Introduction

Rural electrification has been of great interest because it has been seen as an important policy tool for rural development. Rural Electrification in China has been implemented in several stages. Before 1979, rural electrification rate only grew slowly. There is still thirty-seven percent of the rural population, or 245 million people had no access to electricity by 1979 (Peng and Pan 2006). From 1979 to 1998, electrification access grew rapidly, and electricity access rate for rural townships, villages, and households was 99.2% 98.1% and 96.87% respectively by 1998 (Pan et al 2006). From 1998, the focus began to shift to upgrading, renovating and consolidating the rural electricity system to increase supply capacity and reliability as well as providing electricity access to the remaining non-electrified areas. The Brightness Program was put forwarded in 1996 aiming at providing electricity access to non-electrified households mainly using local renewable resources (Wang et. al. 2006).

Rural electrification influences economic, society and environment in multiple ways. The World Bank (2008) has identified several benefits of rural electrification: provision of domestic lighting and use of electric appliance, health and education benefit, productive use, more spare time and additional environmental benefit for off-grid renewable electrification projects. Moreover, rural development and poverty reduction are often listed as important policy goals of rural electrification projects (Javadi et. al. 2013). Hence, it is imperative to analyze and evaluate the socioeconomic impacts of rural electrification in China.

Literature Review

Rural electrification has long been regarded a “special” kind of investment based on the justification that it can serve as a catalyst to rural economic development, promoting “social goods” such as health and education and benefiting the poor (Pearce and Webb 1987). Economic development can occur through job creation in local enterprises brought by electrification and higher productivity due to mechanization in the industry. Education benefits come from extended hours of studying at night, freeing up child labor to study and learning from Information Communication Technologies (ICTs) (Kanagawa and Nakata 2008). Using a cross-sectional survey of 100 households in Madagascar, Daka and Ballet (2011) found that lighting in the evening allows children to study more hours and freed up parents especially mothers’ time to help their children with homework.

Besides descriptive studies, quasi-experiment methods are also used to analyze the impact of electrification projects. To study the household socioeconomic outcomes in India, Khandker et al (2012) used an instrumental variable approach, where the proportion of households in the village with electricity served as an instrument. They showed that electrification access increased weekly study hours by more than an hour, and the average completed schooling year increased 0.3 years for boys and 0.5 years for girls. Using land gradient as an instrument, Dinkelman (2011) found a 9-9.5% increase of female employment due to rural electrification project in South Africa.

Research on rural electrification in China has mainly focused on the economic viability of rural electrification in China, its technical and institutional challenges and potential solutions (Zhang and Kumar 2011; Byrne et. al. 1998). There are few papers on impact assessment of rural electrification projects in China. Furthermore, most of the studies have only accessed the direct impact of electrification on changing energy use pattern. To analyze the implementation and impact of China's National Township Electrification Program, Shyu (2012) conducted household survey and interviewed relevant stakeholders in two townships in Qinghai and Tibet provinces. The survey result showed the amount of traditional energy sources used for lighting and electrical appliances has significantly decreased after electrification. Pereira et al. (2011) surveyed households before and after they got electricity access, and found that there were a dramatic increase in the acquisition of electric home appliance soon after the power system was installed, and 15% of the families use electricity for productive purposes such as small retail store, restaurants and commercial processing of raw materials.

However, this is little attention to the socioeconomic consequences of these changes in energy use. Yang (2003) analyzed provincial level time-series data in six province of China with different level of economic development, and showed that at provincial level investing one million Yuan in rural power network will increase net income per capita by 0.2-1.8 Yuan per year in each province studied. The increase in income is most prominent in economically developed provinces.

From my knowledge, there is no natural experiment that evaluates the socioeconomic impact of rural electrification at village level in China. In this study, a rigorous impact evaluation will be conducted to assess whether the rural electrification projects in China have improved rural standard of living. Income and educational level are chosen as the outcome variables in the subsequent regression analysis because they are the two key dimensions of standard of living and worldwide surveys have shown that increase in income and education level are important outcomes of rural electrification (Saghir 2005).

Data and methodology

The dataset used for impact evaluation is from 2003 Rural Survey on World Bank Project Evaluation in China. The survey was conduced by Center for Chinese Agriculture Policy, Chinese Academy of Sciences, University of California at Davis and University of Toronto. Data was collected for six provinces across rural China including Jiang Su, Si Chuan, Shan xi, Gan Su, He Bei, Ji Lin, which used multi-stage stratified sampling. It surveyed 36 counties, 216 township and 2459 villages. Socioeconomic indicators of the village pertaining to income, land use, labor force information, infrastructure, geographic information and environment were collected for both 1997 and 2002. Among these villages, 236 villages implemented electrification project in 1998, and 517 did not implemented any electrification project during 1997-2002. Villages that implemented electricity projects in 1998 are included in the treatment group, while villages without any electricity project during 1997-2002 are considered as the control group.

Impact evaluation attempts to establish the causal relationship between the project implemented and outcome, and estimates the average treatment effect on the treated (ATT) of the project by the difference between outcome occurred and outcome that would have occurred if the project was not implemented for the same object, which is called the counterfactual (equation 1).

$$ATT = E(Y_{1i} - Y_{0i} | G_i = 1) = E(Y_{1i} | G_i = 1) - E(Y_{0i} | G_i = 1) \quad (1)$$

Y is the outcome variable; Y_{1i} is the outcome if treated, and Y_{0i} is the outcome if not treated.
G_i is the binary indicator of whether the object is in the treatment group.

However, in reality, it is impossible to observe the exact counterfactual because the same object cannot be treated and untreated at the same time. Hence, constructing a legitimate counterfactual is the key for accurate impact evaluation. The Difference-in-Differences (DiD) method is a natural experiment that establishes the causality between the project and outcome, which is superior to simple OLS regression analysis. The DiD approach constructs a counterfactual by computing the difference of outcome variables before and after the project implementation for both the treatment and control group (equation 2).

$$ATT_{DiD} = E(Y_{ai}^{T} - Y_{bi}^{T} | G_i = 1) - E(Y_{ai}^{C} - Y_{bi}^{C} | G_i = 0) \quad (2)$$

Superscript T indicates treatment group, and C indicates the control group.
Subscript a and b refer to after and before the project implementation.

The villages in the treatment and control group may have diverse socioeconomic characteristics and natural endowment, and these unobserved characteristics may affect both the assignment of electrification project and the outcome variables. Those potential confounding variables that are constant between 1997 and 2002 could be differenced out because the same village is observed both before and after the treatment, even though data for these characteristics may not be available. The ATT_{DiD} also takes the natural rate of change over time into account by subtracting change of outcome in control group from the change of outcome in treatment group. For example, it cancels out the effect of income changes due to fluctuations in macroeconomic condition over years because it happens to both treatment and control group.

$E(Y_{ai}^{C} - Y_{bi}^{C} | G_i = 0)$ is a good counterfactual if the treatment and control group would have followed the same trend without the project. To improve the validity of the equal trend assumption, DiD approach is combined with Propensity Score Matching (PSM). Propensity Score Matching (PSM) matches the baseline socioeconomic conditions of the treatment and control groups. In the PSM-DiD approach, only the matched villages are selected for subsequent DiD analysis. Since the matched villages have similar baseline conditions, the equal trend assumption is more likely to hold. The PSM-DiD approach has been adopted in recent literature, and was shown to reduce bias and inconsistency (Rishika 2013).

Model Specification

The DiD regression model is specified in equation 1.

$$Y_{it} = \beta_0 + \beta_1 G_i * D_t + \beta_2 G_i + \beta_3 D_t + \beta_4 W_{1it} + \cdots + \beta_{3+r} W_{rit} + u_{it} \quad (1)$$

Where:
Y_{it} is the outcome variable; there are two outcome variables: net income per capita and percentage of people with high school diploma or above
G_i is the binary indicator of treatment: whether the village implemented any electrification project in 1998
D_t is the binary indicator of time period. $D_t = 0$ when year = 1997; $D_t = 1$ when year = 2002
W_{rit} are the additional covariates
u_{it} is the error term

The coefficient β_1 of the interaction term $G_i * D_t$ gives the estimated effect of rural electrification project. The covariates are divided into three categories: village characteristics, other development projects implemented during the survey period and county-fixed effects, which potentially affect the outcome variable and correlate with the treatment. For DiD with PSM, caliper matching with caliper of 0.01 is used to match the baseline.

Results

Table 1 (see Appendix) shows the summary statistics for the outcome and key independent variables. 31% of the villages in the sample had implemented rural electrification project in 1998. In 1997, the average net income per capita was 1417 Yuan, and percentage of people with high school diploma or above was 5%. Both sample average income and education have improved in 2002.

Table 2 presents the regression results on income for DiD models and DiD with matching of the baseline. In the DiD model without covariates, the electrification project has increased net income per capita by 174 Yuan. After accounting for village characteristics, the effect of the electrification project on income diminished to 146 Yuan. The result remains unchanged in the PSM-DiD model, and the impact is statistically significant at 10% level. This increase is also practically significant because it represents a 10% increase of income compared to the baseline.

The reason why the magnitude of the impact decreased significant after controlling for village characteristics can be explained by the financial concerns for selecting the location of the project. Since most of the electricity projects in the survey are funded by the World Bank, financial viability is often a great concern. Those villages with better infrastructure and other conditions that are conducive to economic development and financial viability of the electrification project have higher propensity to be selected for the project (World Bank 2008).

Table 3 shows the impact of electrification on education for DiD models and DiD with matching of the baseline. In the DiD model, electrification increased the percentage of people with high school diploma or above by 0.4%, and the impact is statistically significant at 10% significance level. In the PSM-DiD model, the result remains unchanged. However, this improvement is not very significant practically. In a typical 300 people village in China, there is only one additional person who got high school degree or above by 2002 due to the electrification project implemented in 1998.

Discussion

The regression results show that income and education benefits are statistically significant, but the improvement in education is not very significant practically. This is contrary to findings in the literature from other countries. The possible reason is in China admission into high school or university is quite competitive. Though better lighting and access to audio and video learning resources can be beneficial to student's academic performance by studying longer hours and learning more effectively, other factors such as teaching quality affordability and parental education are also key determinants of student's academic success. Knight and Li (1996) showed that the effect of parental education on children's education attainment becomes larger beyond basic education. Freeing up parents' time to help with homework is listed as one of the reasons for improving education level due to electrification. Since few parents in rural China have college degree, their ability to help decreases beyond basic education. Meanwhile, though lighting provides opportunity to study in the evening, children can also choose to watch TV or have other types of entertainment, so it does not necessarily lead to increase of study hours. Therefore, providing electricity alone may not have a significant impact on whether the children can get high school or higher degrees.

The positive impact on per capita income due to electrification found in this study is consistent with the literature. This can come from the development and increased productivity of Township and Village Enterprises (TVE) as shown by Yang (2003). In addition, it may also be the result of productive use of electricity found by Pereira et al. (2011), which creates more jobs and increases the number of small businesses.

There are some limitations associates with the model and dataset. DiD estimator is biased if there are other time-variant omitted variables that are not included in the regression models. However, such biases are reduced by inclusion of county-fixed effect in the model, which accounts for unobserved characteristics and policy initiatives at county level during 1997-2002.

Several limitations are pertaining to the dataset. Firstly, data is only available at the village level, and policy impact may vary across households. For example, it is interesting to analyze how does the policy affect household below the poverty line, which is related to the policy goal of poverty reduction. Nevertheless, since the sample is stratified, the result is still a good estimate of average effect as both wealthier and poorer villages are represented. Secondly, the data is limited to six provinces in China, so external validity issues may exist when the findings are generalized to the whole country. However, since the provinces selected are geographically representative and have varying degrees of economic development, the ATT in this study can be a reasonable estimate of the project effect across the whole country. Thirdly, the project implemented in each village may not be uniform. For example, the project of some villages may mainly involve renovating consolidating and upgrading existing grid and facility, while other villages are given new access to electricity. Though this is not distinguished in the dataset, the amount of investment in the project is included as a control variable that can be seen as a proxy for the scope and intensity of the project.

Hence, despite the above limitations, the evaluation results still provide a sound estimate of average effect of the electrification project in China, which will provide guidance for future electrification projects in both China and other developing countries. Additional household survey may be helpful to analyze other impacts of electrification such health and gender equality. Household surveys can also be used to further investigate the causal mechanisms of income increase and possible improvement in education as well as the distribution of the socioeconomic benefits. These evidences can be used for design and implementation of future electrification projects.

Conclusion

This paper evaluated the impact of China's rural electrification projects. The results showed that rural electrification project in China brought substantial increase in rural income. This change can be due to productive use of electricity and increased productivity of TVEs. However, the improvement in education attainment beyond basic education is not practically significant, which showed that the causal link from electrification to longer study hours and academic success may not hold. More in-depth surveys can be helpful to understand the causal mechanisms.

This study not only offers insights about the past lessons of rural electrification, but also is useful for future electrification projects. In China, though over 99% of villages have gotten electricity, in absolute number there are still 4 million people in China without electricity access in 2010 (IEA 2010). In the electrified villages, improving system capacity and reliability is also ongoing. Understanding the impact of the project can help to better target and design effective electrification projects in the future.

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Appendix

Table 1: Summary statistics of key variables in 1997 and 2002

	No. of Observations	Mean	Min.	Max.	Standard Deviation
Electrification Project in 1998 (1=Yes; 0=No)	753	0.31	0	1	-
Net income per capita (1997)	753	1417	97	7148	1039
Net income per capita (2002)	753	1805	100	5950	1273
% of high school graduate or above (1997)	753	0.05	0	0.44	0.05
% of high school graduate or above (2002)	753	0.06	0	0.37	0.06

The summary statistics was calculated using data for six Chinese provinces in 1997 and 2002 from 2003 Rural Survey on World Bank Project Evaluation.

Table 2: Summary of regression results for different specifications: net income per capita

	DiD without matching				PSM-DiD
	(1)	(2)	(3)	(4)	(5)
$G_i * D_t$ (Yuan)	174 (130)	174** (82)	147* (82)	146* (82)	146* (82)
County-Fixed Effect	No	Yes	Yes	Yes	Yes
Village characteristics	No	No	Yes	Yes	Yes
Other projects	No	No	No	Yes	Yes
No. of Obs.	1506	1506	1502	1490	1470

These regressions were estimated using data for six Chinese provinces in 1997 and 2002 from 2003 Rural Survey on World Bank Project Evaluation. Robust standard errors are given in parentheses under the coefficients. The individual coefficient is statistically significant at *10% level, **5% level and ***1% significance level. The following are included in the regression model but not reported: amount of project investment per capita, village characteristics (% of Han Chinese, land area, labor, road, tap water access, distance to road, soil erosion, villagers working at township and county governments, village debt) and other projects (Build road or bridge, school, clinic, irrigation, drainage, telephone line, Radio/TV cable, land improvement, watershed management, terracing, downtown planning, logging band and foresting, eco-forest, grain for green, building pasture, activity and recreation room, grain crop, cash crop, orchard, green house, economic forest, livestock, fishpond, family business, computer, microcredit)

Table 3: Summary of regression results for different specifications: % of high school graduate and above

	DiD without matching				PSM-DiD
	(1)	(2)	(3)	(4)	(5)
G_i * D_t (Yuan)	0.005 (0.006)	0.005** (0.002)	0.005* (0.002)	0.004* (0.002)	0.004* (0.002)
County-Fixed Effect	No	Yes	Yes	Yes	Yes
Village characteristics	No	No	Yes	Yes	Yes
Other projects	No	No	No	Yes	Yes
No. of Obs.	1506	1506	1502	1490	1470

These regressions were estimated using data for six Chinese provinces in 1997 and 2002 from 2003 Rural Survey on World Bank Project Evaluation. Robust standard errors are given in parentheses under the coefficients. The individual coefficient is statistically significant at *10% level, **5% level and 1% significance level. The following are included in the regression model but not reported: Amount of project investment per capita, village Characteristics (% of han Chinese, land area, labor, road, tap water access, distance to road, soil erosion, villagers working at township and county governments, village debt) and other projects (Build road or bridge, school, clinic, irrigation, drainage, telephone line, Radio/TV cable, land improvement, watershed management, terracing, downtown planning, logging band and foresting, eco-forest, grain for green, building pasture, activity and recreation room, grain crop, cash crop, orchard, green house, economic forest, livestock, fishpond, family business, computer, microcredit)

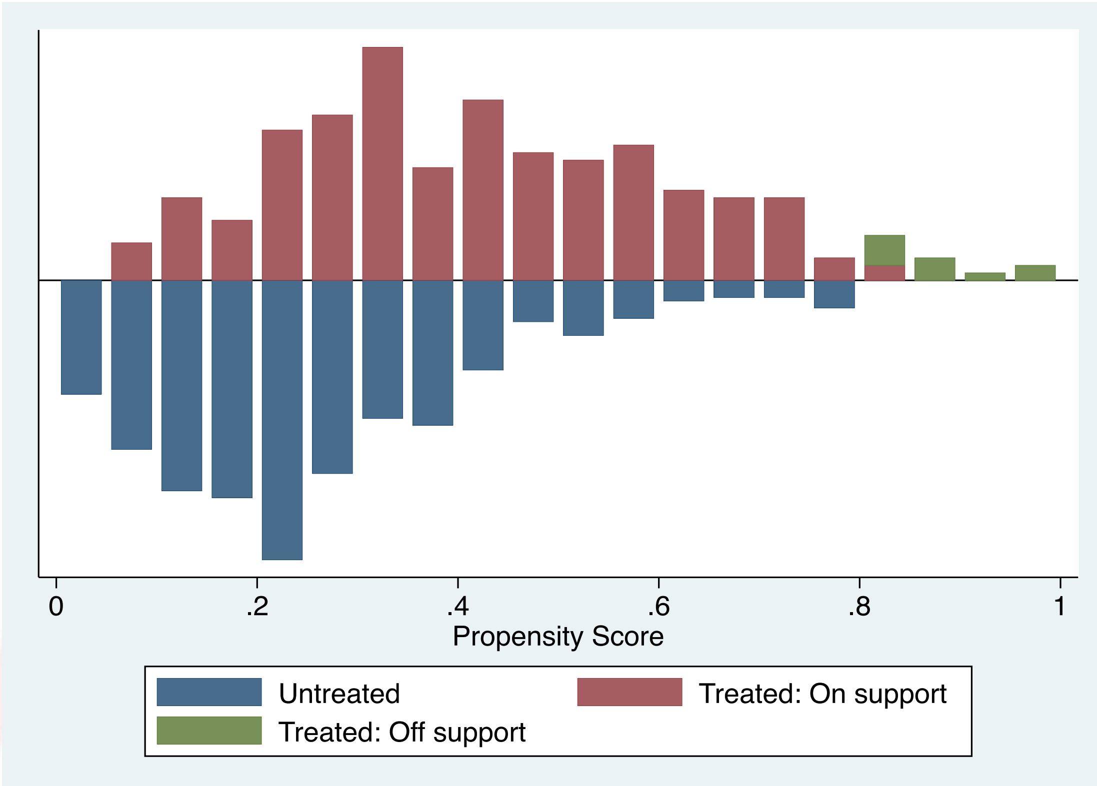

Figure 4: Propensity score matching result of baseline data in 1997

PSM matches data in 1997 from 2003 Rural Survey on World Bank Project Evaluation using caliper matching with a caliper of 0.01. The variables included in matching are % of Han Chinese, land area, labor, road, tap water access, distance to road, soil erosion, villagers working at township and county governments, village debt, % of household with electricity access, number of migrants, number of illiterates, number of schools, number of clinics, % of phone users, number of village and township enterprises, number of farmer's professional associations.

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