Rural Electrification and Women's Work in India

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Abstract

In 2005, the Indian government launched a large–scale rural electrification program that reached more than 400,000 villages across the country. This paper estimates the effects of this electrification scheme on female labor force outcomes measured by female non–farm employment and firm ownership shares at the village level. The paper uses a difference–in–difference design with state and district fixed effects to identify short to medium–run impacts on the outcome variables. The electrification program is associated with a 0.5 percentage point increase in female employment share and a 0.7 percentage point increase in female firm ownership share in the average treated village. No statistically significant effects on female literacy share are detected. The positive impact of electrification on female employment share is greater when electricity access extends to access for agricultural use. Positive effects are larger in villages with a substantial share of population belonging to Scheduled Caste communities. The impact of electrification on female labor outcomes is negative when the access to electricity is limited to domestic use.

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1 Introduction

The impact of the introduction of electricity on consumption, earnings, labor supply, and economic opportunity has been widely documented (Assunção et al., 2017; Burlig and Preonas, 2016; Lipscomb et al., 2013). However, the aggregate impact of electrification on female labor outcomes remains ambiguous. In the South African context, Dinkelman (2011) finds that while electrification increased employment on the extensive and intensive margin for both men and women, female wages declined.

This paper extends the study of rural electrification on female labor market outcomes by estimating the impact of the national rollout of an electrification program on female labor market outcomes in the rural Indian context. This study reports impacts on the following outcome variables – female non–farm employment share, female firm ownership share and female literacy share. The analysis further distinguishes between access to electrification for domestic and agricultural purposes since the distinction has implications for the direction of impact.

In the Indian context, Burlig and Preonas (2016) find using high–resolution geospatial data that rural electrification led to modest increases in per–capita consumption expenditure at the village level. This study builds on this evidence by focusing on the impacts of rural electrification on female rural labor market outcomes. I employ a difference–in–difference strategy with state and district–level fixed effects to uncover the impact of India's large–scale national rural electrification program, the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGVVY) or the "Prime Minister's Rural Electrification Program". This program was rolled out in 2005 and aimed to extend electricity to more than 400,000 rural Indian villages across all Indian states that did not have access to electricity at baseline. The study sample comprises of 245,844 villages that did not have access to electricity as of 2001. The treatment group comprises of villages in the sample that had access to electricity in 2011, and the control group is formed by villages that remained without electricity in 2011.

I find that rural electrification was associated with a 0.5 percentage point increase in female non–farm employment share and 0.7 percentage point increase in female firm ownership share. I find no statistically significant impacts on female literacy share at the village level. The estimate of impact on female literacy share is confounded by non–parallel pre–trends. I also find that the positive impact on female labor outcomes increases if I isolate the impact of access to electricity for agricultural purposes. The overall association between electrification for domestic purposes and female labor market outcomes is negative. The positive and

statistically significant impacts of rural electrification on female labor market outcomes are considerably larger in villages with a higher share of population belonging to marginalized communities (Scheduled Castes).

1.1 Contribution to the Literature

This study contributes to two broad strands of literature. First, the findings from this study add to the empirical evidence on the impact of large–scale infrastructural projects on local economic outcomes in developing countries. Other studies have established the limitations of infrastructure projects such as large–scale rural road construction, rural electrification and canal construction in transforming rural economies in India (Asher and Novosad, 2020; Burlig and Preonas, 2016; Asher et al., 2021a). I extend the methods and underlying data used in these studies to investigate the female labor market impacts of large–scale infrastructural projects aimed at engineering structural transformation in rural India.

My emphasis on studying the impact of a large–scale rural infrastructure development program on female labor outcomes specifically builds on two strands of economic literature – gender–biased technological change and the projected U–shaped relationship between economic growth and female labor force participation.

The gender–biased technological change framework builds on the central theory of the skill–biased technological change model (Tinbergen, 1974) that under conditions of multiple labor groups producing imperfectly substitutable goods, factor–augmenting technological change will create biased labor demand shifts. This framework has been used to investigate labor demand gaps between skilled and unskilled labor across US and OECD contexts (Autor et al., 1998; Goldin and Katz, 1998; Autor et al., 2003). This paper contributes to the literature on gender–biased technological change (Black and Spitz-Oener, 2007; Taniguchi and Yamada, 2022), and specifically the narrow but growing body of literature on gender–biased technological change in developing country contexts (D'Agostino, 2017; Juhn et al., 2014; Dinkelman, 2011).

Assuming that electrification unlocks local economic growth, the U–shaped theory of female labor force participation predicts that female labor force participation could increase or decrease depending on the baseline level of income per capita and the degree of social stigma toward female labor participation beyond the household (Goldin, 1995). Yet another channel of impact is through altered time use of women wherein availability of electricity in the household may reduce time spent on unpaid household chores. In the US context, the diffusion of modern electric household technologies accompanied an increase in aggregate

labor supply of married women between 1940–50 (Goldin, 2006; Bose et al., 2022).

2 Conceptual Framework

To estimate the impact of rural electrification on women's labor outcomes, I rely on a household–level utility framework within a stigmatized equilibrium following Goldin (1995). The model relies on two underlying assumptions. First, I assume that women's participation in work outside the household results in disutility from stigma associated with women's participation in the marketplace. Second, I assume that decisions about workforce participation are made at the household level in rural India. Under these assumptions, rural electrification would impact women's workforce participation on the extensive margin through a combination of income and substitution effects.

At baseline, a household faces a trade–off between the utility from avoiding stigma from women's work in the marketplace and unpaid home production of goods and services on one hand, and on the other hand, the utility from additional income earned from her participation in the marketplace. In this framework, electrification can be interpreted as a technology shock that would increase income for rural households by enabling micro–enterprises and improving productivity of existing income–generating activities. This results in an increase in the budget set faced by the household due to additional income. As a result, the trade–off skews toward utility from avoiding stigma and women's unpaid work at home resulting in a new equilibrium where women's participation in the workplace is reduced from baseline, i.e. a negative income effect. However, the increased productivity and economic opportunity generated by electrification would also increase the opportunity cost of the utility generated by restricting female members' labor force participation beyond the household. As a result, the equilibrium shifts toward greater female labor force participation, i.e. a positive substitution effect. The net impact on female labor force participation will be determined by the relative magnitudes of resulting income and substitution effects. The magnitude of income and substitution effects are in turn dependent on the degree of economic growth generated by rural electrification and the extent of utility derived from avoiding stigma. We would expect the latter to differ substantially based on baseline gender norms. Methodological advancements in the measurement of local gender norms (Singh et al., 2022) suggest substantial geographical heterogeneity in gender norms across India. Finally, the extent of the substitution effect is also determined by the relative demand shifts toward or away from female labor as a result of the positive technological shock generated by electrification.

3 Data

A village–level panel dataset was constructed by combining data on access to electricity with outcomes on female non–farm employment, firm entrepreneurship, and literacy shares. The components of the analysis dataset include three consecutive Indian Population Censuses (1991, 2001, and 2011) matched with three successive Indian Economic Censuses (1998, 2005, and 2013).

The Population Census Data is a comprehensive census of households in India, with publicly available data at the village and town level. The Population Census Abstract (PCA) comprises the number of households, population of men and women by community sub–groups, and number of workers across various occupation categories. The Population Census also includes village and town directories, that present data on various amenities including access to electricity. The Economic Census of India is a complete survey of non–farm economic entities. This census spans all formal, informal, government, and private firms that are engaged in any sector excluding crop production. The sampling frame for the Economic Census is the house listing of the most recent Population Census conducted. These datasets were extracted from and merged using geographic identifier concordances provided on the Socio–Economic High Resolution Rural Urban Geographic (SHRUG) data platform (Asher et al., 2021b).

The primary outcome variables for this study are female non–farm employment share and firm–ownership share. These variables have been defined as the ratio of the number of females employed in non–farm occupations to the total number of individuals (males and females) employed in non–farm sectors. Similarly, the female firm–ownership variable is the ratio of the number of female firm owners to the total number of firm owners in a village. An additional outcome variable measuring the female literacy share was included in the analysis because education is an important mechanism through which a society shifts across female labor force participation equilibria. The female literacy share variable is the ratio of the total literate females to the total number of literate individuals in a village. The outcome variables have been defined as shares instead of absolute values, as any observed effects of absolute levels of female employment or firm ownership could reflect a mechanical population size effect rather than a meaningful impact on female employment or entrepreneurship share.

The study sample was limited to all villages that did not have access to electricity in 2001, as indicated by Population Census village directory data. This was necessary as the focus of the present study is the RGVVY electrification program, which was only scaled up in 2005.

The resulting sample yields data for 254,649 villages. Table 1 shows the summary statistics of the villages at baseline. While the average female population share is about fifty percent, the baseline non–farm employment share and firm ownership share are substantially low.

Table 1
Summary Statistics

	Mean(SD)
Total population	1293.95
	(1454.36)
Total female population	623.21
	(699.12)
Female non–farm employment share	0.19
	(0.19)
Female firm ownership share	0.07
	(0.16)
Female literacy share	0.38
	(0.08)
Total Scheduled Caste population	287.35
	(502.48)

Note: The table shows means and standard deviations (in parentheses) of village–level variables at baseline in the sample of villages that were matched across all analysis datasets.

4 Empirical Strategy

The aim of the study is to estimate the causal effect of rural electrification on female human capital development. Cross–sectional estimates of the association between rural electrification and female human capital development are prone to bias arising from a range of confounding factors that vary across villages that have access to electricity, and those that do not. Finally, state governments across India vary substantially in terms of implementation efficacy.

The primary empirical specification in this study is a difference in difference regression with state and district fixed effects, within the set of all villages that remained without access to electricity, as of 2001, prior to the start of the RGVVY program. The difference

in difference estimator is defined in the following equation:

$$Y_i = \alpha + \beta_0 + \beta_1 Treatment_i + \gamma T_i + \delta Treatment_i * T_i + \chi_i + \epsilon_i$$

Here, Y_i is the outcome variable (for e.g. female non–farm employment share), measured in village i; β_1 is the effect specific to the group of villages that received electricity at some point during the RGVVY electrification period (2001–2011) to account for average characteristic differences between electrified and non–electrified villages during the study period; γ estimates the time trend common to the electrified and non–electrified village groups, and δ is the true effect of the treatment. Additionally, a state and district–specific fixed effect estimator, χ_i, has been included in the equation to account for possible variation arising due to differences in governance efficiency and gender norms surrounding female labor force participation across states.

The identification assumption is that in the absence of rural electrification, the village–level female labor and education outcomes would have followed the same pattern across time across the two comparison groups–villages that were electrified under the program, and those that were not.

To test the plausibility of this assumption, outcome patterns have been shown using data from the most recent census available prior to the study period in the Appendix (see Table A.1.) The implications of the pre–trend analysis for interpretation of the results have been discussed in the next section.

5 Results

5.1 Average effects of Rural Electrification on Primary outcomes

Table 2 shows the impact of electrification on the three primary outcome variables – the female share of non–farm employment, female share of firm owners, and female share of the literate population at the village level. The parameter of interest is the difference–in–difference estimator denoted by the interaction term $Electrification X 2011$ in Table 2. The coefficients on the interaction variable suggests that access to electricity did have a positive and statistically significant impact on the non–farm employment share as well as the firm ownership share for women. Specifically, rural electrification was associated with a 0.5 percentage point increase in female employment share within non–agricultural sectors and a 0.7 percentage point increase in firm ownership share. No discernible impact on female literacy share is detected at the village level.

Table 2
Average Impacts of Rural Electrification

	(1) Non-farm employment	(2) Firm ownership	(3) Literacy
Electrification	-0.0137***	-0.0113***	0.00555***
	(0.001)	(0.001)	(0.000)
Year = 2011	0.0879***	0.0743***	0.0574***
	(0.001)	(0.001)	(0.000)
Electrification X 2011	0.00470***	0.00687***	0.000482
	(0.001)	(0.001)	(0.000)
N	254649	237385	254533

Standard errors in parentheses
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: Standard errors have been clustered at the village level. The dependent variables are the female share of non–farm employed, firm owner, and literate population in the village respectively. All regressions include village population as weights and include state and district fixed effects.

However, it is difficult to empirically disentangle substitution and income effects from electrification that impact the female employment outcome variables without additional survey data. These effects would impact female labor force participation in opposite directions. One approach given the data at hand is investigating the impact of electrification separately based on type of electricity access. The census village amenities directory capture access to electricity disaggregated by whether electricity is accessible for domestic, agricultural or commercial purposes. None of the villages in the analysis sample had access to electricity for commercial purposes at the time of endline. However, there was substantial variation in terms of access to electricity for domestic or agricultural purposes.

Table 3 shows the impacts of rural electrification for agricultural purposes on female labor market outcomes, whereas Table 4 shows analogous impacts of electrification for domestic purposes. It is important to note that the impact of electrification for agricultural purposes is not only positive and statistically significant but the point estimates are higher than the modest aggregate impacts reported in Table 2. On the other hand, access to electricity for domestic purposes is associated with a statistically significant decline of 1.3 percentage points

on female non–farm employment share and negative or negligible impacts on female firm ownership and literacy shares. This is plausible if we consider access to electrification for domestic purposes as an income shock to households as opposed to a technological change augmenting factor productivity. Access to electrification for agricultural purposes on the other hand can be interpreted as a factor–augmenting technological shock and therefore, has the potential to impact labor demand. If this theory holds, the negative impacts in Table 3 are being driven by an income effect that is not diluted by substitution effects.

Table 3

Average Impacts of Rural Electrification for Agricultural purposes

	(1)	(2)	(3)
	Non-farm employment	Firm ownership	Literacy
Electrification	-0.0197***	-0.0147***	0.00416***
	(0.002)	(0.002)	(0.001)
Year = 2011	0.0826***	0.0711***	0.0560***
	(0.001)	(0.001)	(0.000)
Electrification X 2011	0.0133***	0.00949***	0.00361***
	(0.002)	(0.002)	(0.001)
N	182796	169761	182689

Standard errors in parentheses

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: Standard errors have been clustered at the village level. The dependent variables are the female share of non–farm employed, firm owner, and literate population in the village respectively. All regressions include village population as weights and include state and district fixed effects.

Table 4
Average Impacts of Rural Electrification for Domestic purposes

	(1)	(2)	(3)
	Non-farm employment	Firm ownership	Literacy
Electrification	0.0102***	-0.00170	0.0162***
	(0.003)	(0.004)	(0.001)
Year = 2011	0.115***	0.0782***	0.0868***
	(0.004)	(0.004)	(0.001)
Electrification X 2011	-0.0129**	-0.00258	-0.0156***
	(0.004)	(0.004)	(0.001)
N	80407	73982	80320

Standard errors in parentheses
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: Standard errors have been clustered at the village level. The dependent variables are the female share of non–farm employed, firm owner, and literate population in the village respectively. All regressions include village population as weights and include state and district fixed effects.

Table 5 implements the primary specification on a sub–sample of villages where the share of marginalized communities (Scheduled Castes) is greater than 50% of the population. This subset of villages is substantially more economically disadvantaged compared to the rest of the sample. On one hand, because these villages are on the left-end of the X–axis if we plot female workforce participation against village–level income, the projected U–shape trajectory would suggest that a positive income shock should decrease female labor force participation in these villages. However, on the other hand, these villages are likely to have a lower baseline stigma toward women's labor participation outside the household for two reasons. First, these communities are familiar with the multiple breadwinner model due to economic necessity. Second, the honor–income tradeoff is less likely to be binding since men and women from Scheduled Caste communities are discriminated against regardless because of their relative position in the caste–hierarchy. Additionally, strong sanctions on female mobility are driven by fears of "pollution of purity". For these reasons, we would expect communities that are at the top of the caste hierarchy to be more susceptible to the stigma surrounding women's work and engagement with strangers outside the household.

The results in Table 5 affirm the latter hypothesis. In villages with high Scheduled Caste population shares, electrification is associated with a 1.7 percentage point and 1.16 percentage point increase in female non–farm employment share and firm ownership share respectively.

Table 5
Average Impacts of Rural Electrification
in Villages with high Marginalized Caste (SC) population shares

	(1)	(2)	(3)
	Non-farm employment	Firm ownership	Literacy
Electrification	-0.0125***	-0.00286	0.00510***
	(0.003)	(0.003)	(0.001)
Year = 2011	0.0820***	0.0713***	0.0528***
	(0.003)	(0.003)	(0.001)
Electrification X 2011	0.0170***	0.0116**	0.00109
	(0.004)	(0.004)	(0.001)
N	29258	27458	29245

Standard errors in parentheses
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: Standard errors have been clustered at the village level. The dependent variables are the female share of non-farm employed, firm owner, and literate population in the village respectively. All regressions include village population as weights and include state and district fixed effects.

I implement a formal test of the identification assumption in a pre–trends analysis in Appendix Table A.1. For the pre–trends analysis, I implement the main specification using the same group of treatment and control villages using 1991–2001 as the time period of analysis. The year 2001 serves as the baseline time period in the primary analysis. The assumption of parallel pre–trends requires that there is no differential impact on the outcome variables across treatment and control villages in the preceding time period (1991–2001). I find that this requirement holds for the primary outcome variable of interest – female non–farm employment share. I find a negative and statistically significant coefficient on female firm ownership share in the preceding time period. However, this implies that the estimates of impact of electrification on female firm ownership are likely underestimates of the true effect given the negative pre–trends. However, the impact of electrification on literacy share

reported in the study cannot be interpreted as causal because of a positive and statistically significant coefficient on the difference–in–difference parameter in the pre–trends analysis.

6 Discussion

The large–scale and geographically granular analysis in this paper suggests a positive average impact of rural electrification on female labor outcomes at the village level in India. The effects on female non–farm labor share and firm ownership share are positive and statistically significant. However, the magnitude of impact is substantially smaller than the analogous impact of rural electrification on female labor outcomes in other contexts (Dinkelman, 2011). The positive effects on female labor outcomes in poorer and marginalized villages are comparable to the impact estimates reported by Dinkelman (2011) in the South African context. Estimates of similar magnitude are also found in the present study when we study the impact of access to electricity for agricultural purposes. Interestingly, the impact of access to electricity for domestic purposes produces a negative and statistically significant impact on female labor outcomes. In addition to extending the evidence of the impact of rural electrification on female labor outcomes in the rural Indian context, the results from this study also highlight the importance of distinguishing between electricity access for domestic and non–domestic purposes.

It is possible that the outcome variables measured reflect short or medium–term changes. The rural electrification program was launched in 2005, and as of March 2008, 47,826 previously unelectrified villages had received electricity. The outcomes reported in this study were measured in 2013. An evaluation report of the scheme published by India's planning commission, NITI Ayog, in May 2014 states that 93.3 percent of the electrification aims of the scheme were achieved between 2007–2012. Depending on the timing of implementation in a specific state, the years since intervention for this study ranges from one to six years. However, results by (Burlig and Preonas, 2016) suggest that the economic outcomes of electrification under the RGVVY scheme were quantitatively similar for villages that were electrified toward the beginning of the sample period and those that were electrified toward the end.

Due to data limitations, I am unable to detect the impact of rural electrification on female employment outcomes on the intensive margin. I would require granular gender disaggregated village–level wage data to detect effects on female labor participation beyond the extensive margin. This data limitation also constraints the ability to estimate gender–specific labor demand elasticities to the technological shock (i.e. rural electrification).

7 Conclusion

In this study, I have leveraged village–level census records to estimate the impact of a large–scale rural electrification program on female non–farm labor shares and firm ownership shares in India. I find marginal and statistically significant positive impacts of rural electrification on female labor market outcomes in the full sample. Effects are higher in villages that are particularly socio–economically disadvantaged. The type of electrification access – for domestic or non–domestic purposes – leads to opposite and statistically significant results on the primary outcome variables.

This study contributes to the specific literature on the impact of rural electrification on gender outcomes and the broader scholarship on structural transformation and female labor outcomes. This paper is particularly relevant in the Indian context where the female labor force share has been declining steadily since 2005. The results from this study affirm that infrastructure investments that unlock economic opportunity beyond home production of goods and services can improve female labor outcomes.

Future research can combine time–use records with census data to clearly distinguish income and substitution effects of rural electrification on female labor. Finally, the analysis presented in this study would be substantially enhanced by incorporating measures of local gender norms which mediate the extent to which women's economic participation responds to growth in local economic opportunity.

Appendix

Table A.1
Test for Parallel Pre–trends

	(1) Non-farm employment	(2) Firm ownership	(3) Literacy
Electrification	-0.00369*	0.00195	-0.00266**
	(0.002)	(0.002)	(0.001)
Endline (2001)	-0.0181***	0.00450***	-0.0837***
	(0.001)	(0.001)	(0.001)
Treatment X Endline	-0.00152	-0.0101***	0.0162***
	(0.002)	(0.002)	(0.001)
N	196257	179575	196014

Standard errors in parentheses

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: Standard errors have been clustered at the village level. The dependent variables are the female share of non-farm employed, firm owner, and literate population in the village respectively. All regressions include village population as weights and include state and district fixed effects.

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