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Did it increase energy consumption? A difference-in-differences evaluation of a rural electrification policy in Gujarat, India using night-time lights data

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ABSTRACT

Electricity access is an important issue and building capacity for it requires drawing relevant lessons from past policies. In this study, we evaluate the effect of the Jyotigram Yojana, or the lighted village scheme, a supply-side policy intervention during 2003–08 to increase rural electricity access in Gujarat, India. We hypothesize that policy implementation is associated with increased electricity consumption. To test this hypothesis, we exploit variation in the timing of policy implementation at the village level, and use a generalized difference-in-differences strategy for identification. Further, we use night-time luminosity measured through remote sensing as a proxy for electricity consumption, and control for weather, village fixed effect, year fixed effect, and village or administrative block specific time trend. We find that while the overall effect of the policy on night-time luminosity was not statistically significant, the effects were likely heterogeneous, with the night-time luminosity increasing in some districts after policy implementation and decreasing in others. We conclude that the policy might have had a re-distributive effect on electricity access or consumption and recommend adopting a more holistic approach – incorporating both supply-side and demand-side measures – to increase electricity access.

1. Introduction

The first target of the sustainable development goal on energy (SDG 7) is: “By 2030, ensure universal access to affordable, reliable, and modern energy services” (UN DESA, 2023). However, the progress on this front has been inadequate and even showing signs of slowing further. Based on the current rate of energization, over 600 million people are likely to lack access to electricity by 2030 and over 2.4 billion access to clean cooking fuel (IEA et al., 2021). Though the problem is the most pressing in the South Asia and sub-Saharan Africa, the number of people with access to clean cooking and electricity in South Asia has increased significantly over the past decade.

India, in particular, has witnessed rapid progress on expanding electricity access in recent years. In April 2018, Indian government announced that it had achieved complete rural electrification. While expanding access by connecting households to the electricity grid has been the priority in the past, the policy dialogue on energy access is increasingly highlighting the need to ensure reliability, affordability, and sustainability of electricity access (United Nations, 2015; World Bank, 2017; Aklin et al., 2021).

In line with this shift, the *Deen Dayal Upadhyaya Gram Jyoti Yojana* (DDUGJY), a national-level program aimed at providing electricity distribution infrastructure in rural India, was launched in July 2015 (Ministry of Power, 2015). A key feature of the DDUGJY is separation of agricultural and residential electricity feeders in rural areas such that households would receive 24-h reliable electricity supply while agricultural consumers would be provided electricity for a fixed, but adequate time period. A crucial point to note about the DDUGJY in particular is the definition of an “electrified” village. The DDUGJY follows the census definition of an electrified village, which is: (1) basic infrastructure such as distribution transformer and distribution lines are provided in the inhabited locality and hamlets; (2) electricity is provided to public places such as schools, village local government office, health centers, community centers and so on; and (3) number of households electrified is at least 10 per cent of the total number of households in the village (Ministry of Power, 2004). Thus, while at the village-level, a village may be “electrified”, household-level electrification may still be low.

To bridge the gap between village-level and household-level electrification and increase demand for household electricity, the

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Government of India also introduced the *Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya)* program in September 2017. This program aimed to provide a free electricity connection to any willing household, covering both above poverty line (APL) and below the poverty line (BPL) households in rural areas and BPL households in urban areas. Even so, affordable access to electricity at the household-level is far from being universal. The problem is intertwined. First, one of the main expectations from electricity distribution utilities is to reduce aggregate technical and commercial losses (AT&C) arising from billing and collection inefficiencies and power theft (NITI Aayog et al., 2021). This has resulted in increased metering of household electricity and higher tariffs for residential electricity ((NITI Aayog et al., 2021)). And, second, feeder separation under the DDUGJY also emphasizes metering of household electricity (Ministry of Power, 2015). Therefore, even when households receive a free electricity connection, they may not be able to afford the recurring cost and run the risk of disconnection (Fairley, 2019). As a consequence, the very policies aimed at improving electricity supply in rural areas may lower electricity access and consumption.

However, research examining the impact of these recent policies on electricity access specifically, and energy transition broadly, is still limited (Goyal, 2021; Goyal et al., 2022; Goyal and Howlett, 2023). Recent studies highlight two main findings – that both access and quality of electricity supply has improved substantially, particularly since 2015 (Aklin et al., 2021), but despite substantial improvements inequities still persist, particularly for the marginalized rural communities who tend to be concentrated in geographically remote areas (Pelz et al., 2021). Both these studies rely on self-reported assessment of electricity duration and reliability collected through surveys. A study by Duguoa et al. (2018) examines the impact of large-scale village-level electrification using 2011 census and night-time lights data and finds a positive correlation between increased access and electricity consumption proxied by night-time lights. There is still a gap in understanding whether quality-focused reforms such as the DDUGJY have positively affected electricity consumption.

In this paper, we empirically assess whether village-level electrification policies have translated into increased household-level electricity consumption using night-time lights data. Our rural electrification data comes from the state of Gujarat. Between 2003 and 2008, the state implemented its flagship rural electrification program, *Jyotigram Yojana* (JGY), the design of which was later adopted at the national-level as the DDUGJY. The aim of the JGY was also to separate household and agricultural electricity feeders in rural areas to provide 24-h, three-phase electricity supply to rural households. The JGY also followed the census definition of an "electrified village".[2]

Feeder separation under the JGY involved physical separation of the agricultural and non-agricultural feeders through the installation specially designed transformers (Shah et al., 2008). Post-separation, non-agricultural users comprising of households, schools, village local government office, health centers, community centers, and small commercial users, among others. received 24 h high-quality (three-phase) electricity. The supply to agricultural users was restricted to 8 h per day following a pre-determined schedule and timing of day according to season and moisture stress (Shah et al., 2008). The policy feature that distinguished the JGY from predecessor policies was its emphasis on improving both access to and quality of electricity supply.

Moreover, simultaneously with the JGY, the state government of Gujarat passed the Gujarat Electricity Industry (Reorganization and Regulation) Act, 2003. This separated the Gujarat State Electricity Board (GEB) into separate entities for generation, transmission, and distribution with the intention of reducing the transmission and distribution (T&D) and the AT&C losses. Distribution assets were transferred to four sub-regional DISCOMs to create competition and improve overall finances and performance (Debroy, 2013). Therefore, although our analysis uses data from just one state and an earlier decade, it reflects current national-level rural electrification policies and challenges of India.

2. Welfare effects of rural household electrification

Examining rural household electrification is of significance owing to the welfare effects that it generates. An immediate benefit of rural household electrification is the quality and cost of lighting. It is found that compared to kerosene or candle lighting, the brightness or luminous intensity of an electric bulb is much higher and costs less per unit of lighting (Nieuwenhout et al., 1998; Van der Plas and de Graaff, 1988). This allows households to extend their productive hours or shift to activities bringing in higher returns. As a consequence, studies conducted in different country contexts find positive effects of rural electrification on income, consumption expenditure, poverty reduction, and labor supply and productivity (Dinkelman, 2011; Khandker et al., 2013; Lipscomb et al., 2013; van de Walle et al., 2017; Peters and Sievert, 2016).

Other welfare effects for rural households identified in the literature are improved educational outcomes for children, reduced fertility, and reduced indoor air pollution for those who switch to electric cookstoves. As children can study beyond evening hours, there is a positive impact on their educational outcomes (Khandker et al., 2013). Reduction in fertility has been observed in rural areas, potentially explained by better access to information on family planning and contraception through television (Peters and Vance, 2011; Grimm et al., 2017). In addition, access to affordable electric cookstoves have the potential to reduce indoor air pollution and improve health outcomes (Pattanayak et al., 2019).

Specifically pertaining to JGY, evidence suggests that the short-to-medium term impact of JGY on net farm income is negative as there was a simultaneous increase in irrigation costs owing to rationing of farm electricity (Chindarkar et al., 2020). In terms of other welfare effects, previous research has found positive effect of improved quality of rural electricity supply on operational capacity of primary health centers (PHCs), access to health information, and utilization of health services (Chen et al., 2019). As yet, no study examines the effect of the JGY on electricity consumption over a reasonable time period.

While not taking away from the need and significance of rural electrification, studies have also shown null or counterintuitive effects of rural electrification. A randomized experiment in the Indian state of Uttar Pradesh that provided access to solar micro-grids found that while electrification rates increased, no significant effects were found on consumption, savings, or time spent working or studying (Aklin et al., 2017). In another study, quasi-experimental analysis using household data from Rwanda observed an increase in lighting usage among electrified villages. However, no significant effects on income or time spent studying by children were observed once regional differences were factored in Bensch et al. (2011). One plausible explanation for the null effects might be the length of time between electrification and observation of welfare outcomes, which likely require a longer timeframe to manifest. The time between the baseline and endline observation for the Uttar Pradesh randomized experiment was one year while the Rwanda study usescross-sectional data. Related to JGY, Chindarkar et al. (2020) observe a decrease in per acre net farm income in the short-to-medium term, which they posit is driven by increased per acre irrigation costs.

3. Evidence from night-time lights studies in low- and middle-income countries

There is a growing body of literature using night-time lights data to

[2] JGY began implementation in September 2003 and followed the census definition of an "electrified village". The definition was modified in February 2004 (prior change was in October 1997) and has remained the same since. Therefore, except for the first six months, the definition of an "electrified village" under JGY has remained unchanged.

examine development outcomes and validating access to electrification based on household surveys or administrative data. Wang et al. (2012) find a positive correlation between night-time lights and poverty reduction over a three-year period in China. Prakash et al. (2019) and Singhal et al. (2020) find that in the context of India, night-time lights data are strongly correlated with economic activity and closely track regional inequality. Using a novel method of combining day-time imagery and night-time lights data from five African countries, Jean et al. (2016) find that they can predict poverty levels (consumption expenditure and asset index) fairly accurately (explaining about 75 percent variation in the poverty data).

The advantage of using night-time lights data is its ease of access and high frequency, unlike survey data that may suffer from self-reporting errors and missingness; and administrative data that may be potentially manipulated or hard to access (Chen and Nordhaus, 2011; Henderson et al., 2012). However, some studies have found that night-time lights data – when used as a proxy for economic activity or output – may suffer from measurement errors, particularly in low-output and low-density regions such as remote rural areas that rely primarily on agriculture (Chen and Nordhaus, 2011; Gibson et al., 2021).

Min and Gaba (2014) and Min et al. (2013) use night-time lights data to validate ground-based data on electrification collected through household surveys in Vietnam and Africa (Senegal and Mali), respectively, and find strong correlation between survey data and night-time lights data. Dugoua et al. (2018) find a similar strong correlation between night-time lights data and large-scale village-level rural electrification data from the 2011 census in India. An important takeaway from these studies is that night-time lights data can fairly accurately capture luminosity in rural areas – especially in those with high electrification, such as Gujarat – even with the challenges of lower luminosity compared to urban areas and intermittent power supply.

4. Research methods

4.1. Data collection

We use the Defense Meteorological Satellite Program Operational LineScan System (DMSP-OLS) time-series dataset on nighttime lights (Defense Meteorological Program Operational LineScan System, 2014) to construct a proxy for electricity consumption. This dataset records the night-time light intensity detected using satellite imagery at a high spatial resolution of approximately 1 km × 1 km for the entire globe. Specifically, the average visible lights data product measures luminosity from stable sources, such as energy use in villages, towns, or cities and gas flaring. This data product has been employed previously in various studies in the social sciences, including for the estimation of electrification and electricity consumption at a granular level (Chand et al., 2009). In fact, it has been validated as an "adequate proxy" for local electricity consumption in India, particularly in areas with a high electrification and reasonable duration of electricity supply (Dugoua et al., 2018). The use of the raw data may, however, result in bias in time-series analysis due to variations in satellite orbit and instrument quality during the period 1992–2012. To address this, we use a calibrated, consistent time-series of the data developed by Zhang et al. (2016).

The dataset on policy implementation was obtained from the Government of Gujarat through the Right to Information (RTI) Act, 2005. This dataset contains the exact date of commissioning of each JGY feeder at the village level, where a village is uniquely identified by a combination of the village name, the block name, and the district name. As per this dataset, JGY feeders were commissioned in 4093 villages in the state during 2003–08. We match this information with the data on nighttime lights using a village level spatial map of Gujarat based on the Census of India 2001 Meiyappan et al. (2018). The spatial map consists of towns and cities too and, henceforth, we use the term village to refer to these as well. After harmonizing the names of blocks and districts between the two datasets, only 183 out of 4093 villages in the JGY dataset are unmatched.

We obtained data on weather from the ERA5-Land dataset of the European Monitoring Centre for Medium-Range Weather Forecasts (ECMWF). The ERA5-Land dataset provides gridded information on weather at a high spatial resolution (approximately 9 km × 9 km) and temporal resolution (hourly and monthly) based on climate reanalysis (Muñoz-Sabater et al., 2021). We extracted monthly information at the village level by computing the average values within the spatial boundaries of each village using the geospatial data abstraction library (GDAL) in Python. Further, we collected data on water table depth from the Water Resources Information System of India (WRIS). This dataset records the seasonal water table depth in the state along with the location of each monitored well. We use the QGIS software to identify the five nearest wells for each village and compute their mean seasonal water depth to estimate the water table at the village level.

4.2. Empirical strategy

According to our dataset, the JGY feeders were commissioned in approximately 4000 villages in the state of Gujarat. This implementation occurred over the period 2003 and 2008 (Fig. 1). The share of villages covered by the scheme increased from less than 1% in 2003 to 7% in 2004 18% in 2005 and 21% by 2008. We exploited the variation in the rollout of the JGY scheme to inform our empirical strategy. Specifically, we used the generalized difference-in-differences technique to estimate the effect of the policy on electricity consumption at the village level in Gujarat.

To check whether villages with policy implementation were systematically different from those without, we examine the luminosity trends by segregation (Fig. 2). We observe that villages that were included in policy implementation had higher night-time luminosity than villages that were not. This indicates that JGY villages and non-JGY villages are likely to be different on characteristics that explain night-time luminosity as well (Table A3). However, the trends in the two groups are largely parallel over more than a decade preceding policy implementation. This suggests that our empirical strategy is likely to be valid for this study. In addition, our empirical specification – described in section 4.3 – includes an annual trend at the village or the administrative block level (akin to a generalized difference-in-differences specification) in order to control for any potential effect that may be driven by differential trends of luminosity as well as other characteristics between JGY and non-JGY villages.

We use three forms of the policy variable depending on our sample and analysis (see section 4.3). First, we use a binary variable to indicate whether policy has been implemented in a specific village. Second, we use share of villages in the block in which policy has been implemented as there might be positive externalities from policy implementation in nearby villages (especially if one feeder covered more than one village in the block). Third, we include a variable indicating the number of days since policy was implemented as the effect of the policy might have varied (i.e., increased) over time.

We control for weather and (in a robustness check) water table depth. Although socioeconomic characteristics at the village level during our study period are likely to influence electricity consumption, we are unable to control for these due to the lack of granular, longitudinal data. Also, we do not incorporate the effect of electricity tariff on consumption as we do not have access to region-wise data on these. We do, however, include village fixed effect to control for time invariant characteristics at the village level. Further, we include year fixed effect to control for ad hoc factors that might influence night-time luminosity in a given time period in the entire state. In addition, we control for village or block specific trend to control for the effect of time-varying characteristics at a highly localized level that predate policy implementation.

We interpret the coefficient for the policy variable as the difference-in-differences (DD) estimate for the effect of the policy on night-time

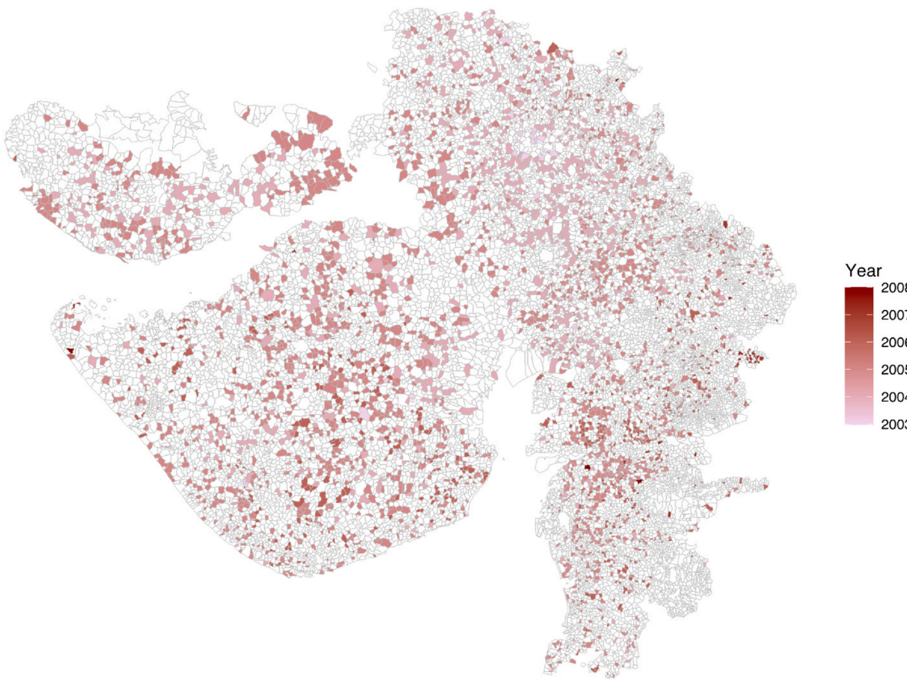

Fig. 1. Village-wise rollout of the Jyotigram Yojana in Gujarat, India.

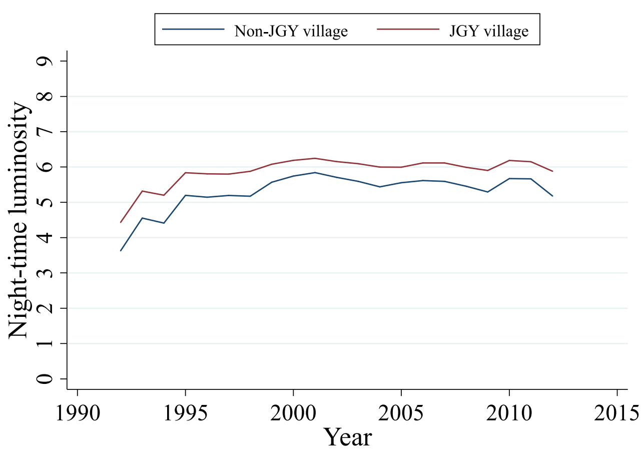

Fig. 2. Trends in natural log of night-time luminosity in villages with and without the Jyotigram Yojana (JGY).

luminosity, with night-time luminosity being a proxy for electricity consumption. We expect policy implementation to be associated with an increase in night-time luminosity as the policy involved segregating the agricultural feeder from the regular feeder in order to provide uninterrupted electricity on the regular feeder and to curtail the electricity supply on the agricultural feeder to 6–8 h a day.

4.3. The model

Not every village in the Census of India 2001 was covered by the scheme. This might be either due to the characteristics of electricity consumption in the village (for example, limited use of electricity for agriculture) or because one feeder covered more than one village. We cannot account for the latter as we do not have comprehensive data on feeder-village mapping for the entire state. Therefore, we construct three different samples for the analysis. First, the complete sample includes all villages in the state of Gujarat as per the Census of India 2001. Meanwhile, the JGY sample includes only the villages in our policy implementation dataset that match with the Census of India 2001. Finally, the non-JGY sample includes the villages in the Census of India 2001 that are not present in our policy implementation dataset. We analyze the effect of the policy on electricity consumption for the complete sample as well as for JGY and non-JGY sample separately, but using different independent variables.

4.3.1. Complete sample

For the complete sample, the main specification we use is shown in the equation below:

$$\ln(luminosity)_{i,b,y} = \alpha + \beta_1 segregated_{i,b,y} + \beta_2 share\_segregation_{b,y} + \boldsymbol{\gamma}\, \boldsymbol{weather}_{i,b,y} + \delta\, zero\_luminosity_{i,b,y} + \eta_{i,b} + \theta_y + \rho_b ever\_segregated_{i,b} * y + \varepsilon_{i,b,y}$$

where,

$\ln(luminosity)_{i,b,y}$ is the natural log of the nighttime luminosity (measured in Digital Number or DN) of the village i in the administrative block b in the year y,

$segregated_{i,b,y}$ is a binary variable with the value 1 if a JGY feeder was commissioned in the village i in the year y,

$share\_segregation_{b,y}$ is the fraction of the villages in the block b where a JGY feeder has been commissioned by year y,

$\boldsymbol{weather}_{i,b,y}$ is a vector consisting of the mean temperature (in Kelvin), the surface pressure (in Pascal), and the total precipitation (in meter),

$zero\_luminosity_{i,b,y}$ is a flag to indicate whether the recorded luminosity for the village in this time period is zero (see Dugoua et al., 2018),

ρ_b is the annual trend for all villages within an administrative block where a JGY feeder was ever commissioned (i.e., $ever\_segregated_{i,b} = 1$),

$\eta_{i,b}$ is the village fixed effect,

θ_y is the year fixed effect, and

$\varepsilon_{i,b,y}$ is the error term.

Note that the variable indicating the number of days since policy was implemented is not relevant for this sample as it would not have a valid value for the villages that were absent in our policy implementation dataset.

4.3.2. Villages in which a JGY feeder was ever commissioned

For the JGY sample, the specification we use is shown in the equation below:

$$\ln(luminosity)_{i,b,y} = \alpha + \beta_1 segregated_{i,b,y} + \beta_2 days\_since\_segregation_{i,b,y} + \beta_3 share\_segregation_{b,y} + \boldsymbol{\gamma}\ \boldsymbol{weather}_{i,b,y} + \delta\ zero\_luminosity_{i,b,y} + \eta_{i,b} + \theta_y + \zeta_{i,b} * y + \varepsilon_{i,b,y}$$

where,

$\ln(luminosity)_{i,b,y}$ is the natural log of the night-time luminosity (measured in Digital Number or DN) of the village i in the administrative block b in the year y,
$segregated_{i,b,y}$ is a binary variable with the value 1 if a JGY feeder was commissioned in the village i in the year y, and
$days\_since\_segregation_{i,b,y}$ is the number of days since the commissioning of a JGY feeder in village i in the block b until the end of the year y.
$share\_segregation_{b,y}$ is the fraction of the villages in the block b where a JGY feeder has been commissioned by year y,
$\boldsymbol{weather}_{i,b,y}$ is a vector consisting of the mean temperature (in Kelvin), the surface pressure (in Pascal), and the total precipitation (in meter),
$zero\_luminosity_{i,b,y}$ is a flag to indicate whether the recorded luminosity for the village in this time period is zero,
$\eta_{i,b}$ is the village fixed effect,
θ_y is the year fixed effect,
$\zeta_{i,b}$ is the village specific annual trend, and
$\varepsilon_{i,b,y}$ is the error term.

4.3.3. Villages in which a JGY feeder was never commissioned

For the non-JGY sample, the specification we use is shown in the equation below:

$$\ln(luminosity)_{i,b,y} = \alpha + \beta_1 share\_segregation_{b,y} + \boldsymbol{\gamma}\ \boldsymbol{weather}_{i,b,y} + \delta\ zero\_luminosity_{i,b,y} + \eta_{i,b} + \theta_y + \lambda_b * y + \varepsilon_{i,b,y}$$

where,

$\ln(luminosity)_{i,b,y}$ is the natural log of the nighttime luminosity (measured in Digital Number or DN) of the village i in the administrative block b in the year y, and
$share\_segregation_{b,y}$ is the fraction of the villages in the block b where a JGY feeder has been commissioned by year y.
$\boldsymbol{weather}_{i,b,y}$ is a vector consisting of the mean temperature (in Kelvin), the surface pressure (in Pascal), and the total precipitation (in meter),
$zero\_luminosity_{i,b,y}$ is a flag to indicate whether the recorded luminosity for the village in this time period is zero,
$\eta_{i,b}$ is the village fixed effect,
θ_y is the year fixed effect,
λ_b is the block specific annual trend, and
$\varepsilon_{i,b,y}$ is the error term.

Note that the variables indicating whether a JGY feeder was commissioned in the village (i.e., $segregated_{i,b,y}$) the number of days since policy was implemented ($days\_since\_segregation_{i,b,y}$) are not relevant for this sample as the former will have the value 0 for all villages in this sample while the latter would not have a valid value for the villages in this sample.

4.3.4. District-wise analysis

For each sample, we also examine policy effect by district to check whether the impact of the policy varied geographically. For this, we use the models presented above for each district and then run a metanalysis to compare the estimates across districts.

In addition, we conduct several robustness checks for each sample. For the full sample, we check for variation in the study period (1992–2012 and 2001–11), variation in form of dependent variable (linear and log), sensitivity to exclusion/inclusion of share of segregation in the administrative block, and sensitivity to trend variable (block specific trend and district specific trend). For the JGY sample, we conduct robustness checks on the specification of days since policy implementation (no variable, quadratic, and spline), variation in control variables (exclusion/inclusion of weather and water table depth), variation in study period (1992–2012 and 2001–11), variation in trend variable (village specific trend, block specific trend, and district specific trend), variation in the form of the dependent variable (linear and log), and variation based on rural-urban status.

5. Results

The summary statistics for the main variables are shown in Table 1. In the complete sample, the night-time luminosity varied between 0 and 6300 DN, with mean of 581.43 DN (SD: 605.82). The variation was high due to the fat tail of the distribution. We used the natural log of luminosity as the distribution of this variable approximates the normal curve better. Also, it is a slightly better proxy for electricity consumption than the linear form of the variable (Dugoua et al., 2018).

During the study period, the average luminosity has been inconsistent. In 1992, the average ln(luminosity) in the sample was 3.80. It increased rapidly to over 4.5 in 1994 and over 5.0 in 1995. However, since then it has varied between 5 and 6, reaching a high of 5.9 in 2001, but falling to 5.3 in 2012. The spatial distribution of luminosity is shown in Fig. 3. This shows that, prima facie, there was relatively little detectable change in luminosity following the scheme.

5.1. Complete sample

The main result from the regression on the complete sample is shown in Table 2. In the complete sample, we observe that, ceteris paribus, policy implementation in a given village (β: −0.005; 95% CI: −0.018, 0.007) or an increase in the share of villages in the administrative block covered by the policy (β: −0.031; 95% CI: −0.072, 0.009) had no statistically significant effect on night-time luminosity in the village. Among the other variables, an increase in temperature was associated with an increase in night-time luminosity while an increase in precipitation was associated with a decrease in night-time luminosity.

5.2. Villages in which a JGY feeder was ever commissioned

In the JGY sample, we observe that policy implementation itself was

Table 1
Descriptive statistics for the complete sample.

	Mean	SD	Minimum	Maximum
Luminosity (Digital Number or DN)	581.43	605.82	0.00	6300.00
Ln (luminosity)	5.42	2.25	0.00	8.75
Segregated (1 = yes)	0.08	0.27	0.00	1.00
Share segregated (%)	0.08	0.12	0.00	0.53
Pressure (Pascal)	99,540	1054	92,219	100,972
Temperature (Kelvin)	299.73	0.68	295.77	302.30
Precipitation (meter)	0.00	0.00	0.00	0.01
N				392,322

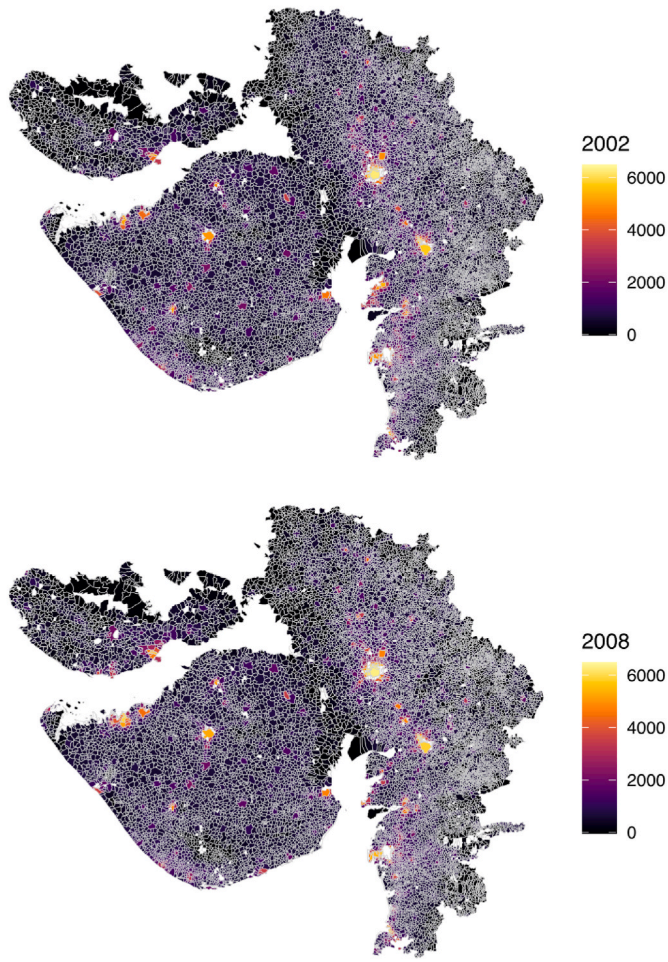

Fig. 3. Night-time luminosity before and after JGY implementation.

Table 2
The regression of night-time luminosity on policy implementation in the complete sample, the JGY sample, and the non-JGY sample.

	Complete sample	JGY Sample	Non-JGY Sample
Segregated	−0.005	−0.039***	–
	[−0.018,0.007]	[−0.056,−0.022]	
Share segregated	−0.031	0.261***	−0.114***
	[−0.072,0.009]	[0.182,0.339]	[−0.161,−0.066]
Days since segregation	–	0.000	–
		[−0.000,0.000]	
Pressure	−0.000	0.000	−0.000
	[−0.000,0.000]	[−0.000,0.001]	[−0.000,0.000]
Temperature	0.032***	0.007	0.036***
	[0.023,0.041]	[−0.011,0.024]	[0.026,0.047]
Precipitation	−7.586***	−4.331	−8.649***
	[−10.357,−4.816]	[−9.853,1.191]	[−11.843,−5.456]
Zero luminosity	−5.122***	−5.070***	−5.123***
	[−5.139,−5.104]	[−5.117,−5.023]	[−5.142,−5.104]
Adjusted R^2	0.919	0.917	0.922
N	3.90e+05	81,809	3.08e+05

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, year fixed effect, and an annual trend for all villages within an administrative block where a JGY feeder was ever commissioned. The standard errors are clustered at the village level.

associated with a slight reduction in night-time luminosity. The coefficient for this variable is −0.039 (95% CI: −0.056, −0.022), indicating that – after controlling for the weather, village fixed effect, year fixed effect, and the village specific time trend – the night time luminosity of the village decreased by approximately 3.9%, on average, after policy implementation. This is slightly surprising as policy implementation was expected to increase night-time luminosity (relative to the baseline trend). However, we observe that share of JGY in the administrative block is associated with an increase in night-time luminosity (β: 0.261; 95% CI: 0.182, 0.339), indicating that a 10 percentage point increase in the share of villages with feeder segregation within the block is associated with approximately 2.6% increase in night-time luminosity in a JGY village. This suggests that while policy implementation in a village may have led to some reduction in night-time luminosity, the net effect was positive for villages in blocks with more than approximately 15% villages covered directly by the policy.

Further, we observe that days since commissioning did not have a significant effect on night-time luminosity. The spline specification indicates that the effect over time might not have been linear but rather quadratic: the initial effect (for the first year or so) of the policy on night-time luminosity was negative, but there after it resulted in some improvement in night-time luminosity (Table A6).

5.3. Villages in which a JGY feeder was never commissioned

We observe that in the non-JGY sample the share of villages in the block under JGY is associated with a reduction in night-time luminosity. The estimated coefficient is −0.114 (95% CI: −0.161, −0.066), indicating that a 10 percentage point increase in the share of villages with feeder segregation within the block is associated with approximately 1.14% decrease in night-time luminosity in a non-JGY village within that block. This suggests that the policy might have had a slight redistributive effect. As the policy was rolled out, JGY villages in blocks with high share of policy implementation witnessed a small increase in night-time luminosity while non-JGY villages in the same blocks witnessed a small reduction in night-time luminosity. This would also explain why the overall effect was not statistically significant.

The robustness checks indicate that the results for the policy implementation and days since policy variables are more sensitive to the specification while those for the share of villages in the block are fairly robust.

5.4. District-wise analysis

District-wise analysis for the full sample is shown in Fig. 4. The panel on the left corresponds to the policy implementation variable while the panel on the right corresponds to the share of JGY in the administrative block. We observe that in the following districts the policy had a positive effect on night-time luminosity when considering the implementation effect and the effect of rollout in the administrative block: Bharuch (largely) and Vadodara. In addition, in Ahmedabad and Gandhinagar policy rollout had a positive effect in the administrative block, but not necessarily in the village. On the other hand, villages in Amreli, Banaskantha, Jamnagar, Narmada, Panchmahals, and Surat experienced a reduction in night-time luminosity as the share of villages covered under JGY at the block level increased. In Panchmahals, especially, this was accompanied with a negative effect of policy implementation in the villages itself.

While we do not have granular, household level or longitudinal village level data to unpack the mechanisms driving this outcome, there are three plausible explanations for the heterogeneous effect of the policy. First, we observe that the districts with an increase in night-time luminosity had – on average – a higher share of segregated villages than the districts with a decrease in night-time luminosity (Fig. 5). As initially the scheme required co-financing by the local government, it is plausible that districts that were richer or were more likely to benefit from it were

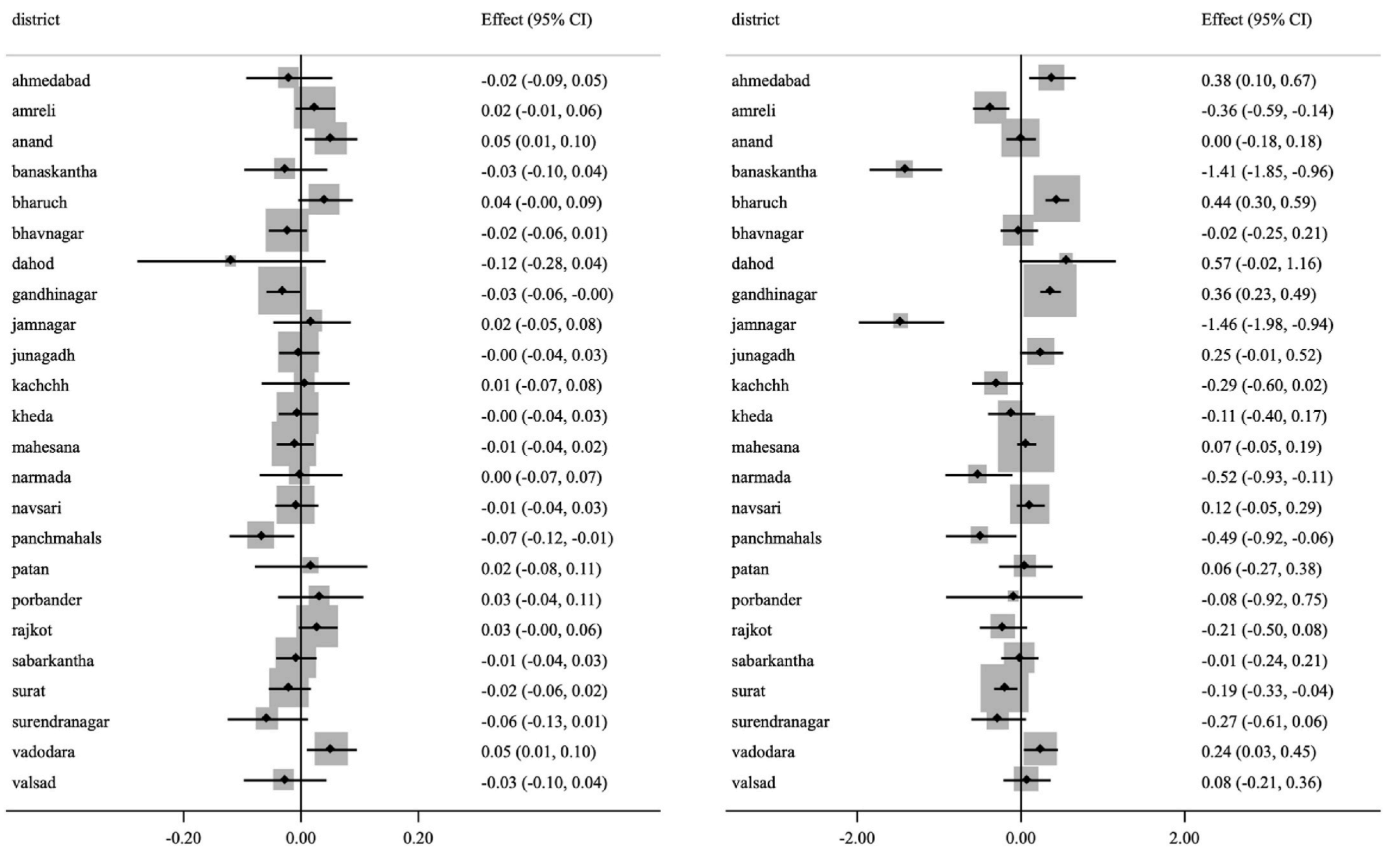

Fig. 4. District-wise assessment of policy implementation in the complete sample. The panel on the left indicates the effect of feeder segregation within a village on the night-time luminosity of that village while the panel on the right indicates the effect of the share of villages with feeder segregation within the block of a village on the night-time luminosity of that village.

quicker at adopting and implementing the policy (Chindarkar, 2017). It is plausible that a higher share of segregation may have resulted in changes in electricity supply, for example, due to changes in the behavior of electricity distribution utilities, which were also simultaneously undergoing administrative transformation (Chindarkar, 2017).

Second, we note that districts with an increase in night-time luminosity had – on average – larger villages, towns, or cities than the districts with a decrease in night-time luminosity. It is, therefore, plausible that the district-level heterogeneities may have been driven by the differential impact of the policy on non-JGY villages, which were adversely affected, in comparison to non-JGY towns or cities, for which the policy did not have a statistically significant effect (Table A14). Such a difference could result from the influence of the policy on both electricity supply and electricity demand.

Third, JGY implementation may have induced inter-district migration, with people moving to villages with more opportunities due to increased electricity access. Shah and Verma (2008), for example, provide qualitative evidence of how the availability of electricity resulted in a boost to the non-farm economy in certain villages, with the setting up of small ancillary units such as flour mills, oil mills, tailoring, and welding. This could have reduced electricity consumption in villages in the emigrating district while increasing electricity consumption in villages in the immigrating district.

6. Conclusion and policy implications

In this study, we evaluated the effect of the JGY on electricity consumption in Gujarat, India, using night-time luminosity. We find that, in the complete sample, the effect of policy implementation on night-time luminosity was not statistically significant (β: −0.005; 95% CI: −0.018, 0.007), implying that policy implementation did not result in an increase in electricity consumption in the state. In the subset of villages that are documented to have commissioned a separate electricity feeder for agriculture (i.e., the JGY sample), we find that while policy implementation in a village was associated with a reduction in electricity consumption (in that village), an increase in the share of feeder segregation in the administrative block containing the village was associated with an increase in electricity consumption (in that village). In contrast, in the non-JGY sample (i.e., villages where a JGY feeder was never commissioned), an increase in the share of feeder segregation in the administrative block containing the village was associated with a reduction in electricity consumption (in that village).

The results of the state-wide analysis point to heterogeneities in the effect of the policy. This was also seen in our district-wise analysis. Specifically, we find that the JGY rollout was associated with an increase in night-time luminosity in districts such as Ahmedabad, Bharuch, Gandhinagar, and Vadodara, indicating that their electricity consumption likely increased due to policy implementation. On the other hand, the JGY rollout was associated with a decrease in night-time luminosity in some districts – for example, Amreli, Banaskantha, Jamnagar, Narmada, Panchmahals, and Surat, which seemed to have a lower share of feeder segregation and a less urbanized composition than the former – suggesting that policy implementation might have led to a reduction in electricity consumption there. These heterogeneities could have resulted from local governments that expected to benefit from the policy and/or were able to meet the co-financing requirement adopting or implementing it sooner, a change in electricity supply due to the behavior of electricity distribution utilities, the varied effect of the policy on rural versus urban areas, and/or inter-district migration caused or catalyzed by the policy.

Taken together, the state-wide and the district-wise analysis indicate that rather than uniformly increasing electricity consumption

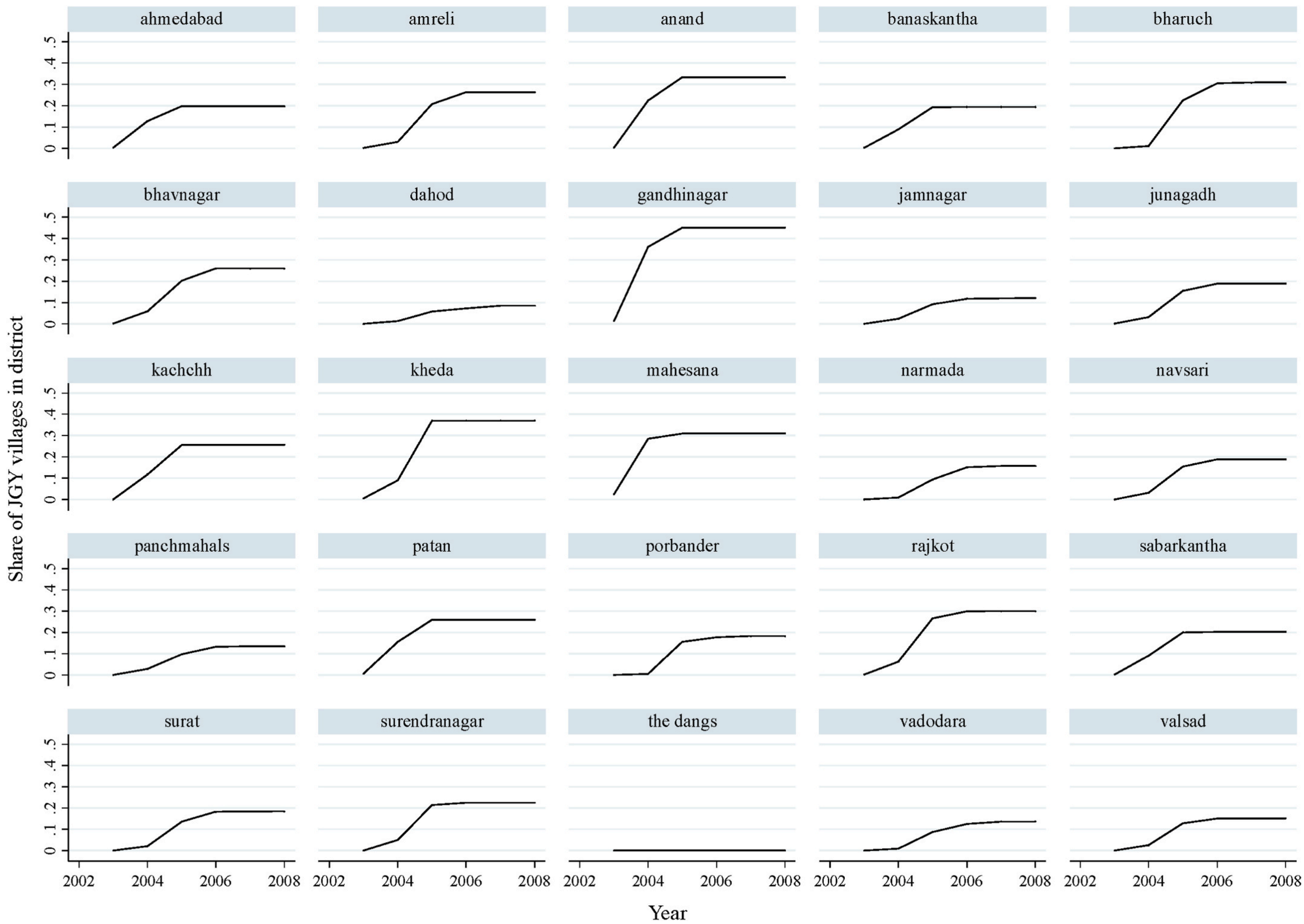

Fig. 5. District-wise rollout of the Jyotigram Yoajana

throughout the state, the JGY might have had a re-distributive effect. In so far as this reduction in electricity consumption was related to curtailing inefficient or wasteful irrigation, for example, this is not a problem. However, a key premise of the policy was that curtailment of electricity for agriculture would allow the state to provide reliable, round-the-clock electricity to rural Gujarat, presumably increasing electricity access (and, thereby, electricity consumption). We do not find evidence to suggest that the increase in electricity consumption was, in fact, realized.

To the best of our knowledge, no other study has systematically assessed the effect of the JGY on electricity access or electricity consumption. In a broader 'quick assessment' of the policy in 55 villages across 10 districts in the state, Shah et al. (2008) found that the scheme – along with other policies adopted by the government – had been successful in enhancing the financial viability of the state electricity board, managing the electricity subsidy for agriculture, potentially reducing groundwater use, improving the quality of life in rural Gujarat through reliable, round-the-clock electricity supply, and providing a strong impetus to the non-farm economy in the state. However, some farmers complained that the electricity supply was still inadequate and unreliable, while marginal farmers, tenants, and landless farm laborers – who were reliant on the groundwater market in the state – were adversely affected by the policy.

Subsequent work examining other effects – such as on farm incomes and groundwater – has indicated that the policy might not have had the desired effects. A study by Chindarkar et al. (2020) found that JGY increased per acre irrigation costs for farmers in the short-to-medium term and consequently resulted in a decrease in the per acre net farm income and observed heterogeneity based on district-level share of JGY. In another study, Chindarkar and Grafton (2019) found that JGY is associated with greater, not less, groundwater depletion (as premised by the policy) and also observed some heterogeneity based on district-level share of JGY. We find that the effect of the policy on electricity consumption might have, similarly, been heterogeneous.

What might explain the discrepancy between the perceived benefit of the policy in improving electricity supply and its limited effect on electricity consumption? It could be that night-time luminosity is a poor proxy for electricity access and suffers from significant measurement error. However, as noted earlier, Dugoua et al. (2018) have found a strong correlation between night-time luminosity measured by the DMSP and rural electrification as well as average hours of electricity supply in India. Thus, it is likely that the findings are not an artefact of our research design.

Another possibility is that both policy design and policy evaluation in the case of the JGY scheme has focused primarily, if not only, on reliable, round-the-clock electricity supply. In contrast, affordability is a key dimension of electricity access and electricity consumption. Chindarkar and Goyal (2019), for example, have found the household electricity tariff in Gujarat to be amongst the highest in India and to exhibit little variation by income category. Further, they have argued for a more evidence-informed electricity tariff design that considers the significant heterogeneities in price elasticity of electricity consumption in India. It might, therefore, be the case that the lack of emphasis on electricity access as a whole, rather than electricity supply, has resulted in the weak relationship between policy implementation and electricity consumption.

If so, our study underscores the drawback of emphasizing reliable, round-the-clock electricity supply as the sole remedy for lack of universal access. In contrast, a better understanding of electricity demand characteristics might be essential for effective policy design. Further, electricity tariff design might require special attention in order to ensure affordability for every segment of society. While we could not incorporate the cost of electricity in our analysis due to lack of village- or district-level data on electricity tariff during the time-period of our study, future research could examine whether and how electricity pricing influenced electricity consumption in the state.

As the DDUGJY – which has been rolled out at the national level – is similar in its design to the JGY, a mid-term evaluation of that policy can shed light on whether it is in fact increasing electricity access or electricity consumption in a desired manner. Rather than relying on night-time luminosity – as we had to do due to lack of granular, temporal data – such an evaluation could be based on feeder-level data on electricity consumption. This would create a better understanding of the short- and medium-term effects of the policy, and yield insights that help improve its design.

While we focused on the effect of a specific policy on electricity consumption in India, our study has implications for policy designing that are relevant to other low- and middle-income countries that strive to achieve universal access for affordable and clean energy. In addition, our use of night-time lights data for this study suggests that satellite imagery offers opportunities for monitoring progress towards the sustainable development goal on energy (SDG 7), specifically, and evaluating public policy, broadly. Although due to the time-period of our study, we were constrained to use (older) data from the DMSP, the (newer) data from the VIIRS offers better accuracy and a more fine-grained resolution. Future research should, therefore, consider combining such data with rich administrative data for public policy analysis and evaluation.

CRediT authorship contribution statement

Namrata Chindarkar: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **Nihit Goyal:** Conceptualization, Data curation, Methodology, Formal analysis, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

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

Data availability

The data that has been used is confidential.

Appendix

Table A1
Descriptive statistics for the non-JGY sample

	Mean	SD	Minimum	Maximum
Luminosity	565.26	620.96	0.00	6300.00
Ln (luminosity)	5.30	2.34	0.00	8.75
Segregated	0.00	0.00	0.00	0.00
Share segregated	0.08	0.11	0.00	0.53
Pressure	99,487	1104	92,219	100,972
Temperature	299.70	0.69	295.77	302.30
Precipitation	0.00	0.00	0.00	0.01
N				310,296

Table A2
Descriptive statistics for the JGY sample

	Mean	SD	Minimum	Maximum
Luminosity	642.59	540.39	0.00	6300.00
Ln (luminosity)	5.87	1.78	0.00	8.75
Segregated	0.39	0.49	0.00	1.00
Share segregated	0.10	0.14	0.00	0.53
Pressure	99,741	811	95,282	100,930
Temperature	299.83	0.62	296.66	302.25
Precipitation	0.00	0.00	0.00	0.01
N				82,026

Table A3
The regression of whether a village is a JGY village based on village-level characteristics in 2001.

	(1)
ln(night-time luminosity)	0.0125*** [0.0091,0.0159]
Population ('000 people)	0.0070** [0.0026,0.0114]
Population, scheduled tribes ('000 people)	−0.0351*** [−0.0422,−0.0281]
Expenditure (million INR)	0.0209*** [0.0185,0.0233]

(*continued on next page*)

Table A3 (*continued*)

	(1)
Irrigated area ('000 ha)	0.1010*** [0.0697,0.1323]
Electricity for all purposes (0/1)	0.0794*** [0.0599,0.0989]
Electricity for agricultural use (0/1)	0.0557*** [0.0274,0.0841]
N	18,022

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

Note: The unit of observation is the village (or town or city). Regression estimates are presented with 95% confidence intervals in the brackets below. The standard errors are robust.

Table A4
Variation in the independent variable in the regression of night-time luminosity on policy implementation in the complete sample.

	(1)	(2)	(3)
Segregated	−0.008 [−0.020,0.004]	–	−0.005 [−0.018,0.007]
Share segregated	–	−0.037 [−0.076,0.002]	−0.031 [−0.072,0.009]
Pressure	−0.000 [−0.000,0.000]	−0.000 [−0.000,0.000]	−0.000 [−0.000,0.000]
Temperature	0.033*** [0.024,0.042]	0.032*** [0.023,0.041]	0.032*** [0.023,0.041]
Precipitation	−7.494*** [−10.269,−4.719]	−7.586*** [−10.356,−4.816]	−7.586*** [−10.357,−4.816]
Zero luminosity	−5.121*** [−5.139,−5.104]	−5.122*** [−5.139,−5.104]	−5.122*** [−5.139,−5.104]
Adjusted R^2	0.919	0.919	0.919
N	3.90e+05	3.90e+05	3.90e+05

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

Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, the year fixed effect, and an annual trend for all villages within an administrative block where a JGY feeder was ever commissioned. The standard errors are clustered at the village level.

Table A5
Variation in the specification in the regression of night-time luminosity on policy implementation in the complete sample.

	(1)	(2)	(3)	(4)
Segregated	−0.005 [−0.018,0.007]	0.002 [−0.007,0.011]	0.002 [−0.007,0.011]	−0.006 [−0.019,0.006]
Share segregated	−0.031 [−0.072,0.009]	−0.039 [−0.079,0.001]	−0.023 [−0.065,0.019]	−0.052* [−0.093,−0.011]
Pressure	−0.000 [−0.000,0.000]	−0.000 [−0.000,0.000]	−0.000*** [−0.000,−0.000]	–
Temperature	0.032*** [0.023,0.041]	0.032*** [0.023,0.041]	0.042*** [0.033,0.050]	–
Precipitation	−7.586*** [−10.357,−4.816]	−7.567*** [−10.337,−4.798]	−7.890*** [−10.681,−5.099]	–
Zero luminosity	−5.122*** [−5.139,−5.104]	−5.122*** [−5.139,−5.104]	−5.155*** [−5.172,−5.138]	−5.123*** [−5.141,−5.106]
Adjusted R^2	0.919	0.919	0.916	0.919
N	3.90e+05	3.90e+05	3.90e+05	3.92e+05

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

Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect and the year fixed effect. The standard errors are clustered at the village level. Column (1) is based on a specification including an annual trend for all villages within an administrative block where a JGY feeder was ever commissioned. Column (2) is based on a specification including an annual trend for each administrative block. Column (3) is based on a specification including an annual trend for each district. Column (4) is based on a specification including an annual trend for all villages within an administrative block where a JGY feeder was ever commissioned, but without control variables for the weather.

Table A6
Variation in the time-period under investigation and the functional form of the dependent variable in the regression of night-time luminosity on policy implementation in the complete sample.

	(1)	(2)	(3)
Segregated	−0.005 [−0.018,0.007]	0.004 [−0.006,0.015]	−4.783 [−10.673,1.108]
Share segregated	−0.031 [−0.072,0.009]	−0.001 [−0.035,0.033]	−138.510*** [−159.090,−117.930]
Pressure	−0.000 [−0.000,0.000]	−0.001** [−0.001,−0.000]	0.107*** [0.059,0.156]
Temperature	0.032*** [0.023,0.041]	0.036*** [0.022,0.050]	27.450*** [23.955,30.945]
Precipitation	−7.586*** [−10.357,−4.816]	0.861 [−2.268,3.989]	−425.619 [−1486.617,635.378]
Zero luminosity	−5.122*** [−5.139,−5.104]	−5.228*** [−5.252,−5.205]	−206.927*** [−210.571,−203.283]
Adjusted R^2	0.919	0.913	0.322
N	3.90e+05	2.23e+05	3.90e+05

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

Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, year fixed effect, and an annual trend for all villages within an administrative block where a JGY feeder was ever commissioned. The standard errors are clustered at the village level. Column (1) is based on a specification including the natural log of night-time luminosity for the entire study period (the main specification of this study). Column (2) is based on a specification including the natural log of night-time luminosity for the time period 2000–12 (both exclusive). Column (3) is based on a specification including the level of night-time luminosity.

Table A7
Variation in the independent variable in the regression of night-time luminosity on policy implementation in the JGY sample.

	(1)	(2)	(3)	(4)	(5)
Segregated	−0.012 [−0.026,0.003]	−0.040*** [−0.057,−0.023]	−0.039*** [−0.056,−0.022]	−0.007 [−0.024,0.009]	0.007 [−0.011,0.025]
Share segregated	–	0.264*** [0.186,0.342]	0.261*** [0.182,0.339]	0.279*** [0.200,0.358]	0.284*** [0.205,0.363]
Days since segregation	–	–	0.000 [−0.000,0.000]	−0.000** [−0.000,−0.000]	–
Days since segregation^2	–	–	–	0.000*** [0.000,0.000]	–
Days since segregation, <410	–	–	–	–	−0.000*** [−0.000,−0.000]
Days since segregation, 410–1743	–	–	–	–	0.000 [−0.000,0.000]
Days since segregation, >1743	–	–	–	–	0.000*** [0.000,0.000]
Pressure	0.000 [−0.000,0.001]	0.000 [−0.000,0.001]	0.000 [−0.000,0.001]	0.000 [−0.000,0.000]	0.000 [−0.000,0.000]
Temperature	0.003 [−0.015,0.021]	0.006 [−0.012,0.024]	0.007 [−0.011,0.024]	0.009 [−0.009,0.026]	0.006 [−0.011,0.024]
Precipitation	−4.627 [−10.150,0.896]	−4.330 [−9.851,1.191]	−4.331 [−9.853,1.191]	−4.857 [−10.393,0.679]	−5.347 [−10.912,0.219]
Zero luminosity	−5.072*** [−5.119,−5.025]	−5.070*** [−5.117,−5.024]	−5.070*** [−5.117,−5.023]	−5.066*** [−5.113,−5.020]	−5.067*** [−5.113,−5.020]
Adjusted R^2	0.917	0.917	0.917	0.917	0.917
N	81,809	81,809	81,809	81,809	81,809

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, the year fixed effect, and a village-specific annual time trend. The standard errors are clustered at the village level.

Table A8
Variation in controlling variables in the regression of night-time luminosity on policy implementation in the JGY sample.

	(1)	(2)	(3)
Segregated	−0.039*** [−0.056,−0.022]	−0.038*** [−0.055,−0.021]	−0.014 [−0.031,0.002]
Share segregated	0.261*** [0.182,0.339]	0.264*** [0.185,0.342]	0.205*** [0.132,0.277]
Days since segregation	0.000 [−0.000,0.000]	0.000 [−0.000,0.000]	−0.000** [−0.000,−0.000]
Water table	–	–	−0.000 [−0.000,0.000]
Pressure	0.000 [−0.000,0.001]	–	0.000* [0.000,0.001]
Temperature	0.007 [−0.011,0.024]	–	0.043*** [0.026,0.059]
Precipitation	−4.331 [−9.853,1.191]	–	−9.562** [−15.415,−3.709]
Zero luminosity	−5.070*** [−5.117,−5.023]	−5.070*** [−5.116,−5.023]	−5.178*** [−5.241,−5.115]
Adjusted R^2	0.917	0.917	0.909
N	81,809	82,026	60,013

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, the year fixed effect, and a village-specific annual time trend. The standard errors are clustered at the village level. Column (1) is based on a specification controlling for weather. Column (2) is based on a specification without any control for weather. Column (3) is based on a specification for weather as well as the pre-monsoon water table depth.

Table A9
Variation in time-period under investigation in the regression of night-time luminosity on policy implementation in the JGY sample.

	(1)	(2)
Segregated	−0.039*** [−0.056,−0.022]	−0.012 [−0.027,0.004]
Share segregated	0.261*** [0.182,0.339]	0.179*** [0.110,0.248]
Days since segregation	0.000 [−0.000,0.000]	−0.000*** [−0.000,−0.000]
Pressure	0.000 [−0.000,0.001]	−0.002** [−0.003,−0.001]
Temperature	0.007 [−0.011,0.024]	−0.022 [−0.056,0.012]
Precipitation	−4.331 [−9.853,1.191]	−3.569 [−9.870,2.732]
Zero luminosity	−5.070*** [−5.117,−5.023]	−5.124*** [−5.202,−5.047]
Adjusted R^2	0.917	0.896
N	81,809	42,852

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, the year fixed effect, and a village-specific annual time trend. The standard errors are clustered at the village level. Column (1) is based on the sample for the time-period 1992–2012 while Column (2) is based on the sample for the time-period 2000–11.

Table A10
Variation in time trend in the regression of night-time luminosity on policy implementation in the JGY sample.

	(1)	(2)	(3)
Segregated	−0.039*** [−0.056,−0.022]	−0.043*** [−0.060,−0.026]	−0.029** [−0.046,−0.012]
Share segregated	0.261*** [0.182,0.339]	0.279*** [0.202,0.356]	0.139** [0.052,0.226]
Days since segregation	0.000 [−0.000,0.000]	−0.000*** [−0.000,−0.000]	−0.000*** [−0.000,−0.000]
Pressure	0.000 [−0.000,0.001]	0.000 [−0.000,0.000]	−0.000* [−0.001,−0.000]
Temperature	0.007 [−0.011,0.024]	0.006 [−0.012,0.023]	0.011 [−0.007,0.028]
Precipitation	−4.331 [−9.853,1.191]	−3.675 [−9.086,1.737]	−4.622 [−10.020,0.776]
Zero luminosity	−5.070*** [−5.117,−5.023]	−5.112*** [−5.157,−5.068]	−5.137*** [−5.182,−5.093]
Adjusted R^2	0.917	0.906	0.902
N	81,809	81,809	81,809

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect and the year fixed effect. The standard errors are clustered at the village level. Column (1) is based on a specification including a village-specific annual trend, while Column (2) is based on a specification including a block-specific annual trend and Column (3) is based on a specification including a district-specific time trend.

Table A11
Variation in the functional form of the dependent variable in the regression of night-time luminosity on policy implementation in the JGY sample.

	(1)	(2)
Segregated	−0.039*** [−0.056,−0.022]	−5.713 [−13.875,2.450]
Share segregated	0.261*** [0.182,0.339]	−29.424 [−72.482,13.634]
Days since segregation	0.000 [−0.000,0.000]	−0.040** [−0.067,-0.012]
Pressure	0.000 [−0.000,0.001]	0.175** [0.070,0.279]
Temperature	0.007 [−0.011,0.024]	11.325** [4.027,18.622]
Precipitation	−4.331 [-9.853,1.191]	113.279 [−2071.705,2298.263]
Zero luminosity	−5.070*** [−5.117,−5.023]	−194.518*** [−203.229,−185.808]
Adjusted R^2	0.917	0.512
N	81,809	81,809

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect and the year fixed effect. The standard errors are clustered at the village level. Column (1) is based on a specification including the natural log of night-time luminosity while Column (2) is based on a specification including the level of night-time luminosity.

Table A12
Variation in time-period under investigation in the regression of night-time luminosity on policy implementation in the non-JGY sample.

	(1)	(2)
Share segregated	−0.114*** [−0.161,−0.066]	0.010 [−0.031,0.051]
Pressure	−0.000 [−0.000,0.000]	−0.003*** [−0.003,-0.002]
Temperature	0.036*** [0.026,0.047]	−0.038*** [−0.057,−0.020]
Precipitation	−8.649*** [−11.843,−5.456]	2.798 [−0.876,6.471]
Zero luminosity	−5.123*** [−5.142,−5.104]	−5.162*** [−5.189,−5.136]
Constant	4.900 [−15.387,25.187]	315.328*** [248.940,381.717]
Adjusted R^2	0.922	0.910
N	3.08e+05	1.62e+05

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, the year fixed effect, and a block-specific annual time trend. The standard errors are clustered at the village level. Column (1) is based on the sample for the time-period 1992–2012 while Column (2) is based on the sample for the time-period 2000–11.

Table A13
The regression of night-time luminosity on policy implementation in the rural subgroup (i.e., excluding towns and cities) for the complete sample, the JGY sample, and the non-JGY sample.

	Complete sample	JGY Sample	Non-JGY Sample
Segregated	0.000 [−0.012,0.013]	−0.039*** [−0.056,−0.022]	–
Share segregated	−0.029 [−0.070,0.013]	0.260*** [0.182,0.339]	−0.112*** [−0.160,−0.063]
Days since segregation	–	0.000 [−0.000,0.000]	–
Pressure	−0.000* [−0.000,−0.000]	0.000 [−0.000,0.000]	−0.000* [−0.000,−0.000]
Temperature	0.031*** [0.022,0.040]	0.006 [−0.011,0.024]	0.035*** [0.025,0.046]
Precipitation	−7.776*** [−10.589,−4.963]	−4.273 [−9.793,1.248]	−8.964*** [−12.224,−5.705]
Zero luminosity	−5.126*** [−5.143,−5.108]	−5.071*** [−5.118,−5.024]	−5.127*** [−5.146,−5.108]

(*continued on next page*)

Table A13 (*continued*)

	Complete sample	JGY Sample	Non-JGY Sample
Adjusted R^2	0.920	0.921	0.923
N	3.77e+05	81808.000	2.96e+05

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

Note: The unit of observation is the village. Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, year fixed effect, and an annual trend for all villages within an administrative block where a JGY feeder was ever commissioned. The standard errors are clustered at the village level.

Table A14

Variation in rural-urban status in the regression of night-time luminosity on policy implementation in the non-JGY sample.

	Rural	Urban
Share segregated	−0.112*** [−0.160,−0.063]	−0.000 [−0.123,0.122]
Pressure	−0.000* [−0.000,−0.000]	−0.000 [−0.001,0.001]
Temperature	0.035*** [0.025,0.046]	−0.001 [−0.025,0.024]
Precipitation	−8.964*** [−12.224,−5.705]	−5.990 [−14.132,2.152]
Zero luminosity	−5.127*** [−5.146,−5.108]	0.000 [0.000,0.000]
Constant	10.984 [−9.567,31.534]	13.645 [−62.455,89.745]
Adjusted R^2	0.923	0.502
N	2.96e+05	5040.000

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

Note: The unit of observation is the village (or town or city). Regression estimates are presented with 95% confidence intervals in the brackets below. All regressions include the village fixed effect, the year fixed effect, and a block-specific annual time trend. The standard errors are clustered at the village level.

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