--------|----------|
| ABC             |        |         |        |        |        |          |
| kWh             | 120.78 | 363.46  | 81.00  | 8.00   | 160.00 | 63,830   |
| Bill (PKR)      | 6,805  | 103,467 | 1,467  | 300.00 | 4,384  | 63,830   |
| Payment (PKR)   | 6,827  | 115,238 | 937.00 | 0.00   | 3,485  | 63,830   |
| Paid (0/1)      | 0.64   | 0.48    | 1.00   | 0.00   | 1.00   | 63,830   |
| Collection loss | 0.27   | 0.44    | 0.00   | 0.00   | 1.00   | 55,196   |
| Arrears (PKR)   | 22,755 | 85,013  | 0.00   | 0.00   | 2,527  | 63,830   |
| Protected, A-1a | 0.43   | 0.50    | 0.00   | 0.00   | 1.00   | 57,442   |
| Lifeline, A-1a  | 0.04   | 0.20    | 0.00   | 0.00   | 0.00   | 57,442   |
| Combing         |        |         |        |        |        |          |
| kWh             | 112.91 | 158.74  | 87.00  | 27.00  | 159.00 | 57,338   |
| Bill (PKR)      | 5,135  | 22,457  | 1,612  | 555.00 | 4,385  | 57,323   |
| Payment (PKR)   | 5,063  | 21,682  | 1,212  | 0.00   | 3,697  | 57,338   |
| Paid (0/1)      | 0.69   | 0.46    | 1.00   | 0.00   | 1.00   | 57,338   |
| Collection loss | 0.26   | 0.44    | 0.00   | 0.00   | 1.00   | 53,159   |
| Arrears (PKR)   | 16,254 | 74,787  | 0.00   | 0.00   | 794.00 | 57,338   |
| Protected, A-1a | 0.48   | 0.50    | 0.00   | 0.00   | 1.00   | 52,531   |
| Lifeline, A-1a  | 0.05   | 0.21    | 0.00   | 0.00   | 0.00   | 52,531   |
| Control         |        |         |        |        |        |          |
| kWh             | 115.06 | 169.75  | 85.00  | 22.00  | 160.00 | 79,371   |
| Bill (PKR)      | 4,410  | 53,647  | 1,527  | 428.00 | 3,929  | 79,371   |
| Payment (PKR)   | 4,602  | 64,954  | 1,079  | 0.00   | 3,454  | 79,371   |
| Paid (0/1)      | 0.65   | 0.48    | 1.00   | 0.00   | 1.00   | 79,371   |
| Collection loss | 0.26   | 0.44    | 0.00   | 0.00   | 1.00   | 70,059   |
| Arrears (PKR)   | 19,925 | 94,183  | 0.00   | 0.00   | 1,714  | 79,371   |
| Protected, A-1a | 0.45   | 0.50    | 0.00   | 0.00   | 1.00   | 72,997   |
| Lifeline, A-1a  | 0.04   | 0.20    | 0.00   | 0.00   | 0.00   | 72,997   |

*Notes:* All consumer-months, July 2025–July 2026, 115 transformers; levels not winsorized. Collection loss is defined for positive bills; protected and lifeline on tariff A-1a consumers.

Table D.3: Effects on consumption and billing, transformer level

|                               | kWh<br>(1)     | log(1+kWh)<br>(2) | asinh(kWh)<br>(3) | Bill (PKR)<br>(4) | log(1+Bill)<br>(5) |
|-------------------------------|----------------|-------------------|-------------------|-------------------|--------------------|
| <b>A. ABC vs. Control</b>     |                |                   |                   |                   |                    |
| ATT                           | -9.6<br>(10.6) | -0.106<br>(0.073) | -0.108<br>(0.074) | -601.0<br>(802.5) | -0.154<br>(0.114)  |
| Control mean                  | 118.1          | 4.600             | 5.280             | 4,572.5           | 8.089              |
| Transformer-months            | 895            | 895               | 895               | 895               | 895                |
| Treated transformers          | 30             | 30                | 30                | 30                | 30                 |
| Control transformers          | 39             | 39                | 39                | 39                | 39                 |
| <b>B. Combing vs. Control</b> |                |                   |                   |                   |                    |
| ATT                           | -6.9<br>(9.0)  | -0.037<br>(0.059) | -0.037<br>(0.060) | -965.0<br>(867.9) | -0.076<br>(0.093)  |
| Control mean                  | 118.1          | 4.600             | 5.280             | 4,572.5           | 8.089              |
| Transformer-months            | 984            | 984               | 984               | 984               | 984                |
| Treated transformers          | 37             | 37                | 37                | 37                | 37                 |
| Control transformers          | 39             | 39                | 39                | 39                | 39                 |

Notes: Transformer-month panel, July 2025–July 2026; outcomes are means over the consumers billed on the transformer in the month. Estimator and cohorts as in Table 5, with the transformer as the panel unit; heteroskedasticity-robust standard errors in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table D.4: Effects on payment, arrears, tariff status, connections and meter replacement, transformer level

|                               | Payment<br>(PKR)<br>(1) | Collection<br>loss<br>(2) | Arrears<br>(PKR)<br>(3) | Share<br>protected<br>(4) | Share<br>lifeline<br>(5) | New<br>connections<br>(6) | Consumers<br>billed<br>(7) | Share meters<br>replaced<br>(8) |
|-------------------------------|-------------------------|---------------------------|-------------------------|---------------------------|--------------------------|---------------------------|----------------------------|---------------------------------|
| <b>A. ABC vs. Control</b>     |                         |                           |                         |                           |                          |                           |                            |                                 |
| ATT                           | -781.9<br>(531.2)       | 0.014<br>(0.016)          | -964.7<br>(1,819.5)     | -0.007<br>(0.016)         | -0.002<br>(0.005)        | -0.142<br>(0.205)         | -1.9<br>(6.3)              | -0.020*<br>(0.010)              |
| Control mean                  | 4,283.1                 | 0.309                     | 22,865.6                | 0.433                     | 0.058                    | 0.235                     | 156.6                      | 0.012                           |
| Transformer-months            | 895                     | 895                       | 895                     | 895                       | 895                      | 895                       | 895                        | 895                             |
| Treated transformers          | 30                      | 30                        | 30                      | 30                        | 30                       | 30                        | 30                         | 30                              |
| Control transformers          | 39                      | 39                        | 39                      | 39                        | 39                       | 39                        | 39                         | 39                              |
| <b>B. Combing vs. Control</b> |                         |                           |                         |                           |                          |                           |                            |                                 |
| ATT                           | -936.9<br>(678.4)       | -0.002<br>(0.018)         | -1,445.7<br>(1,208.8)   | -0.015<br>(0.020)         | 0.003<br>(0.006)         | -0.166<br>(0.197)         | -0.5<br>(4.8)              | 0.037*<br>(0.021)               |
| Control mean                  | 4,283.1                 | 0.309                     | 22,865.6                | 0.433                     | 0.058                    | 0.235                     | 156.6                      | 0.012                           |
| Transformer-months            | 984                     | 984                       | 984                     | 984                       | 984                      | 984                       | 984                        | 984                             |
| Treated transformers          | 37                      | 37                        | 37                      | 37                        | 37                       | 37                        | 37                         | 37                              |
| Control transformers          | 39                      | 39                        | 39                      | 39                        | 39                       | 39                        | 39                         | 39                              |

Notes: As Table D.3; shares protected and lifeline are among tariff A-1a consumers, new connections and consumers billed are counts, and share meters replaced is the share of accounts on the transformer whose meter status reads REPLACED in the month. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table D.5: Consumption and billing, consumer level, alternative samples

|                               | kWh<br>(1)      | log(1+kWh)<br>(2) | asinh(kWh)<br>(3)  | Bill (PKR)<br>(4)  | log(1+Bill)<br>(5) |
|-------------------------------|-----------------|-------------------|--------------------|--------------------|--------------------|
| <b>A. ABC vs. Control</b>     |                 |                   |                    |                    |                    |
| Per-protocol                  | 7.2<br>(6.0)    | -0.009<br>(0.064) | -0.022<br>(0.070)  | 346.1<br>(288.0)   | 0.045<br>(0.072)   |
| Control mean                  | 122.0           | 4.010             | 4.594              | 3,995.9            | 6.965              |
| Consumer-months               | 93,393          | 93,393            | 93,393             | 93,393             | 93,393             |
| Treated transformers          | 27              | 27                | 27                 | 27                 | 27                 |
| Control transformers          | 26              | 26                | 26                 | 26                 | 26                 |
| Consumers                     | 7,484           | 7,484             | 7,484              | 7,484              | 7,484              |
| As-treated                    | 10.9**<br>(4.3) | 0.102*<br>(0.055) | 0.103*<br>(0.061)  | 501.7**<br>(204.9) | 0.111**<br>(0.056) |
| Control mean                  | 120.5           | 4.011             | 4.598              | 3,948.4            | 7.024              |
| Consumer-months               | 137,019         | 137,019           | 137,019            | 137,019            | 137,019            |
| Treated transformers          | 51              | 51                | 51                 | 51                 | 51                 |
| Control transformers          | 29              | 29                | 29                 | 29                 | 29                 |
| Consumers                     | 11,540          | 11,540            | 11,540             | 11,540             | 11,540             |
| Balanced panel                | -4.3<br>(6.4)   | -0.102<br>(0.065) | -0.115*<br>(0.069) | -117.4<br>(288.4)  | -0.061<br>(0.075)  |
| Control mean                  | 111.6           | 3.746             | 4.296              | 3,658.1            | 6.587              |
| Consumer-months               | 109,824         | 109,824           | 109,824            | 109,824            | 109,824            |
| Treated transformers          | 28              | 28                | 28                 | 28                 | 28                 |
| Control transformers          | 39              | 39                | 39                 | 39                 | 39                 |
| Consumers                     | 8,448           | 8,448             | 8,448              | 8,448              | 8,448              |
| <b>B. Combing vs. Control</b> |                 |                   |                    |                    |                    |
| Per-protocol                  | 6.2<br>(7.0)    | 0.038<br>(0.056)  | 0.035<br>(0.061)   | 320.3<br>(343.2)   | 0.054<br>(0.058)   |
| Control mean                  | 121.3           | 3.996             | 4.579              | 3,991.2            | 6.994              |
| Consumer-months               | 86,250          | 86,250            | 86,250             | 86,250             | 86,250             |
| Treated transformers          | 20              | 20                | 20                 | 20                 | 20                 |
| Control transformers          | 26              | 26                | 26                 | 26                 | 26                 |
| Consumers                     | 7,749           | 7,749             | 7,749              | 7,749              | 7,749              |
| Balanced panel                | 2.5<br>(7.1)    | 0.031<br>(0.056)  | 0.032<br>(0.058)   | 171.0<br>(308.8)   | 0.041<br>(0.049)   |
| Control mean                  | 111.6           | 3.746             | 4.296              | 3,658.1            | 6.587              |
| Consumer-months               | 117,286         | 117,286           | 117,286            | 117,286            | 117,286            |
| Treated transformers          | 36              | 36                | 36                 | 36                 | 36                 |
| Control transformers          | 39              | 39                | 39                 | 39                 | 39                 |
| Consumers                     | 9,022           | 9,022             | 9,022              | 9,022              | 9,022              |

Notes: As Table 5. *Per-protocol*: sample of Section 5.5. *As-treated*: transformers classified by the treatment received, ABC cohorts dated by LESCO's installation record, uncontaminated Control and non-installed ABC transformers as comparison. *Balanced panel*: consumers billed in all 13 months. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table D.6: Payment, arrears and tariff status, consumer level, alternative samples

|                               | Payment<br>(PKR)<br>(1) | Paid<br>(0/1)<br>(2) | Collection<br>loss<br>(3) | Arrears<br>(PKR)<br>(4) | Protected<br>(0/1)<br>(5) | Lifeline<br>(0/1)<br>(6) |
|-------------------------------|-------------------------|----------------------|---------------------------|-------------------------|---------------------------|--------------------------|
| <b>A. ABC vs. Control</b>     |                         |                      |                           |                         |                           |                          |
| Per-protocol                  | 158.6<br>(354.9)        | −0.007<br>(0.011)    | 0.007<br>(0.012)          | 1,864.8*<br>(1,070.6)   | −0.031***<br>(0.012)      | 0.001<br>(0.003)         |
| Control mean                  | 4,179.1                 | 0.701                | 0.245                     | 10,081.0                | 0.482                     | 0.024                    |
| Consumer-months               | 93,393                  | 93,393               | 83,565                    | 93,393                  | 83,664                    | 83,664                   |
| Treated transformers          | 27                      | 27                   | 27                        | 27                      | 27                        | 27                       |
| Control transformers          | 26                      | 26                   | 26                        | 26                      | 26                        | 26                       |
| Consumers                     | 7,484                   | 7,484                | 6,915                     | 7,484                   | 6,770                     | 6,770                    |
| As-treated                    | 306.4<br>(247.5)        | −0.008<br>(0.008)    | 0.008<br>(0.009)          | 2,339.4***<br>(784.7)   | −0.039***<br>(0.010)      | −0.002<br>(0.004)        |
| Control mean                  | 4,140.5                 | 0.708                | 0.246                     | 9,657.5                 | 0.489                     | 0.027                    |
| Consumer-months               | 137,019                 | 137,019              | 120,070                   | 137,019                 | 123,847                   | 123,847                  |
| Treated transformers          | 51                      | 51                   | 51                        | 51                      | 51                        | 51                       |
| Control transformers          | 29                      | 29                   | 29                        | 29                      | 29                        | 29                       |
| Consumers                     | 11,540                  | 11,540               | 10,419                    | 11,540                  | 10,616                    | 10,616                   |
| Balanced panel                | −172.2<br>(320.1)       | −0.009<br>(0.010)    | 0.011<br>(0.011)          | 1,573.0<br>(1,187.4)    | −0.011<br>(0.011)         | 0.003<br>(0.003)         |
| Control mean                  | 3,756.6                 | 0.656                | 0.262                     | 18,136.5                | 0.457                     | 0.039                    |
| Consumer-months               | 109,824                 | 109,824              | 96,208                    | 109,824                 | 100,622                   | 100,622                  |
| Treated transformers          | 28                      | 28                   | 28                        | 28                      | 28                        | 28                       |
| Control transformers          | 39                      | 39                   | 39                        | 39                      | 39                        | 39                       |
| Consumers                     | 8,448                   | 8,448                | 7,629                     | 8,448                   | 7,950                     | 7,950                    |
| <b>B. Combing vs. Control</b> |                         |                      |                           |                         |                           |                          |
| Per-protocol                  | 231.1<br>(419.9)        | 0.004<br>(0.015)     | −0.003<br>(0.016)         | −43.0<br>(413.2)        | −0.005<br>(0.022)         | 0.002<br>(0.002)         |
| Control mean                  | 4,153.7                 | 0.703                | 0.246                     | 9,504.0                 | 0.486                     | 0.029                    |
| Consumer-months               | 86,250                  | 86,250               | 79,951                    | 86,250                  | 80,378                    | 80,378                   |
| Treated transformers          | 20                      | 20                   | 20                        | 20                      | 20                        | 20                       |
| Control transformers          | 26                      | 26                   | 26                        | 26                      | 26                        | 26                       |
| Consumers                     | 7,749                   | 7,749                | 7,369                     | 7,749                   | 7,365                     | 7,365                    |
| Balanced panel                | −51.5<br>(352.0)        | −0.005<br>(0.011)    | 0.007<br>(0.013)          | −560.9<br>(692.1)       | −0.005<br>(0.019)         | 0.000<br>(0.003)         |
| Control mean                  | 3,756.6                 | 0.656                | 0.262                     | 18,136.5                | 0.457                     | 0.039                    |
| Consumer-months               | 117,286                 | 117,286              | 105,449                   | 117,286                 | 108,570                   | 108,570                  |
| Treated transformers          | 36                      | 36                   | 36                        | 36                      | 36                        | 36                       |
| Control transformers          | 39                      | 39                   | 39                        | 39                      | 39                        | 39                       |
| Consumers                     | 9,022                   | 9,022                | 8,358                     | 9,022                   | 8,597                     | 8,597                    |

Notes: As Table 6; samples as in Table D.5. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

## E Feeder-Level Analysis

The feeder panel is built from LESCO’s CP22 feeder accounts for the 667 11kV feeders in the Eastern and Southern circles, January 2024–April 2026, and was verified against the monthly CP22 reports (on the 14,224 feeder-months present in both, units received, billed and lost agree exactly). Feeder-months with negative measured loss or loss above 100 percent are treated as missing. A feeder is treated if it carries at least one ABC-arm transformer under the randomisation-time assignment: 21 feeders are treated and 646 serve as controls (629 with baseline data); two further assigned feeders sit in a discontinued sub-division that does not appear in the accounts.

We estimate

$$Y_{ft} = \alpha_f + \gamma_t + \beta \text{Treat}_f \times \text{Post}_t + \varepsilon_{ft}, \quad (2)$$

where  $Y_{ft}$  is the feeder loss rate,  $\text{Treat}_f$  equals one for treated feeders and  $\text{Post}_t$  equals one from December 2025, with feeder and month fixed effects and standard errors clustered by feeder. We also report alternative post periods, a donut specification that drops the December 2025 transition month, and a specification that interacts each feeder’s baseline loss with month effects. We also apply the ETWFE estimator with cohorts defined by the month of the first ABC installation on the feeder. Combing-arm feeders are pooled with the controls, since combining began after the feeder panel ends.

Table E.1 shows that treated feeders are larger and have much higher baseline losses than other feeders (26.9 against 17.0 percent,  $p = 0.022$ ), because the sampling frame was drawn from high-loss areas; feeder fixed effects absorb the level differences but the comparison is not randomised. Table E.2 reports the TWFE estimates:  $-3.7$  percentage points (SE 2.1) in the preferred specification, between  $-2.5$  and  $-4.8$  across post-period definitions, and significant at the 10 percent level in four of the five columns. The ETWFE aggregate is  $-2.3$  (SE 2.4,  $p = 0.33$ ), with cohort estimates of mixed sign and precision (Table E.3; the November 2025 cohort is a single feeder). Figure E.1 shows the treated and control series and Figure E.2 the dynamic estimates with 12 months of leads, which fluctuate around zero with confidence intervals covering zero at 11 of 12 lead periods; treated-feeder losses were, however, elevated in parts of 2024 before converging. At a median ABC share of 1.7 percent the feeder-level dose is small, and a feeder-wide movement of several points is more than that dose would produce.

Table E.1: Feeder-level balance: treated vs. control feeders, July 2024–June 2025

|                        | Control<br>(1)   | Treated<br>(2)    | Treated–Control<br>(3) |
|------------------------|------------------|-------------------|------------------------|
| Loss rate (%)          | 17.0<br>[14.2]   | 26.9<br>[18.1]    | 9.9**<br>(4.0)         |
| Units received (MWh)   | 915<br>[696]     | 1,727<br>[614]    | 812***<br>(137)        |
| Net units billed (MWh) | 797<br>[636]     | 1,365<br>[723]    | 568***<br>(160)        |
| Units lost (MWh)       | 94<br>[208]      | 359<br>[395]      | 265***<br>(87)         |
| Consumers (count)      | 2,784<br>[3,514] | 5,766<br>[3,299]  | 2,983***<br>(734)      |
| Sanctioned load (kW)   | 9,122<br>[7,420] | 16,010<br>[7,510] | 6,888***<br>(1,665)    |
| Feeders                | 629              | 21                |                        |

*Notes:* One observation per feeder, the feeder-level mean over the baseline months; treated = carries at least one ABC-arm transformer. Columns (1)–(2): means, standard deviations in brackets; column (3): difference, standard error in parentheses, from Welch two-sample  $t$ -tests. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table E.2: TWFE estimates: effect of ABC on the feeder loss rate

|                     | (1)<br>Dec+        | (2)<br>Aug+       | (3)<br>Oct+        | (4)<br>Donut       | (5)<br>Diff. trends |
|---------------------|--------------------|-------------------|--------------------|--------------------|---------------------|
| Treat $\times$ Post | –3.698*<br>(2.131) | –2.458<br>(2.334) | –3.699*<br>(2.040) | –3.479*<br>(2.053) | –4.842**<br>(2.288) |
| Observations        | 10,904             | 10,904            | 10,904             | 10,540             | 10,831              |
| Adjusted $R^2$      | 0.516              | 0.516             | 0.516              | 0.513              | 0.563               |
| Feeder FE           | Yes                | Yes               | Yes                | Yes                | Yes                 |
| Month FE            | Yes                | Yes               | Yes                | Yes                | Yes                 |
| Post cutoff         | Dec 2025+          | Aug 2025+         | Oct 2025+          | Dec 2025+          | Dec 2025+           |
| Diff. trends        |                    |                   |                    |                    | Yes                 |

*Notes:* Dependent variable: feeder loss rate in percent, bounded to  $[0, 100]$ ; feeder panel, January 2024–April 2026, 21 treated feeders. Post = 1 from the cutoff month shown; column (4) drops the December 2025 transition month; column (5) interacts each feeder’s baseline (July 2024–June 2025) mean loss with month fixed effects. Standard errors clustered by feeder in parentheses. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table E.3: ETWFE estimates by feeder installation cohort

| Installation cohort | ATT<br>(1) | SE<br>(2) | $p$ -value<br>(3) | 95% CI<br>(4)  |
|---------------------|------------|-----------|-------------------|----------------|
| July 2025           | –3.96      | 4.64      | 0.393             | [–13.07, 5.15] |
| August 2025         | 6.13       | 5.15      | 0.234             | [–3.98, 16.25] |
| September 2025      | –3.66      | 3.48      | 0.294             | [–10.50, 3.18] |
| October 2025        | –6.61*     | 3.51      | 0.060             | [–13.51, 0.28] |
| November 2025       | –4.61***   | 0.53      | <0.001            | [–5.66, –3.56] |
| Overall ATT         | –2.34      | 2.37      | 0.326             | [–7.00, 2.33]  |

*Notes:* Dependent variable: feeder loss rate in percent, bounded to  $[0, 100]$ ; feeder panel, January 2024–April 2026. Cohort defined by the calendar month of the first ABC installation on the feeder; cohort sizes 5, 4, 6, 5 and 1 feeders (July–November 2025). Standard errors clustered by feeder. \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

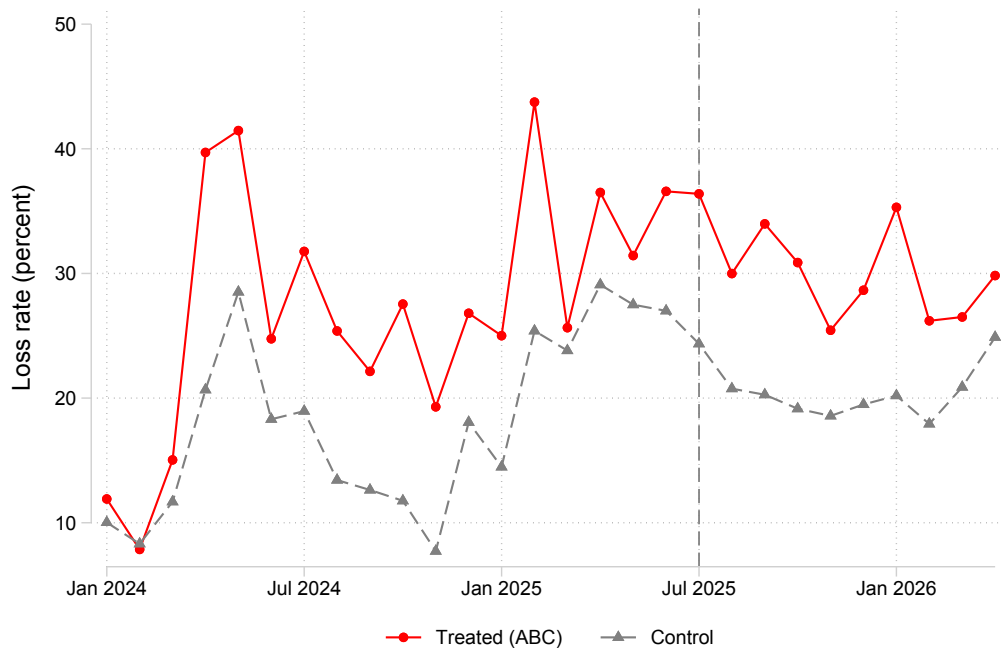


Figure E.1: Feeder loss rate by treatment status, January 2024–April 2026

*Notes:* Monthly mean of the feeder loss rate, in percent and bounded to  $[0, 100]$ , for treated and control feeders; the dashed line marks July 2025, the first ABC installation month.

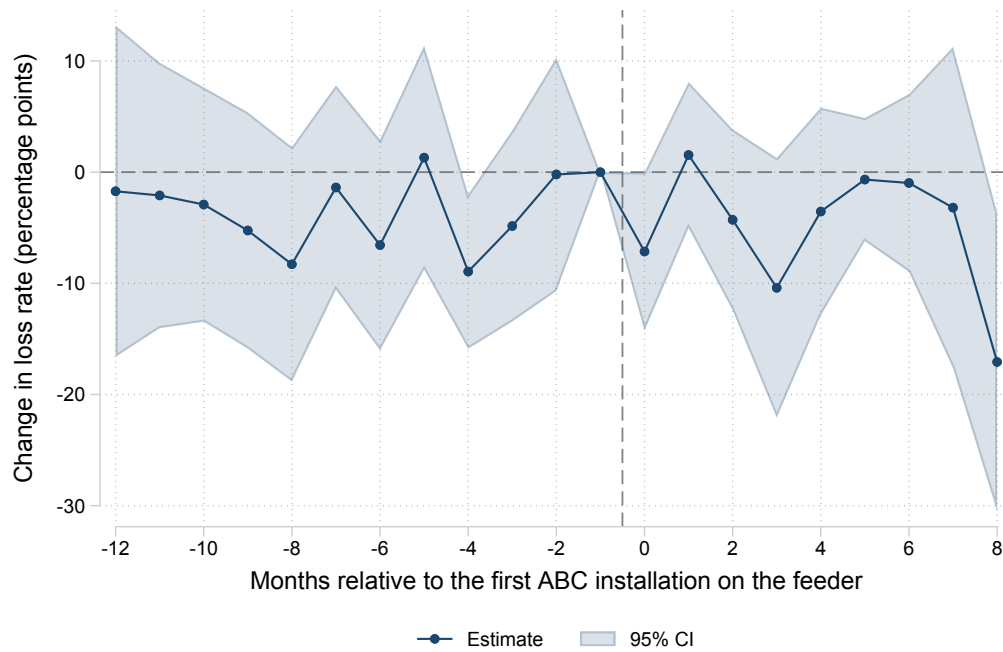


Figure E.2: Dynamic estimates: feeder loss rate by months since the first ABC installation

*Notes:* Estimates in percentage points of the feeder loss rate, from a stacked cohort-by-event-time difference-in-differences against never-treated feeders, base period  $e = -1$ , 12 months of leads; shaded bands are 95 percent confidence intervals, standard errors clustered by feeder. Later event times pool fewer cohorts as the window ends.

## References

- Ahmad, H. F., Ali, A., Meeks, R. C., Wang, Z., and Younas, J. (2025). Down to the wire: Leveraging technology to improve electric utility cost recovery. *American Economic Journal: Applied Economics*, 17(4):60–99.
- Bryan, G., Choi, J. J., and Karlan, D. (2021). Randomizing religion: The impact of protestant evangelism on economic outcomes. *Quarterly Journal of Economics*, 136(1):293–380.
- Burgess, R., Greenstone, M., Ryan, N., and Sudarshan, A. (2020). The consequences of treating electricity as a right. *Journal of Economic Perspectives*, 34(1):145–169.
- Bursztyn, L., Fiorin, S., Gottlieb, D., and Kanz, M. (2019). Moral incentives in credit card debt repayment: Evidence from a field experiment. *Journal of Political Economy*, 127(4):1641–1683.
- Callaway, B. and Sant’Anna, P. H. C. (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics*, 225(2):200–230.
- Callen, M., Gulzar, S., Hasanain, A., Khan, M. Y., and Rezaee, A. (2020). Data and policy decisions: Experimental evidence from Pakistan. *Journal of Development Economics*, 146:102523.
- de Chaisemartin, C. and D’Haultfoeuille, X. (2020). Two-way fixed effects estimators with heterogeneous treatment effects. *American Economic Review*, 110(9):2964–2996.
- Forum of Regulators (2021). Electricity theft and anti-theft measures in the power sector. Technical report, Forum of Regulators, Ministry of Power, New Delhi, India.
- Goodman-Bacon, A. (2021). Difference-in-differences with variation in treatment timing. *Journal of Econometrics*, 225(2):254–277.
- NEPRA (2024). State of industry report 2024. Technical report, National Electric Power Regulatory Authority, Islamabad, Pakistan.
- Wooldridge, J. M. (2021). Two-way fixed effects, the two-way Mundlak regression, and difference-in-differences estimators. Technical report, SSRN Working Paper 3906345.