Electricity Access and Rural Firms: Evidence from a Large-Scale Rural Electrification Programme in India

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Abstract

One of the important mechanisms through which large-scale rural electrification programmes may improve household welfare is by changing the operating environment for rural businesses and firms. This paper evaluates whether rural electrification under the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) was associated with outcomes of rural informal manufacturing enterprises in India. Combining enterprise-level data from the 62nd and 67th rounds of the National Sample Survey (NSS), corresponding to 2005–06 and 2010–11, with district-level RGGVY rollout information, the analysis exploits differences in the duration of programme exposure across districts. The average results show a clear increase in electricity use and adjustment in the composition of energy expenditure. Operating expenses, fixed assets, and outstanding loans also increase with exposure, while receipts, gross value added, profit, employment, and labour-productivity outcomes do not show broad-based improvements. The heterogeneity analysis shows a consistent relative pattern for own-account enterprises across firm-scale and electricity-use outcomes. Taken together, the results suggest that RGGVY improved the electricity-use margin and was associated with stronger relative responses among household-based enterprises, but did not generate a broad expansion of rural informal manufacturing.

Keywords: rural electrification; informal firms; NSS enterprise survey; RGGVY; electricity use; India.

JEL Codes: O13, O14, O18, Q41, L25.

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1 Introduction

Electricity access has been found to increase household non-farm income and participation in non-farm business activities and employment(Rao, 2013; Dinkelman, 2011). However, this finding raises an obvious question: from where does this additional non-farm income come? Electricity may help households start new enterprises, improve the survival of existing enterprises, increase operating hours, use machines and equipment, and shift from fuel-based input to electricity (Rao, 2013; Khurana and Sangita, 2022a; Kassem, 2024a). For a long period, Manufacturing activity in India has historically been concentrated in urban areas, but rural India has become increasingly important for overall development. Over the last two decades, rural areas have accounted for a sizeable share of manufacturing employment, output, and the number of enterprises (Ghani et al., 2012). This makes rural firms central to debates on structural transformation, non-farm employment, and household welfare. Yet rural enterprises continue to operate under severe constraints. Inadequate infrastructure, unreliable electricity, limited access to credit, thin local markets, and shortages of skilled labour can all restrict enterprise growth (Allcott et al., 2016; Abeberese, 2017; Pelz et al., 2021; Nandwani et al., 2025). Electricity is especially important in this setting because it is not merely a household amenity; it is a production input that shapes machine use, lighting, storage, operating hours, and the ability to adopt more productive technologies (Allcott et al., 2016; Jain and Nandan, 2020).

This paper examines whether rural electrification under the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) affected rural informal manufacturing enterprises in India. RGGVY was launched in 2005 as one of India's flagship rural electrification programmes. It merged earlier rural electrification schemes and aimed to electrify unelectrified villages, intensively electrify partially electrified villages, strengthen rural distribution infrastructure, and provide free electricity connections to Below Poverty Line households (Banerjee et al., 2014; Chaurey et al., 2012). The programme was implemented in a staggered manner across districts under the Tenth and Eleventh Five-Year Plans. This staggered rollout generated variation in the duration of district exposure to the programme, which is used in this paper to study whether more exposed districts experienced differential changes in rural enterprise outcomes.

Rural manufacturing in India is dominated by small, household-based enterprises, many of which operate with one or two workers and without regular hired labour. For these firms, electricity may matter less as a large-scale industrial input and more as a basic operating condition. The central research question is whether RGGVY exposure improved the performance of rural informal manufacturing firms. Electricity can affect firms through multiple channels and in different ways; therefore, figuring out these are important in our context. A reliable connection can allow firms to use machinery more intensively, extend operating time, reduce dependence on fuel-based inputs or costly self-

generation, improve product quality, and enable storage or preservation (Allcott et al., 2016; Abeberese, 2017). Electrification may also reduce entry barriers and encourage the formation or expansion of electricity-using enterprises (Kassem, 2024b; Khurana and Sangita, 2022b). However, electrification need not automatically generate firm growth. If local demand is weak, supply quality is poor, electricity is costly, credit markets are thin, or firms lack complementary machinery and skills, electricity access may increase without producing large gains in output, employment, or productivity (Jain and Nandan, 2020; Pelz et al., 2021).

The empirical analysis combines harmonised NSS enterprise data from the 62nd and 67th rounds, corresponding to 2005–06 and 2010–11, with district-level RGGVY rollout information. The sample is restricted to rural manufacturing enterprises. The main treatment variable is the duration of district exposure to RGGVY. The baseline NSS 62 round is assigned zero exposure, while NSS 67 captures differential cumulative exposure based on the district's first RGGVY sanction year. The preferred specifications include district fixed effects, survey-year fixed effects, industry fixed effects, and firm-level controls for female ownership, proprietary status, establishment status, registration, and months operated. Standard errors are clustered at the district level. The main outcomes include firm receipts, operating expenses, gross value added, a profit/surplus proxy, employment, wage bill, electricity use and expenditure, fuel expenditure shares, fixed assets, and outstanding loans.

The updated estimates show that RGGVY exposure is most clearly reflected in the electricity-use margin. An additional year of exposure is associated with a higher probability of electricity use, higher electricity expenditure and electricity expenditure share, and a lower fuel share. For firm scale, operating expenses and fixed assets increase significantly, while receipts, GVA, and profit remain statistically insignificant; the loan coefficient is also positive, although it is estimated on a much smaller sample. Labour and labour-productivity outcomes remain statistically insignificant. The heterogeneity results show a more favourable exposure gradient for own-account enterprises relative to establishments across scale and electricity-use outcomes. These interaction coefficients capture relative differences between enterprise types and are not, by themselves, estimates of the total exposure effect for own-account enterprises. Overall, the evidence points to changes in electricity use and selected input and asset margins rather than broad-based expansion in output or employment.

2 Literature Review

A large body of literature studies how infrastructure affects firms by reducing production costs, improving market access, increasing reliability of input supply, and changing incentives to invest in machinery and technology. In India, studies of road and transport

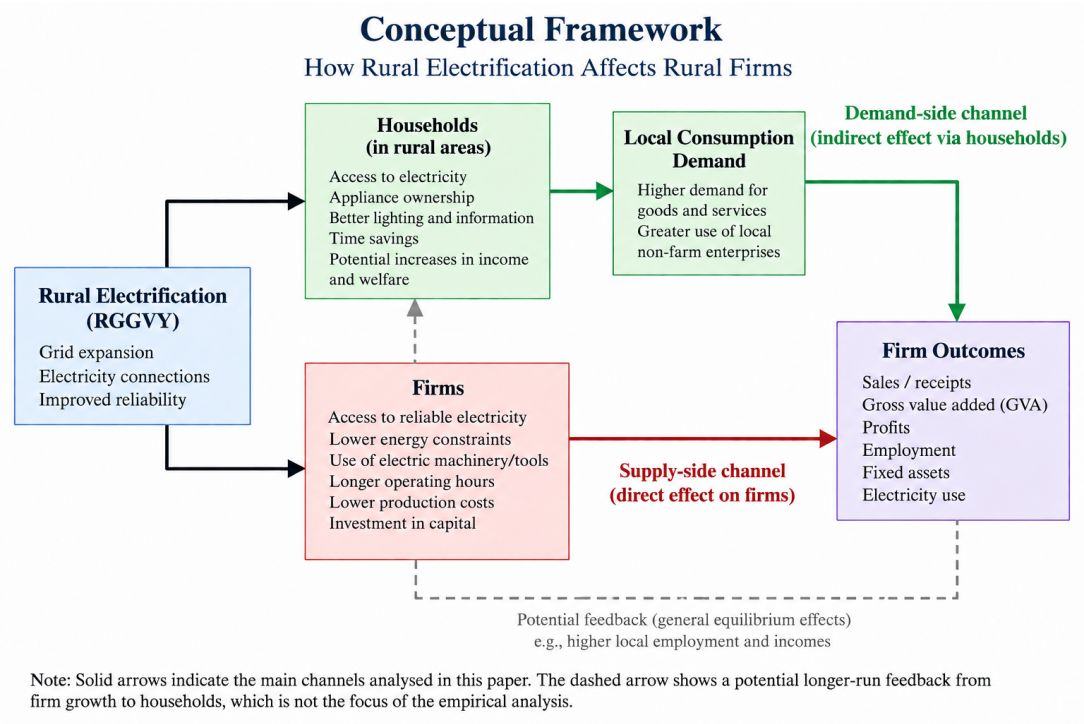


Figure 1: Conceptual framework linking rural electrification to rural firm outcomes

infrastructure show that improvements in connectivity can affect firm location, productivity, and market access (Datta, 2012; Ghani et al., 2016). Infrastructure improvements may affect informal and formal enterprises differently, with stronger responses among bigger firms (Nandwani et al., 2025).

The second body of literature evaluates that evaluates rural electrification, and RGGVY has mostly focused on household or village-level impact of the program. The benchmark evaluation by Burlig and Preonas (2024) shows that RGGVY substantially increased electrification but produced limited average development effects. This finding has shifted attention from simple access expansion to the quality, reliability, and productive use of electricity. Since Much of the RGGVY literature focuses on household welfare, village electrification, or aggregate development outcomes, the firm channel remains comparatively underexplored. Another strand of literature studies electricity constraints and firm behaviour. Allcott et al. (2016) show that electricity shortages reduce industrial output and producer surplus in India, especially for plants that cannot fully insure themselves through generators. Abeberese (2017) shows that higher electricity costs reduce electricity-intensive production, machine intensity, output, and productivity growth among Indian firms. Jain and Nandan (2020) show that electricity prices influence firms' decisions on electricity use, self-generation, productivity, and profitability. These studies establish that electricity conditions matter for firm behaviour, but they primarily focus on formal or larger manufacturing firms. A related literature on rural non-farm businesses and microenterprises suggests that electricity access can increase business participation

and earnings, but productive use remains uneven and constrained by affordability, demand, and complementary inputs (Khurana and Sangita, 2022b; Pelz et al., 2021).

The effect of electrification may differ across firms depending on their initial size, capital intensity, ability to invest in electricity-using equipment, and capacity to cope with unreliable supply. On the one hand, small firms may benefit more from infrastructure expansion because they face more binding constraints. On the other hand, larger firms may benefit more because they are better positioned to convert infrastructure access into measurable output gains.

Allcott et al. (2016) show that electricity shortages reduce revenues and producer surplus among Indian manufacturing plants. They also argue that shortages distort the plant-size distribution because there are economies of scale in generator use, making larger plants more capable of self-generating electricity, while smaller plants are more exposed to outages and supply interruptions. Using firm-level evidence across cities, Reyes (2021) shows that business-environment effects vary by firm size, age, and country development level. This suggests that aggregate estimates can hide important distributional differences across firms. Thus, the direction of size heterogeneity is theoretically ambiguous.

Abeberese (2017) shows that electricity costs affect Indian firms' production choices and productivity growth, while Jain and Nandan (2020) show that electricity tariffs influence firms' electricity consumption patterns and performance. These studies imply that access to electricity alone may not be sufficient; firms also require the capacity to reorganise production, adopt machinery, or substitute across energy inputs. Since this capacity is likely correlated with firm size, the effect of electrification may differ between small and large firms.

This paper brings these literatures together by studying rural informal manufacturing firms using NSS enterprise data. We extend the logic of studying the impact of improvement in rural infrastructure on firm outcomes to electricity infrastructure. We ask whether a large rural electrification programme changed firm outcomes, and whether the response was concentrated among smaller rural enterprises or otherwise. This paper adds to the RGGVY evidence base by examining whether district-level exposure to the programme is associated with changes in rural manufacturing enterprise outcomes. If firms respond even when average household or village effects are limited, then RGGVY may have operated partly through local production and non-farm enterprise margins. If firms do not respond, the finding is equally relevant because it suggests that electrification alone may be insufficient for enterprise growth.

The paper examines not only average firm outcomes but also heterogeneity by enterprise type, focusing on whether own-account enterprises respond differently from establishments. This comparison is especially relevant because own-account enterprises are typically household-based and operate without regular hired labour. In a separate retrospective cohort exercise, we also examine whether the rollout of RGGVY is associated

with a greater number of surviving small-firm cohorts established before and after the programme's rollout.

3 The Rajiv Gandhi Grameen Vidyutikaran Yojana

At the time of independence, India had only around 1,500 electrified villages out of nearly 560,000 villages (Banerjee et al. (2014)), as electricity development was mainly concentrated in towns and industrial areas. After Independence, electricity access was recognised as important for socio-economic development and modernization. However, the main priority continued to be industrial and urban electrification, while rural electrification received limited attention until the late 1960s (Fetter and Usmani (2024)). This policy approach was influenced by the view that industrialization and urbanization were the main drivers of economic growth, and that rural development would follow gradually as a secondary outcome (Ministry of Power, Government of India (4 05)). In the following decades, several reforms and programmes were introduced for rural electrification, and electricity was recognised as a 'basic need' in the Fifth Five-Year Plan (1974-79). Despite these efforts, nearly 125,000 villages were still unelectrified in 2004.

The Rajiv Gandhi Grameen Vidyutikaran Yojana was launched in 2005 as a centrally sponsored rural electrification programme. It brought together earlier rural electrification efforts and aimed to expand electricity access through three broad components: electrification of unelectrified villages, intensive electrification of already electrified villages, and strengthening of rural distribution infrastructure. The programme also provided free electricity connections to Below Poverty Line households (Banerjee et al., 2014; Chaurey et al., 2012; Lok Sabha Secretariat, 2013). Its larger policy objective was to move toward universal rural electricity access and to reduce rural infrastructure constraints.

RGGVY was implemented through projects sanctioned and awarded across districts under the Tenth and Eleventh Five-Year Plans. The rollout was not uniform across time. The implementation of the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) followed a multi-level institutional approval process. As documented by the Ministry of Power (2013), the Detailed Project Reports (DPRs) prepared and submitted by State Governments were first examined and appraised by the Rural Electrification Corporation (REC[1]). After appraisal, the DPRs were placed before the Monitoring Committee (MC), which acted as the sanctioning authority under RGGVY. On the basis of REC's assessment and recommendations, the Monitoring Committee approved the projects. Districts were mainly covered in different phases corresponding to India's Tenth (2002–2007) and Eleventh (2007–2012) Five-Year Plans, with project consideration broadly following a "*first come, first served*" approach.

[1] REC was established in 1969 and provides financial assistance for power-sector projects across India

Table 1 reports the year-wise implementation progress from the administrative rollout data. Project sanctions were concentrated in 2005 and 2008, while project awards were spread across 2005 - 2010. The number of BPL household connections also increased sharply, especially in 2005, 2006, and 2008. RGGVY received over Rupees 253 billion in funds, and around 17.5 million households were connected to the grid(Sreekumar and Dixit (2011)). It also considered the development of micro enterprises, small to medium industries, "to facilitate overall rural development, employment generation, and poverty alleviation"(Ministry of Power, Government of India (4 05)). This is what makes this analysis important because we try to evaluate where this goal was achieved or not.

Table 1: Year-wise summary of RGGVY implementation progress

	2004	2005	2006	2007	2008	2009	2010	Total
Number of sanctioned projects	7	175	56	3	323	9	9	582
Number of awarded projects	0	100	105	39	183	124	25	576
BPL household connections	167,402	4,950,677	2,833,591	202,259	13,004,210	115,111	90,988	21,364,238
Plan-wise number of projects		241				341		

Notes: The table summarises administrative implementation progress under RGGVY. Project counts refer to sanctioned or awarded projects, not unique districts, because multiple projects could be sanctioned within the same district. The first plan-wise total refers to projects under the Tenth Plan period and the second to projects under the Eleventh Plan period. The table is adapted from administrative implementation data used in the RGGVY literature.

The staggered rollout(Figure 2) is central to the empirical strategy because districts that entered the programme earlier had more years of exposure by the NSS 67 round than districts that entered later. The empirical treatment variable is constructed from this staggered rollout. For each district, we identify the first year in which the district received an RGGVY sanction. The duration of exposure is then defined as the number of years between the second survey year and the first sanction year. NSS 62, conducted in 2005-06, is treated as the baseline round and assigned zero exposure. NSS 67, conducted in 2010-11 is post treatment period. This treatment measure captures the intensity of exposure rather than only whether a district was ever treated or not.

A duration-based instrument is equally important for studying firms because the productive effects of electrification may not appear immediately. Firms may require time to obtain a connection, adjust production processes, purchase equipment, alter energy inputs, or expand operating hours. At the same time, a longer duration of exposure does not guarantee stronger effects if supply quality remains poor or if other constraints bind. For this reason, the empirical analysis interprets the duration coefficient as the association between additional years of RGGVY exposure and firm outcomes, conditional on district, year, and industry fixed effects.

4 Data and descriptive statistics

The analysis uses harmonised NSS enterprise data from NSS 62(2005-2006) and NSS 67(2010-2011) as the main sample and NSS 73(2015-2016)to check how number of firms in

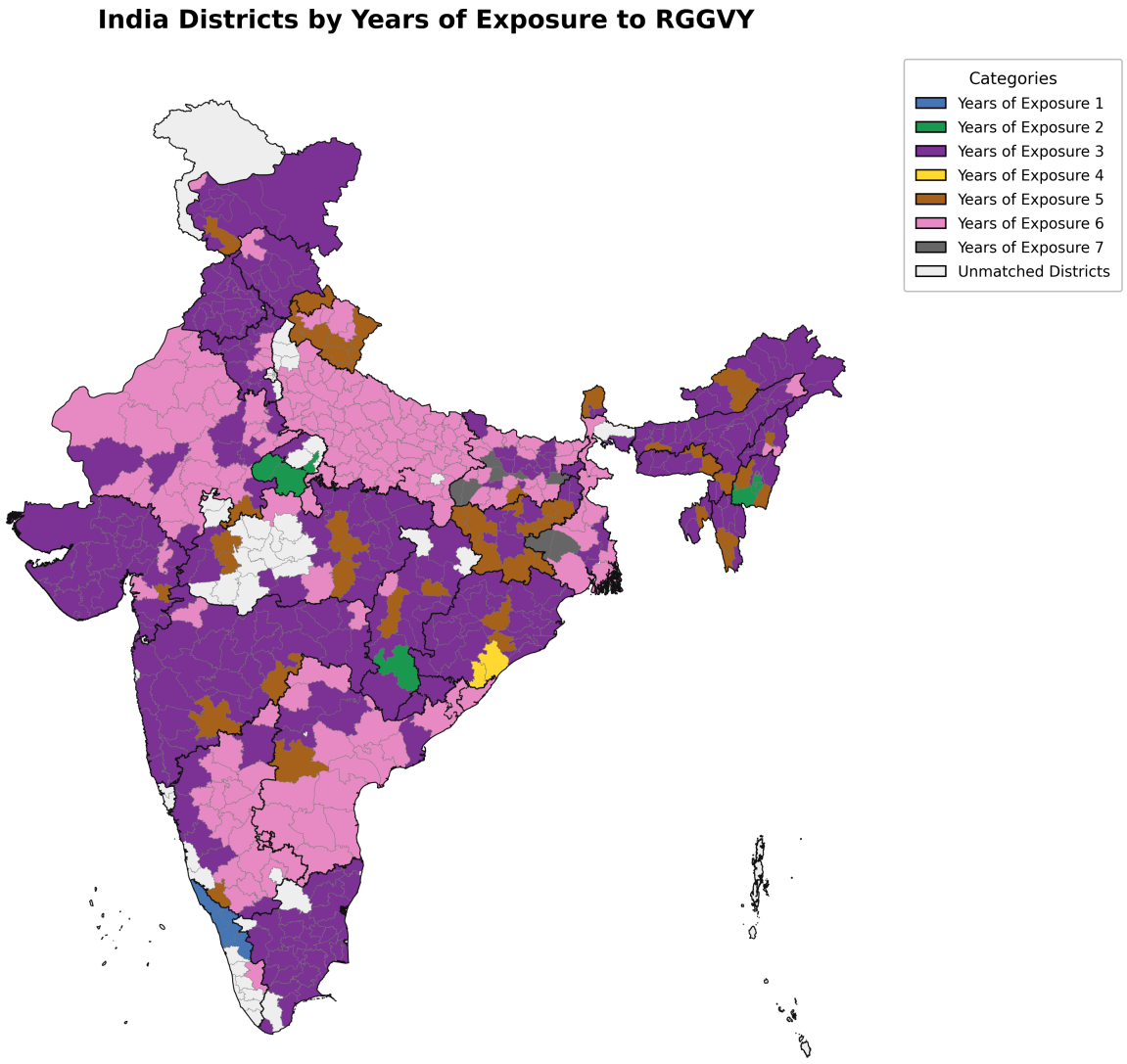


Figure 2: Geographical Distribution of RGGVY Exposure

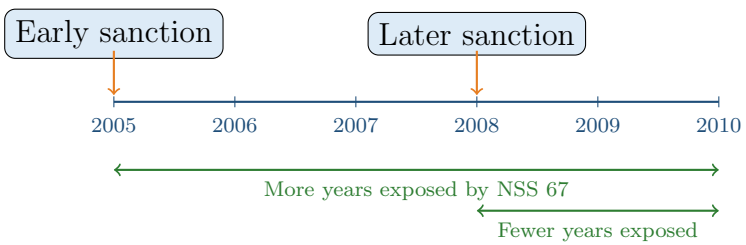


Figure 3: Duration of RGGVY Exposure

a district vary with the RGGVY rollout. The sample is restricted to rural manufacturing enterprises. The data contain rich information on different enterprise-level variables. The NSS enterprise surveys are well suited to our question because they cover unincorporated enterprises, including own-account enterprises and small establishments that are typically absent from formal-sector datasets such as the Annual Survey of Industries. These firms are important for rural livelihoods and non-farm employment, but they may face different constraints and respond differently to infrastructure improvements.

The NSS enterprise data are repeated cross-sections, not a firm panel. Therefore, the analysis compares firms in districts with different levels of exposure over time rather than tracking the same enterprise before and after electrification. The lowest common geographic unit is the district, so the RGGVY data are merged at the district level.

Table 2: Descriptive statistics for main outcome variables, NSS 62 and NSS 67

	NSS 62 (2005–06)			NSS 67 (2010–11)		
Outcome variable	Mean	SD	Obs.	Mean	SD	Obs.
Scale and performance						
Receipts (IHS)	11.244	2.134	42,039	11.749	1.777	51,606
Operating expenses (IHS)	9.822	2.736	42,039	10.392	2.306	51,606
GVA (IHS)	10.611	2.305	42,039	11.155	1.834	51,606
Profit/surplus proxy (IHS)	10.619	2.296	42,039	11.158	1.827	51,606
Fixed assets (IHS)	10.562	1.918	41,952	11.067	1.675	51,576
Outstanding loans (IHS)	10.755	2.871	6,162	11.173	1.945	4,999
Labour						
Total workers (IHS)	1.456	0.701	42,038	1.419	0.750	51,596
Wage bill (IHS)	3.168	5.152	42,038	11.622	1.399	16,042
GVA per worker (IHS)	9.959	1.968	42,021	10.547	1.475	51,594
Wage per worker (IHS)	2.751	4.455	42,021	10.171	0.844	16,042
Electricity and energy						
Electricity user	0.498	0.500	41,020	0.702	0.457	51,112
Electricity charges (IHS)	4.137	4.420	41,020	5.598	3.896	51,112
Electricity share of expenses	0.102	0.207	41,020	0.121	0.204	51,097
Fuel/lubricant expenditure (IHS)	5.428	3.926	41,020	4.898	4.169	51,112
Fuel/lubricant share of expenses	0.140	0.248	41,020	0.098	0.204	51,097
Power cuts reported as problem	0.212	0.409	41,883	0.267	0.442	22,391
Operating intensity and type						
Months operated	10.642	2.659	42,017	11.178	2.168	51,607
Hours worked per day	6.851	2.345	42,008	7.666	2.644	51,446
Annual operating hours (IHS)	8.255	0.594	41,987	8.445	0.501	51,445
Registered enterprise	0.175	0.380	42,008	0.216	0.411	51,608
Own-account enterprise	0.739	0.439	42,039	0.691	0.462	51,608
Establishment	0.261	0.439	42,039	0.309	0.462	51,608
Small firm	0.735	0.441	42,038	0.752	0.432	51,596

Notes: The table reports unweighted means, standard deviations, and non-missing observations for the main analysis outcomes in NSS 62 and NSS 67. Monetary variables are deflated to 2005–06 prices before IHS transformation. Binary variables and expenditure shares are reported in levels. The small-firm indicator equals one for enterprises with total workers at or below the median worker count in the NSS 62–67 analysis sample. Hours worked per day and annual operating hours are unavailable for NSS 67 in the harmonised analysis file.

The empirical analysis examines four sets of outcomes that correspond to the main channels through which rural electrification may affect enterprise behaviour. The first group captures firm scale and performance. These outcomes include real receipts, real operating expenses, real gross value added (GVA), a profit or surplus proxy, real fixed assets, and real outstanding loans. Receipts capture the scale of sales or business activity,

Table 3: Baseline Characteristics of Own-Account Enterprises by RGGVY Sanction Timing

Outcome	Sanction 2005	Sanction 2008	N
Receipts	32.3	31.2	24,946
Operating expenses	16.3	14.2	24,946
Gross value added	15.9	17.0	24,946
Profit proxy	15.9	17.0	24,946
Fixed assets	18.0	20.7	24,902
Total workers	1.70	1.59	24,946
Wage bill	0.0	0.3	24,946
GVA per worker	9.9	11.6	24,932
Wage bill per worker	0.0	0.2	24,932
Positive electricity spending (%)	19.4	38.8	24,221
Electricity charges	0.5	0.8	24,221
Electricity share of expenses (%)	5.8	10.8	24,221
Fuel and lubricant spending	2.3	1.7	24,221
Fuel share of expenses (%)	19.8	14.8	24,221
Power cuts reported (%)	9.3	11.2	24,880
Months operated	10.59	10.52	24,935
Hours operated per day	6.46	6.34	24,921
Annual operating hours	2,083.84	2,024.17	24,910
Registered enterprise (%)	3.0	3.6	24,925

Notes: The table reports baseline means for own-account rural manufacturing enterprises observed in NSS 62 whose districts were first sanctioned under RGGVY in either 2005 or 2008. Monetary variables are reported in thousands of real 2005–06 rupees. Expenditure shares and binary outcomes are reported in percentage points. The number of observations varies because of outcome-specific missing values.

Table 4: Baseline Characteristics by RGGVY Sanction Timing: Full Sample

Outcome	Sanction 2005	Sanction 2008	N
Receipts	59.3	83.9	33,323
Operating expenses	36.4	51.8	33,323
Gross value added	22.5	31.7	33,323
Profit proxy	22.8	32.1	33,323
Fixed assets	25.4	37.6	33,258
Total workers	1.94	1.97	33,322
Wage bill	3.2	6.8	33,322
GVA per worker	10.6	13.3	33,306
Wage bill per worker	0.5	1.1	33,306
Positive electricity spending (%)	21.7	42.8	32,570
Electricity charges	1.1	2.2	32,570
Electricity share of expenses (%)	6.0	11.1	32,570
Fuel and lubricant spending	5.3	3.6	32,570
Fuel share of expenses (%)	19.5	14.2	32,570
Power cuts reported (%)	10.3	12.5	33,248
Months operated	10.55	10.45	33,307
Hours operated per day	6.58	6.52	33,296
Annual operating hours	2,108.5	2,064.2	33,281
Registered enterprise (%)	4.4	5.6	33,298

Notes: The table reports survey-weighted baseline means for rural manufacturing enterprises observed in NSS 62 whose districts were first sanctioned under RGGVY in either 2005 or 2008. Monetary variables are reported in thousands of real 2005–06 rupees. Expenditure shares and binary outcomes are reported in percentage points. The number of observations varies because of outcome-specific missing values.

while GVA measures the value created by the enterprise after deducting intermediate inputs. The profit proxy is constructed as the difference between receipts and expenses, where the relevant harmonised components are available. Fixed assets capture the capital stock of the enterprise, and outstanding loans capture a finance or indebtedness margin.

The second group captures labour use and labour productivity. These outcomes include total workers, wage bill, GVA per worker, and wage bill per worker. These variables allow the analysis to examine whether electrification is associated with greater labour absorption, higher wage payments, or more productive use of labour. This distinction is important because electricity may raise output without necessarily increasing employment if it allows firms to substitute toward machinery or operate more efficiently.

The third group captures electricity-use mechanisms. These include an indicator for whether the enterprise uses electricity, real electricity charges, the share of electricity expenditure in total expenses, real fuel and lubricant expenditure, the fuel/lubricant share in total expenses, and whether the enterprise reports power cuts as a problem. These variables are central to the mechanism of the paper. If RGGVY affected firms through productive electricity access, the first-order response should be visible in electricity use or in the composition of energy-related expenditure, even if broader firm-performance outcomes respond weakly.

The fourth group captures operating intensity and enterprise characteristics. These include months operated, hours worked per day, annual operating hours, registration status, and enterprise type. Enterprise type is particularly important because the NSS distinguishes own-account enterprises from establishments. Own-account enterprises are typically smaller, more household-based, and less likely to employ hired workers. They may therefore respond differently to electricity access than larger informal establishments.

All monetary variables are deflated to 2005-06 prices before transformation. Since enterprise-level monetary variables are highly skewed, the preferred specifications use the inverse hyperbolic sine transformation. This transformation has two advantages in the present context. First, it reduces the influence of extreme values, which are common in enterprise surveys. Second, unlike the logarithm, it accommodates zero and negative values, which are relevant for outcomes such as profit or surplus. Accordingly, the main outcome variables are defined as IHS transformations of real monetary values, while binary variables are estimated in levels.

The OAE (own-account enterprise) classification follows the NSS enterprise survey definition. Own-account enterprises are enterprises that do not employ hired workers on a fairly regular basis, while establishments employ at least one hired worker on a fairly regular basis. A separate small-firm indicator is used only for the retrospective cohort analysis in Section 7; it equals one for enterprises with total workers at or below the sample median in the NSS 62–67 analysis sample.

The descriptive are given in table 2 table 2 table 3 and table 4. Table 2 reports the

basic sample structure by survey round and the rest rest report baseline difference across major groups based on early or late treatment for different subsets of sample.

5 Empirical Strategy

The empirical strategy exploits variation in the duration of district exposure to RGGVY across survey rounds. The main analysis uses NSS 62 and NSS 67, corresponding to 2005–06 and 2010–11. NSS 62 is treated as the baseline round and assigned zero RGGVY exposure. For NSS 67, exposure is calculated from the first year in which a district received an RGGVY sanction. Districts sanctioned earlier experienced more years of exposure by 2010–11 than districts sanctioned later. This generates a continuous treatment measure that captures cumulative programme exposure rather than a simple treated-versus-untreated contrast.

The baseline estimating equation is:

$$Y_{ijdt} = \alpha + \beta DOE_{dt} + \gamma X_{ijdt} + \theta_j + \mu_d + \eta_t + \varepsilon_{ijdt}, \tag{1}$$

where Y_{ijdt} denotes an outcome for enterprise i, industry j, district d, and survey year t. The variable DOE_{dt} measures the cumulative years of district exposure to RGGVY. The vector X_{ijdt} contains firm-level controls used in the updated specifications: female ownership, proprietary status, establishment status, registration status, and months operated. Industry fixed effects θ_j absorb time-invariant differences across manufacturing industries. District fixed effects μ_d control for time-invariant district characteristics such as geography, historical infrastructure, market access, and persistent local economic conditions. Survey-year fixed effects η_t absorb aggregate changes common to all districts between NSS 62 and NSS 67. Standard errors are clustered at the district level, which is the level at which RGGVY exposure is assigned.

The coefficient of interest is β. It measures whether firms located in districts with more exposure to RGGVY experienced differential changes in outcomes relative to firms in districts with lower exposure, conditional on the firm-level controls and the district, year, and industry fixed effects. Because the NSS enterprise data are repeated cross-sections rather than a firm panel, β should not be interpreted as the effect of electrification on the same enterprise over time. Instead, it captures whether the distribution of firm outcomes changed differentially across districts with different exposure durations.

The identifying assumption is that, absent differential exposure to RGGVY, rural manufacturing firms in earlier- and later-exposed districts would have followed similar changes in outcomes between 2005–06 and 2010–11, conditional on the included controls and fixed effects. However, selection into earlier programme rollout remains a concern if districts receiving RGGVY earlier were also on different economic trajectories. For this

reason, the results are interpreted cautiously as exposure gradients or associations rather than definitive firm-level causal effects.

To examine heterogeneity by enterprise type, the updated specification interacts DOE_{dt} with an own-account enterprise indicator:

$$Y_{ijdt} = \alpha + \beta_1 DOE_{dt} + \beta_2 OAE_i + \beta_3 (DOE_{dt} \times OAE_i) + \gamma X_{ijdt} + \theta_j + \mu_d + \eta_t + \varepsilon_{ijdt}. \quad (2)$$

Here, β_1 captures the exposure gradient for establishments, the reference group, while β_3 captures the additional differential exposure gradient for own-account enterprises. The total exposure gradient for own-account enterprises is $\beta_1 + \beta_3$. Accordingly, a positive and statistically significant β_3 establishes that the OAE gradient is more favourable than the establishment gradient; it does not by itself establish that the total OAE gradient is statistically different from zero.

6 Results

Table 6 reports the updated electricity-mechanism estimates after adding firm-level controls. The clearest result is on the extensive margin of electricity use. An additional year of RGGVY exposure is associated with a 1.35 percentage-point increase in the probability that a firm reports using electricity, significant at the 1 percent level. Electricity charges are also higher and weakly significant, while electricity's share of total expenses rises and the fuel share declines, both significant at the 5 percent level. These results are consistent with an adjustment in the composition of energy use toward electricity. The coefficient on reported power-cut problems remains small and statistically insignificant.

Table 7 reports the updated estimates for firm scale and performance outcomes. Receipts, GVA, and the profit/surplus proxy remain statistically insignificant, so the results do not indicate a broad expansion in output or value added. In contrast, operating expenses and fixed assets are positive and statistically significant at the 5 percent level. The coefficient on outstanding loans is also positive and significant, although the loan outcome is available for a much smaller sample. The pattern therefore points to adjustment in selected input, asset, and finance margins rather than broad-based firm growth.

Table 8 reports the updated labour and productivity estimates. The coefficients on total workers, wage bill, GVA per worker, and wage per worker are all statistically insignificant. Thus, after adding firm-level controls, the evidence continues to show no average increase in employment intensity, wage payments, or labour productivity.

Taken together, the average estimates suggest that RGGVY exposure is more clearly visible in electricity use and selected input and asset margins than in output, employment, or labour productivity. Electrification therefore appears to improve the productive-use

Table 5: Baseline Characteristics by RGGVY Sanction Timing: Non-OAE Enterprises

Outcome	Sanction 2005	Sanction 2008	N
Non-OAE enterprises (count)	3,269	5,108	8,377
Receipts	460.3	602.6	8,377
Operating expenses	335.2	421.2	8,377
Gross value added	121.9	176.7	8,377
Profit proxy	125.0	181.4	8,377
Fixed assets	134.9	203.7	8,356
Total workers	5.40	5.74	8,376
Wage bill	49.6	70.7	8,376
GVA per worker	21.2	30.6	8,374
Wage bill per worker	7.3	10.7	8,374
Positive electricity spending (%)	55.4	79.9	8,349
Electricity charges	9.2	15.1	8,349
Electricity share of expenses (%)	9.8	13.6	8,349
Fuel and lubricant spending	46.8	21.9	8,349
Fuel share of expenses (%)	14.4	8.5	8,349
Power cuts reported (%)	25.6	25.3	8,368
Months operated	10.03	9.79	8,372
Hours operated per day	8.24	8.27	8,375
Annual operating hours	2,475.1	2,458.2	8,371
Registered enterprise (%)	25.1	25.4	8,373

Notes: The table reports survey-weighted baseline means for rural manufacturing enterprises observed in NSS 62 that are not classified as own-account enterprises and whose districts were first sanctioned under RGGVY in either 2005 or 2008. Non-OAE enterprises are establishments employing at least one hired worker on a fairly regular basis. The first row reports unweighted enterprise counts in each sanction-timing group. Monetary variables are reported in thousands of real 2005–06 rupees. Expenditure shares and binary outcomes are reported in percentage points. The number of observations varies because of outcome-specific missing values.

Table 6: RGGVY exposure and electricity mechanisms, NSS 62–67

	Electricity use	IHS electricity charges	Electricity share	Fuel share	Power-cut problem
DOE	0.0135***	0.0738*	0.0037**	-0.0042**	0.0030
	(0.0050)	(0.0381)	(0.0017)	(0.0019)	(0.0098)
Mean dep. var.	0.611	4.948	0.112	0.117	0.231
District FE	Yes	Yes	Yes	Yes	Yes
Survey-year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	84,984	84,984	84,974	84,974	61,100
R-squared	0.366	0.451	0.212	0.266	0.239

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All specifications include district fixed effects, survey-year fixed effects, NIC2 industry fixed effects, and enterprise controls. Standard errors are clustered at the district level.

Table 7: RGGVY exposure and firm scale/performance, NSS 62–67

	IHS receipts	IHS expenses	IHS GVA	IHS profit proxy	IHS fixed assets	IHS loan total
DOE	0.0168	0.0430**	0.0066	0.0061	0.0350**	0.1083**
	(0.0170)	(0.0200)	(0.0192)	(0.0192)	(0.0161)	(0.0478)
Mean dep. var.	11.522	10.136	10.911	10.916	10.840	10.942
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	86,408	86,408	86,408	86,408	86,293	10,298
R-squared	0.507	0.532	0.318	0.323	0.395	0.689

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All specifications include district fixed effects, survey-year fixed effects, NIC2 industry fixed effects, and enterprise controls. Standard errors are clustered at the district level. Monetary outcomes are deflated to 2005–06 prices and transformed using the inverse hyperbolic sine transformation.

Table 8: RGGVY exposure and labour outcomes, NSS 62–67

	IHS workers	IHS wage bill	IHS GVA per worker	IHS wage per worker
DOE	-0.0024	0.0158	0.0091	0.0020
	(0.0047)	(0.0273)	(0.0185)	(0.0236)
Mean dep. var.	1.436	5.503	10.283	4.801
District FE	Yes	Yes	Yes	Yes
Survey-year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	86,404	55,435	86,385	55,418
R-squared	0.639	0.928	0.212	0.926

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include district fixed effects, survey-year fixed effects, NIC2 industry fixed effects, and enterprise controls. Standard errors are clustered at the district level.

margin without automatically generating broad rural manufacturing growth.

6.1 Heterogeneity

The average estimates may conceal differences across enterprise types. Tables 9 and 10 examine whether own-account enterprises respond differently from establishments. In these specifications, the coefficient on DOE is the exposure gradient for establishments, while $OAE \times DOE$ measures the additional differential gradient for own-account enterprises.

Table 9 shows a strong relative pattern across scale outcomes. The interaction coefficient is positive and statistically significant at the 1 percent level for receipts, expenses, GVA, profit, fixed assets, and loans. This means that the exposure gradient for own-account enterprises is more favourable than the gradient for establishments across all six outcomes. The establishment gradient itself is negative and weakly significant for receipts and statistically insignificant for the remaining scale outcomes. Importantly, the interaction coefficient should not be interpreted as the total exposure effect for OAEs. The total OAE gradient is the sum of the DOE coefficient and the interaction coefficient, and its statistical significance requires a separate linear-combination test.

Table 10 shows that the relative OAE pattern is also visible in electricity mechanisms. The $OAE \times DOE$ interaction is positive and statistically significant for electricity use, electricity charges, and electricity's share of expenses, and negative and statistically significant for the fuel share. The interaction for reported power cuts is small and statistically insignificant. The reference-group DOE coefficients are statistically insignificant across these mechanism outcomes. These results are consistent with a stronger relative shift toward electricity use among own-account enterprises than among establishments.

The heterogeneity evidence therefore points to own-account enterprises as the group with the clearest relative response to RGGVY exposure. These enterprises are likely to

Table 9: Heterogeneity by own-account enterprises: scale outcomes, NSS 62–67

	IHS receipts	IHS expenses	IHS GVA	IHS profit proxy	IHS fixed assets	IHS loan total
DOE	-0.0368*	-0.0342	-0.0324	-0.0339	-0.0181	0.0696
	(0.0208)	(0.0271)	(0.0232)	(0.0232)	(0.0192)	(0.0476)
OAE × DOE	0.0739***	0.1064***	0.0537***	0.0550***	0.0733***	0.1165***
	(0.0127)	(0.0206)	(0.0118)	(0.0118)	(0.0126)	(0.0215)
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	86,408	86,408	86,408	86,408	86,293	10,298
R-squared	0.508	0.534	0.318	0.324	0.396	0.691

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The coefficient on $OAE \times DOE$ captures the differential exposure gradient for own-account enterprises relative to establishments. The coefficient on DOE represents the exposure gradient for establishments, the omitted category. All specifications include district fixed effects, survey-year fixed effects, NIC2 industry fixed effects, and firm controls. Standard errors are clustered at the district level.

Table 10: Heterogeneity by own-account enterprises: electricity mechanisms, NSS 62–67

	Electricity user	IHS electricity charges	Electricity share	Fuel share	Power-cut problem
DOE	0.0021	-0.0630	-0.0000	0.0020	-0.0008
	(0.0051)	(0.0413)	(0.0023)	(0.0022)	(0.0096)
OAE × DOE	0.0158***	0.1893***	0.0052***	-0.0086***	0.0058
	(0.0028)	(0.0233)	(0.0017)	(0.0013)	(0.0042)
District FE	Yes	Yes	Yes	Yes	Yes
Survey-year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes
Observations	84,984	84,984	84,974	84,974	61,100
R-squared	0.367	0.453	0.213	0.268	0.239

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The coefficient on $OAE \times DOE$ captures the differential response of own-account enterprises relative to establishments. All specifications include district fixed effects, survey-year fixed effects, NIC2 industry fixed effects, and enterprise controls. Standard errors are clustered at the district level.

operate closer to the margin of basic infrastructure access, where electricity can affect lighting, small tools, storage, processing, and working hours. At the same time, the estimates should be interpreted as differential gradients relative to establishments, and the total OAE exposure gradient should be assessed separately.

6.2 Pre-trend

A concern with the exposure-based design is that districts receiving greater future RGGVY exposure may already have been on different enterprise trajectories before the programme. To examine this, I use NSS 56 Schedule 2.2 on unorganised manufacturing enterprises from 2000–01 and append it with NSS 62 from 2005–06. Both rounds are treated as pre-programme rounds for this diagnostic exercise. Since the main heterogeneous results are concentrated among own-account enterprises, I estimate a pre-trend version of the OAE specification.

The pre-trend test uses future RGGVY exposure rather than actual exposure. Future exposure is defined from the district's later RGGVY sanction timing and measures how much exposure a district would have by the NSS 67 round. The estimating equation is

$$\begin{aligned} Y_{ijdt} = \alpha &+ \delta_1 \left(FutureDOE_d \times NSS62_t \right) \\ &+ \delta_2 \left(FutureDOE_d \times NSS62_t \times OAE_i \right) + \gamma X_{ijdt} + \mu_d + \eta_t + \theta_j + \varepsilon_{ijdt}. \end{aligned} \tag{3}$$

Here, δ_1 captures the differential pre-programme trend associated with future exposure for establishments or non-OAE firms, while δ_2 is the OAE differential pre-trend. If δ_2 is statistically significant for the same outcomes where the main OAE interaction results are significant, the heterogeneity results would require more cautious interpretation.

Table 11 reports the weighted pre-trend test for the OAE heterogeneity model. The OAE differential pre-trend is statistically insignificant for receipts, GVA, profit proxy, total workers, fixed assets, and electricity use. This diagnostic therefore does not indicate differential pre-trends for these outcomes over the NSS 56–62 pre-programme period.

7 Number of Small Firms

We use the reported year of initial operation to construct district-by-entry-year-by-NIC2 panels separately for NSS 67 and NSS 73, focusing only on small firms. Small firms are defined by enterprises with total workers at or below the median worker count in the main NSS 62–67 analysis sample. This definition captures the dominant rural informal manufacturing margin, where one- and two-worker firms account for most enterprises. This category makes 73.5% of the total sample.

Table 11: OAE heterogeneity pre-trend test, NSS 56–62

	IHS receipts	IHS GVA	IHS profit proxy	IHS workers	IHS fixed assets	Electricity use
Future DOE	0.00264	-0.0334	-0.0325	-0.00989	-0.0197	-0.00820
	(0.0428)	(0.0451)	(0.0451)	(0.00978)	(0.0498)	(0.0106)
OAE × Future DOE	-0.0136	0.0115	0.0109	0.0101	0.0115	-0.00229
	(0.0228)	(0.0225)	(0.0225)	(0.00737)	(0.0239)	(0.00584)
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes	Yes
Observations	111,740	111,740	111,740	111,739	111,386	110,846
R-squared	0.596	0.499	0.499	0.450	0.428	0.386

Notes: This table reports weighted placebo pre-trend estimates using NSS 56 and NSS 62. "Future DOE" is RGGVY exposure that a district would have by NSS 67, based on later sanction timing. The OAE interaction tests whether own-account enterprises had a differential pre-programme trend relative to establishments. All regressions include district fixed effects, survey-year fixed effects, NIC2 industry fixed effects, and firm controls. Standard errors are clustered at the district level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The outcome is the inverse hyperbolic sine of the weighted number of surviving small firms in a district-entry-year-industry cell. Event time is defined as the reported entry year minus the district's first RGGVY sanction year. Because districts receive RGGVY at different times, event time is not the same as calendar year: for example, "2 yrs before" means two years before that district's first sanction.

The event-study analysis is implemented as a retrospective cohort design. For each NSS round, we collapse the firm-level data to district-entry-year-NIC2 cells. Let N^s_{djt} denote the weighted number of surviving small firms in district d, industry j, and reported entry year t, observed in NSS round s. The estimated model is

$$\operatorname{asinh}(N^s_{djt}) = \sum_{k \neq -1} \beta_k \mathbf{1}\{t - S_d = k\} + \Gamma \bar{X}^s_{djt} + \mu_d + \lambda_t + \theta_j + \varepsilon^s_{djt}, \tag{4}$$

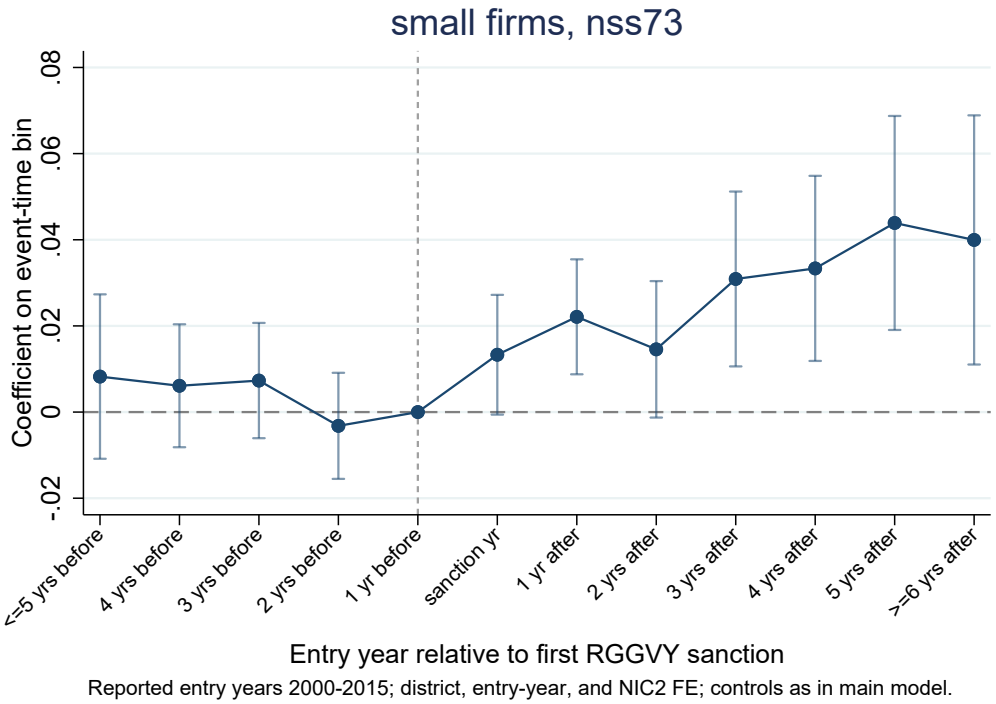
where S_d is the first RGGVY sanction year in district d. The omitted event-time category is one year before sanction, $k = -1$. The coefficients β_k compare surviving small-firm cohorts in each event-time bin with cohorts one year before sanction, within the same district fixed-effect, entry-year fixed-effect, and industry fixed-effect structure.

The specification follows the main empirical model as closely as this retrospective panel allows. It includes district fixed effects μ_d, entry-year fixed effects λ_t, and NIC2 industry fixed effects θ_j, with standard errors clustered by district. The vector $\bar{X}^s_{djt}$ contains weighted cell means of the available firm-level controls used in the main regressions: female ownership, proprietary status, and partnership status, together with missing-control indicators. For NSS 67, the final post-sanction bin pools event years three or more years after sanction. For NSS 73, the final post-sanction bin pools event years six or more years after sanction.

This design does not observe all firms born in a district-year. It observes only firms that were alive in the NSS survey round and reports their year of initial operation.

The estimates therefore describe the composition of surviving small-firm cohorts around RGGVY timing. They should not be interpreted as annual firm births or as the number of firms caused by RGGVY.

Figure 4: Small-firm retrospective entry event study, NSS 73



Notes: Outcome is asinh(weighted surviving small firms) in district-entry-year-NIC2 cells. The model includes district, entry-year, and NIC2 fixed effects and weighted cell controls. Event time is reported year of initial operation relative to first RGGVY sanction year. The omitted category is one year before sanction. The NSS 73 panel uses reported entry years 2000–2015; the final plotted bin pools six or more years after sanction.

The NSS 73 estimates are more positive in later event years, especially from three to six or more years after sanction. This pattern is consistent with a possible longer-run association between electrification and the number of small-firm.

7.1 Robustness

The main heterogeneity pattern is robust to alternative fixed-effect structures. In particular, the positive differential exposure gradient for OAEs remains visible after allowing common changes to differ across states and manufacturing industries. The result is also not driven by any single state: the $OAE \times DOE$ coefficient remains positive when states are excluded one at a time. The net OAE exposure gradients are less stable and are generally not statistically significantly positive. These additional results, reported in Appendix A.2, reinforce the distinction between a relative OAE-establishment difference and a positive absolute effect for OAEs.

8 Discussion and Conclusion

This paper examines whether district-level exposure to RGGVY was associated with outcomes of rural informal manufacturing enterprises in India. Using harmonised NSS 62 and NSS 67 enterprise data merged with district-level RGGVY rollout information, the analysis compares firms across districts with different durations of programme exposure. The preferred specifications include district, survey-year, and industry fixed effects together with firm-level controls, and standard errors are clustered at the district level.

The updated average results show a clear distinction between electricity-use responses and broad firm expansion. RGGVY exposure is positively associated with electricity use, electricity charges, and electricity's share of expenditure, while the fuel share declines. This pattern is consistent with an adjustment in the composition of energy use. On firm scale, operating expenses and fixed assets increase significantly, and the loan coefficient is also positive, although the loan result is based on a much smaller sample. At the same time, receipts, GVA, and profit remain statistically insignificant, and there is no evidence of average effects on employment, wage payments, or labour productivity. The results therefore do not support a broad interpretation of rural manufacturing growth, but they do indicate changes in electricity use and selected input, asset, and finance margins.

The OAE heterogeneity results sharpen this interpretation. Relative to establishments, own-account enterprises display significantly more favourable exposure gradients for receipts, expenses, GVA, profit, fixed assets, and loans. The same relative pattern appears in the electricity mechanisms: the OAE interaction is positive for electricity use, electricity charges, and electricity's share of expenses, and negative for the fuel share. These interaction coefficients identify differential responses relative to establishments. They should not be interpreted as the total exposure effect for own-account enterprises, which is given by the sum of the reference-group coefficient and the interaction coefficient and requires a separate linear-combination test for statistical significance.

This relative OAE pattern is consistent with the idea that household-based enterprises operate close to the margin of basic infrastructure access. Electricity can improve lighting, permit the use of small tools and machines, facilitate storage or processing, and extend operating hours. Such changes can matter for the operating environment of own-account enterprises even when they do not generate large average increases in output or employment across the rural manufacturing sector.

The separate retrospective cohort exercise provides additional, but conceptually different, evidence on small firms. It uses surviving firms' reported year of initial operation and therefore observes only enterprises that were alive at the time of the NSS survey. The positive post-sanction pattern among surviving small-firm cohorts in NSS 73 is consistent with a possible longer-run association between electrification and the presence of small firms, but the design cannot measure true firm births or exits.

The policy implication follows from the contrast between improved productive-use margins and weak broad-based growth effects. Rural electrification can relax an important infrastructure constraint, but it should not be treated as a stand-alone rural industrialisation policy. For electricity access to translate into broader enterprise growth, firms may also require reliable supply, affordable tariffs, credit, machinery, technical skills, repair services, and market access. Without these complementary conditions, electrification may increase the scope for productive electricity use without producing large gains in output, employment, or productivity.

Several limitations remain. The NSS enterprise data are repeated cross-sections rather than a firm panel, so the analysis cannot follow the same enterprise before and after electrification. RGGVY exposure is measured at the district level, while actual electricity access, hours of supply, voltage quality, and reliability vary within districts. The duration measure captures the timing of programme rollout rather than the quality of electricity received by each firm. Some outcomes, especially loans and reported power-cut problems, are available for smaller or less comparable samples. The pre-trend exercise provides a useful diagnostic for the OAE results, but it does not eliminate concerns about non-random programme timing. The estimates should therefore be interpreted as district-level exposure gradients rather than definitive firm-level causal effects.

Overall, the absence of broad average output and labour effects does not imply that electrification was irrelevant for rural firms. The evidence instead points to a more specific pattern: RGGVY exposure is associated with greater electricity use and selected input and asset adjustments, while own-account enterprises display systematically more favourable relative gradients than establishments. Rural electrification therefore appears to be an important but incomplete condition for rural enterprise development.

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Appendix

Electricity Access and Rural Firms: Evidence from a Large-Scale Rural Electrification Programme in India

Rohan Yadav

A.1 Rajiv Gandhi Grameen Vidyutikaran Yojana

Before the formal launch of RGGVY, 127 rural electrification projects were approved in the first meeting of the Monitoring Committee held on 21 July 2005. Of these, 111 projects had originally been sanctioned under the Accelerated Electrification of One Lakh Villages and One Crore Households (AEOLV-OCH) scheme.[2] Although AEOLV-OCH had a somewhat different scope, these projects subsequently received *ex post facto* approval under RGGVY. This reflected a broader move toward bringing earlier rural electrification initiatives within a common policy framework. Table A.1 reports the number of projects sanctioned and the corresponding approved costs in selected Monitoring Committee meetings.

Table A.1: Projects Sanctioned in Monitoring Committee Meetings under Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)

Sl. No.	Meeting	Date	Projects Sanctioned	Project Cost (Cr)
1	1st Meeting	21.07.2005	127	4904.34
2	7th Meeting	09.05.2006	24	576.06
3	8th Meeting	20.07.2006	26	2023.46
4	15th Meeting	22.01.2008	215	7975.52
5	16th Meeting	04.02.2008	26	2168.09
6	19th Meeting	13.03.2008	51	2049.22
7	20th Meeting	19.03.2008	13	812.57
8	21st Meeting	28.03.2008	11	1022.46

- Source—Comptroller and Auditor General of India (CAG, 2013) Performance Audit Report on RGGVY.

[2]The Accelerated Electrification of One Lakh Villages and One Crore Households (AEOLV-OCH) scheme, launched by the Ministry of Power in 2004, was an important precursor to RGGVY. It aimed to accelerate electricity access in unelectrified villages and households using both conventional grid extension and decentralised technologies such as solar PV, biomass gasifiers, mini-hydel systems, and hybrid solutions.

Table A.2: Description of Outcome Variables: Scale, Performance, and Labour

Label	Variable used in analysis	Description
Receipts	`receipts_real`; `ihs_receipts`	Total annual receipts of the enterprise. The raw NSS receipt items are annualised where needed and then deflated to real 2005–06 rupees. The main regression uses the inverse hyperbolic sine transformation.
Operating expenses	`expenses_real`; `ihs_expenses`	Total annual operating expenses of the enterprise. The measure combines principal and other operating expenses where available, annualises the reported reference-period values, and deflates them to real 2005–06 rupees.
Gross value added	`gva_real`; `ihs_gva`	Gross value added reported in the NSS enterprise blocks, annualised and deflated to real 2005–06 rupees. When the preferred GVA item is unavailable, the workflow uses the available fallback GVA or block total from the harmonised files.
Profit proxy	`profit_proxy_real`; `ihs_profit_proxy`	Proxy for enterprise surplus. It is constructed as receipts minus operating expenses when both are available. If that difference cannot be computed but GVA is available, GVA is used as the fallback. The real version is deflated to 2005–06 rupees.
Fixed assets	`fixed_assets_real`; `ihs_fixed_assets`	Value of fixed assets reported by the enterprise. The harmonised measure uses the fixed-assets block in each NSS round and is deflated to real 2005–06 rupees.
Outstanding loans	`loan_total_real`; `ihs_loan_total`	Total outstanding loan amount reported by the enterprise, deflated to real 2005–06 rupees. This variable is missing for enterprises with no usable loan information, so its sample size is smaller than for most outcomes.
Total workers	`total_workers`; `ihs_total_workers`	Total number of workers reported in the NSS employment block. The measure includes the enterprise's reported workforce, including working owners, hired workers, and helpers where these are captured by the round-specific employment total.
Wage bill	`wage_bill_real`; `ihs_wage_bill`	Total compensation paid by the enterprise, annualised and deflated to real 2005–06 rupees. Missing wage bill is set to zero only when hired workers are reported as zero, to improve comparability for own-account enterprises.
GVA per worker	`gva_per_worker`; `ihs_gva_per_worker`	Real gross value added divided by total workers. It is defined only for enterprises with positive total workers and non-missing real GVA.
Wage bill per worker	`wage_per_worker`; `ihs_wage_per_worker`	Real wage bill divided by total workers. It is defined only for enterprises with positive total workers and non-missing real wage bill.

Notes: The table describes scale, performance, and labour outcome variables used in the NSS enterprise-survey analysis of rural unincorporated manufacturing enterprises. Monetary variables are converted to real 2005–06 rupees before transformation or tabulation. The prefix `ihs_` denotes the inverse hyperbolic sine transformation. All variables are constructed from the harmonised NSS enterprise-survey files.

Table A.3: Description of Outcome Variables: Electricity, Energy, and Enterprise Operations

Label	Variable used in analysis	Description
Electricity-use indicator	`elec_user`	Indicator equal to one when the enterprise reports positive electricity spending, and zero otherwise when electricity-expenditure information is available. It captures the extensive margin of enterprise electricity use.
Electricity charges	`electricity_charges_real`; `ihs_electricity_charges`	Enterprise spending on electricity, deflated to real 2005–06 rupees. The main monetary regression uses the inverse hyperbolic sine transformation.
Electricity share of expenses	`elec_share_exp`	Electricity charges divided by operating expenses. The variable is defined when operating expenses are positive and both components are observed. In descriptive tables, the ratio is generally reported in percentage points.
Fuel and lubricant spending	`fuel_lubricant_real`; `ihs_fuel_lubricant`	Enterprise spending on fuel and lubricants, deflated to real 2005–06 rupees. This variable captures non-electric energy-input costs.
Fuel share of expenses	`fuel_share_exp`	Fuel and lubricant spending divided by operating expenses. The variable is defined when operating expenses are positive and both components are observed. In descriptive tables, the ratio is generally reported in percentage points.
Power cuts reported	`power_cut_problem`	Indicator for whether the enterprise reports power cuts or electricity interruptions as a problem. This is a perceived constraint measure and not a direct measure of the number or duration of outages.
Months operated	`months_operated`	Number of months during the reference year in which the enterprise operated. Values outside the feasible range of zero to twelve are set to missing in the final data-preparation step.
Hours operated per day	`hours_day`	Usual number of hours operated per day, harmonised from the available round-specific operating-hours variables. Values outside the feasible range of zero to twenty-four are set to missing.
Annual operating hours	`annual_hours`; `ihs_annual_hours`	Approximate annual operating hours, constructed as months operated multiplied by 30 days and by usual hours operated per day: $$\texttt{annual_hours} = \texttt{months_operated} \times 30 \times \texttt{hours_day}.$$ The regression version uses the inverse hyperbolic sine transformation.
Registered enterprise	`registered_any`	Indicator equal to one if the enterprise reports being registered under at least one applicable authority or registration system, and zero otherwise when registration information is available.

Notes: The table describes electricity, energy-input, operating-intensity, and registration outcomes used in the NSS enterprise-survey analysis. Monetary variables are converted to real 2005–06 rupees before transformation or tabulation. The prefix `ihs_` denotes the inverse hyperbolic sine transformation. Electricity and fuel expenditure shares are estimated as proportions but are generally multiplied by 100 when reported in descriptive tables.

A.2 Additional Identification and Robustness Checks

This appendix reports additional checks on the main OAE heterogeneity results. The exercises focus on three issues. First, I examine whether the estimated difference between own-account enterprises and establishments is sensitive to the fixed-effect structure. Second, I use pre-programme NSS rounds to test whether the OAE pattern was already present before RGGVY. Third, I examine whether the results are driven by any single state.

An important distinction throughout the analysis is between the differential OAE coefficient and the total exposure gradient for OAEs. In the interaction model, the coefficient on $OAE \times DOE$ measures how the exposure gradient for own-account enterprises differs from that for establishments. The total, or net, exposure gradient for OAEs is instead given by

$$\beta_{\text{OAE}} = \beta_{\text{DOE}} + \beta_{\text{OAE}\times\text{DOE}}.$$

The additional results show that the differential OAE gradient is relatively stable across specifications, whereas the net OAE gradient is less precisely estimated and is generally not significantly positive.

A.2.1 Alternative Fixed-Effect Specifications

The main specification controls for district fixed effects and allows common time shocks to vary across states and manufacturing industries. To examine whether the OAE heterogeneity result depends on this choice of fixed effects, I estimate a sequence of specifications that progressively introduce state-by-survey-year and NIC2-by-survey-year fixed effects.

Figure A.1 reports the coefficient on $OAE \times DOE$. The estimated differential gradient remains positive across the alternative fixed-effect specifications for the main outcomes. The size of the estimates also changes relatively little for several outcomes. This suggests that the relative difference between OAEs and establishments is not explained only by state-level or industry-level changes between NSS 62 and NSS 67.

Figure A.2 reports the corresponding net OAE exposure gradients. These estimates are noticeably weaker. The net gradients for receipts, GVA, and strict profit are generally negative, while those for fixed assets and electricity use are closer to zero or positive but imprecisely estimated. Thus, the stable result across fixed-effect specifications is the relative OAE–establishment difference rather than a consistently positive total exposure gradient for OAEs.

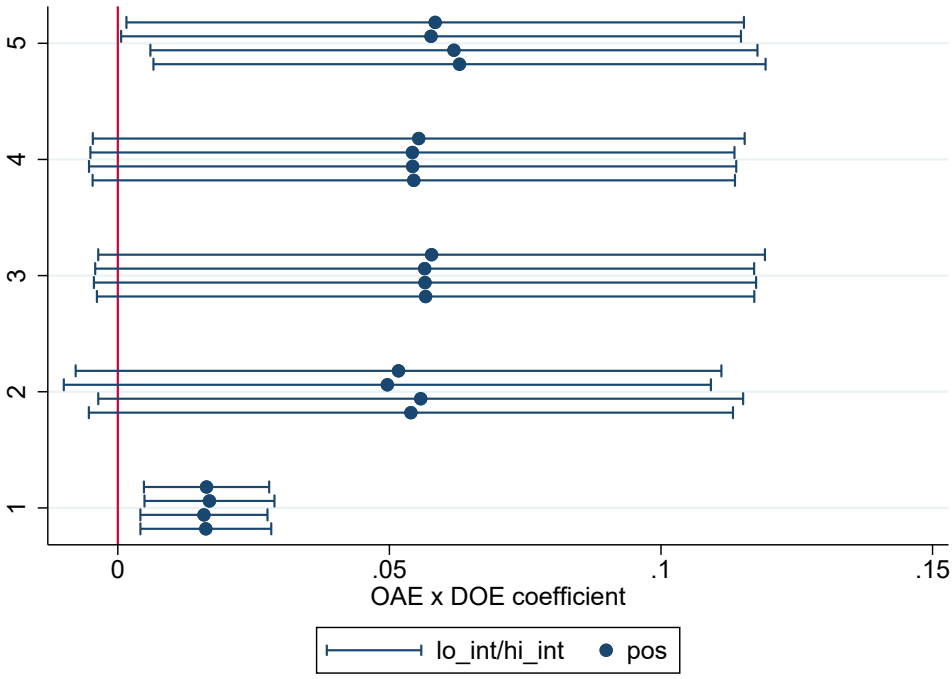


Figure A.1: OAE Differential Exposure Gradient Across Fixed-Effect Specifications

Notes: The figure reports coefficients on $OAE \times DOE$ under alternative fixed-effect specifications. Outcome codes are: 1 = receipts, 2 = GVA, 3 = strict profit, 4 = fixed assets, and 5 = electricity use. The specifications progressively introduce district fixed effects, state-by-survey-year fixed effects, and NIC2-by-survey-year fixed effects. All regressions use NSS survey weights. Standard errors are clustered at the district level. Horizontal bars report 95% confidence intervals.

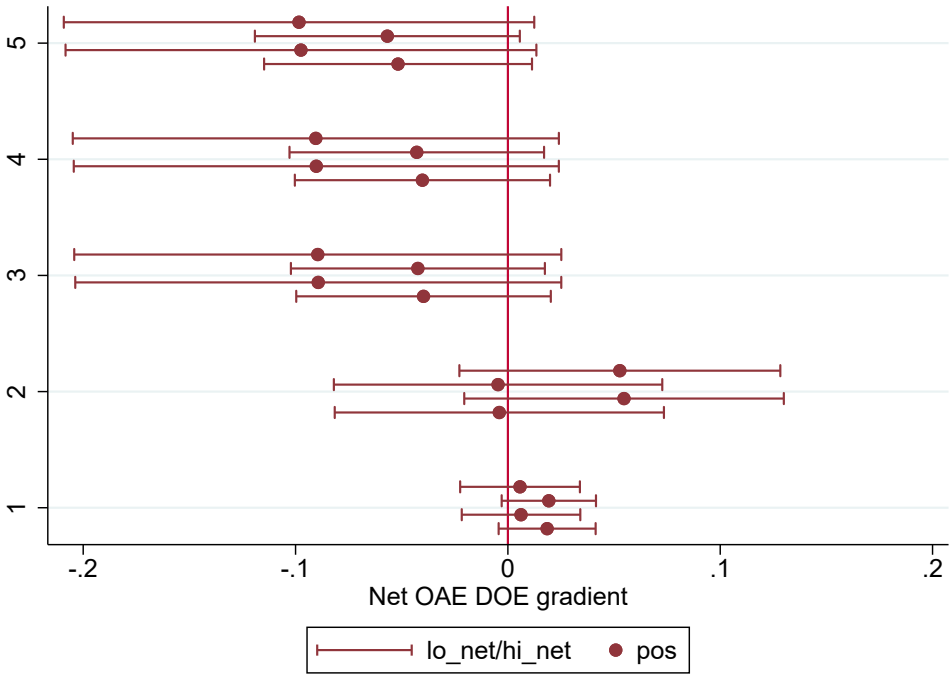


Figure A.2: Net OAE Exposure Gradient Across Fixed-Effect Specifications

Notes: The figure reports the net exposure gradient for own-account enterprises, calculated as $\beta_{\text{DOE}} + \beta_{\text{OAE}\times\text{DOE}}$. Outcome codes are: 1 = receipts, 2 = GVA, 3 = strict profit, 4 = fixed assets, and 5 = electricity use. All regressions use NSS survey weights and district-clustered standard errors. Horizontal bars report 95% confidence intervals.

A.2.2 Pre-treatment Trends

A central identification concern is that districts receiving greater future RGGVY exposure may already have been following different enterprise trajectories before the programme. I examine this possibility using NSS 56 (2000–01) and NSS 62 (2005–06), before the main post-treatment comparison.

Future exposure is constructed from the district's subsequent RGGVY sanction timing. The placebo specifications test whether enterprise outcomes changed differently between the two pre-programme rounds in districts that would later receive different durations of exposure.

Figure A.3 reports these pre-treatment estimates. For the main outcomes, the OAE differential pre-trend and the net OAE pre-trend are statistically insignificant. This reduces the concern that the relative OAE pattern observed after RGGVY simply continues an earlier OAE-specific trend.

The evidence is less favourable for establishments. Separate establishment specifications show negative and statistically significant pre-trends for GVA and strict profit. The pre-trend evidence therefore does not fully support a parallel-trends interpretation for establishments. For this reason, the negative post-period coefficients estimated for establishments are not interpreted as evidence that RGGVY causally reduced establishment outcomes.

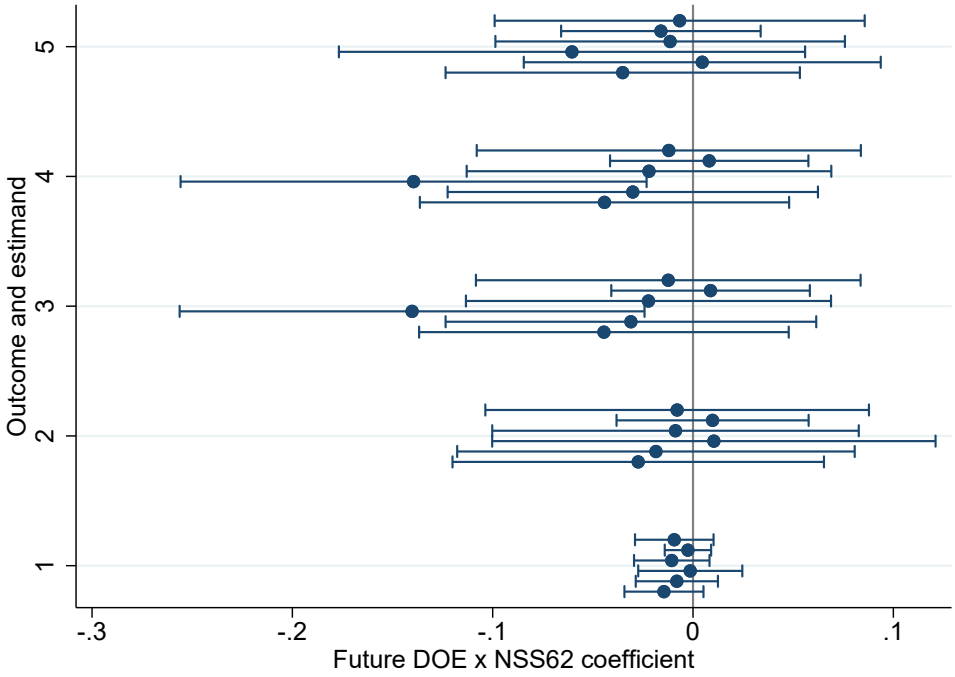


Figure A.3: Pre-treatment Trends for Enterprise Outcomes

Notes: The figure reports weighted placebo estimates using NSS 56 (2000–01) and NSS 62 (2005–06). Future RGGVY exposure is determined by subsequent district sanction timing. Outcome codes are: 1 = receipts, 2 = GVA, 3 = strict profit, 4 = fixed assets, and 5 = electricity use. All specifications include district, survey-year, and NIC2 industry fixed effects. For each outcome, the figure reports six pre-trend estimands: (1) the average full-sample pre-trend, (2) the establishment pre-trend, (3) the OAE differential pre-trend relative to establishments, (4) the net OAE pre-trend, (5) the OAE-only pre-trend, and (6) the establishment-only pre-trend. Standard errors are clustered at the district level. Horizontal bars report 95% confidence intervals.

A.2.3 Leave-One-State-Out Robustness

RGGVY implementation and rural manufacturing conditions vary substantially across Indian states. A further concern is therefore that the main OAE heterogeneity result may be driven by one large or influential state. To examine this, I repeatedly estimate the preferred specification after removing one state from the sample at a time.

Figure A.4 reports the resulting estimates of $OAE \times DOE$. The differential OAE coefficient remains positive across the state omissions for the main outcomes. Although the precision of the estimates changes when individual states are removed, there is no indication that the positive relative OAE gradient is generated by a single state.

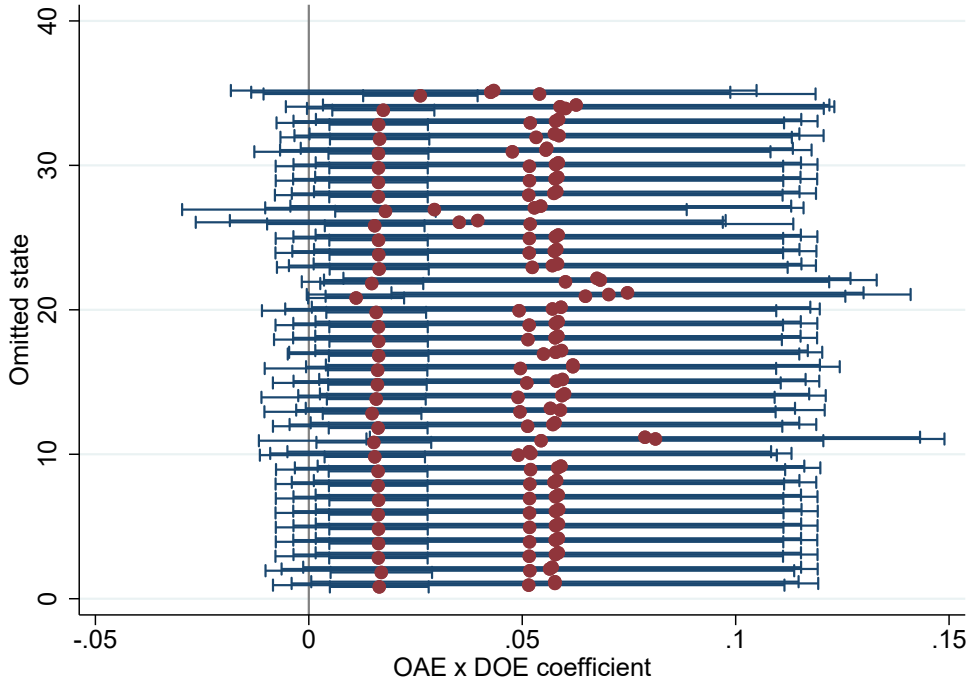


Figure A.4: Leave-One-State-Out Robustness of the OAE Differential

Notes: Each point reports the estimated coefficient on $OAE \times DOE$ after excluding one state from the estimation sample. The exercise is repeated for the principal firm outcomes. All specifications use NSS survey weights and the preferred fixed-effect structure. Standard errors are clustered at the district level. Horizontal bars report 95% confidence intervals.

A.2.4 Summary of the Additional Checks

The additional checks point to a consistent distinction between relative and absolute OAE responses. The coefficient on $OAE \times DOE$ remains positive under stronger fixed-effect structures and when individual states are removed. The pre-treatment analysis also provides little evidence that this relative OAE pattern was already present before RGGVY for the main outcomes.

At the same time, the net exposure gradients for OAEs are considerably less stable and are generally not statistically significantly positive. The additional evidence therefore supports the interpretation used in the main text: RGGVY exposure is associated with a more favourable gradient for own-account enterprises relative to establishments, but the estimates do not provide robust evidence of a broad positive total effect on OAE performance.