Working paper PAK-22225 July 2026

Promoting investment in solar energy across firms in Pakistan: The role of information provision

Azam Chaudhry
Theresa Chaudhry
Phillip Garner
Nikita Grabher-Meyer



IGC

DIRECTED BY LSE UNIVERSITY OF OXFORD

FUNDED BY UKaid from the British people

Promoting Investment in Solar Energy across Firms in Pakistan: The Role of Information Provision

Azam Chaudhry (Lahore School of Economics) **Theresa Chaudhry** (Lahore School of Economics) **Phillip Garner** (Utah Tech University) **Nikita Grabher-Meyer*** (International Labour Organization)

Draft July 2026

IGC Working Paper — Project Reference PAK-22225 Pre-registered: AEA RCT Registry AEARCTR-0010691

*Disclaimer: The views expressed in this paper are those of the author and do not necessarily represent those of the International Labour Organization

Abstract

High electricity costs and rapidly declining solar prices make photovoltaic systems an attractive investment for manufacturing firms in Pakistan. Yet adoption remains limited, particularly among smaller enterprises. We study whether targeted information can shift firms' beliefs about solar and adoption-related intentions through a randomized information experiment with micro and small manufacturing firms in Punjab. Firms were randomly assigned to a placebo video, a solar video emphasizing bank financing, or a solar video emphasizing gradual implementation through incremental installation. We examine whether the intervention changes firms' beliefs about solar – captured by attitudes toward solar and perceived behavioural control – and whether any such changes translate into adoption-related outcomes: expected time to invest, intention to contact a solar installer, and QR-code-based information seeking. We find that while firms' attitudes toward solar are strongly correlated with stated inquiry intentions, the information videos do not meaningfully shift the pre-specified belief indices or primary adoption-intention outcomes. The videos do improve factual knowledge about system costs, expected savings, and the payback period, indicating that the information was received and trusted. However, these factual updates do not translate into broader changes in beliefs or intentions. The results suggest that low adoption in this setting is not simply an information deficit that short informational messages can close. Policies to accelerate green technology adoption among small firms may need to combine credible information with more experiential demonstrations and financing models suited to firms operating outside formal credit markets.

JEL codes: Q42, O33, O19, O12, O14, F64

Keywords: solar energy, information provision, technology adoption, RCT, Pakistan, SMEs

1. Introduction

Pakistan is one of the most vulnerable countries to the impacts of climate change but also one with vast untapped renewable energy potential (Global Climate Risk Index, 2023; World Bank, 2021). Utilizing just 0.071 percent of the country's area for solar photovoltaic installations would be sufficient to meet Pakistan's current electricity needs (ESMAP, 2020). For firms, the transition to solar energy could address several constraints at once: it could reduce dependence on fossil-fuel-based electricity, lower carbon emissions, and mitigate the impact of high grid electricity prices, which are almost universally cited by local firms as a major constraint to competitiveness (Bacon, 2019). Renewable energy adoption may also become increasingly important for access to high-income export markets. As regulatory frameworks such as the European Union's Carbon Border Adjustment Mechanism (CBAM) are enforced, exporters – and potentially their suppliers – may face growing pressure to demonstrate cleaner production processes.

The economic case for solar has strengthened rapidly. Recent advances in solar technology, a large influx of low-cost panels from China, and substantial reductions in system prices have shortened estimated payback periods to roughly 1.5 to 2 years as of September 2024, according to local installers. Yet uptake among Pakistani manufacturing firms remains limited. In a pilot listing exercise of textiles and food & beverages firms across Punjab, only 22 percent of the 1,562 firms identified reported having solar installations. Among the smaller firms that constitute our study population, the rate was closer to 13 percent. This slow diffusion is striking because Pakistan's small and medium-sized enterprises are a central part of the economy and an important source of energy demand. It raises a core question for green industrial development: why do firms fail to adopt a technology that appears privately beneficial?

This paper investigates whether targeted information can help close this adoption gap. We conduct a face-to-face survey with an embedded randomized information provision experiment among 657 manufacturing firm owners across four districts in Punjab, Pakistan. Firms were randomly assigned to one of three groups: a control group that watched a placebo video, a treatment group that watched a peer-to-peer video emphasizing bank financing for solar adoption, and a treatment group that watched a similar video emphasizing gradual implementation. The solar videos featured the narrative of a local factory owner who had successfully transitioned to solar energy and presented information on installation costs, savings, roof-space requirements, maintenance, financing options, and integration with existing energy sources. We measure firms' beliefs about solar and three adoption-related outcomes: expected time to invest, intention to inquire from a solar installer, and use of a QR code linking to further solar information.

The distinction between the two solar messages is central to the interpretation of the experiment, given the gap between the originally conceived population of firms and the realized sample. The original design was motivated by small and medium-sized manufacturers that might require 100–500 kW of solar capacity and could potentially finance the investment through a formal bank loan. The realized sample, however, consists largely of much smaller firms. The median peak employment among field-recruited firms was 8 workers, and only around 5 percent of firms in this segment had ever taken a formal bank loan. For such firms, the bank-financing message in

one of the treatment videos may be poorly matched to their scale and access to credit. By contrast, the message emphasized in the other treatment video, that is, gradual implementation – starting with a smaller system and expanding over time – may be more relevant.

We find that beliefs matter, but that short information provision does not move the beliefs that matter most. Firms with more favourable attitudes toward solar are substantially more likely to report that they intend to contact a solar installer: a one-standard-deviation increase in the attitude index is associated with a 16.8 percentage point increase in stated inquiry intention. The treatment videos also improve factual knowledge. Treated firms update their cost estimates toward the information provided in the videos, are more likely to report savings beliefs in the correct range, and revise expected payback periods downward. However, these factual updates do not translate into robust shifts in the pre-specified belief indices or in the main adoption-related outcomes. Neither treatment arm meaningfully changes expected time to invest or QR-code-based information seeking. The gradual-implementation treatment produces a suggestive increase in stated inquiry intention of about 6 percentage points, but this result is not robust across all inferential approaches and does not survive multiple-testing correction.

These results suggest that low adoption among small manufacturing firms is not simply a factual information deficit that short messages can close. Firms appear able to process and update concrete information about costs, savings, and payback periods. Yet this updating does not translate into broader changes in attitudes, perceived feasibility, or revealed information seeking. The relevant constraint may therefore lie in the gap between knowing that solar can be profitable and believing that adoption is feasible for one's own business. For micro and small firms, this gap may reflect other constraints, for instance, limited liquidity, weak access to formal finance, uncertainty about vendor quality, lack of trust, technical-integration concerns, or the perceived risk of committing scarce capital to an unfamiliar investment.

Several descriptive patterns support this interpretation. The average manufacturing firm in our sample spends 28 percent of its operating costs on energy, and nearly 60 percent spend more than one-fifth of their operating costs on energy. Grid-connected solar offers a potentially cheaper alternative: Sultan et al. (2018) estimate that solar power would be approximately 40 percent cheaper than the local public utility and 60 percent cheaper than generator-supplied electricity under modest assumptions about tariff increases. Firms also express favourable views toward solar. The mean score for overall feelings about solar is 6.7 out of 10, and one-third of firms rate their feelings at the maximum of 10. Ninety-three percent say they will eventually invest in solar, with a mean expected timeline of 21.5 months. Yet the highest-rated barrier, at 8.1 out of 10, is agreement with the statement that "investing in solar is only useful if it can cover all of my electricity needs". Financing is the second highest-rated barrier, at 6.6 out of 10, followed by generator dependence at 6.2. These patterns point to a broader set of perceived constraints around usefulness, feasibility, and scale.

Our research contributes to three strands of literature. First, it contributes to research on technology adoption by firms in developing countries, where profitable technologies often diffuse slowly because of informational, financial, managerial, and behavioural constraints. Second, it contributes to the growing literature on information provision experiments, which

shows that information can update beliefs but often has mixed effects on behaviour (Haaland et al., 2023; Fuster and Zafar, 2022, 2023). Third, it speaks to work on renewable energy adoption. A growing body of evidence recognizes that informational gaps and cognitive biases can hinder solar adoption (Kunreuther et al., 2022; Mukherjee, 2020; De Groote and Verboven, 2019; Palm, 2018; Wolske et al., 2017; Rai and Beck, 2014; Rai and Robinson, 2013), but much of the experimental evidence focuses on households in advanced economies. Litvine and Wüstenhagen (2010) show that information emphasizing the private and social benefits of green electricity increased purchase likelihood among Swiss electricity consumers. Gillingham and Bollinger (2017) find that a community-level ambassador intervention in the United States doubled solar installations relative to baseline. Neumann et al. (2023) show that personalized letters invoking loss aversion and social norms increased photovoltaic adoption among Swiss homeowners. Evidence from developing countries and firms is more limited. In India, Mahadevan et al. (2022) find that personalized product guidance improved customer understanding and increased stated adoption intentions by 15 percent, although actual adoption did not change. Akangbe and Sharifi (2025) use an informational intervention with Nigerian SMEs that modestly increases their adoption intentions and willingness to pay. Exploratory research in Pakistan identifies similar informational and cognitive barriers for residential and commercial solar adoption (Awais et al., 2022; Qureshi et al., 2017; Qamar et al., 2022). To our knowledge, this is the first randomized information provision experiment studying solar adoption beliefs and intentions among manufacturing firms in Pakistan.

The findings refine the role of information in this setting: it can correct factual misperceptions but may not be enough to alter the deeper attitudes and perceived constraints that shape adoption intentions. Policies to accelerate green technology adoption among small firms may therefore need to combine credible information with other interventions that make adoption concrete and financially attainable. Alternative interventions that may be considered include peer demonstrations, trusted vendor matching, rent-to-own contracts, pay-as-you-save models, or incremental installation packages. These possibilities remain to be tested directly, but the evidence suggests that successful green technology policy for small firms must address not only awareness but also feasibility.

The remainder of the paper proceeds as follows. Section 2 presents the theoretical framework. Section 3 describes the experimental design and data collection. Section 4 presents the data and descriptive evidence on adoption barriers. Section 5 reports the main experimental results. Section 6 discusses mechanisms, interpretation, and policy implications. Section 7 concludes.

2. Theoretical Framework

2.1 The Theory of Planned Behavior

We use Ajzen's (1991) Theory of Planned Behaviour (TPB) as a framework for understanding how information may affect firms' decisions around solar adoption. The framework posits that behaviour is shaped by intentions, and that intentions, in turn, are predicted by three types of beliefs: attitudes toward the behaviour, subjective norms, and perceived behavioural control. In our setting, the ultimate behaviour of interest is solar adoption by manufacturing firms.

Empirically, however, we focus on adoption-related intentions and intermediate behaviour: firms' expected time to invest, their stated intention to contact a solar provider, and their actual search for additional information through a QR code.

The first domain is attitude toward adoption. This captures whether the decision-maker views solar as beneficial or harmful for the firm. A manager may have a favourable attitude toward solar if they expect it to reduce electricity costs, improve reliability, protect the firm from future energy-price increases, or appeal to buyers concerned with carbon emissions. Conversely, attitudes may be less favourable if the manager doubts the savings, views the technology as risky or inappropriate for the business, or believes that solar is useful only if it can cover all of the firm's electricity needs. This last belief is especially relevant in our setting, where many firms appear to hold an all-or-nothing view of solar adoption despite the potential benefits of partial coverage.

The second domain is subjective norms. These refer to perceived social pressure or peer influence. A firm owner may be more likely to consider solar if nearby firms, competitors, customers, or suppliers have adopted it. Our intervention is delivered through a peer narrative, which may make the information more credible than a purely technical message. However, the experiment is not designed to isolate social-norm effects, and the treatment content does not directly target normative pressure. We therefore treat subjective norms as part of the broader adoption environment rather than as a central mechanism tested in the paper. We capture related peer exposure descriptively through questions about solar adoption among neighbouring firms.

The third domain is perceived behavioural control: whether the decision-maker believes that adoption is feasible. This dimension is particularly important for micro and small firms. A firm may view solar positively in principle but still believe that it lacks sufficient roof or land space, that solar cannot be integrated with generator-provided and grid electricity, that maintenance will be difficult, or that the investment is financially out of reach. We distinguish between two types of perceived behavioural control. Non-financial perceived control captures practical and technical feasibility, including space constraints and integration with existing energy sources. Financial perceived control encompasses installation and maintenance costs, access to finance, the affordability of monthly payments, and concerns that a solar investment could limit the firm's financial flexibility.

Focus group discussions with manufacturers in Punjab that had already adopted solar suggested that attitudes toward solar and perceived behavioural control were the most relevant TPB domains for solar adoption in this context. We therefore designed the information treatments to target these two domains. Both solar videos include common content intended to improve attitudes toward adoption by presenting solar as useful, cost-saving, technically viable, and relevant for local firms. Both also provide information on costs, savings, payback periods, roof-space requirements, maintenance, and integration with existing energy sources. The videos differ in the way they address behavioural control or feasibility. Treatment 1 presents solar as an investment that can be financed through a formal bank loan. Treatment 2 proposes gradual implementation to begin with a smaller system and expand over time.

This distinction is central to the interpretation of the experiment. The bank-financing message may be most relevant to firms with sufficient scale, collateral, and access to bank credit. The gradual-implementation message may be more relevant to micro and small firms with limited access to formal finance. Because the realized sample contains mainly smaller than originally anticipated, the same general information about solar may have different effects depending on whether the proposed route to adoption matches the firm's circumstances.

The design therefore supports two related but distinct comparisons. Comparisons of either solar treatment to the control group capture the effect of receiving solar information that jointly targets attitudes and perceived behavioural control. These comparisons can show whether exposure to the solar videos changes beliefs and adoption-related outcomes relative to a placebo video. However, because the attitude-oriented content is common across Treatment 1 and Treatment 2, the experiment cannot separately identify the effect of that shared attitude component. The comparison between Treatment 1 and Treatment 2 is more specific: it tests whether the financial feasibility frame matters, contrasting a formal bank-financing message with an incremental-adoption message.

The framework generates three empirical predictions. First, baseline beliefs should predict adoption-related intentions if attitudes and perceived control are meaningful constraints. Second, the information treatments should shift beliefs if firms are misinformed or uncertain about solar. Third, treatment-induced belief changes should be translated into adoption-related intentions or information-seeking behaviour if information relaxes a binding constraint.

A failure at any link in this chain is informative. If information changes factual knowledge but not broader attitudes or perceived control, then limited adoption is unlikely to be explained by factual misperceptions alone. If attitudes predict intentions but are not shifted by the videos, then the shared attitude-oriented content was not sufficient to move the beliefs most relevant for adoption. If the gradual-implementation treatment performs better than the bank-financing treatment, this would suggest that feasibility frames must be matched to firms' scale and financing constraints. More broadly, the framework implies that effective policy may need to move beyond short information provision toward interventions that build trust, reduce risk, or make adoption directly feasible.

3. Experimental Design

3.1 Evolution of the Study Design

The study is a survey-based randomized information experiment with manufacturing firms in Punjab, Pakistan. The design evolved in response to field conditions, and all changes relevant to the main analysis were registered before outcome analysis. The original design targeted approximately 400 manufacturing firms in the textile and food/beverage processing sectors in central Punjab. Data collection under a sector-stratified design was attempted in 2024 but yielded too few complete observations to support the planned analysis. Two factors made the original sampling strategy infeasible: rapid solar adoption among firms in the original sampling

frame, which reduced the pool of eligible non-adopters, and heightened scrutiny by Pakistan's tax authorities, which made firm owners less willing to receive visits or participate in interviews. We therefore treat the 2024 observations as a pilot and exclude them from the analysis sample.

In January 2025, before main data collection began, the registered design was updated to expand eligibility to manufacturing firms across all sectors, drop sector stratification, and retain the target of approximately 400 completed surveys. A subsequent pre-analysis amendment, filed before outcome analysis, documented the realized sample, clarified the hypothesis-testing hierarchy, and specified additional analysis details, including the construction of belief measures, multiple-testing correction, and data-quality rules.

3.2 Sample and Recruitment

Main data collection took place between January 2025 and February 2026. Recruitment proceeded in two stages. In the first stage, from January to August 2025, enumerators recruited firms by phone using Chamber of Commerce lists across the study districts. This approach generated substantial outreach but low conversion: approximately 28,000 calls yielded 111 scheduled interviews and 58 completed surveys with usable data. The low conversion rate reflected continued difficulty reaching decision-makers and reluctance among firms to receive enumerator visits.

In the second stage, from September 2025 to February 2026, enumerator teams recruited firms directly in industrial areas. This field-based approach was substantially more productive and led the study to exceed the originally registered sample target. In total, 657 firms were surveyed, of which 648 were retained in the analysis sample after excluding incomplete surveys. The final analysis sample consists of 215 firms assigned to the control group, 208 assigned to Treatment 1, and 225 assigned to Treatment 2.

Eligibility was determined before randomization. Firms were eligible if they met three criteria: they had no existing solar installation, owned at least part of their premises, and conducted manufacturing on site. Firms that passed screening were randomly assigned to one of the three experimental arms. Because the second recruitment stage relied on direct canvassing in industrial areas, the final sample should not be interpreted as a probability sample of all non-adopting manufacturing firms in Punjab. The recruitment strategy may over-represent firms located in denser or more accessible industrial clusters. This affects external validity, but should not impact the internal validity of the randomized comparisons within the realized sample.

3.3 Treatment Arms

All firms watched a short video, approximately five minutes in length, featuring the same local food-processing factory owner. Prior to the video, firms were asked pre-treatment questions, and after the video, firms were asked post-treatment questions. All steps took place in a single session with the firm.

The control video described how the factory owner navigated the challenges of the Covid-19 pandemic, with a voiceover discussing industry trends in product and process innovation. It contained no solar-related information.

The two treatment videos described the same factory owner's transition to solar energy. Both videos presented information intended to affect attitudes toward solar adoption and perceived behavioural control. They explained installation and maintenance costs, expected electricity bill savings, roof-space requirements, technical integration with grid electricity and generator use, and expected payback periods. The videos stated that a standard 100 kW system costs PKR 8–9 million, generates savings of approximately PKR 600,000 per month in reduced electricity bills, and has a payback period of approximately 1.5–2 years.

The treatment arms differed only in the final section, which framed the feasibility of adoption. Treatment 1 presented a bank-financing case for the full 100 kW system. It described a loan at 21 percent annual interest, with monthly repayments of approximately PKR 280,000 and net savings of approximately PKR 320,000 per month after debt service. Treatment 2 presented gradual implementation. It described starting with a larger inverter and adding 25 kW of panels incrementally, with each 25 kW installation generating approximately PKR 150,000 in monthly savings. This second framing did not mention formal credit and allowed adoption to begin at a smaller scale.

This distinction became especially important because the realized sample was smaller than anticipated in the original design. The financial parameters in the videos were calibrated for small and medium-sized manufacturers for which a 100 kW system would be relevant. Many firms in the realized sample are better characterized as microenterprises: the median peak employment among field-recruited firms was 8 workers, and only a small minority had ever taken a formal bank loan. For these firms, the bank-financing message may have been less applicable, while the gradual-implementation message may have been better matched to their scale and financing constraints.

3.4 Outcome Measures

The primary outcomes capture adoption-related intentions and information-seeking behaviour. The first primary outcome is the respondent's expected time to invest in solar. This was elicited before and after treatment using a balls-in-bins measure. Respondents allocated 10 balls across six time horizons: within 3 months, 3–6 months, 6–12 months, 1–2 years, 2–5 years, and never. We convert this distribution into an expected time to invest by assigning bin midpoints of 1.5, 4.5, 9, 18, 42, and 120 months, respectively. This outcome is analysed using pre-post changes.

The second primary outcome is the respondent's stated intention to contact a solar installation firm within the next six months, measured after treatment on a 0–100 percent scale. The third primary outcome is whether the firm accessed additional information through a uniquely numbered QR code provided at the end of the survey. The QR code linked to a website listing contact information for government-approved solar providers and provides an intermediate behavioural measure of information seeking.

The secondary outcomes measure beliefs about solar adoption. Following Ajzen's theoretical framework, we construct three pre-specified belief indices. The attitude index captures overall feelings toward solar and beliefs about whether solar is useful when it covers only part of the firm's electricity needs. The non-financial perceived behavioural control index captures practical feasibility, including concerns about generator use and roof or land availability. The financial perceived behavioural control index captures concerns about installation and maintenance costs, financing, and affordability. Index components are standardized using the pre-treatment control-group distribution and averaged so that higher values correspond to more favourable beliefs.

We also examine specific factual beliefs as mechanism outcomes. These include beliefs about the cost of a 100 kW solar system, expected electricity bill savings, and expected payback periods. For cost beliefs, we use PKR 8.5 million, the midpoint of the PKR 8–9 million range stated in the videos, as the benchmark for accuracy. These measures help distinguish whether the videos failed to transmit information or whether they transmitted information without shifting broader attitudes and perceived feasibility.

3.5 Empirical Specification

The primary estimand is the intention-to-treat effect of assignment to each treatment arm. For outcomes measured before and after treatment, including expected time to invest and the main belief indices, we estimate first-difference specifications of the form:

$$Post_outcome - pre_outcome = \alpha + \beta_1 T1 + \beta_2 T2 + X'\delta + \varepsilon$$

where T1 and T2 indicate assignment to the bank-financing and gradual-implementation treatments, respectively, and the control group is the omitted category. For outcomes measured only after treatment, including inquiry intention and QR-code usage, we estimate:

$$Outcome = \alpha + \beta_1 T1 + \beta_2 T2 + X'\delta + \varepsilon$$

All specifications are estimated by OLS. We report results both with and without controls. The controlled specifications include pre-randomization firm and respondent characteristics: firm age, log peak employment, sector indicators, family ownership, export status, global value-chain exposure, energy cost share, load-shedding hours, generator ownership, recent equipment updating, respondent gender and education, risk and time preferences, prior borrowing, and missing-value indicators where relevant. The main conclusions are robust to alternative registered sets of control variables.

Standard errors are clustered at the district level. Because there are only four districts, we supplement cluster-robust inference with wild cluster bootstrap p-values and randomization-inference p-values. Randomization inference is our preferred check for treatment-effect p-values because assignment to treatment was randomized. The wild cluster bootstrap provides a complementary robustness check for inference when there are few clusters. We adjust for multiple testing using sharpened false discovery rate q-values following Anderson (2008), computed within the two pre-specified outcome families.

We also estimate belief-updating specifications following Fuster and Zafar (2023) for factual beliefs directly addressed in the videos, such as system costs and payback periods. These specifications test whether posterior beliefs move toward the signals provided in the treatment videos. Specifically, we estimate the following specification:

$Post_belief = \alpha + \lambda \cdot (signal - pre_belief) + X'\delta + \varepsilon$

where λ is the learning rate – the extent to which posterior beliefs move toward the signal – estimated separately for treatment and control groups.

Finally, we examine whether treatment-induced changes in belief indices can be used to estimate the effect of beliefs on adoption-related outcomes using treatment assignment as an instrument. This instrumental-variables exercise is informative only if assignment shifts the relevant belief indices; when there is no first stage, we interpret the IV estimates accordingly. Specifically, we estimate the following specification:

$Outcome = \alpha + \beta \cdot belief_index_hat + X'\delta + \varepsilon$, where belief_index is instrumented by T1 and T2.

4. Data and Descriptive Statistics

4.1 Sample Composition and Randomization

The study was conducted among manufacturing firms located in four industrial districts of Punjab – Faisalabad, Lahore, Sialkot, and Gujranwala – covering 16 manufacturing sectors plus an "other sectors" category. A total of 657 firms completed the survey. After excluding nine incomplete observations, the final analysis sample consists of 648 firms, of which 215 were assigned to the control group, 208 to Treatment 1, and 225 to Treatment 2.

The firms in our sample are small but well-established. The median firm employs eight workers during peak production and has operated for approximately 20 years. Textile firms account for roughly one-quarter of the sample, followed by engineering and automotive firms (13 percent each), with the remaining firms distributed across a diverse set of manufacturing activities including sports goods, chemicals, food processing, and other light manufacturing industries.

Table 1 reports summary statistics for the analysis sample. Several characteristics are particularly relevant for interpreting the experiment. First, only 4.9 percent of firms have ever obtained a loan from a formal financial institution, indicating that formal credit plays a very limited role in financing investment among these firms. Second, only 17 percent own a backup generator, while approximately one-quarter participate in global value chains as export suppliers or exporters themselves. These characteristics give context to both firms' baseline perceptions of solar energy and the differential relevance of the two treatment arms.

Table 1: Sample Descriptive Statistics

Variable	N	Mean	SD	Median	Min	Max
Panel A: Firm characteristics						

Variable	N	Mean	SD	Median	Min	Max
Firm age (years)	657	22.4	15.0	20.0	1	81
Employment (peak)	652	14.3	19.6	8	1	200
Energy cost share (%)	657	28.5	14.4	28.4	2	100
Load-shedding (hrs/day)	657	1.45	0.75	1.0	1	5
Family ownership	657	0.97	0.18	1	0	1
Exporter	657	0.11	0.31	0	0	1
GVC participant	657	0.25	0.43	0	0	1
Generator ownership	657	0.17	0.37	0	0	1
Equipment updated	657	0.18	0.38	0	0	1
Ever borrowed	657	0.05	0.22	0	0	1
Panel B: Respondent characteristics						
Education (1–6 scale)	657	2.48	1.20	2	1	6
Risk preference (1–10)	657	7.07	2.64	7.1	1	10
Time preference (1–10)	657	7.25	2.54	8	1	10
Panel C: Pre-treatment beliefs and expectations						
Overall feelings (1–10)	650	6.70	3.14	8	1	10
SO1 index (attitudes)	650	0.00	0.57	0.06	−1.37	2.25
SO2a index (non-fin. PBC)	648	0.00	0.69	0.04	−1.87	1.06
SO2b index (financial PBC)	649	0.00	0.67	0.14	−3.02	1.06
Expected time to invest (months)	649	21.5	28.7	10.8	1.5	120
Panel D: Post-treatment beliefs						
Overall feelings (1–10)	647	7.10	3.29	8	1	10
SO1 index (attitudes)	647	−0.13	0.66	0.06	−1.37	2.25
SO2a index (non-fin. PBC)	646	−0.18	0.67	−0.26	−1.87	1.06
SO2b index (financial PBC)	647	−0.24	0.79	−0.07	−3.02	1.06
Panel E: Knowledge about solar (accuracy, pre vs. post)						
Solar cost estimate (PKR M), pre	484	7.85	3.01	7.30	0.55	20
Solar cost estimate (PKR M), post	600	8.01	2.35	8.00	0.70	18.8
Absolute cost error (PKR M), pre	484	2.35	1.98	1.50	0	11.5
Absolute cost error (PKR M), post	600	1.48	1.90	1.00	0	10.2
Expected payback (years), post	625	4.19	2.95	3.00	0.83	15.8
Payback in correct 1–3 yr range	625	0.54	0.50	1	0	1

Variable	N	Mean	SD	Median	Min	Max
Savings estimate (1–5 category), post	647	1.93	0.90	2	1	5
Savings in correct range	647	0.57	0.50	1	0	1
Panel F: Post-treatment behavioural outcomes						
Inquiry intention (0–100)	647	53.0	37.8	50	0	100
QR code scanned	657	0.15	0.36	0	0	1
Panel G: Feelings by district						
Faisalabad (N = 297)	291	7.45	3.14	–	–	–
Gujranwala (N = 36)	36	7.22	2.64	–	–	–
Lahore (N = 181)	180	8.14	1.48	–	–	–
Sialkot (N = 143)	143	3.22	2.11	–	–	–

Notes: Belief indices are z-scored to the baseline distribution (mean = 0, SD = 1 at baseline); post-treatment index means are therefore slightly negative, reflecting the common pre/post downward drift present in all arms, including control. Solar cost estimates are conditional on providing an estimate; accuracy is measured against the PKR 8.5 million benchmark stated in the videos, so the absolute cost error is |estimate − 8.5 M|. Payback is "correct" if the estimate falls in the 1–3 year range; savings is "correct" if in the 251–750 K/month band. Inquiry intention and QR scanning are the post-treatment behavioural outcomes; expected time to invest is elicited both pre and post (the pre value is shown here. Feelings are on a 1 (very bad) to 10 (very good) scale.

Table 2 assesses balance across treatment arms. Overall, the randomization achieved good balance on observable baseline characteristics. Standardized mean differences are small throughout, and an omnibus randomization balance test cannot reject joint balance across the treatment groups. Although a small number of individual cluster-robust tests indicate statistically significant differences, these are likely driven by the limited number of district clusters and do not translate into economically meaningful imbalance. All baseline characteristics are included as controls in the main specifications.

Table 2: Balance across Treatment Arms

Variable	Control	T1	T2	SMD, T1	SMD, T2	F-test p
Firm characteristics						
Firm age (years)	23.75	21.25	22.42	−0.16	−0.09	0.001
Employment (peak)	14.38	12.85	15.57	+0.03	+0.11	0.100
Family ownership	0.963	0.962	0.978	−0.01	+0.09	0.027
Exporter	0.135	0.101	0.093	−0.11	−0.13	0.333
GVC participant	0.247	0.250	0.253	+0.01	+0.02	0.936

Variable	Control	T1	T2	SMD, T1	SMD, T2	F-test p
Energy cost share (%)	29.74	27.24	28.40	−0.17	−0.09	0.098
Load-shedding (hrs/day)	1.451	1.445	1.460	−0.01	+0.01	0.919
Generator ownership	0.181	0.154	0.169	−0.07	−0.03	0.895
Equipment updated	0.126	0.188	0.218	+0.17	+0.25	0.326
Ever borrowed	0.056	0.058	0.036	+0.01	−0.10	0.262
Respondent characteristics						
Education (1–6)	2.41	2.54	2.50	+0.10	+0.08	0.551
Risk preference (1–10)	6.83	7.12	7.24	+0.10	+0.16	0.027
Time preference (1–10)	7.00	7.38	7.36	+0.14	+0.14	0.000
Pre-treatment beliefs						
Overall feelings (1–10)	6.51	6.71	6.88	+0.06	+0.12	0.032
SO1 index (attitudes)	−0.032	0.019	0.011	+0.09	+0.08	0.117
SO2a index (non-fin. PBC)	−0.032	−0.034	0.061	0.00	+0.14	0.277
SO2b index (financial PBC)	−0.007	−0.027	0.030	−0.03	+0.06	0.221
Solar cost estimate (PKR M)	7.73	7.76	8.02	−0.01	+0.08	0.895
N	215	208	225			

Notes: Cell entries are treatment-arm means. The p-value column reports cluster-robust Wald tests that T1 and T2 each equal Control. The standardized mean differences (SMD columns, each arm versus control) are all small—every $|SMD| \leq 0.25$, the largest being equipment-updated (0.25)—and an omnibus randomization-based balance test—the sum of the T1-versus-Control and T2-versus-Control Mahalanobis distances over the 18 non-missing baseline covariates (N = 647 randomized firms with complete covariates)—gives p = 0.417 under the actual complete-randomization procedure, with a similar result under within-district permutation (p = 0.348); the joint imbalance across arms is fully consistent with chance. Employment enters the SMD and test in logs. Cost estimate N (conditional on providing an estimate): Control = 157, T1 = 154, T2 = 172.

4.2 Firm Characteristics and Baseline Beliefs

The firms in our sample operate in an environment where energy represents a major production cost. On average, they spend 28 percent of their operating costs on electricity and fuel, and nearly 60 percent devote more than one-fifth of their operating costs to energy alone. At prevailing electricity tariffs, solar power therefore represents a potentially attractive investment. Estimates by Sultan et al. (2018) suggest that grid-connected solar can be approximately 40 percent cheaper than electricity supplied by the public utility and around 60 percent cheaper than generator-produced electricity.

Despite these strong economic incentives, solar adoption remains limited. Firms generally hold favourable views of the technology: the average baseline rating of overall feelings toward solar is 6.7 on a ten-point scale, and one-third of respondents assign the maximum score of ten.

Moreover, 93 percent report that they expect to invest in solar eventually, with an average expected investment horizon of approximately 21.5 months. Taken together, these patterns reveal a striking disconnect between stated intentions and observed adoption. Although most firms view solar positively and expect to adopt it in the future, relatively few have done so. Understanding this gap is the central motivation for the experimental analysis that follows.

4.3 Barriers to Adoption

Our research design was motivated by four broad categories of barriers that may hinder solar adoption among manufacturing firms: structural, informational, cognitive, and behavioural. The descriptive evidence suggests that each may play a role.

Structural barriers. The most prominent structural constraint is limited access to formal finance. More than 95 percent of firms have never obtained a loan from a bank or another formal financial institution. Consistent with this, firms express considerably greater willingness to finance solar through alternative arrangements than through conventional bank loans. Nearly two-thirds (64.7 percent) report that they would probably or definitely consider a rent-to-own arrangement, compared with 38.1 percent for an Energy Service Company (ESCO) and only 26.0 percent for a traditional bank loan. These financing preferences are particularly relevant for interpreting our experimental design, as one treatment emphasizes bank financing, while the other presents gradual implementation as an alternative that relies less on formal credit.

A second structural constraint concerns existing energy infrastructure. Although only 17 percent of firms own a backup generator, many respondents believe that solar cannot be effectively integrated with generator use. Whether we can move this inaccurate perception is an empirical question that motivates our information intervention.

Informational barriers. Firms also differ substantially in their beliefs about the costs and returns to solar investment. Among firms in the control group, only 14 percent correctly identify the range of monthly electricity bill savings highlighted in the treatment videos. The average expected payback period is 4.25 years, more than twice as long as the approximately 1.5–2 years reported by local installers. Cost expectations are closer to prevailing market prices on average but underestimate—the median pre-treatment guess is PKR 7.3 million compared with the benchmark value of PKR 8 to 9 million—and nearly 25 percent could not even hazard a guess; there remains substantial variation across firms. These descriptive patterns suggest that inaccurate or incomplete information may contribute to low adoption.

Cognitive barriers. The distribution of baseline perceptions toward solar reveals substantial heterogeneity. While attitudes are generally favourable, they are far from universal. Approximately one-third of firms assign the maximum rating of 10 out of 10 for “overall feelings toward solar”, and more than half rate solar between 8 and 10. At the same time, roughly one-quarter of firms assign ratings between 1 and 4, indicating a sizeable minority that remains sceptical. This dispersion suggests that firms differ not only in what they know about solar, but also in how they evaluate it.

The strongest perceived barrier is agreement with the statement that "investing in solar is only useful if it can cover all of my electricity needs", which receives an average score of 8.1 out of 10. This reflects an all-or-nothing view of solar adoption rather than a direct concern about investment costs, and corresponds closely to the attitude component of the Theory of Planned Behaviour discussed in Section 2.

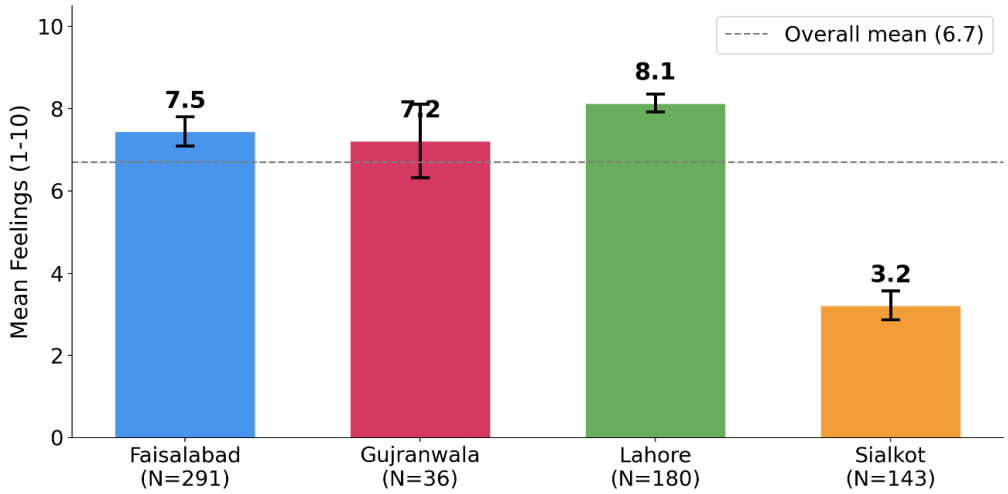
Behavioural barriers. Finally, firms appear to evaluate solar primarily through an economic lens. In an open-ended question about why they would consider investing in solar, 88 percent of respondents cite electricity cost savings, while only 9 percent mention competitiveness or profits. Escaping load-shedding is mentioned by only a small minority of firms, and environmental considerations are almost entirely absent as a primary concern. Together with the evidence on risk and time preferences collected in the survey, these responses suggest that adoption decisions are shaped not only by information but also by firms' broader investment preferences and decision-making processes.

Taken together, the descriptive evidence points to a more nuanced adoption problem than a simple lack of information. Firms generally recognize the economic attractiveness of solar, yet many continue to perceive adoption as financially difficult, operationally challenging, or relevant only under specific conditions. The randomized information experiment allows us to examine whether providing targeted information can alter these beliefs and, in turn, influence adoption-related intentions.

4.4 Geographic Heterogeneity

Attitudes toward solar vary dramatically across districts. Faisalabad, Gujranwala, and Lahore have mean feelings between 7.2 and 8.1 out of 10. Sialkot has a mean of just 3.2 out of 10. Sialkot firms report the lowest finance barriers and the highest non-financial PBC (perceived control) in the sample, and they differ most sharply on the generator-with-solar item (mean 3.5 vs 7.0 elsewhere)—they do not regard generator ownership as making solar impractical—yet they are the most resistant to solar. They are no more concerned than other districts about partial coverage (the all-or-nothing “solar must cover all needs” belief). Notably, none of the 143 firms in Sialkot are classified as “informed” by the composite accuracy measure (a descriptive cross-tabulation, not a formal test). This pattern—high perceived control combined with low enthusiasm and very low baseline feelings—is consistent with Sialkot’s resistance being structural and attitudinal rather than a simple information deficit, though with a single low-attitude district we cannot cleanly separate these explanations.

Figure 2: Baseline Feelings Distribution by District



Source: Authors' calculations based on primary data collected for this project

5. Results

5.1 Beliefs and Intentions

We begin by examining whether firms' beliefs about solar are associated with adoption-related intentions. This analysis establishes whether the belief dimensions identified by the Theory of Planned Behaviour predict firms' intentions before assessing whether the information intervention can shift those beliefs.

Table 3 reports cross-sectional regressions of the stated inquiry intention on all three post-treatment belief indices jointly, with the full set of controls. A clear pattern emerges. Among the three belief dimensions, attitudes toward solar are by far the strongest predictor of firms' stated intention to contact a solar installer: a one-standard-deviation increase in the attitude index is associated with a 16.8 percentage point increase in inquiry intention, and the relationship remains robust across inference procedures. By contrast, neither the financial nor the non-financial perceived behavioural control indices are significantly associated with inquiry intentions.

Table 3: Belief Indices and Adoption Outcomes (joint specifications)

	Inquiry (pp)	Post exp. time (mo)	Pre exp. time (mo)
	(1)	(2)	(3)
SO1 (attitudes)	16.79***	−14.88**	−12.04
	(0.54) [0.010]	(4.28) [0.099]	(6.05) [0.634]
SO2a (non-fin. PBC)	2.20	−2.04	−3.05

	Inquiry (pp)	Post exp. time (mo)	Pre exp. time (mo)
	(1.90) [0.533]	(1.61) [0.261]	(1.31) [0.445]
SO2b (financial PBC)	5.81	−6.42	−4.79
	(2.70) [0.343]	(2.86) [0.313]	(4.23) [0.767]
N	646	646	648
R^2	0.390	0.377	0.321

*Notes: Each column is a single OLS regression of the outcome on all three belief indices jointly, with full controls ($X) and district FE. Column (1): post-treatment inquiry intention (0–100) on the post-treatment indices. Column (2): post-treatment expected time to invest (months) on the post-treatment indices. Column (3): pre-treatment expected time (months) on the pre-treatment indices. Cluster-robust SEs (4 districts) in parentheses; wild cluster bootstrap p-values (Webb weights, 9,999 reps) in brackets. Stars are from cluster-robust p-values: * p < 0.10, ** p < 0.05, *** p < 0.01. Belief indices are z-scored (SD = 1). Columns (1)–(2) are the post-treatment specifications.*

The association is driven almost entirely by firms' overall feelings toward solar rather than by specific beliefs about the technology. Decomposing the attitude index shows that a one-standard-deviation increase in the positive-feelings component is associated with a 20.1 percentage point increase in inquiry intention, whereas the belief that solar is useful even when it covers only part of a firm's electricity needs has essentially no relationship with inquiry. In other words, firms' willingness to engage with solar providers appears to depend more on their general perception of the technology than on any particular factual belief embedded in the attitude index.

The relationship between beliefs and firms' expected time to invest is considerably weaker. More favourable attitudes are associated with an expected investment horizon that is approximately 15 months shorter, but this estimate is not robust across inference methods. The expected-time measure is based on a probabilistic pre-post elicitation and is inherently noisier than the inquiry measure, so we place less weight on these estimates.

Taken together, these results point to attitudes toward solar as the belief dimension most closely associated with adoption intentions. Importantly, it is firms' general perception of solar – not specific beliefs about partial adoption or perceived behavioural control – that is most strongly associated with their willingness to take the first step toward adoption by contacting a solar provider. This finding provides an important benchmark for interpreting the experimental results that follow: if the intervention fails to shift attitudes toward solar, it is unlikely to generate meaningful changes in adoption-related intentions.

5.2 Information Did Not Affect the Belief Indices

We next examine whether the information intervention changed the beliefs it was designed to influence. Following Ajzen's Theory of Planned Behaviour, the videos aimed to improve firms' attitudes toward solar and their perceived behavioral control by providing information on installation costs, expected savings, technical feasibility, financing options (T1), and implementation pathways (T2).

Table 4 shows little evidence that the intervention shifted any of the pre-specified belief indices. Across both treatment arms, estimated effects on attitudes, non-financial perceived behavioral control, and financial perceived behavioral control are uniformly small, ranging from −0.05 to +0.03 standard deviations, and none is robust across the alternative inference procedures employed in the paper. The only sub-0.10 value is SO2a × T2 under the bootstrap (0.061), which is tiny, negative, and null under RI. Thus, the absence of statistically significant effects reflects not only limited precision but also negligible effect sizes.

Table 4: Treatment Effects on Belief Indices (DiD)

	SO1 (attitudes)	SO2a (non-fin. PBC)	SO2b (financial PBC)
	(1)	(2)	(3)
T1 (bank financing)	−0.041	−0.035	−0.054
	(0.016)	(0.024)	(0.051)
T2 (gradual impl.)	0.028	−0.014	0.002
	(0.026)	(0.008)	(0.049)
N	647	645	647
R^2	0.215	0.412	0.437
WCB p (T1)	0.107	0.306	0.305
WCB p (T2)	0.378	0.061	0.952
RI p (T1)	0.381	0.369	0.253
RI p (T2)	0.559	0.716	0.964

*Notes: OLS, change-score (first-difference) specification: the dependent variable is the pre-to-post change in the z-scored index and the pre-treatment level is differenced out (not entered as a covariate). Cluster-robust SEs in parentheses (4 districts). All columns include full controls ($X) and district FE. WCB p = wild cluster bootstrap p-value (Webb weights, 9,999 reps); the corresponding 95% bootstrap CIs all include zero (e.g., SO1: T1 [−0.13, 0.05], T2 [−0.04, 0.24]). RI p = randomization inference p-value (Fisher's exact test, 5,000 permutations, two-sided). * p < 0.10, ** p < 0.05, *** p < 0.01.*

A common pattern emerges across all experimental arms. Between the baseline and endline surveys, respondents report slightly lower attitudes and perceived behavioral control, regardless of whether they viewed a treatment or the placebo video. Because this decline is equally pronounced in the control group, it cannot be attributed to the information intervention itself. Instead, it appears to reflect a common pre-post shift, possibly because completing the survey prompted respondents to think more carefully about practical considerations such as financing, roof space, maintenance, and technical integration. Whatever its source, this common drift affects treated and control firms alike and therefore does not alter the experimental comparison.

The same pattern is evident across districts. Firms in Faisalabad, Gujranwala, and Lahore report modest improvements in their overall feelings toward solar between the baseline and endline surveys, but these improvements occur equally in the treatment and control groups. By contrast, firms in Sialkot – where baseline attitudes are substantially less favorable – show almost no

change over the survey period. This finding is consistent with the descriptive evidence presented in Section 4 that attitudes toward solar appear particularly resistant in Sialkot.

These results provide an important link between the cross-sectional and experimental evidence. Section 5.1 showed that a positive attitude toward solar is the strongest predictor of firms' willingness to contact a solar installer. This section shows that the information intervention did not meaningfully change those attitudes or firms' perceived behavioral control. As we show in the following sections, the videos successfully improved factual knowledge about solar but failed to alter the broader beliefs most closely associated with adoption intentions.

5.3 Information Has Little Effect on Adoption-Related Outcomes

We next examine whether the information intervention changed firms' adoption-related intentions and behavior. Table 5 reports treatment effects for the three pre-specified primary outcomes: expected time to invest, intention to contact a solar installer, and QR-code-based information seeking.

Table 5: Treatment Effects on Primary Outcomes

	PO1: Exp. time (months)	PO2: Inquiry (pp)	PO3: QR usage
	(1)	(2)	(3)
T1 (bank financing)	1.10	0.40	0.020
	(1.12)	(1.71)	(0.026)
T2 (gradual impl.)	−0.44	5.86**	0.024
	(0.61)	(1.32)	(0.025)
N	647	647	648
R^2	0.080	0.325	0.081
WCB p (T1)	0.165	0.731	0.347
WCB p (T2)	0.524	0.026	0.364
WCB 95% CI (T2)	[−2.8, 5.5]	[1.9, 18.6]	[−0.19, 0.17]
FDR q (T2, Family A)	0.62	0.13	0.62
RI p (T1)	0.416	0.902	0.582
RI p (T2)	0.746	0.072	0.512

*Notes: OLS. Cluster-robust SEs in parentheses (4 districts); stars reflect cluster-robust p-values. All columns include full controls ($X) and district FE. PO1 uses DiD specification; PO2 and PO3 are post-only. PO3 is a binary indicator (0/1). WCB = wild cluster bootstrap (Webb weights, 9,999 reps), now reported for all three outcomes and both arms; it also yields a coefficient confidence interval, shown for T2. RI = randomization inference (Fisher's exact test, 5,000 permutations, two-sided), which yields a p-value but not a coefficient interval; the WCB CI and RI p-value are from distinct procedures. FDR q = sharpened Family-A q-value for the registered T2-versus-Control test of each outcome (Family A = the {T2 vs. C, T1 vs. T2} contrasts across PO1/PO2/PO3, six tests); T1-versus-Control is not a Family-A test, so no T1 q-value is reported. T1=T2 RI p-values: PO1 = 0.268, PO2 = 0.088, PO3 = 0.915. * p < 0.10, ** p < 0.05, *** p < 0.01.*

Overall, the intervention had little effect on adoption-related outcomes. Neither treatment arm changed firms' expected time to invest in solar or their likelihood of accessing additional information through the QR code. Estimated effects on expected investment timing are economically small and statistically insignificant across all inference procedures. Similarly, QR-code usage remains low across all three groups, with an overall scan rate of 15 percent and no meaningful differences between treatment and control firms.

The only exception is inquiry intention. Firms assigned to the gradual-implementation treatment (T2) report a 5.9 percentage point higher probability of contacting a solar installer than firms in the control group. This effect is statistically significant under conventional clustered standard errors and the wild cluster bootstrap, but only marginal under randomization inference and it does not survive the pre-specified false discovery rate correction. We therefore interpret this result as suggestive rather than robust evidence that framing solar as an incremental investment may increase firms' willingness to make an initial inquiry.

Taken together, the primary outcomes provide little evidence that the intervention altered firms' adoption-related decisions. The absence of treatment effects is consistent with the findings from Section 5.2: because the videos did not meaningfully change the attitudes and perceptions of feasibility most closely associated with adoption intentions, they also produced little change in firms' stated intentions or subsequent information-seeking behaviour.

One additional pattern is worth noting. Although inquiry intention is positively associated with treatment in T2, it is only weakly related to actual QR-code usage. Firms that report a greater willingness to contact a solar installer are only slightly more likely to seek additional information through the QR code, suggesting that expressed intentions do not necessarily translate into immediate follow-up behaviour.

5.4 Information Improves Factual Knowledge

The previous sections showed that the information intervention did not meaningfully shift firms' attitudes toward solar or their adoption-related intentions. We next examine whether the videos nevertheless improved firms' factual knowledge about solar technology. Table 6 reports treatment effects on three dimensions of knowledge: system costs, expected electricity bill savings, and expected payback periods.

Table 6: Treatment Effects on Factual Knowledge

Panel A: Treatment effects on knowledge outcomes (coef [cluster p; WCB p; RI p])

Outcome	Measure	N	T1	T2
Cost: abs(post log error), ANCOVA	suppl. (cleaner accuracy)	482	−0.07 [0.291; 0.339; 0.121]	−0.11 [0.237; 0.249; 0.017]
Cost: abs(post log error), post-only	suppl. (cleaner accuracy)	600	−0.08 [0.320; 0.217; 0.092]	−0.12 [0.156; 0.054; 0.008]
Cost: change score (abs pre − abs post)	registered (cost-learning)	482	+0.08 [0.262; 0.416; 0.157]	+0.11 [0.333; 0.414; 0.032]

Outcome	Measure	N	T1	T2
Savings: in 501-750K bin	constructed accuracy	647	+0.19 [0.121; 0.248; <0.001]	+0.22 [0.126; 0.327; <0.001]
Savings: in 251-750K range	constructed accuracy	647	+0.11 [0.311; 0.534; 0.003]	+0.14 [0.270; 0.357; <0.001]
Payback: expected years	registered (directional)	625	+0.09 [0.620; 0.544; 0.706]	−0.32 [0.001; 0.032; 0.180]
Payback: in correct 1-3 yr range	suppl. accuracy transform	625	+0.02 [0.234; 0.303; 0.630]	+0.08 [0.119; 0.345; 0.082]

Panel B: Cost estimates (PKR millions)

	Pre-treatment	Post-treatment	Same estimate (%)
Control	7.79	7.75	55.8
T1	7.76	7.99	35.1
T2	8.02	8.22	33.1

Panel C: Learning rates (perception-gap form, Eq 2b)

Group	Learning rate λ
Control	0.39 (WCB p = 0.058)
T1	0.57
T2	0.67
Treated (pooled)	0.61
Treated − Control (direct test)	difference +0.22, cluster p = 0.327; WCB p = 0.305 (n.s.)

Notes: Panel A reports OLS/LPM treatment-effect regressions of each knowledge outcome on T1, T2, full controls ($X), and district FE; each cell is the coefficient with [cluster-robust p (4 districts); wild-cluster-bootstrap p (Webb weights, 9,999 reps); randomization-inference p (5,000 permutations of treatment)]. RI is valid because every Panel A outcome is a randomized treatment effect; RI p-values below 1/5,000 are shown as <0.001. ***Registered vs. constructed measures:*** *COST: the change-score (abs pre log error − abs post log error) is the REGISTERED cost-learning specification (cf. the Eq 2b belief-updating equation, Panel C); the ANCOVA on the absolute post-error (controlling the absolute pre-error) and the post-only level are SUPPLEMENTARY, cleaner accuracy specifications. abs post log error = abs(ln(post estimate / 8.5M)), lower = more accurate. SAVINGS: constructed accuracy outcomes based on the registered F1 savings-belief item—indicators that the endline estimate falls in the correct 501–750K bin (narrow, ~600K signal) or 251–750K range (broad, informed-firm definition); the exact bin/range transformation was not pre-specified; higher = more accurate. PAYBACK: expected payback in years is the REGISTERED primary payback measure and is DIRECTIONAL (a lower value is closer to the 1.5–2 year signal only down to the true range, not a symmetric accuracy measure); the correct 1–3 year indicator is a SUPPLEMENTARY accuracy transform.* ***Sample restrictions:*** *the cost change/ANCOVA outcomes require a numeric estimate at BOTH waves (N=482; 26% declined at baseline); post-only cost requires an endline estimate (N=600); savings N=647, payback N=625. Panel B: descriptive cost-estimate means by arm. Panel C: Fuster-Zafar belief-updating (Eq 2b) in perception-gap form—λ is the positive coefficient on (signal − prior) = −pre_log_acc, with full controls + district FE; λ=1 is full updating to the 8.5M signal.*

The treated–control difference is tested directly (gap × treated = gap × control). ***No significance stars****: we report all three p-values and rely on RI for the randomized treatment effects.*

The evidence suggests that the intervention successfully transmitted factual information, although the strength of the results varies across outcomes and inference methods.

Cost beliefs. The evidence points to modest improvements in firms' knowledge of installation costs, particularly under the gradual-implementation treatment. Firms in the control group revised their estimates very little between the baseline and endline surveys (from PKR 7.79 million to PKR 7.75 million), whereas the median estimate in Treatment 2 coincides with the mean benchmark value presented in the videos (PKR 8.5 million). Consistent with this, more than half of control firms (55 percent) reported exactly the same cost estimate before and after the intervention, compared with only one-third of firms assigned to Treatment 2. Using the registered belief-updating framework of Fuster and Zafar (2023), Treatment 2 improves within-firm cost accuracy under randomization inference, although the effect is not consistently robust across alternative inference procedures. A broader endline specification, which includes firms without a baseline cost estimate, yields a similar pattern. Overall, the evidence suggests that the intervention improved firms' understanding of installation costs, although the magnitude of the effect depends on the specification and inference method.

Savings beliefs. The clearest evidence of factual updating concerns expected electricity bill savings. Relative to the control group, the probability of identifying the correct savings range increases by approximately 19 percentage points under Treatment 1 and 22 percentage points under Treatment 2. Using a broader definition of accurate beliefs, the corresponding increases are 11 and 14 percentage points, respectively. These effects are highly significant under randomization inference, although less precisely estimated using clustered standard errors and the wild cluster bootstrap. Among the three knowledge outcomes, savings beliefs therefore provide the strongest evidence that firms processed and retained the information presented in the videos.

Payback beliefs. Evidence for payback expectations is more limited. Firms assigned to the gradual-implementation treatment report expected payback periods that are approximately 0.3 years shorter, moving them closer to the 1.5–2-year benchmark described in the videos. This effect is statistically significant under the wild cluster bootstrap but not under randomization inference and should therefore be interpreted as suggestive rather than conclusive. Likewise, the probability of reporting a payback period within the correct 1–3-year range increases by around 8 percentage points, although this estimate is only marginally significant.

Finally, we estimate belief-updating models following Fuster and Zafar (2023) for installation cost beliefs. Estimated learning rates increase from 0.39 in the control group to 0.57 under Treatment 1 and 0.67 under Treatment 2, indicating greater updating toward the information provided in the videos. However, the differences across treatment arms are not statistically distinguishable, suggesting that treated firms updated their beliefs more than the control group only modestly.

Taken together, these results contrast substantially with the findings for the pre-registered belief indices. The intervention successfully improved firms' factual understanding of solar costs, expected savings, and, to a lesser extent, payback periods. However, this factual updating did not translate into changes in the broader attitudes or perceptions of feasibility identified by the Theory of Planned Behaviour. Information delivery therefore appears to have succeeded, while broader belief change – and ultimately changes in adoption-related intentions – did not.

5.5 Instrumental Variables

Our pre-analysis plan proposed using treatment assignment as an instrument for the three pre-registered belief indices to estimate the causal effect of beliefs on adoption-related intentions. This strategy relies on a strong first stage: the information intervention must induce meaningful changes in the instrumented beliefs.

As shown in Section 5.2, however, the intervention did not significantly affect any of the three targeted belief indices. Consequently, the corresponding first-stage relationships are weak, and the instrumental variables strategy is not informative for these measures. We therefore cannot identify the causal effect of attitudes or perceived behavioral control on adoption intentions using treatment assignment as an instrument.

This null first stage is itself informative. The cross-sectional results in Section 5.1 show that attitudes toward solar are strongly associated with firms' willingness to contact a solar installer. However, because the intervention did not shift those attitudes, the causal pathway implied by the Theory of Planned Behavior – information → beliefs → intentions → behavior – cannot be established for the targeted belief dimensions.

The intervention did improve several measures of factual knowledge (Section 5.4), raising the possibility of using knowledge-based measures as alternative instruments. We explore this possibility in supplementary analyses, but because these measures were not part of the pre-registered instrumental variables strategy, we treat those results as exploratory.

5.6 The Accuracy Channel (Exploratory)

The registered instrumental variables strategy was not informative because the intervention did not shift the targeted belief indices. However, the intervention did improve several measures of factual knowledge, raising a natural exploratory question: do firms with more accurate knowledge about solar also express stronger adoption intentions?

To examine this possibility, we construct an index of factual accuracy combining firms' knowledge of expected electricity bill savings and payback periods. Because this index was not pre-registered and relies on a constructed measure, the analysis should be interpreted as exploratory rather than causal.

The results in Table 7 suggest that factual knowledge and inquiry intentions are positively related. In OLS regressions, a one-standard-deviation increase in the accuracy index is associated with a 13.6 percentage point increase in stated inquiry intention. Instrumenting the accuracy index with treatment assignment yields a larger estimate of 18.6 percentage points, although the first stage

is relatively weak and the exclusion restriction is unlikely to hold strictly because the videos may affect inquiry through channels other than factual knowledge.

Importantly, the accuracy index is unrelated to firms' expected investment timeline, QR-code usage, or the pre-registered belief indices. Together with the earlier results, this suggests that the intervention successfully increased factual understanding of solar without changing the broader attitudes and perceptions of feasibility that appear to drive adoption intentions.

Accordingly, we view these findings as suggestive rather than causal. They indicate that factual knowledge may matter for firms' willingness to make an initial inquiry, but they do not overturn the main conclusion of the paper: improving factual information alone was insufficient to shift firms' beliefs and decisions around solar adoption targeted by the intervention.

Table 7: The Accuracy Channel (Exploratory)

Panel A: First stage — treatment → factual accuracy index

Accuracy index (instrumented by T1, T2)	T1	T2	Joint F	N
Narrow savings bin (501–750K) — preferred	+0.18 (p = 0.200)	+0.30 (p = 0.112)	7.4	647
Broad savings range (251–750K) — robustness	+0.12 (p = 0.280)	+0.20 (p = 0.142)	21.8	647

Panel B: Accuracy → outcomes (per one-unit change in the accuracy index)

Outcome	OLS (narrow)	IV, narrow	IV, broad	N
Inquiry intention (pp)	+13.6 (p = 0.003)	+18.6 (p = 0.004)	+27.7 (p = 0.016)	647
Expected time (months)	−7.0 (p = 0.167)	−3.6 (p = 0.178)	−5.9 (p = 0.064)	647
QR code usage (prob.)	+0.000 (p = 0.993)	+0.082 (p = 0.417)	+0.118 (p = 0.435)	647
SO1 change (Δ index)	−0.006 (p = 0.932)	+0.075 (p = 0.199)	+0.120 (p = 0.125)	647
SO2a change (Δ index)	+0.060 (p = 0.327)	−0.057 (p = 0.083)	−0.077 (p = 0.136)	645
SO2b change (Δ index)	+0.064 (p = 0.186)	−0.011 (p = 0.938)	−0.005 (p = 0.979)	647

*Notes: **Exploratory and not pre-registered.** The accuracy index is the row-mean of two z-scored, sign-reversed error measures: |payback − 1.75 yr| and the savings-bin distance. The PREFERRED index uses the narrow correct savings*

bin (501–750K, |bin − 3|), matching Table 6's main savings-accuracy outcome; the robustness index uses the broad 251–750K range (which treats 251–500K as fully correct). A cost-inclusive 3-component index was dropped (Cronbach's α ≈ 0.33, internally incoherent). All specifications include full controls ($X) and district FE, with cluster-robust SEs (4 districts); IV instruments the accuracy index with T1 and T2. In Panel B, the OLS column regresses each outcome on the narrow accuracy index, while the IV-narrow and IV-broad columns instrument the narrow and broad indices, respectively, with T1 and T2; coefficients are per one-unit change in the accuracy index (inquiry in percentage points, expected time in months, QR usage as a scan probability, and the SO1/SO2a/SO2b rows as the post−pre change in the corresponding belief index, in baseline-SD units).

5.7 Heterogeneous Treatment Effects

Although the average treatment effects are small, we explore whether the intervention was more effective for particular groups of firms. These analyses were pre-specified unless otherwise noted and should be interpreted cautiously given the limited number of district clusters.

The clearest heterogeneity emerges across districts. As documented in Section 4, firms in Sialkot reported substantially less favourable baseline attitudes toward solar than firms elsewhere (mean attitude score of 3.2, compared with 7.2–8.1 in the other three districts). Consistent with this pattern, the intervention had essentially no effect in Sialkot. Restricting the sample to the remaining districts, the gradual-implementation treatment (T2) increases inquiry intentions by 7.2 percentage points relative to the control group. Although this estimate is only marginally robust under the wild cluster bootstrap, it suggests that information may be more effective where baseline attitudes toward solar are already relatively favourable.

We also find suggestive evidence of heterogeneity by firms' participation in global value chains (Table 8). Firms integrated into global value chains exhibit larger improvements in cost accuracy following the intervention, particularly under Treatment 1. While these interaction effects are only marginally significant and not robust across all inference procedures, they are consistent with the idea that export-oriented firms may be more sensitive to, or accustomed to, processing quantitative information about investment costs and returns.

Table 7: Treatment Heterogeneity

Panel A: GVC × Treatment on Cost Accuracy (log)

	Cost accuracy (log)
	(1)
T1 (bank financing)	0.014
	(0.048)
T2 (gradual impl.)	0.012
	(0.058)
T1 × GVC	0.196
	(0.105)
T2 × GVC	0.324**

	Cost accuracy (log)
	(0.082)
N	482
R^2	0.178
WCB p (T1 × GVC)	0.053
WCB p (T2 × GVC)	0.077

Panel B: Loss-Framing Salience × Treatment on Expected Time (months)

	Main: salience median split	Sensitivity: count ≥ 3
	(1)	(2)
T1 (bank financing)	5.13***	4.38***
T2 (gradual impl.)	−2.67	−0.16
High loss-framing salience	−0.41	20.3***
T1 × High	−3.65	−10.7**
T2 × High	+2.61	−16.7***
Joint F (interactions)	16.3 (p = 0.024)	169 (p = 0.001)

Panel C: Sector-Specific Effects

Sector	Outcome	T1 effect (cluster p)	T2 effect (cluster p)	WCB p (T1 / T2)	Robust to WCB?
Textiles	Cost accuracy	0.266 (p = 0.022)	0.243 (p = 0.016)	0.223 / 0.178	No
Engineering	Inquiry	+5.0 pp (p = 0.639)	+15.3 pp (p = 0.001)	0.653 / 0.137	No

*Notes: Panel A: OLS. Cluster-robust SEs in parentheses (4 districts). Full controls ($X) and district FE. GVC is a binary indicator for global value chain participation. WCB = wild cluster bootstrap (Webb weights, 9,999 reps). Panel B: OLS with full controls and district FE; the dependent variable is expected time to invest and the reported stars/p-values are cluster-robust only (the wild cluster bootstrap and randomization inference were not run for these subgroup interactions). Column (1) is the MAIN specification: the moderator is an above/below-sample-median split of the intensity-weighted loss-framing salience index. Column (2) is a SENSITIVITY using a cruder measure (high = a count of ≥ 3 of 4 loss-framed choices, the 6.7-percent tail); that measure ignores response intensity. Panel C: within-sector subsample regressions (T1 and T2 estimated jointly in a single regression restricted to firms in that sector) with full controls and district FE. The p-values shown are cluster-robust. * p < 0.10, ** p < 0.05, *** p < 0.01.*

By contrast, we find little evidence that treatment effects vary systematically with firms' sector, education, risk preferences, time preferences, firm size, energy intensity, generator ownership, or previous borrowing experience (Appendix Tables A1 and A2). None of these interaction effects is robust across inference methods.

Overall, the heterogeneity analysis reinforces the paper's central findings. Where the intervention appears most effective, it does so by increasing firms' willingness to seek additional information or by improving factual knowledge rather than by shifting the broader beliefs and decisions around solar adoption.

6. Discussion

6.1 Why Did the Information Intervention Fail?

The central finding of this study is that the information intervention successfully transmitted factual knowledge but failed to change the broader beliefs most closely associated with adoption intentions. Firms updated their understanding of solar costs, expected savings, and payback periods, yet these improvements did not translate into more favourable attitudes toward solar or stronger perceptions that adoption was feasible.

This distinction helps reconcile the main results. The cross-sectional analysis showed that attitudes toward solar are the strongest predictor of firms' willingness to contact a solar installer. However, the intervention did not meaningfully shift those attitudes. Instead, it primarily affected factual knowledge. The evidence therefore suggests that factual information alone is insufficient to change the broader evaluations that underpin adoption decisions.

This does not imply that information is unimportant. Rather, it suggests that the relevant barriers extend beyond factual misunderstandings. Attitudes toward solar appear to reflect deeper assessments of feasibility, confidence, and practical relevance that are unlikely to change through a short informational video alone. These beliefs may instead be shaped by firms' prior experiences, local business environments, peer networks, and the financial constraints under which they operate.

6.2 Structural Barriers

Several features of the sample help explain why information alone may have had limited impact.

Financing. With 95.1 percent of firms having never taken any loan, the formal financial system is essentially absent for this population. Nearly two-thirds express willingness to use rent-to-own arrangements, but only a quarter would consider a bank loan. In exploratory cross-sectional regressions, some financing-preference measures are associated with inquiry and expected time to invest (the pattern is mixed across measures), but in all cases they are stable structural features unmoved by treatment.

Partial-coverage usefulness beliefs. The all-or-nothing belief that solar is only useful if it covers all electricity needs (mean 8.1 pre-treatment, 8.9 post-treatment)—a registered SO1 attitude component, distinct from the separately measured generator/integration concern—appears to be a deep-seated view about the practical value of partial solutions. The videos depict a partial system that supplements grid power, yet the belief strengthens. This suggests that something more—such as experiential evidence, i.e., seeing a functioning system that supplements rather than replaces grid power, competitive pressures, or peer persuasion—may be needed to shift this perception.

Geographic heterogeneity. The dramatic difference between Sialkot (feelings of 3.2/10) and the other three districts (7.2–8.1/10) suggests that attitudes reflect local conditions and social dynamics. This implies that individual-level information treatments may be insufficient when negative attitudes have already become entrenched.

6.3 Policy Implications

The results point toward several directions for future policy and follow-up research.

Consider rent-to-own programs. Nearly two-thirds of firms are willing to consider rent-to-own, and this willingness is associated with higher inquiry and a shorter expected time to invest. This financing mechanism is best aligned with the financial realities of firms that have never used formal credit. It would essentially be a scaled-up version of the "hire-purchase" contract tested among Pakistani micro-entrepreneurs in Bari et al. (2024).

Test demonstrations and peer evidence. Because these videos moved knowledge but not the attitudes that predict intentions, a natural next step is to test whether experiential evidence shifts what information could not. Pilot installations, factory tours, and peer demonstrations that let firms see solar working in practice are a promising arm for a follow-up experiment; our data show that videos explaining the economics were insufficient, but they do not establish that demonstrations would succeed.

Provide concrete cost information. While information alone does not change attitudes or behavior, the knowledge channels show that firms do absorb and retain factual content. Policy communications should emphasize specific, verifiable cost and savings figures rather than general messages about solar's benefits. Even if factual knowledge does not shift attitudes directly, it may contribute to longer-term updating as firms encounter confirming evidence.

Explore competitive framing. In exploratory, non-pre-registered item-level regressions, competitive framing ("falling behind competitors") is associated with higher inquiry and abstract loss framing ("losses from not investing") with lower inquiry. These associations are significant only under cluster-robust inference and do not survive the wild cluster bootstrap, so they are at best suggestive; nevertheless, concrete competitive language is a hypothesis to test in subsequent research.

Target receptive populations. GVC firms show the largest cost-information response, and a few sectors stand out (textiles for cost accuracy, engineering for inquiry), so they could, in principle, serve as demonstration cases. We stress that these patterns of heterogeneity are marginal at best under the wild cluster bootstrap and rest on small subsamples with only four clusters, but they provide a suggestive direction for targeting firms in the future.

6.4 Limitations

Several limitations should be considered when interpreting the results. First, the study includes only four district clusters, requiring inference methods designed for settings with few clusters. Although we report wild cluster bootstrap and randomization-inference results alongside conventional clustered standard errors, statistical power remains limited.

Second, the realized sample differs from the population envisioned in the original design. Most participating firms are microenterprises rather than the small and medium-sized firms for which the treatment videos were originally developed. This mismatch may have reduced the relevance of the bank-financing treatment and contributed to the weak average treatment effects.

Third, the study measures adoption-related intentions and information-seeking behaviour rather than actual solar adoption. A planned follow-up survey will examine whether firms subsequently contacted installers or invested in solar systems.

Finally, because the intervention did not shift the pre-registered belief indices, the instrumental variables strategy proposed in the pre-analysis plan could not identify the causal effect of beliefs on intentions. The exploratory analyses based on factual knowledge provide useful insights but should be interpreted cautiously because they rely on constructed measures and stronger identifying assumptions.

7. Conclusion

Using a randomized experiment with 657 micro and small manufacturing firms in Pakistan, this paper examined whether targeted information can accelerate the adoption of solar energy. The results paint a consistent picture. Information successfully improved firms' factual understanding of solar technology, but it did not change the broader beliefs most closely associated with adoption intentions.

The intervention increased the accuracy of firms' beliefs about installation costs, expected savings, and payback periods. However, these improvements did not translate into more favourable attitudes toward solar, stronger perceptions that adoption was feasible, or meaningful changes in adoption-related intentions and behaviour. The only exception is suggestive evidence that framing solar as a gradual investment may increase firms' willingness to contact a solar installer, although this effect is not robust across all inference procedures.

These findings suggest that low solar adoption among small manufacturing firms cannot be explained simply by a lack of factual information. Instead, firms appear able to update factual knowledge while leaving broader evaluations of the technology largely unchanged. Information changed what firms knew; however, this was not sufficient to impact their evaluation of a solar investment.

More broadly, the results contribute to a growing literature showing that correcting information is often easier than changing behaviour. In the context of renewable energy adoption by firms, factual information appears to be a necessary but insufficient condition for investment. Future interventions may therefore need to complement information with financing mechanisms suited to firms operating outside formal credit markets, experiential demonstrations that reduce uncertainty, and approaches that leverage peer learning, competitive pressure, and local business networks. Whether such interventions can overcome the attitudinal and structural barriers identified in this study remains an important question for future research.

References

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211.

Akangbe, O., & Sharifi, A. (2025). Nigeria's path to green energy transition: Insights from business preferences for solar PV adoption. *Renewable Energy*, *253*, 123604.

Anderson, M. L. (2008). Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects. *Journal of the American Statistical Association*, 103(484), 1481–1495.

Awais, M., Fatima, T., & Awan, T. M. (2022). Assessing behavioral intentions of solar energy usage. *Management of Environmental Quality*, 33(6).

Bacon, R. (2019). Learning from Power Sector Reform: The Case of Pakistan. SSRN.

Bari, F., Malik, K., Meki, M., & Quinn, S. (2024). Asset-based microfinance for microenterprises: Evidence from Pakistan. *American Economic Review*, *114*(2), 534-574.

Cameron, A. C., Gelbach, J. B., & Miller, D. L. (2008). Bootstrap-Based Improvements for Inference with Clustered Errors. *Review of Economics and Statistics*, 90(3), 414–427.

De Groote, O., & Verboven, F. (2019). Subsidies and Time Discounting in New Technology Adoption: Evidence from Solar Photovoltaic Systems. *American Economic Review*, 109(6), 2137–2172.

ESMAP. (2020). Global Photovoltaic Power Potential by Country. World Bank.

Fisher, R. A. (1935). *The Design of Experiments*. Edinburgh: Oliver and Boyd.

Fuster, A., & Zafar, B. (2023). Survey experiments on economic expectations. In *Handbook of Economic Expectations* (pp. 107–130). Elsevier.

Global Climate Risk Index. (2023). Germanwatch.

Haaland, I., Roth, C., & Wohlfart, J. (2023). Designing Information Provision Experiments. *Journal of Economic Literature*, 61(1), 3–40.

Jessoe, K., & Rapson, D. (2014). Knowledge is (Less) Power: Experimental Evidence from Residential Energy Use. *American Economic Review*, 104(4), 1417–1438.

Kunreuther, H., Polise, A., & Spellmeyer, Q. (2022). Addressing Biases that Impact Homeowners' Adoption of Solar Panels. *Climate Policy*, 22(8), 1–7.

Mahadevan, M., Meeks, R., & Yamano, T. (2023). Reducing Information Barriers to Solar Adoption: Experimental Evidence from India. *Energy Economics*, 120, 106600.

Palm, J. (2018). Household Installation of Solar Panels—Motives and Barriers in a 10-year Perspective. *Energy Policy*, 113, 1–8.

Qamar, S., Ahmad, M., Oryani, B., & Zhang, Q. (2022). Solar Energy Technology Adoption by MSMEs. *Environmental Science and Pollution Research*, 29(32), 49385–49403.

Sultan, M., Wu, J., Aleem, F. e., & Imran, M. (2018). Cost and Energy Analysis of a Grid-Tie Solar System Synchronized with Utility and Fossil Fuel Generation with Major Issues for the Attenuation of Solar Power in Pakistan. *Solar Energy*, 174, 967–975.

Webb, M. D. (2022). Reworking Wild Bootstrap Based Inference for Clustered Errors. *Canadian Journal of Economics*, 55(2), 839–870.

World Bank. (2021). South Asia Climate Roadmap. World Bank.

Appendix Table A1: Registered Behavioral and Demographic Moderators (Treatment × Moderator on Inquiry)

Moderator (specification)	T2 × M	Joint cluster p	WCB p (T2×M)	RI p (T2×M)	Robust?
Risk preference (median split)	−0.9 pp	0.942	0.799	0.892	No
Risk preference (continuous)	−0.23	0.754	0.753	0.848	No
Time preference (median split)	+1.0 pp	0.155	0.857	0.884	No
Time preference (continuous)	−0.14	0.190	0.921	0.907	No
Education (median split)	+5.2 pp	0.138	0.686	0.487	No
Education (1–6 level, linear)	−1.15	0.611	0.411	0.673	No
Firm size, log employment (continuous)	−3.88	0.254	0.362	0.325	No
Export status (binary)	−19.7 pp	0.002	0.129	0.057	No (cluster only)

Notes: OLS regressions of inquiry intention (0–100) on T1, T2, the moderator, and its two treatment interactions (T1×M, T2×M), with full controls ($X) and district FE (N ≈ 647). "Joint cluster p" is the cluster-robust test of T1×M = T2×M = 0. WCB and RI p-values are for the T2×M term: wild cluster bootstrap (Webb weights, 9,999 reps) and randomization inference (5,000 permutations of treatment assignment, with the interaction recomputed under each permutation via factor notation). Education is an ordinal 1–6 level, not a cardinal measure, so its linear coefficient is per one-category step rather than per year.

Appendix Table A2: Firm-Structural Moderators (Treatment × Moderator Joint Tests)

Moderator	Inquiry	Expected time	Joint-p range (all outcomes)	Robust?
Energy intensity (above-median share)	0.259	0.510	0.26–0.51	No
Generator ownership	0.168	0.295	0.11–0.66	No
Prior formal credit	0.088	0.351	0.08–0.35	No

Notes: Cluster-robust joint p-values for the test that both treatment-arm interactions (T1 × M = T2 × M = 0) are zero, from OLS with full controls ($X) and district FE (4 clusters). Energy intensity and generator ownership are evaluated on expected time, inquiry, and two cost-accuracy measures; prior credit on expected time, inquiry, and the three belief indices.

Funding: This work was supported by the International Growth Centre (IGC) [PAK-22225, 2023–25]; the WTO Chairs Program for Pakistan; and Utah Tech University.

Ethics approval: The Research Ethics Review Committee of the Lahore School of Economics granted ethics approval on June 9, 2023. The Research Ethics Subcommittee of the School of Economics of the University of East Anglia granted its approval on September 8, 2023.

Declaration of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments: We thank Murtaza Hamid, Aymen Junaid, and Sara Qasim for excellent research assistance and field management. We thank Naeema Arshad for her work producing the treatment videos.

Pre-registration: AEA RCT Registry AEARCTR-0010691. PAP Amendment Version 3 filed March 10, 2026, prior to any analysis of outcome data.



theigc.org