American Economic Review 101 (December 2011): 3078–3108
http://www.aeaweb.org/articles.php?doi=10.1257/aer.101.7.3078

The Effects of Rural Electrification on Employment: New Evidence from South Africa†

By Taryn Dinkelman*

This paper estimates the impact of electrification on employment growth by analyzing South Africa's mass roll-out of electricity to rural households. Using several new data sources and two different identification strategies (an instrumental variables strategy and a fixed effects approach), I find that electrification significantly raises female employment within five years. This new infrastructure appears to increase hours of work for men and women, while reducing female wages and increasing male earnings. Several pieces of evidence suggest that household electrification raises employment by releasing women from home production and enabling microenterprises. Migration behavior may also be affected. (*JEL* H54, L94, L98, O15, O18, R23)

Electricity is pervasive in all industrialized countries and largely absent in the developing world: about 1.6 billion people worldwide lack access to electricity (Jamal Saghir 2005). Even though many would consider electricity to be a "marker" for development, and despite several historical episodes of widespread electrification in developed countries (for example, the rural electrification of America in the 1930s), we know little about the direct effects that new access to modern energy infrastructure will have on the process of development.

* Department of Economics and the Woodrow Wilson School of Public and International Affairs, Princeton University, 357 Wallace Hall, Prospect Avenue, Princeton, NJ 08540 (e-mail: tdinkelm@princeton.edu). This paper would not have been possible without the electrification data and institutional background provided by individuals at Eskom (Jenny Barnard, Sheila Brown, Ed Bunge, Innocent Nxele, Jim Stephenson, Steven Tait, and Amos Zuma) and energy experts at the University of Cape Town (Trevor Gaunt, Gisela Prasad). I am indebted to Anne Case, David Lam, James Levinsohn, Justin McCrary, Jeffrey Smith, and Gary Solon for their valuable guidance in the preparation of this paper. I am also grateful for helpful comments from Lori Beaman, Diether Beuermann, Matias Busso, HwaJung Choi, John DiNardo, Ann Ferris, Raymond Fisman, Ben Keyes, Claudia Martínez A., Nancy Qian, Dori Posel, Samara Potter-Gunter, Mark Rosenzweig, James Tybout, Rebecca Thornton, Martin Wittenberg, and seminar participants at Brown University, UCLA, UC-Riverside, Dartmouth College, Duke University, the Harris School of Public Policy at Chicago, the Harvard School of Public Health, the Inter-American Development Bank, the Institute for International Economic Studies at Stockholm University, the Harvard Kennedy School of Government, the University of KwaZulu-Natal, the London School of Economics, the University of Michigan, Michigan State University, Northwestern University, the University of North Carolina-Chapel Hill, Pennsylvania State University, Princeton University, Resources for the Future, Syracuse University, the University of Washington-St. Louis, the University of Western Ontario, the University of Virginia, Yale University, and the World Bank's Microeconomics of Growth Network Conference (2009). Data collection was funded through a National Science Foundation Doctoral Dissertation Grant (SES-0649443), and an Eva Mueller New Directions in Demography research award. I gratefully acknowledge support from the Fogarty International Center of the US National Institutes of Health (D43TW000657), and the Population Studies Center at the University of Michigan.

† To view additional materials, visit the article page at http://www.aeaweb.org/articles.php?doi=10.1257/aer.101.7.3078.

The primary objective of this paper is to analyze the impact of new access to modern energy on an outcome of considerable interest: the ability of the poor to use their labor resources for market production. In this paper, I estimate the causal impact of household electrification on employment growth in rural communities by analyzing rural electrification roll-out in postapartheid South Africa. As a second objective, I investigate the mechanisms through which this new infrastructure affects rural labor markets. Since energy infrastructure is likely to expand in poor areas over the next few decades,[1] this analysis provides important lessons for many countries as well as for researchers studying the changing nature of developing country labor markets.

The roll-out of grid infrastructure in South Africa provides a particularly good opportunity to evaluate the effects of electrification on market employment. It was rapid, extended into rural areas, and targeted low capacity household use rather than industrial users (Trevor Gaunt 2003). In 1993, a year before the end of apartheid, over two-thirds of South African households were without electricity and more than 80 percent relied on wood for home production.[2] Following the new government's commitment to universal electrification, 2 million households, or almost one quarter of all households across the country, were newly connected to the grid by 2001. This is twice as many households as the number of US farms connected during the first five years of Roosevelt's Rural Electrification Act (Robert T. Beall 1940).

Evaluating the effects of this electrification, or of any infrastructure roll-out, is not straightforward. A large literature on the relationship between infrastructure and economic growth acknowledges that infrastructure could be targeted towards growing areas, or towards politically important areas.[3] Such selection biases any comparison of electrified and nonelectrified areas, and in unpredictable ways. Confounding trends in the economy make it even more difficult to tease out the effects of infrastructure on any economic outcomes.

In this paper, I use two empirical strategies to identify the impact of electricity, taking into account endogenous project placement and confounding economic trends. In the main approach, I estimate community-level employment growth rates in communities that do and do not receive an electricity project between 1996 and 2001, instrumenting for project placement. To do this, I collect and match administrative data on roll-out in rural KwaZulu-Natal (KZN) with geographical data and two census surveys. I use land gradient to generate exogenous variation in electricity project allocation to communities. Higher gradient raises the average cost of a household connection, making gradient an important factor in prioritizing areas for electrification. I argue and provide evidence from a placebo experiment that in the

[1] World Bank commitments to energy infrastructure in Africa rose from $447 million in 2001 to $790 million in 2007. The World Bank's Lighting Africa initiative aims to provide 250 million Africans with modern sources of energy by 2030 (EnergyNet Limited 2004, The World Bank 2007).

[2] Jacques Charmes (2005) and Saghir (2005) document the time intensity of home production in developing countries. South Africans (mainly women) spend on average two working days per week in fuel-wood collection (Debbie Budlender, Ntebaleng Chobokoane, and Yandiswa Mpetsheni 2001), and rural households spend an average of three hours per day on food preparation (author's calculations using 1997 October Household Survey data from Statistics South Africa (1997)).

[3] The tradition in the macroeconomics literature has been to estimate the effects of public infrastructure on total factor productivity using time-series data. David Aschauer (1989) is a classic reference; see David Canning (1998) for cross-country evidence, and Johannes W. Fedderke and Zeljko Bogetic (2009) for South African evidence. The World Bank (1994) and Emmanuel Jimenez (1995) provide good overviews of the infrastructure literature relevant for developing countries.

case of rural KZN, an area with poor agricultural prospects, gradient is unlikely to directly affect employment outcomes conditional on covariates.

As a complement to the main analysis, I use a fixed effects strategy to estimate the impact of electrification on a richer set of labor market outcomes: employment, hours of work, wages and earnings. For this analysis, I construct a four-period panel of magisterial districts (agglomerations of communities) from cross-sectional household survey data in 1995, 1997, 1999, and 2001 and address nonrandom project placement and confounding economic trends by directly controlling for magisterial district fixed effects and trends. This estimates the labor market effects of electrification using only within-district variation in electrification.

Results from both analyses show that employment in rural KZN increases in the wake of electrification. Female employment measured in the census rises by a significant 9 to 9.5 percentage points (instrumental variable results), which translates into 15,000 more women participating in the labor force, or 0.75 percent of the estimated 2 million new jobs created across the country over the period (Daniela Casale, Colette Muller, and Dorrit Posel 2004). The fixed effects analysis using household survey data largely supports these female employment results, although precise inference is more difficult with the small samples in this dataset. Electrification increases employment on the intensive margin for women: in districts with the average increase in electrification over the period (15 percent), women work about 8.9 more hours per week, a 3.5 percent increase. In both analyses, male employment rises (insignificantly) in electrifying areas, although to a lesser extent than for females.

Having established that household electrification increases employment in rural communities, I turn to investigating mechanisms in the second part of the paper. I first explore the impact of electrification on home production activities and find that newly electrified communities experience substantial shifts away from using wood at home, and toward electric cooking and lighting. This suggests that household electrification operates as a labor-saving technology shock to home production in rural areas, releasing female time from home to market work.

Second, I rule out the possibility that household electrification stimulated large scale rural industrialization and hence a shift in labor demand by showing the absence of cross-community employment spillovers. As further evidence that electricity stimulated a net increase in labor supply to the market, the fixed effects analysis indicates that female wages fall (albeit imprecisely) in districts where electrification is expanding more rapidly. This fact is difficult to reconcile with electricity causing large net increases in labor demand.

More plausibly, electricity may have lowered the cost of producing new, home-based services for the market, thereby presenting individuals with alternative ways to use their labor time in self employment and micro enterprises. The data are unable to provide direct evidence on these mechanisms, but I argue that since employment results for men and women are not statistically different from each other, it seems likely that the South African electrification did not exclusively affect rural labor markets through the channel of freeing time from home production. Rather, the reduced-form market employment results capture a combination of increased labor supplied to the market (via the home production channel) as well as increased small-scale labor demand (via new opportunities for producing new goods and services for the market).

A final channel that I investigate relates to migration. I discuss how differential in- and out-migration affect interpretation of the employment results. I show that differential in-migration cannot explain all of the employment effects of electrification, and I explain how differential out-migration, while substantial, is also unlikely to account for employment effects, given the profile of out-migrants from rural areas documented in other datasets and by other researchers. Rather, the migration analysis broadly suggests that people may be induced to stay in or to move towards areas in which infrastructure is rolling out.

This paper contributes to two literatures. First, it adds to what we know about the microeconomic effects of physical infrastructure in developing countries, placing new emphasis on labor market effects in an area that has recently focused on poverty, health, and education outcomes.[4] The results here suggest that studies that ignore employment effects could be missing important economic impacts, particularly when the infrastructure has a home production bias. Second, the main result that female employment rises in electrifying areas connects with a large literature on the effects of changing constraints on women's work in the process of economic development.[5]

The paper begins by discussing how household electrification may affect rural labor markets through home and market production. Sections II, III, and IV describe the context of South Africa's electrification, data, and empirical strategies. Section V presents the main results, while Section VI investigates the channels through which electrification affects employment. Section VII concludes.

I. Theoretical Impacts of Household Electrification

New access to household electrification may change the nature of work in the home as well as the amount and type of work that can be done in the market. Providing new public infrastructure to a location also may affect migration of employed and unemployed individuals. Outlining the form each of these changes may take is important for interpreting the empirical results in the paper.

To begin, home production activities are important in my study area. Figures 1A and 1B show the fraction of rural African households in KZN reporting different sources of fuel for cooking and lighting in the 1996 and 2001 census, separately for communities that get new access to electricity or not during this period. Almost 80 percent of households cook with wood and light their homes using candles in the mid-1990s. In electrified areas, the fraction of households cooking with electricity increases almost threefold in five years, while the fraction of households using electric lighting more than triples.

The labor supply effect of such a shock to the technology of home production is, however, ambiguous.[6] With this new technology, households become more productive

[4] For example, see David Cutler and Grant Miller (2005); Michael Lokshin and Ruslan Yemtsov (2005); Randall Akee (2006); Esther Duflo and Rohini Pande (2006); Abhijit Banerjee, Duflo, and Nancy Qian (2007); Rocio Titiunik et al. (2007).

[5] See, for example, Claudia Goldin (1995); Goldin and Lawrence Katz (2000); Kristin Mammen and Christina Paxson (2000); Jeremy Greenwood, Ananth Seshadri, and Mehmet Yorukoglu (2005); Martha Bailey and William Collins (2010); and Daniel Coen-Pirani, Alexis Leon, and Steven Lugauer (2008).

[6] Gary Becker (1965) and Reuben Gronau (1986) provide the canonical models of home production, within which the labor supply effects of a shock to home production technology can be shown to be ambiguous.

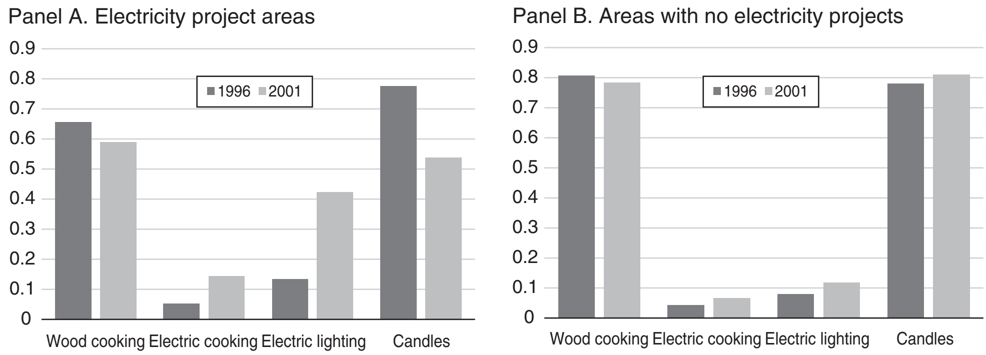

Figure 1. Changing Home Production Techniques by Electricity Project Status

Note: Bar graph shows fraction of households in rural KZN analysis sample reporting each type of main fuel for cooking and lighting across electricity project and nonproject areas.

in time-intensive activities like food preparation and storage, and so may substitute more time towards these home-based activities. The same shock also increases the length of the effective day, producing an endowment effect that increases the demand for all normal goods, leading households to supply more labor to market. The more income-elastic the demand for market-intensive goods is, the stronger this endowment effect will be in pushing households to supply more labor to the market. Which effect dominates is theoretically ambiguous; however, the substitution effect is likely to be smaller since the demand for home-produced goods (e.g., number of meals) is bounded above. Therefore, we expect the advent of household electricity to change the nature of home production and increase labor supplied to the market, particularly for individuals who specialize in home production (i.e., women).[7]

Electricity may also change work opportunities in rural areas, by stimulating the growth of new firms that create jobs outside the home.[8] Quite apart from this, electricity may directly create jobs within households by enabling the production of new goods and services for the market: for example, food preparation and storage for larger groups becomes easier; operating small appliances to provide market services becomes feasible (e.g., hairdryers, cell phone charging stations, local craft production). In this way, household electrification could unleash previously unrealized demand for labor and an increase in market work, even without the growth of firms.

Household electrification may also affect migration behavior in multiple ways. In- and out-migration could be important responses to electrification, as people gravitate toward areas that are more desirable places to live. However, if in-migrants to electrifying areas already have jobs elsewhere or if out-migrants from nonelectrified areas take their jobs with them, we might mistakenly attribute employment growth to new household electrification, when the main effect of the roll-out is merely to change the composition of the community.

[7] Responses to the technology shock may of course differ across households. If there is heterogeneity across households in initial home production technologies, or in the degree of substitutability of home for market commodities (for example, meals versus child care), then the labor supply effects of electrification may differ across these types of households. I present some evidence for this heterogeneity in online Appendix 2.

[8] Juan Pablo Rud (2009) documents the role that rural electrification played in industrializing India.

To isolate how important each of these channels is in explaining the impact of rural electrification on market employment, it would be ideal to show what happens to (i) home production activities, (ii) market employment, (iii) the prevalence and size of firms in rural areas, (iv) the prevalence of home-based microenterprises in rural areas, (v) market wages in areas that gain new access to electricity, and (vi) migration flows. Data limitations restrict the empirical analysis in this paper to (i), (ii), (v), and (vi). I investigate whether new access to household electrification increases employment in the market and whether these effects differ by gender, whether changes in methods of home production and changes in wages support a labor supply channel, whether there is any evidence for the labor demand channels, and the extent to which migration into and out of electrifying and nonelectrifying areas can account for employment effects. The results of these analyses substantially improve our understanding of the impacts of this infrastructure in a poor, rural setting.

II. South Africa's Electrification Program

By 1990, most economic entities and residential areas in South Africa's cities and commercial farms had been electrified. In contrast, one of the legacies of apartheid was that many African households were denied access to basic services, particularly if they were living in designated homeland areas (Gaunt 2003).[9] At the time of the first democratic elections in 1994, over two-thirds of African households did not have access to electricity. After the elections, all homelands were legally reintegrated into South Africa (A. J. Christopher 2001) and the South African government assumed responsibility for basic service provision for all citizens.

As part of a National Electrification Programme (NEP), South Africa's national electricity utility (Eskom) committed to electrifying 300,000 households annually from 1995 onwards, to address the service delivery backlog. These targets were regarded as "firm and non-negotiable" (Eskom 1996) and new connections were fully subsidized by the utility (Gaunt 2003). Since Eskom was a monopolist in electricity generation and distribution during this period, industry commentators describe the support for this roll-out commitment as partly strategic. Eskom was interested in signaling to the government that full access to previously disadvantaged communities could be provided, without introducing competition into the industry.[10] As a result, Eskom met its connections targets in most years. Between 1993 and 2003, about US $1.4 billion was spent on household electrification and about 28 percent of all KZN households, or 470,000 households, were electrified. Almost all of these connections provided households with a minimum level of service, enough to power a few basic appliances.[11]

[9] Homelands were pockets of land designated for African settlement and functioning as labor reserves for the economy. Throughout, I retain the use of apartheid-era racial classifications: African for black South Africans, and white, and Indian.

[10] Personal communication with Trevor Gaunt, head of Department of Electrical Engineering at the University of Cape Town (May 31, 2006).

[11] Service was limited to a power supply that could simultaneously power a few small home appliances, e.g., two lights, a small television or radio, a small refrigerator and a water heater (South African Department of Minerals and Energy 2004). Newly connected households in my study area report large increases in ownership of electric kettles, refrigerators and lighting (own calculations, KwaZulu-Natal Income Dynamics Study, IFPRI et al. 1993 and 1998).

Even though all households within an area received the basic connection once the area was selected for electrification, this community-level selection was not random. Almost by definition, networked infrastructure of any kind requires that even identical consumers be connected in some order. And, in the context of the NEP, local political pressures and connections costs each played an important role in prioritizing communities for electrification. Gaunt (2003, p. 91) comments that although objective criteria were identified for ranking communities, political pressures were part of the "not-easily-identifiable but good reasons for selecting particular target groups." In KZN, both the 1994 provincial elections and the 1995/1996 local government elections were hotly contested by the two leading political parties in that province. This political rivalry arguably influenced local public goods allocations. In the rest of this paper, I treat these political factors as omitted variables.[12]

Annual Eskom reports (Eskom 1996–1999) and interviews with planning engineers also point to the central role of costs in allocating projects to places. The dual pressures of connections targets and internal financing meant that Eskom had strong incentives to prioritize areas with lowest average cost per household connection.[13] These cost factors are central to the main identification strategy in this paper. The bulk of electrification cost is in laying distribution lines out from electricity sub-stations to households. Three factors reduce the cost of these distribution lines: proximity to existing substations and power lines; higher density settlements; and terrain, or land gradient. The less of an incline the land has, the fewer hills and valleys and the softer the soil, the cheaper it is to lay power lines and erect transmission poles (Eskom 1996, Nicola West, Barry Dwolatzky, and Alan Meyer 1997).

I assemble measures of these three cost factors in my data. Distance from the grid and household density are important control variables, since both are likely to be correlated with economic opportunities that could directly affect changes in employment. In contrast, land gradient is much less likely to directly affect employment growth, conditional on other spatial variables and district fixed effects. Land gradient forms the basis of my instrumental variables strategy that addresses the biases arising from selection on unobservable variables and confounding trends. Section IV further motivates for using gradient in this way.

III. Data and Sample Characteristics

For the main analysis of the employment effects of electrification, I construct a panel dataset of community aggregate variables using 1996 and 2001 South African census data. To this community-level panel, I add in three additional pieces of data: spatial data collected from Eskom on the location of electrification infrastructure in KZN at baseline (1996), administrative data on project placement across the province between 1990 and 2007, and measures of geography at baseline (community land gradient, distances between each community and the nearest electricity substation,

[12] I use data from local elections in 2000 to shed some light on the importance of political factors in assignment of projects to communities in online Appendix 3.

[13] Jennifer Barnard (2006) describes factors affecting network extension to rural communities in KZN: "In the case of an electrical network, ideally the best route would run along the least slope, avoid forests, wetlands, and other ecologically sensitive areas, be routed near to roads and avoid households, while running near densely populated areas in order to easily supply them with electricity."

road and town).[14] For some parts of the analysis, I also refer to the 10 percent micro census data for 1996 and 2001.

The unit of analysis for the IV strategy is a community-year. Communities are small, with most having fewer than 900 households. They fall uniquely into 10 districts across the province (on average, there are 181 communities per district), and each district operates much like a local labor market.[15] I restrict the sample to rural ex-homeland communities in KwaZulu-Natal (KZN). This province is home to one-fifth of the population of South Africa and, in the early 1990s, contained about 30 percent of the entire African population living in homeland areas. Households in these rural areas are more reliant on traditional fuels than urban households and so are more likely to experience larger effects of electrification. There are also potentially fewer economic confounders in rural than urban areas in the first years after the end of apartheid.

My second empirical strategy uses individual-level data on employment, hours of work, wages, earnings, demographics, and household fuel sources from four cross sectional household surveys: the 1995, 1997, and 1999 South African October Household Survey (OHS) and the 2001 September Labor Force Survey (LFS). These micro data are collapsed to magisterial district (MD) aggregates that are larger than communities (38 in my sample) but smaller than census districts.

A. *Sample Characteristics*

Tables 1 and 2 present means and standard deviations of key variables used in the main analysis. All variables are derived from the 100 percent census sample, so results are not weighted. Table 1 provides descriptive statistics of baseline variables for the full sample of 1,816 communities (column 1), and separately by Eskom project status of the community (columns 2 and 3). Communities in the sample are poor: 61 percent of households live on less than 6,000ZAR per year, approximately US $840 at a 2006 USD/ZAR exchange rate. On average, over half of households in a community are female headed, and the female/male adult sex ratio is well over 1. These values underscore the historical function of the homelands as migrant labor communities.

The table also shows values of the three key variables influencing the cost of electrification projects. Average household density is 22 per square kilometer, and communities are on average 19 kilometers away from the nearest electricity substation in 1996. Main roads and towns are farther away, at an average distance of 38 kilometers. That communities are closer to the electricity grid than to towns is largely because all white commercial farms in rural areas had grid electrification by the end of the 1980s. The final row in the table shows that average community land gradient is 10 degrees. This is "strongly sloping," according to the Food and Agriculture Organisation's (FAO) gradient classification (FAO 1998). The first map in Figure 2 shows the spatial distribution of the gradient variable, along with

[14] Details of data sources and data linking procedures are in online Appendix 1: Data.

[15] In household survey data, only a handful of people report working outside of their district. In contrast, over half of all women and 60 percent of men work outside of their community (own calculations, census 2001 micro data, 10 percent sample).

Table 1—Baseline Community Variables by Electrification Project Status and Gradient

	Means (standard deviation)			Differences in means (standard error)		
					By gradient	
Covariates in 1996	Full sample (1)	Eskom project (2)	No project (3)	Columns 2–3 (4)	No controls (5)	Controls (6)
Poverty rate	0.61	0.59	0.61	−0.024**	0.00	0.002
	(0.19)	(0.17)	(0.20)	(0.01)	(0.00)	(0.00)
Female-headed HHs	0.55	0.55	0.55	0.00	0.005***	0.001
	(0.13)	(0.12)	(0.13)	(0.01)	(0.00)	(0.00)
Adult sex ratio ($N_{females}/N_{males}$)	1.48	1.41	1.49	−0.080***	0.011***	0.004**
	(0.28)	(0.25)	(0.29)	(0.02)	(0.00)	(0.00)
Indian, white adults × 10	0.00	0.00	0.00	0.00	0.000	0.000
	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
Kilometers to road	37.95	35.62	38.54	−2.917**	−0.201	−0.156
	(24.57)	(24.18)	(24.64)	(1.44)	(0.41)	(0.18)
Kilometers to town	38.57	36.34	39.13	−2.790***	0.278	0.180
	(18.12)	(15.34)	(18.72)	(1.06)	(0.41)	(0.13)
Men with high school	0.06	0.08	0.06	0.016***	−0.002***	−0.003**
	(0.05)	(0.05)	(0.05)	(0.00)	(0.000)	(0.00)
Women with high school	0.07	0.08	0.06	0.020***	−0.002***	0.000
	(0.05)	(0.05)	(0.05)	(0.00)	(0.000)	(0.00)
Household density	22.05	32.56	19.41	13.152***	−0.523*	−0.944***
	(30.48)	(49.31)	(22.75)	(1.76)	(0.31)	(0.30)
Kilometers from grid	19.06	15.75	19.89	−4.139***	−0.235	0.029
	(13.32)	(10.20)	(13.88)	(0.77)	(0.36)	(0.12)
Land gradient	10.10	9.12	10.35	−1.232***		
	(4.89)	(4.21)	(5.02)	(0.29)		
N communities	1,816	365	1,451	1,816	1,816	1,816

Notes: Details of variable construction are in the online Data Appendix. Column 5 shows coefficients from a regression of each covariate on gradient; column 6 additionally controls for all other covariates and district fixed effects. Differences in columns 4–6 are significant at $p < 0.01$***, $p < 0.05$**, or $p < 0.1$* level. The Bonferroni joint test of significance across all ten main covariates requires $p < 0.005$ to reject the null of all coefficients zero at a 5 percent level of significance and $p < 0.001$ to reject at the 1 percent level. The maximum p-value is 0.000 in column 4, 0.002 in column 5, and 0.002 in column 6.

community boundaries of the sample (online Appendix 1 contains larger color versions of these maps). Shaded areas are communities included in the analysis sample. The geographic fragmentation that characterized the former homeland of KwaZulu is evident: the apartheid government forcefully resettled Africans to areas deemed inhospitable for white settlement, wherever those happened to be, with the result that these homeland areas were not geographically contiguous across the province (Christopher 2001). Note also that gradient varies widely across the region, with dark-shaded areas being the steepest.

Administrative data indicate that 20 percent of communities in the sample area received an Eskom project between 1996 and 2001. The remainder either never received an electricity project or had a project only after 2001, or prior to 1996. The strength of defining electrification status using project data is that new access to infrastructure can be directly identified, rather than inferred from time variation in electricity use, which may be correlated with changes in wealth that are difficult to control for in a two-wave panel.

Several features of project placement are evident in the second map in Figure 2, which shows the distribution of (dark-shaded) electrified and (light-shaded) nonelectrified areas. Being close to the original grid is neither necessary nor sufficient for electrification between 1996 and 2001. Proximity to a town is also not necessary for electrification. Finally, electrified areas are distributed across several districts rather than clustered in one area. This important fact makes it possible to include district fixed effects in the main analysis to absorb aggregate differences in employment growth rates across local labor markets.

Stark differences across communities with and without an Eskom project are evident in columns 2 to 4 of Table 1. Compared to nonelectrified areas, electrified communities are significantly less poor, have fewer adult women relative to men, have higher fractions of high school–educated adults, and are almost three kilometers closer to the nearest road and town. Given that low average cost areas were prioritized for projects, it is not surprising that electrified areas have significantly higher household densities, are 4.1 kilometers closer to the nearest substation, and have a 1.2-degree flatter average gradient than areas without an Eskom project. If electricity projects had been randomly assigned to communities, most of these observable characteristics would be balanced across project and nonproject areas. Instead, a joint test of the hypotheses that each of these differences in column 4 is zero can be rejected at the 1 percent level.[16]

Since the main analysis is based on using gradient to instrument for project placement, I compare values of each covariate across steep and flat areas in the last two columns of Table 1. I regress each covariate on gradient alone (column 5) and then include all other covariates and ten district fixed effects as controls (column 6). There are no significant differences in poverty rate, the fraction of female-headed households, any of the distance variables or the fraction of females with high school. There are remaining, although small, differences in the adult sex ratio (0.004), household density (0.94 households per square kilometer), and fraction of men with high school (0.003), although a joint test for each difference's being zero cannot be rejected at the 1 percent level. Column 6 shows that gradient balances more of the community-level variables at baseline than the Eskom project assignment, conditional on all other controls.

B. *Describing Community-Level Employment Rates*

The main outcome variable this article analyzes is the employment-to-population rate of African women and men aged 15 to 59 (inclusive). Census employment questions are broad, but similar across years.[17] Table 2 presents average employment rates for men and women across Eskom project and nonproject areas in 1996 and 2001, as well as the differences in these rates across years (in rows labeled Δ_t) and across project assignment areas (in column 4).

Two striking points emerge from this table: Employment rates are very low for men and women and are falling—and falling faster—for men in electrified areas between 1996 and 2001. In column 2, female employment remains low (7 percent)

[16] I implement this as a Bonferroni test. The relevant p-value for rejection of this joint null at the 1 percent level of significance, given ten variables, is $p < 0.01 / 10 = 0.001$. If at least one p-value is less than 0.001, the null is rejected. In column 4, the null is decisively rejected at the 1 percent level, while in column 6, this null is not rejected at the 1 percent level.

[17] See online Appendix 1: Data for details on the construction of employment variables.

Table 2—Average Community-Level Employment Rates in 1996 and 2001

	Year	Means (standard deviation) Full sample (1)	Eskom project (2)	No project (3)	Difference: Column 2–3 (4)
Female employment rate	1996	0.07	0.09	0.06	0.021***
		(0.08)	(0.07)	(0.08)	(0.00)
	2001	0.07	0.08	0.06	0.017***
		(0.07)	(0.07)	(0.07)	(0.00)
Difference	Δ_t	0.000	−0.003	0.001	−0.004
		(0.002)	(0.005)	(0.00)	(0.00)
Male employment rate	1996	0.14	0.16	0.13	0.031***
		(0.11)	(0.11)	(0.11)	(0.01)
	2001	0.10	0.11	0.10	0.014**
		(0.09)	(0.09)	(0.09)	(0.01)
Difference	Δ_t	−0.04***	−0.050***	−0.033***	−0.017***
		(0.00)	(0.01)	(0.00)	(0.01)
N		1,816	365	1,451	

Note: Differences within communities over time are shown in Δ_t rows.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

and steady across communities between 1996 and 2001, while male employment falls from 14 to 10 percent. Employment is uniformly higher in electrified than in nonelectrified communities in 1996. Comparing changes in employment rates in Eskom project areas to the same change in nonproject areas (column 4), the unadjusted difference-in-differences estimate for women is not significantly different from zero, while for men it is a statistically significant −1.7 percentage points.

That South Africa has low levels of employment is not a new insight (for example, see Stephan Klasen and Ingrid Woolard 2009 and Banerjee et al. 2007). However, the employment rates in Table 2 are extremely low even for this country. This is partly because the census asks only broad questions on employment and does not probe for work activities, as a labor force survey might do. Another reason for these low employment rates is that the analysis sample includes only rural, ex-homeland areas of KwaZulu-Natal. As described by Cally Ardington and Frances Lund (2006, p. 12), the homelands "consigned millions of people to rural areas with few employment opportunities." These ex-homeland areas are ill suited for agriculture, and work opportunities are concentrated in civil service (mainly teaching) and domestic work, both jobs favoring the employment of women. Many jobs in these areas are also marginal, with workers working under 20 hours per week (Ardington and Lund 2006), and large fractions of households rely on income from welfare grants (old age pensions) and migrant workers to get by. Individual-level data from surveys designed to capture all types of work do reflect employment in rural areas of KZN is very low and employment in agriculture is almost nonexistent.[18]

[18] In online Appendix 4, I show that the community census data likely undercounts employment relative to household and labor force survey data, and that this undercount appears somewhat larger for men than for women. Across several datasets, I also show that agriculture does not account for much employment in these areas.

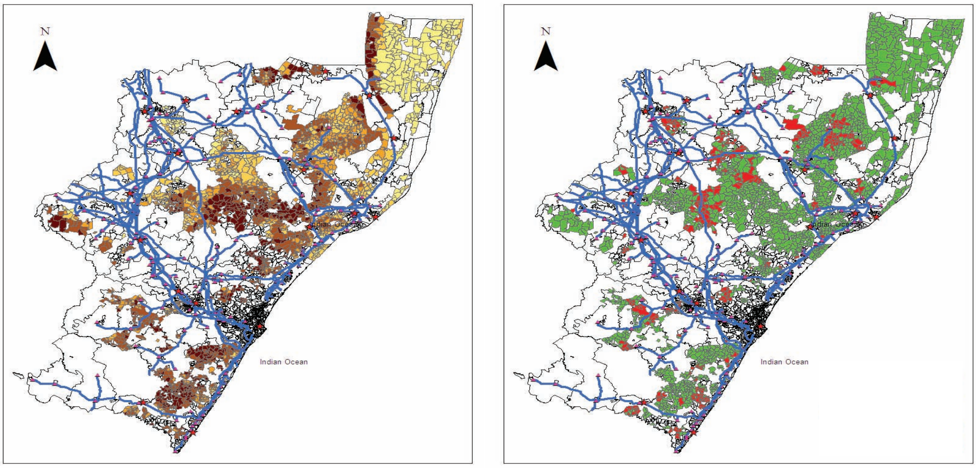

FIGURE 2. SPATIAL DISTRIBUTION OF GRADIENT AND ELECTRICITY PROJECT AREAS IN KWAZULU-NATAL

Notes: Shaded communities are in the analysis sample ($N = 1{,}816$). Thick lines depict electricity gridlines in 1996, triangles are electricity substations in 1996, and stars represent towns. Gradient is shown in the figure on the left: steeper areas are shaded dark, flatter areas are shaded light. Electricity Project areas are depicted in the figure on the right: project areas are shaded dark, lighter shaded areas are electrified after 2001 or not at all.

Source: Author's calculations.

The large drop in employment for men in Eskom project relative to nonproject areas should not be interpreted as the causal effect of electrification. Rather, these changes in employment rates for men and women are confounded by broad changes in the South African labor market during the 1990s. Figure 3A shows trends in male and female employment in rural KZN (including but not restricted to homeland areas) over time using the OHS and LFS household surveys in 1995, 1997, 1999, and 2001. These are the same data used in the fixed effects analysis in Section VC. Employment rates using these data are higher than in the census, but still extremely low. Employment for men falls significantly between 1995 and 2001 and falls to a lesser extent for women. Figure 3B shows (log) wage trends using the same data. Over the period, male wages are roughly constant, while female wages fall and are lower in 2001 than in 1995. Dissecting overall changes in employment, Banerjee et al. (2007) document large shifts in the composition of jobs away from commercial agricultural and mining sectors, and toward service and retail sectors. These trends had a heavy impact on jobs in male-dominated sectors in the 1990s. The types of new jobs created during this time were predominantly low skill and in the informal sector, in sectors that favor female workers (Casale, Muller, and Posel 2004), and there is evidence that the number of jobs for self-employed workers and household workers increased substantially between 1995 and 2001 (Banerjee et al. 2007).

A common challenge in evaluating the economic effects of an expansion in infrastructure revolves around how to control for expansions in the economy that may confound the effects of the new infrastructure. The South African case presents a different challenge. Eskom was more likely to be electrifying households in areas that were experiencing longer-term declines in employment and economic activity. This is because grid expansion was constrained by initial network placement, and the network that existed at the end of apartheid had been set up to service commercial farms and previously white towns. Hence, many of the factors that determined whether a community got early access to electricity were the same factors that increased a community's exposure to the industrial restructuring of the 1990s. The results of this type of selection are evidenced in the greater decline in male employment rates in electrifying areas, shown in Table 2. In the next section, I outline two different empirical strategies that deal with endogenous project placement and these confounding factors in alternate ways.

IV. Empirical Strategies

Let y_{jdt} be outcome y (for example, the female employment rate) for community j and district d in time period $t = [0, 1]$. T_{jdt} is an indicator variable for whether a community has received an electricity project by time period t. If electrification T_{jdt} was randomly assigned across communities, we could estimate the average treatment effect of electrification (α_2) by ordinary least squares as in (1):

$$(1) \qquad y_{jdt} = \alpha_0 + \alpha_1 t + \alpha_2 T_{jdt} + \mu_j + \delta_j t + \rho_d + \lambda_d t + \epsilon_{jdt},$$

where μ_j is a community fixed effect, $\delta_j t$ is a community trend, ρ_d is a district fixed effect, $\lambda_d t$ is a district trend and ϵ_{jdt} is an idiosyncratic error term. To eliminate μ_j and ρ_d, rewrite equation (1) in first differences:

$$(2) \qquad \Delta y_{jdt} = (y_{jdt+1} - y_{jdt}) = \alpha_1 + \alpha_2 \Delta T_{jdt} + \lambda_d + (\delta_j + \Delta\epsilon_{jdt}).$$

With the two wave census panel, I can measure Δy_{jdt}, ΔT_{jdt}, and λ_d, but not δ_j. OLS estimation of (2) will not identify the causal effects of electrification as long as $\delta_j + \Delta\epsilon_{jdt}$ is correlated with ΔT_{jdt}. If electricity projects are allocated to communities growing faster for unobservable reasons then $\hat{\alpha}_{2,OLS}$ would be biased upwards. However, the results in the previous section suggest that we should be more concerned with negative selection, and a downward bias in $\hat{\alpha}_{2,OLS}$ in the South African case.[19]

To deal with factors that could affect a community's growth path (δ_j), I first control for a vector of community covariates $(\mathbf{X}_{jd0})$ measured in 1996 in estimating equation (2). Covariates include household density; fraction of households living below a poverty line; distances to the grid, road, and town; fraction of adults that are white or Indian to proxy for local employers; fraction of men and women with a completed high school certificate; and two standard proxies for community poverty, the share of female-headed households and the female/male sex ratio (Guy Standing, John Sender, and Jeremy Weeks 1996). I also include a set of ten district fixed effects, so that all comparisons across project and nonproject areas occur for areas in the same local labor markets.

Even with these controls, however, confounding trends in community-level employment and unmeasured political factors that could affect project placement

[19] Measurement error in ΔT_{jdt} presents another practical challenge for estimating equation (2). See the discussion of this issue in online Appendix 4.

are still of concern. To overcome these challenges to identification, I instrument for program placement using average community land gradient (Z_j). The system of equations to be estimated is:

$$(3)\ \Delta y_{jdt} = (y_{jdt+1} - y_{jdt}) = \alpha_1 + \alpha_2 \Delta T_{jdt} + \mathbf{X}_{jd0}\boldsymbol{\beta} + \lambda_d + (\delta_j + \Delta\epsilon_{jdt})$$

$$(4)\qquad \Delta T_{jdt} = \pi_0 + \pi_1 Z_j + \mathbf{X}_{jd0}\boldsymbol{\pi_2} + \gamma_d + \tau_{jdt},$$

where $(\delta_j + \Delta\epsilon_{jdt})$ and τ_{jdt} are unobserved. The identification assumption is that conditional on baseline community characteristics, proximity to local economic centers and grid infrastructure, and district fixed effects, land gradient does not affect employment growth independently of being assigned an electrification project.

One concern with using land gradient as an instrumental variable in a rural setting is that it may directly affect agricultural outcomes. In rural KZN, the direct impact of gradient on agricultural productivity and agricultural employment growth is limited, since most people are not farming. Under 10 percent of employed individuals are involved in agriculture.[20] A second concern is that individuals may sort, nonrandomly, across flat and steep areas, which could result in differential employment growth, independent of new electrification. While mobility *within* homeland areas during this time is limited by a lack of property titling and the role of tribal authorities in land allocation, in-migration and out-migration do occur, as I describe in the last part of the article.[21] I show that differential in-migration to flatter areas cannot account for the employment effects of electrification and argue that selective out-migration cannot explain employment effects either, given the profile of rural out-migrants.

Conditional on instrument validity, $\alpha_{2,IV}$ captures the local average treatment effect (LATE) of electricity projects on community-level employment growth. In my results, community composition drives marginal effects. So, if individuals living in flatter areas can better afford electricity once it arrives, or if individuals living in flatter communities have fewer other home production demands (i.e., child care), then a larger than average treatment effect may be measured for these areas. Employment returns to electrification may also differ by gradient, leading to larger estimated employment effects for marginal than for average communities. For example, flatter areas always have lower commuting costs, so individuals in flatter areas always face a higher net wage. Since these individuals are initially closer to the employment participation margin, they will always be more likely to respond when electricity arrives.[22] These reasons lead us to expect IV estimates to be larger than average treatment effects.

[20] Farming accounted for only 10 percent of household earnings in homeland areas by the mid-1980s (Nick Vink and Stefan Schirmer 2002). Ardington and Lund (1996, p. 48) write that "a significant percentage of the income of rural households is sourced outside the household and indeed outside rural areas" and that "land is nowhere the 'main source' of income for the majority of rural households" (Ardington and Lund 1996, p. 55). Online Appendix 4 provides more details about the low levels of agricultural employment in rural KZN.

[21] Personal communication, Department of Land Affairs, Pietermaritzburg (June 2006).

[22] A potential threat to validity arises if gradient is strongly correlated with road access (e.g., Nathan Nunn and Diego Puga 2007 discuss the impact of terrain ruggedness on transportation costs). Changing economic activities in distant markets may be more easily accessible for flatter communities, hence making gradient itself a "treatment." To test whether employment is responding only to access to roads, I reestimate results for communities without main roads. Results for female employment, presented in online Appendix 3, are similar.

To complement the IV strategy, I present an alternative identification strategy which I refer to as the MD-FE/MD-trends analysis. I pool information from four cross-sections of South Africa household survey data to estimate the impact of electrification on male and female employment, hours of work, wages, and earnings. The sample is restricted to African men and women living in rural areas of KZN, for which there are at least 900 respondents per year. The major drawback to using these data is that respondents can be situated only in the magisterial district (MD) in which they reside, which cannot be linked to the Eskom project data.

I regress each of the labor market outcomes on age, age-squared, and years of education, obtain the residuals from these regressions, and average the residuals within year (t), magisterial district (m), and sex (s) to create up to 304 observations on outcomes (4 years $\times$ 38 m observations each for males and females). I also construct the fraction of households with electric lighting for each MD-year ($ELEC_{mt}$). This is a reasonable proxy for expanding access to the grid since almost all households getting access to the grid were able to use electric lighting. Then, I estimate regressions of these residuals ($\bar{\hat{\epsilon}}_{mt}$) on $ELEC_{mt}$, a common time trend (t), and a full set of MD fixed effects (λ_m) and MD-specific trends ($\delta_m t$):[23]

$$\bar{\hat{\epsilon}}_{mt} = \gamma_0 + \gamma_1 ELEC_{mt} + \gamma_2 t + \lambda_m + \delta_m t + \nu_{mt}. \tag{5}$$

Without controlling for MD-FE and MD-specific trends, γ_1 is identified using variation in electric lighting within and across MDs. In the MD-FE/MD-trends specification, γ_1 is identified using variation in electric lighting within the MD over time, after accounting for λ_m and $\delta_m t$. Including MD-specific trend terms controls for differential trends across MDs with different rates of electrification that could confound the labor market impacts (this is analogous to the correlation between δ_j and project status ΔT_{jdt} in the main empirical strategy). Although these regressions are estimated on a small sample, making precise estimation difficult, they provide useful complementary evidence of the effects of electrification on employment on the extensive and intensive margins and on earnings and wages. Moreover, given the richer set of labor market outcome variables, these results are informative about whether electrification affects net labor demand or supply in rural areas.

V. Results

A. *Assignment of Electricity Projects to Communities*

First-stage estimates for the allocation of an electricity project to a community are presented in Table 3. The outcome variable is an indicator for whether a community received an electricity project between 1996 and 2001. The coefficient on gradient indicates that for a two–standard deviation increase in gradient (about 10 degrees), the probability of receiving an Eskom project falls by about 8 percentage points. Across columns, the size of the coefficient does not change substantially with the addition of more controls, while the precision of the estimate improves.

[23] Instrumenting for $ELEC_{mt}$ is not possible in this framework, as gradient has no predictive power in explaining electrification rates at the more aggregated magisterial district level.

TABLE 3—ASSIGNMENT TO ESKOM PROJECT: FIRST STAGE OLS ESTIMATES

Dependent variable: Eskom project = [1 or 0]	(1)	(2)	(3)	(4)
Gradient × 10	−0.083**	−0.075**	−0.078***	−0.077***
	(0.040)	(0.034)	(0.027)	(0.027)
Kilometers to grid × 10		−0.040*	−0.012	−0.011
		(0.021)	(0.023)	(0.023)
Household density × 10		0.017***	0.012**	0.013**
		(0.004)	(0.006)	(0.006)
Poverty rate		0.023	0.019	0.017
		(0.069)	(0.070)	(0.069)
Female-headed HHs		0.393***	0.165	0.155
		(0.120)	(0.107)	(0.107)
Adult sex ratio		−0.173***	−0.130***	−0.121***
		(0.052)	(0.042)	(0.042)
Indian, white adults × 10		−1.236***	−1.116**	−1.105**
		(0.401)	(0.459)	(0.452)
Kilometers to road × 10		0.003	−0.010	−0.010
		(0.009)	(0.010)	(0.010)
Kilometers to town × 10		0.016	0.008	0.008
		(0.015)	(0.015)	(0.016)
Men with high school		−0.269	−0.185	−0.152
		(0.500)	(0.411)	(0.417)
Women with high school		1.046**	0.965**	0.984**
		(0.475)	(0.413)	(0.409)
Δ_t water access				0.012
				(0.048)
Δ_t toilet access				0.155
				(0.104)
District fixed effects	N	N	Y	Y
Mean of outcome variable	0.20	0.20	0.20	0.20
N communities	1,816	1,816	1,816	1,816
R^2	0.01	0.07	0.18	0.18
F-statistic on gradient	4.20	4.87	8.34	8.26
Pr > F	0.04	0.03	0.00	0.00

Notes: Robust standard errors clustered at subdistrict level. Ten district fixed effects included in columns 3 and 4. Change in fraction of households with access to water and flush toilet measured between 1996 and 2001.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

The inclusion of district fixed effects in this first stage is important, as a large amount of the variation in gradient comes from cross-district variation (see Figure 3). This means that without controlling for district, the first stage compares project assignment across very different places in terms of gradient and in terms of local labor market conditions. By controlling for district as in columns 3 and 4, I compare places that are in the same local labor market, but which are slightly flatter or steeper.

The two other cost variables have coefficients of expected sign in the first stage results of Table 3: a three-quarter–standard deviation increase in distance from the grid (about 10 kilometers) reduces the probability of electrification by 1 percentage point, although this is not significant when all other controls are added. A one-third–standard deviation increase in household density (10 households) per square kilometer increases the probability of electrification by about 1.3 percentage

Figure 3. Employment Rates and Hourly Wages over Time by Gender

Notes: Figures show fraction of adult African men and women employed and average hourly log wage rate (in ZAR) for the employed, using data from October Household Surveys 1995, 1997, 1999, and the September Labour Force Survey 2001. Sample includes individuals living in rural KZN. Dashed lines are 95 percent confidence intervals. The unit of observation is the individual.

points. The influence of household density is robust and strongly significant across specifications.

These project assignment regressions provide mixed evidence on whether electrified areas are positively selected on wealth. While areas with more adult women than adult men (i.e., poorer areas) are significantly less likely to receive an electricity project, areas with more white and Indian adults (i.e., richer areas) are also less likely to be electrified during these years. The community poverty rate and fraction of female-headed households also have large positive coefficients in all specifications, suggesting that projects may be targeted to poorer areas. This lack of strong evidence for project placement in richer areas and strong predictive power of two of the three cost variables is consistent with the overarching sociopolitical motivation for the roll-out.

B. *Employment Effects of Electrification: OLS and IV Results*

Coefficients from OLS and IV regressions of employment are presented in Table 4 for women and Table 5 for men. The tables provide estimated coefficients and robust standard errors for a subset of control variables, clustered at the subdistrict level.[24] The dependent variable in each column is the change in female (or male) employment rate between 1996 and 2001. Columns 1 to 4 in each table present OLS results, and columns 5 to 8 present the IV results (reduced form coefficients from regressions of employment rate on gradient and all other controls are presented in online Appendix 3).

The coefficient on Eskom project in column 1 of each table echoes the descriptive statistics in Table 2: there is no significant growth in female employment across project and nonproject areas, while male employment falls by 1.7 percent. Adding

[24] The subdistrict level is one level of aggregation up from the community level and one level below the district. Inference is robust to estimating standard errors using Conley's spatial error correction methods (Timothy Conley 1999); see online Appendix 3.

Table 4—Effects of Electrification on Employment: Census Community Data

	Δ_t female employment rate							
	OLS regression coefficients				IV regression coefficients			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Eskom project	−0.004	−0.001	0.000	−0.001	0.025	0.074	0.090*	0.095*
	(0.005)	(0.005)	(0.005)	(0.005)	(0.045)	(0.060)	(0.055)	(0.055)
A. R. 95 percent C.I.							*[0.05; 0.3]*	*[0.05; 0.3]*
Poverty rate		0.029***	0.033***	0.031***		0.027**	0.032**	0.031**
		(0.011)	(0.010)	(0.010)		(0.012)	(0.013)	(0.013)
Female-headed HHs		0.042**	0.051***	0.047**		0.014	0.036	0.033
		(0.019)	(0.019)	(0.020)		(0.031)	(0.026)	(0.026)
Adult sex ratio		0.019**	0.017**	0.020***		0.033**	0.029**	0.032***
		(0.009)	(0.008)	(0.007)		(0.014)	(0.012)	(0.012)
Baseline controls?	N	Y	Y	Y	N	Y	Y	Y
District fixed effects?	N	N	Y	Y	N	N	Y	Y
Δ_t other services?	N	N	N	Y	N	N	N	Y
N communities	1,816	1,816	1,816	1,816	1,816	1,816	1,816	1,816

Notes: Robust standard errors clustered at subdistrict level. Eskom project is instrumented with mean community land gradient. See Table 3 for full list of control variables. The last two columns provide confidence intervals (C.I.) from the Anderson-Rubin (A.R.) test for the coefficient on Eskom project. The test is robust to weak instruments and implemented to be robust to heteroskedasticity.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table 5—Effects of Electrification on Employment: Census Community Data

	Δ_t male employment rate							
	OLS regression coefficients				IV regression coefficients			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Eskom project	−0.017**	−0.015***	−0.009	−0.010*	−0.063	0.069	0.033	0.035
	(0.007)	(0.006)	(0.006)	(0.006)	(0.073)	(0.082)	(0.064)	(0.066)
A. R. 95 percent C.I.							*[−0.05; 0.25]*	*[−0.05; 0.25]*
Poverty rate		0.062***	0.064***	0.063***		0.059***	0.064***	0.062***
		(0.020)	(0.018)	(0.018)		(0.022)	(0.019)	(0.019)
Female-headed HHs		0.217***	0.233***	0.227***		0.187***	0.227***	0.220***
		(0.029)	(0.030)	(0.030)		(0.042)	(0.034)	(0.034)
Adult sex ratio		0.018*	0.012	0.017		0.034*	0.018	0.023
		(0.011)	(0.011)	(0.011)		(0.019)	(0.015)	(0.015)
Baseline controls?	N	Y	Y	Y	N	Y	Y	Y
District fixed effects?	N	N	Y	Y	N	N	Y	Y
Δ_t other services?	N	N	N	Y	N	N	N	Y
N communities	1,816	1,816	1,816	1,816	1,816	1,816	1,816	1,816

Notes: Robust standard errors clustered at subdistrict level. Eskom project is instrumented with mean community land gradient. See Table 3 for full list of control variables. The last two columns provide confidence intervals (C.I.) from the Anderson-Rubin (A.R.) test for the coefficient on Eskom project. The test is robust to weak instruments and implemented to be robust to heteroskedasticity.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

community-level controls and district fixed effects in columns 2 and 3 increases the coefficient on electrification slightly, with the female employment effect still not significantly different from zero and male employment becoming less negative and less statistically significant. The positive, significant coefficients on poverty rate, sex ratio, and female-headed households in both tables indicate that female and male employment rises faster in poorer places in the late 1990s.

IV estimates of electrification are substantially larger than OLS estimates and significantly positive for women in Table 4 columns 8 and 9. Since column 5, Table 1 indicated that gradient is correlated with some of the control variables especially when district fixed effects are not controlled for, and since the *F*-statistic on the excluded variable in the first stage is larger once other controls absorb residual variation (Table 3), my preferred estimates are in columns 8 and 9 of Tables 4 and 5.[25] In these columns, female employment increases by 9 to 9.5 percentage points, or between 30 and 35 percent from baseline, in the wake of an electricity project. The Anderson-Rubin (AR) test for whether electrification raises female employment strongly rejects zero, and the 5 percent confidence interval is wider than the standard 5 percent confidence interval, ranging from 5 to 35 percentage points. Male employment increases by a substantially smaller 3.5 percentage points, and this is not significantly different from zero under either the standard test or the AR test (column 9, Table 5). Although I cannot reject that the male and female employment effects are the same, there is no reduced form for male employment (column 5, Table 5).[26] It is therefore difficult to precisely estimate the impact on male employment using these census data; part of this may be related to the fact that the census undercounts male employment more than female employment in these areas (see online Appendix 4 for details).

Another aspect of these results that bears mentioning is the sensitivity of the female employment results to the inclusion of district fixed effects as in equation (3). This reflects the fact that differences in gradient are larger across districts than within districts. Excluding district fixed effects means that employment effects are identified off of cross-district comparisons in female employment growth. Since local labor markets differ substantially across districts, including district fixed effects allows me to identify the effect of electrification by comparing slightly steeper to slightly flatter areas within the same local labor market.

The IV results suggest that in a nonelectrified community with the median number of adult women in 1996 ($N = 285$), a 9 percentage point increase in female employment raises the number of women working by 26 women, from 19 to 45. If we assume this 9 percentage point increase applies to the entire group of electrified communities (rather than marginal communities only), this translates into an increase of approximately 15,000 newly employed women out of the baseline female population of 165,637. This is 0.75 percent of the estimated 2 million new jobs created across the country over the period (Casale, Muller, and Posel 2004).

Threats to Validity in the IV Strategy.—If employment rates in steep and flat areas evolve differently even in the absence of new electricity, the gradient IV would

[25] To address concerns about overoptimistic inference with a possibly weak instrument, heteroskedasticity-robust Anderson-Rubin (AR) confidence intervals are computed for the main Eskom project parameter estimate in the second stage and shown in Tables 4 and 5. These AR confidence intervals have correct coverage properties in the presence of weak instruments, while standard Wald tests do not (Anna Mikusheva and Brian Poi 2006; Victor Chernozhukov and Christian Hansen 2008).

[26] I implemented this test by differencing the male and female outcome variables within community and estimating the same OLS and IV regressions using this new dependent variable. This test respects the correlated structure of the error terms ($\Delta\epsilon_{jdt}$) across male and female regressions (see online Appendix 3).

TABLE 6—OLS COEFFICIENTS FROM PLACEBO EXPERIMENT AND REDUCED FORM REGRESSIONS FOR FEMALE EMPLOYERS: CENSUS COMMUNITY DATA

	Placebo experiment:	Growth in major employers	
	Δ_t female employment	Δ_t schools	Δ_t Indian, White adults
	(1)	(2)	(3)
Gradient × 10	−0.001	0.007	0.000
	(0.001)	(0.028)	(0.000)
Sample	Areas electrified before 1996	Full sample	Full sample
N communities	373	1,816	1,816
R^2	0.11	0.06	0.04

Notes: Each column shows coefficients from OLS regressions of outcome variables on community gradient and all community-level controls as in Table 3. Robust standard errors clustered at subdistrict level. In column 1, sample is restricted to areas that had electricity projects prior to 1996. In column 2, the outcome variable is the change in the number of schools in a community between 1996 and 2001. In column 3, the outcome is the change in the fraction of Indian and white adults in the community between 1996 and 2001; the fraction of Indian/white adults in the community is excluded from this regression.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

be invalid. Without more years of data, this is difficult to check directly. Instead, I implement an indirect placebo test using historical administrative data on electricity projects. These data identify areas that are electrified prior to 1996, which were excluded from the main analysis. For these areas, there should be no reduced-form relationship between gradient and employment growth between 1996 and 2001, since they have already received an electricity project. If there is, this would suggest that gradient has a direct effect on employment growth. To test this, I estimate OLS regressions of the change in female employment in areas electrified prior to 1996 $(N = 373)$ on gradient and the full set of controls. Column 1 of Table 6 contains the results of this placebo test. The coefficient on gradient is small (-0.001) and insignificant, yet significantly different from the 0.007 reduced form coefficient on gradient in column 5, Table 4, panel A. Thus, there is no evidence of any reduced-form relationship between gradient and female employment in the set of areas already electrified by 1996 (the same is true for males; results not shown). This boosts confidence in the research design.

A second potential threat to the validity of the IV strategy arises if flatter communities received positive labor demand shocks concurrent with electricity projects. Unfortunately, no dataset captures the presence of firms in rural KZN regions. Instead, I test whether there are larger increases in the major sources of female labor demand in flatter communities. Individual-level census data suggest that most women in these areas work as teachers or domestic workers. In columns 2 and 3 of Table 6, I test whether gradient is negatively correlated with growth in new schools (using data from Statistics South Africa[27]) or with the growth in new employer households (proxied for by the change in fraction of Indian and white adults in the population).

[27] Statistics South Africa. 1995 and 2000. "South African Schools Register of Needs."

Table 7—Employment, Hours of Work, Wages and Earnings for Africans in Rural KZN 1995–2001: Household Survey Data

	Females		Males		Females		Males	
	OLS (1)	FE (2)	OLS (3)	FE (4)	OLS (5)	FE (6)	OLS (7)	FE (8)
	Panel A. Employment [1/0]				*Panel B. Usual weekly hours of work*			
MD electrification rate	0.126**	0.128	0.090	0.134	6.646***	8.920	5.671**	13.090
	(0.058)	(0.149)	(0.077)	(0.164)	(1.771)	(6.634)	(2.597)	(12.947)
Trend (1995–2001)	−0.010	0.046**	−0.051***	−0.075***	−0.407	−0.588	−0.322	−1.424
	(0.012)	(0.020)	(0.012)	(0.022)	(0.491)	(0.872)	(0.620)	(1.701)
N	152	152	152	152	151	151	151	151
Mean of outcome	0.25	0.25	0.42	0.42	42.82	42.82	46.94	46.94
R^2	0.06	0.63	0.09	0.76	0.06	0.42	0.03	0.45
	Panel C. Log hourly wage				*Panel D. Log monthly earnings*			
MD electrification rate	−0.148	−1.380	0.101	0.171	−0.070	−0.616	0.414**	1.107**
	(0.253)	(1.046)	(0.211)	(0.483)	(0.225)	(0.995)	(0.191)	(0.477)
Trend (1995–2001)	−0.079***	0.132	−0.027	0.077	−0.091**	−0.065	−0.047	−0.085
	(0.030)	(0.137)	(0.032)	(0.063)	(0.037)	(0.131)	(0.033)	(0.063)
N	146	146	148	148	146	146	148	148
Mean of outcome	1.17	1.17	1.49	1.49	6.42	6.42	6.80	6.80
R^2	0.03	0.52	0.00	0.51	0.03	0.52	0.05	0.57

Notes: Columns 1, 3, 5, and 7 show coefficients from OLS regressions of magisterial district (MD) residuals on MD electrification rates, a linear time trend, and a constant. Columns 2, 4, 6, and 8 show coefficients from the same regressions, including MD fixed effects and MD specific trends. Unit of observation is the MD-year. Robust standard errors, clustered at the MD level. Panel C and D regressions exclude MDs in which no one reports positive earnings. Data are from October Household Surveys 1995, 1997, and 1999 and the September Labour Force Survey 2001. Mean MD electrification rate is 0.3, and the average change between 1995–2001 is 0.15.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Despite the fact that the number of schools across rural KwaZulu-Natal increases by almost 20 percent between 1995 and 2000, which undoubtedly increases the demand for teachers, column 2, Table 6 shows this increase is uncorrelated with community gradient. And although other researchers have documented the growth in low skill, informal sector jobs in the economy during the 1990s (Banerjee et al. 2007; Casale, Muller, and Posel 2004), the results in column 3, Table 6 indicate no differential expansion in this source of demand for female workers in flat relative to steep areas of rural KZN.

C. *Employment and Wage Effects of Electrification: Results from the MD-FE/MD-Trends Analysis*

To provide supporting evidence on the employment effects estimated using the IV strategy and to shed light on the mechanisms through which electricity raises employment, I turn to results from the MD-FE/MD-trends analysis. Table 7 presents coefficients from OLS and FE regressions of equation (5), for employment rates (panel A), usual weekly hours of work (panel B), log hourly wages (panel C), and log monthly earnings (panel D). Standard errors are robust to heteroskedasticity and clustered at the MD level. Recall that the MD fixed effects and MD-specific trends control for the differential economic trends that could confound the impact of electrification on labor market outcomes. The coefficient on electrification is identified off of the variation in electrification rates over time, within an MD, after MD trends have been accounted for.

Consider first the estimates for employment: in areas where electrification increases, male and female employment increase substantially in the OLS specification. The average increase in electrification over the period (0.15) translates into a 1.3 percentage point increase in employment for men and a 1.8 percentage point increase for women, although male-female differences are not statistically different from zero. Coefficients are similar under OLS and FE specifications. However, once all fixed effects and trend terms are included, none of the electrification coefficients is precisely estimated in this small sample. Weekly hours of work exhibit the same pattern, with OLS coefficients being estimated more precisely than FE coefficients. Women work 8.9 hours more and men work 13 hours more per week in MDs with higher electrification rates, compared to the same MDs in periods of lower electrification. For the average change in electrification rate (0.15), this amounts to between 1.3 and 1.9 hours more work per week. The male-female differences are again not statistically different from each other. The magnitude of this intensive margin response is consistent with the new work being informal and perhaps in self-employment rather than in full-time formal sector positions.

It is worth comparing the employment results in Table 4 with those of Table 7. Both approaches show female employment rising in electrifying areas, on either the extensive or intensive margins. Male employment effects are never significantly different from zero once selection has been accounted for, but the coefficients on electrification are still generally large and positive. Using variation in project status across steep and flat communities in the same local labor market, Table 4 tells us that in areas that received an Eskom project, female employment increased by 9.5 percentage points, relative to baseline female employment of about 7 percent. Using a different source of variation, household survey results in Table 7 indicate that employment increases by a smaller 1.8 percentage points for women in MDs with the average change in electrification rates. Hours of work increase slightly more, at 3 to 4 percent in electrifying areas.

There are three reasons why these results differ in magnitude. First, while the IV strategy focuses on changes in small communities, the MD-FE/MD-trend analysis examines changes in larger MDs. It is not clear that we should expect analysis at different levels of aggregation to produce results of the same magnitude. Second, each strategy uses different sources of variation: the IV strategy compares flat to steep areas while the MD-FE/MD-trends analysis uses variation within the same MD over time. Again, it is not clear that we should expect these comparisons to be identical, although it is comforting that they point in the same direction. Finally, new access to electricity is measured in different ways under each strategy: as a binary variable in the IV strategy and as the fraction of households with electric lighting in the MD-FE/MD-trends strategy. We can use information on the change in fraction of households using electric lighting in project versus nonproject areas to rescale the community-level IV results. In census communities that experience the Eskom-induced increase in electric lighting (65 percent, explained in Table 8 below), female employment rises by 6 percentage points (0.095×0.63). This rescaled employment result from the IV analysis is much closer to the results from the MD-FE/MD-trend analysis.

Table 8—Effects of Electricity Projects on Household Energy Sources and Other Household Services: Census Community Data

Outcome is Δ_t in:	OLS No controls (1)	OLS Controls (2)	IV No controls (3)	IV Controls (4)
(1) Lighting with electricity	0.251***	0.221***	0.577***	0.635***
Mean: 0.08	(0.032)	(0.031)	(0.188)	(0.227)
(2) Cooking with wood	−0.045***	−0.039***	−0.266	−0.275*
Mean: −0.035	(0.012)	(0.012)	(0.179)	(0.147)
(3) Cooking with electricity	0.068***	0.056***	0.250**	0.228**
Mean: 0.037	(0.009)	(0.009)	(0.107)	(0.101)
(4) Water nearby	−0.029	0.005	−0.483*	−0.372
Mean: 0.007	(0.029)	(0.024)	(0.249)	(0.248)
(5) Flush toilet	0.003	0.008	0.018	0.067
Mean: 0.03	(0.006)	(0.005)	(0.069)	(0.068)

Notes: Each cell in the table presents the Eskom project coefficient (and standard error) from an OLS or IV regression of the dependent variable on an Eskom project indicator and (in columns 2 and 4) all control variables described in Table 3. Robust standard errors clustered at subdistrict leve1. Outcome variables measure the change in fraction of households using different energy sources or with access to basic services. Change in water (toilet) access excluded from the set of controls in rows 4 and 5. Each regression contains $N = 1{,}816$ except for change in fraction of households using wood; there are nine communities with missing data on this variable.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Turning to the effects of electrification on wages and earnings in the lower panel of Table 7: wages for women fall in areas where electricity is rolling out (panel C, columns 1 and 2), and more so in the MD-FE specification. For the average change in fraction of households with electric lighting, women's wages fall by about 20 percent (1.38×0.15), while for men, the coefficient on electrification rate is positive but not significant. Combining the increase in female hours of work, a large (but insignificant) increase in employment on the extensive margin, and the decline in wages, it is not surprising that there are no significant differences in female earnings across electrifying and nonelectrifying areas (panel D, column 5) or within an MD that sees growing electrification over time (panel D, column 6). In contrast, male earnings do rise significantly when electrification rates are higher, by about 16 percent for the average increase in electrification (0.15×1.10). This also makes sense, given that men appear to be working more hours without any decline in average wages.

The combined results of subsections VB and VC suggest the following interpretation: when communities get new access to household electricity, employment on the extensive margin increases for women and possibly for men, although male effects are difficult to estimate precisely. On the intensive margin, the best household survey evidence we have indicates that electrification raises hours of work for women and men, although precise estimation of these effects is precluded by the small sample size. And, given the results of the placebo test, there is no strong evidence that contemporaneous expansions in sources of demand for female work confound these employment results. In the next section, I investigate several channels through which electrification may have affected employment in these rural areas.

VI. Channels

A. *Electrification and Home Production: A Labor Supply Channel*

In order for electrification to affect employment through the channel of reduced time in home production, households must switch out of traditional fuels when their communities are connected to the grid and spend less time in home production. There are no data on time use to show the latter effect. However, the simple averages in Figure 1 and results presented in Table 8 illustrate that households do make large adjustments to their home production technologies in the wake of household electrification. Each coefficient reported in this table is from a separate regression, where the outcome variable is the change in fraction of households using electricity for lighting or cooking or using wood for cooking. Columns 1 and 3 do not contain any additional controls, while columns 2 and 4 report results from regressions containing all relevant control variables. Robust standard errors are clustered at the subdistrict level.

Both OLS and IV regression results illustrate substantial shifts towards using electricity for home production, with IV results larger than OLS estimates. Average rates of electric lighting rise by 23 percentage points more in communities with an electricity project than in communities without in the OLS comparison of row 1, column 2. In the same column, reliance on wood for cooking falls by 3.9 percentage points, and cooking with electricity rises by 5.6 percentage points. Column 4 indicates that in areas chosen to be electrified because of their flatter gradient, use of electric lighting increases by a substantial and significant 63 percentage points, wood use falls by 27 percentage points, and cooking with electricity rises by 23 percentage points.[28]

To check that gradient is not simply picking up easier access to all types of services that could affect home production, rows 4 and 5 of Table 8 present results for two additional outcome variables: the change in fraction of households with access to piped water close to home and the change in fraction of households with a flush toilet at home. There is no evidence that electrified regions experience differential changes in either of these basic services. In fact, the IV results for water services in columns 5 and 6 are in the opposite direction to what we would expect if gradient were simply a noisy measure of wealth.

In combination with the main results of the previous section—rising female employment and some indication of falling female wages in electrifying areas—the results on changing home production in Table 8 suggest that one important channel through which electricity affects the rural labor market is by "freeing up" women's time for the market. This is, of course, unlikely to be the only way in which this infrastructure roll-out affects rural areas. In fact, the similarity of the male and female employment results hints at electricity's facilitating new activities for men and women that would allow them to start to produce market goods and services at home (e.g., food preparation, personal services requiring electric appliances). However, we would like to be more confident that electrification does not stimulate large net increases in labor demand in these communities. This is what I test for next.

[28] Online Appendix 2 discusses reasons why the IV results are larger than OLS results.

Table 9—Testing for Spillovers by Excluding Adjacent Areas without Electricity Projects

Outcome: Δ_t female employment	OLS (1)	IV (2)	*N* communities (3)
Panel A.			
Full sample	−0.001	0.095*	1,816
	(0.005)	(0.055)	
Panel B.			
Excluding nonproject areas < 1 km from project site	−0.004	0.076	1,205
	(0.006)	(0.057)	
Panel C.			
Excluding nonproject areas < 5 km from project site	−0.003	0.069	840
	(0.008)	(0.077)	

Notes: Each cell in columns 1 and 2 shows the coefficient (standard error) on the Eskom project indicator from regressions of the change in female employment rates for different subsamples of the data. Panel A reproduces the main result from the full sample in Table 4; panels B and C restrict the sample to exclude nonproject communities that are within a 1 km or 5 km radius of any project community. All controls described in Table 3 included. Robust standard errors clustered at subdistrict level.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

B. *Electrification and Labor Demand*

Communities as defined in the census data are small. Hence, any electricity project that generates new firms and new demand for labor should have spatial spillover effects into neighboring areas. If firms create jobs for people living in neighboring areas, positive spillovers in these nonelectrified areas would dampen any effects of household electrification. If people move out of neighboring nonelectrified areas towards electrified areas to get one of the new jobs, a negative spillover would amplify electrification effects. In both cases, the effect is the sum of an incumbents' effect and a spillover effect. In both cases, OLS and IV coefficients should be substantively different when adjacent nonelectrified areas most susceptible to these spillovers are excluded from the analysis.

To test this, I reestimate OLS and IV regressions after excluding nonelectrified areas within a one- and five-kilometer radius of an electrified area. Table 9 presents results for each restriction. OLS coefficients are never significantly different from zero, while IV coefficients are large, positive, and close to the main IV estimate: neither 0.076 nor 0.069 could be rejected in the full sample analysis. Using this test, there is no evidence of large spillovers across communities.

Combining this lack of spatial spillovers with the facts that the roll-out was driven by household targets, capacity was too small to stimulate even midsize manufacturing or service enterprises (South African Department of Minerals and Energy 2004), and female wages are not increasing in electrifying areas, it is implausible that household electrification created jobs by sparking the industrialization of rural KZN.

C. *Migration and Labor Market Effects of Electrification*

A final channel through which electrification may affect measured employment growth is through migration. In Table 10 (panel A, columns 1 and 2), I present

Table 10—Effects of Electrification on Population Growth, Skill Composition of Labor Force and Employment of Incumbents

	Δ_t log population		Δ_t females with high school		Δ_t males with high school	
	OLS (1)	IV (2)	OLS (3)	IV (4)	OLS (5)	IV (6)
Panel A.						
Eskom project	0.171***	3.897***	0.001	0.129*	0.001	0.076
	(0.045)	(1.427)	(0.005)	(0.058)	(0.003)	(0.050)
N	1,816	1,816	1,816	1,816	1,816	1,816
	Δ_t log non–in-migrant population		Δ_t female employment excluding in-migrants		Δ_t male employment excluding in-migrants	
Panel B.						
Eskom project	0.181***	4.349***	0.000	0.116*	−0.008	0.086
	(0.048)	(1.586)	(0.005)	(0.069)	(0.005)	(0.069)
N	1,816	1,816	1,816	1,816	1,816	1,816

Notes: Each cell shows the coefficient (standard error) on an Eskom project indicator from the OLS or IV regressions of each outcome on all controls as in Table 3. Dependent variable in panel A, columns 1–2, is change in log African population; in columns 3–6 it is the change in fraction of women or men that have a completed high school education. Dependent variable in panel B, columns 1 and 2, is the change in log African non–in-migrant population where in-migrants have been subtracted from the total number of adults in the community in each year. In columns 3–6 of panel B, the outcomes are change in female and male employment rates where the employment variables exclude the number of in-migrants to each community in each year. Robust standard errors clustered at subdistrict level. Regressions in panel A, columns 3–6, exclude controls for baseline fraction of women or men with completed high school.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

coefficients from OLS and IV regressions of the log of adult population on an Eskom project indicator and all other control variables. Even after controlling for all other variables, electrified areas have significantly higher population growth rates than nonelectrified areas. Population grows by 17 percent more in Eskom project areas, and this growth is 380 percent higher in the IV specification.[29] Given these large differences in population growth, it is important to consider how migration may affect the interpretation of the main employment results.

One possibility is that individuals move towards areas that are electrifying, or away from nonelectrifying areas, since the availability of this new infrastructure affects the quality of life across areas. This type of response would be captured as part of the IV employment results. A second possibility is that for reasons unrelated to infrastructure roll-out, flat areas have higher in-migration rates or lower out-migration rates than steep areas. In this case, migration flows could confound IV employment results. In either case, it is differential migration by employed individuals that is relevant for interpreting our employment results. For example, if individuals who already have jobs elsewhere move into electrifying areas at higher rates, the direct impact of electricity on employment creation would be inflated. At the same

[29] Clearly, in small communities, numerically small increases in population can translate into large percentage changes. The average number of females (males) in these communities in 1996 is 356 (274). This rises to 446 (319) by 2001. Just considering the raw changes in number of adults over time, electrified areas grow at about 6 percent per year while nonelectrified areas grow at about 3 percent.

time, if employed adults leave at higher rates from areas that are not being electrified, this would artificially deflate employment in nonproject areas. Either type of migration flow would change the composition of the population in electrified relative to nonelectrified areas.

In columns 3 to 6 of Table 10, panel A, I present some evidence that this type of compositional change is present in my sample. I estimate OLS and IV regressions of the change in fraction of men and women with a high school education on all controls (except 1996 education variables) and present coefficient estimates for the Eskom project indicator. While OLS results indicate no differential change in the fraction of skilled females and a falling fraction of skilled men in communities getting access to the grid, the IV results do give us some pause: in columns 4 and 6, the coefficient on Eskom project is large and positive, and even larger than the corresponding coefficients in the employment regressions of Tables 4 and 5. A combination of skilled migrants flowing toward flatter areas at higher rates and skilled migrants leaving steeper areas at higher rates could account for these compositional changes.

Ideally, it would be possible to estimate employment effects of electrification net of all compositional change. As a first step, differential in-migration can be ruled out as a confounder of the employment results in Table 4. By redefining the employment to population rate to exclude the total number of recent in-migrants from both the numerator and denominator (people who move into communities in the five years before the census), I reestimate the main OLS and IV regressions for the set of incumbents. The new employment variable is therefore the most conservative measure of employment for incumbents. Panel B, columns 3 through 6, demonstrate that electrification effects are still present and, if anything, are larger for incumbent women, and not significant for men. However, panel B, columns 1 and 2, indicate that in-migration is only part of the story: growth of the incumbent population (excluding recent in-migrants in 1996 and in 2001) remains higher in areas that receive an Eskom project by virtue of gradient.

While census data do not allow me to directly test whether higher out-migration from nonelectrifying areas accounts for all of the main employment result, note that out-migrants would need to be employed *before* they migrate for this to be of concern. If out-migrants are unemployed before migrating, then out-migration that is higher from nonelectrifying areas would work against finding any positive employment effect of electrification. In fact, although out-migrants from rural KZN do tend to be more educated than those remaining, they are significantly *less* likely to be employed, relative to incumbents.[30] Other researchers have also documented these facts. In an early study, Catherine Cross, Tobias Mngadi, and Themba Mbhele (1998) document high rates of rural-to-rural migration in KwaZulu Natal for the purpose of finding work or finding places to live with better infrastructure. Rulof Burger et al. (2003) use 1996 census data to show that young men leave rural areas of the former Transkei for urban areas, and that they do so in search of employment (their analysis does not cover women). These men are not initially employed in rural areas,

[30] In online Appendix 3, I use cross-sectional data from a migration module included in the 2002 September Labour Force Survey to show that out-migrants from rural KZN have significantly higher levels of education than incumbents, yet significantly lower rates of employment than incumbents.

despite having some secondary schooling. Cally Ardington, Anne Case, and Victoria Hosegood (2009) show that large cash transfers (pensions) to rural households in a former homeland area of KZN facilitate an increase in employment of prime-age adults, particularly of women. They show that this extra household income affects employment through the channel of financing migration for work. Hence, out-migration of people without jobs could be higher from steeper than flatter areas in my sample, but this would not explain the employment effects I estimate in the data.

The results for population growth and composition change in Table 10 hint at two additional ways that electrification of rural households may affect labor markets. Electrification appears to encourage people to relocate and may prevent the outflow of individuals from rural areas. A general equilibrium approach, as well as a richer dataset linking migrants to places of origin and destination, would be required to understand these effects more fully. However, given the profile of out-migrants and the results for incumbent-only employment rates, we can conclude that even this type of migration in response to electrification cannot account for all of the employment effects of electrification documented in Section V.

VII. Conclusion

This article uses the mass roll-out of household electrification in South Africa to measure the direct effects of public infrastructure on employment in rural labor markets and to investigate the mechanisms through which these effects operate. Addressing endogenous placement of infrastructure and confounding trends using two different identification strategies, I show that employment grows in places that get new access to electricity. Results from aggregate census data combined with administrative and spatial data on electricity project roll-out indicate large increases in the use of electric lighting and cooking and reductions in wood-fueled cooking over a five-year period, as well as a 9 to 9.5 percentage point increase in female employment.

Further evidence from household-level surveys points towards employment growth on the extensive and intensive margins for women, and possibly for men (although effect sizes are large for men, they are not significant at conventional levels). The fact that female wages fall, while male earnings rise with no significant change in male wages, provides additional evidence that electrification did not spark large increases in the demand for labor through rural industrialization. While electrification of households changed the technology of home production and likely had an effect on female labor supply, the evidence presented here cannot rule out that electricity also altered the types of feasible market activities for all adults. Since similar employment effects for men and women cannot be rejected under either the IV strategy or the MD-FE/MD-trends strategy, it is likely that electrification does not exclusively operate on rural labor markets through the mechanisms of releasing time from home production.

The final result in the paper highlights the challenge that migration presents for research into the effects of infrastructure roll-out. Although migration potentially confounds labor market effects, we saw that electrification raises employment of incumbent women, separately from any in-migration response. Moreover, I argue that the profile of out-migrants works against the outflow of individuals explaining all of the electrification effects. These results raise interesting questions about how infrastructure-building could transform rural communities into more urban entities, either by stimulating in-migration or stemming the tide of out-migration. Addressing such questions successfully is likely to require a general equilibrium approach that is beyond the scope of this paper.

This paper presents some of the first evidence on the impact of infrastructure for rural electrification on labor markets in a developing country. Regardless of the mechanism, electrification enabled South Africans living in rural areas to increase their participation in modern labor markets. More generally, the analysis highlights three important lessons. First, any evaluation of infrastructure projects should consider the employment effects of infrastructure provision alongside other direct effects on welfare (e.g., income, health, education). Second, the effects of an infrastructure expansion should be interpreted within the specific context of existing economic conditions in a country—in the case of South Africa, this context included the structural changes after the end of apartheid. Finally, despite multiple biases that make it challenging to cleanly identify the impact of infrastructure on the economy as well as the mechanisms through which it operates, it is still possible to shed a great deal of light on these effects by combining the results from several different empirical approaches.

REFERENCES

Akee, Randall. 2006. "The Babeldaob Road: The Impact of Road Construction on Rural Labor Force Outcomes in the Republic of Palau." IZA Discussion Paper 2452.

Ardington, Cally, Anne Case, and Victoria Hosegood. 2009. "Labor Supply Responses to Large Social Transfers: Longitudinal Evidence from South Africa." *American Economic Journal: Applied Economics*, 1(1): 22–48.

Ardington, Cally, and Frances Lund. 2006. "Employment Status, Security, and the Management of Risk: A Study of Workers in Kwamsane, KwaZulu-Natal." South African Labour and Development Unit Working Paper 06/02.

Ardington, Elizabeth, and Frances Lund. 1996. "Questioning Rural Livelihoods." In *Land, Labour and Livelihoods in Rural South Africa*, ed. Michael Lipton, Frank Ellis, and Merle Lipton, 31–58. KwaZulu-Natal and Northern Province: Indicator Press.

Aschauer, David Alan. 1989. "Is Public Expenditure Productive?" *Journal of Monetary Economics*, 23(2): 177–200.

Bailey, Martha J., and William J. Collins. 2010. "Did Improvements in Household Technology Cause the Baby Boom? Evidence from Electrification, Appliance Diffusion, and the Amish." *American Economic Journal: Macroeconomics*, 3(2): 189–217.

Banerjee, Abhijit, Esther Duflo, and Nancy Qian. 2007. "Railroad to Success: The Effect of Infrastructure on Economic Growth." http://chinasummerinstitute.org/pdf/7Qian-On%20the%20Road.pdf (accessed October 2011).

Banerjee, Abhijit, Sebastian Galiani, Jim Levinsohn, Zoe McLaren, and Ingrid Woolard. 2007. "Why Has Unemployment Risen in the New South Africa." National Bureau of Economic Research Working Paper 13167.

Barnard, Jenny. 2006. "An Investigation into Using GIS in Electrification and Network Planning in Rural Kwazulu-Natal." GISDevelopment.net. http://www.geospatialworld.net/index.php?option=com_content&view=article&id=16413%3Aan-investigation-into-using-gis-in-electrification-and-network-planning-in-rural-kwazulu-natal&catid=164%3Autility-power&Itemid=41&limitstart=2 (accessed October 12, 2011).

Beall, Robert T. 1940. *United States Department of Agriculture Yearbook: Rural Electrification*. Washington, DC: United States Department of Agriculture.

Becker, Gary. S. 1965. "A Theory of the Allocation of Time." *Economic Journal*, 75: 493–517.

Budlender, Debbie, Ntebaleng Chobokoane, and Yandiswa Mpetsheni. 2001. "A Survey of Time Use: How South Africans Spend Their Time." Statistics South Africa. http://www.statssa.gov.za/publications/TimeUse/TimeUse2000.pdf (accessed January 2006).

Burger, Rulof, Murray Leibbrandt, Cecil Mlatsheni, and Servaas van der Berg. 2003. "Migration and the Changing Rural-Urban Interface in South Africa: What can We Learn from Census and Survey Data?" South African Labour and Development Research Unit.

Canning, David. 1998. "A Database of World Stocks of Infrastructure, 1950–95." *World Bank Economic Review*, 12(3): 529–47.

Charmes, Jacques. 2005. " A Review of Empirical Eveidence on Time Use in Africa from U.N.-Sponsored Surveys." In *Gender, Time Use And Poverty In Sub-Saharan Africa*, ed. Mark Blackden and Quentin Wodon, 39–74. Washington, DC:The World Bank.

Chernozhukov, Victor, and Christian Hansen. 2007. "The Reduced Form: A Simple Approach to Weak Inference." Unpublished.

Christopher, A.J. 2001. *The Geography of Apartheid*. Johannesburg: Witwatersrand University Press.

Coen-Pirani, Daniel, Alexis Leon, and Steven Lugauer. 2008. "The Effect of Household Appliances on Female Labor Force Participation: Evidence From Micro Data." Unpublished.

Casale, Daniela, Colette Muller, and Dorrit Posel. 2004. "'Two Million Net New Jobs': A Reconsideration of the Rise in Employment in South Africa, 1995–2003." *South African Journal of Economics*, 72(5): 978–1002.

Conley, Timothy. G. 1999. "GMM Estimation with Cross Sectional Dependence." *Journal of Econometrics*, 92(1): 1–45.

Cross, Catherine, Tobias Mngadi, and Themba Mbhele. 1998. "Constructing Migration: Infrastructure, Poverty and Development in Kwazulu-Natal." *Development Southern Africa*, 15(4): 635–59.

Cutler, David, and Grant Miller. 2005. "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States." *Demography*, 42(1): 1–22.

Dinkelman, Taryn. 2011. "The Effects of Rural Electrification of Employment: New Evidence from South Africa: Dataset." *American Economic Review*. http://www.aeaweb.org/articles.php?doi=10.1257/aer.101.7.3078.

Duflo, Esther, and Rohini Pande. 2007. "Dams." *Quarterly Journal of Economics*, 122(2): 601–46.

EnergyNet Limited. 2004. "Rural Energy 21: Bringing Power to Africa." http://www.energynet.co.uk/AEF/AEF2004/index.htm (accessed April 2006).

Eskom. 1996–1999. "Eskom Annual Reports." Sandton, South Africa.

Fedderke, J. W., and Z. Bogetic. 2009. "Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures." *World Development*, 37(9): 1522–39.

Food and Agricultural Organization of the United Nations (FAO). 1977. "A Framework for Land Evaluation." Soils Bulletin No. 32. http://www2.alterra.wur.nl/Internet/webdocs/ilri-publicaties/publicaties/Pub22/pub22.pdf (accessed October 2011).

Gaunt, Trevor. 2003. "Electrification Technology and Processes to Meet Economic and Social Objectives in Southern Africa." PhD diss. University of Cape Town.

Goldin, Claudia. 1995. "The U-Shaped Female Labor Force Function in Economic Development and Economic History." In *Investment in Women's Human Capital*, ed. T. P. Schultz, 61–90. Chicago: University of Chicago Press.

Goldin, Claudia, and Lawrence F. Katz. 2000. "Career and Marriage in the Age of the Pill." *American Economic Review*, 90(2): 461–65.

Greenwood, Jeremy, Ananth Seshadri, and Mehmet Yorukoglu. 2005. "Engines of Liberation." *Review of Economic Studies*, 72(1): 109–33.

Gronau, Reuben. 1986. "Home Production: a Survey." In *Handbook of Labor Economics*, Vol. 1. ed. O. Ashenfelter and R. Layard, 273–304. Amsterdam, North-Holland.

IFPRI, University of Natal and University of Wisconsin. 1993 and 1998. "KwaZulu Natal Income Dynamics Survey 1993 and 1998." http://sds.ukzn.ac.za/default.php?11,0,0,0,0 (accessed April 2007).

Jimenez, Emmanuel. 1995. "Human and Physical Infrastructure: Public Investment and Pricing Policies in Developing Countries." In *Handbook of Development Economics*. Vol.3B. ed. J. Behrman and T. N. Srinivasan, 2773–2843. Amsterdam: Elsevier Science, North-Holland,

Klasen, Stephan, and Ingrid Woolard. 2009. "Surviving Unemployment without State Support: Unemployment and Household Formation in South Africa." *Journal of African Economies*, 18(1): 1–51.

Lokshin, Michael, and Ruslan Yemtsov. 2005. "Has Rural Infrastructure Rehabilitation in Georgia Helped the Poor?" *World Bank Economic Review*, 19(2): 311–33.

Mammen, Kristin, and Christina Paxson. 2000. "Women's Work and Economic Development." *Journal of Economic Perspectives*, 14(4): 141–64.

Mikusheva, Anna, and Brian Poi. 2006. "Tests and Confidence Sets with Correct Size in the Simultaneous Equations Model with Potentially Weak Instruments." *The Stata Journal*, 1(1): 1–11.

Nunn, Nathan, and Diego Puga. 2007. "Ruggedness: The Blessing of Bad Geography in Africa." Unpublished.

Rud, Juan Pablo. 2009. "Electricity Provision and Industrial Development: Evidence from India." Unpublished.

Saghir, Jamal. 2005. "Energy and Poverty: Myths, Links and Poverty Issues." The World Bank Energy Working Notes 4.

South African Department of Education. 1995 and 2000. "South African Schools Register of Needs Databases 1995 and 2000." Available upon request from the Department of Education.

South African Department of Minerals and Energy. 2004. "Electricity Supply Guide." Department of Minerals and Energy.

Standing, Guy, John Sender, and Jeremy Weeks. 1996. *Restructuring the Labour Market: The South African Challenge*. Geneva:International Labour Office.

Statistics South Africa. 1995. "October Household Survey" http://sada.nrf.ac.za/ahdetails.asp?catalognumber=0059 (accessed April 2007).

Statistics South Africa. 1996. "South African Census - 10% Sample of Unit Records" http://sada.nrf.ac.za/ahdetails.asp?catalognumber=0129 (accessed April 2006). Available to order from www.statssa.gov.za.

Statistics South Africa. 1996. "1996 South African Population Census Community Profile Databases and GIS Database" Available to order from www.statssa.gov.za.

Statistics South Africa. 1997. "October Household Survey" http://sada.nrf.ac.za/ahdetails.asp?catalognumber=0076 (accessed April 2007).

Statistics South Africa. 1999. "October Household Survey" http://sada.nrf.ac.za/ahdetails.asp?catalognumber=0114 (accessed April 2007).

Statistics South Africa. 2001. "South African Census - 10% Sample of Unit Records" http://sada.nrf.ac.za/ahdetails.asp?catalognumber=0139 (accessed April 2006).

Statistics South Africa. 2001. "South African Labour Force Survey, September 2001". http://sada.nrf.ac.za/ahdetails.asp?catalognumber=0128 (accessed April 2007).

Statistics South Africa. 2001. "South African Labour Force Survey, September 2002". http://sada.nrf.ac.za/ahdetails.asp?catalognumber=0132 (accessed April 2007).

Statistics South Africa. 2001. "2001 South African Population Census Community Profile Databases and GIS Database" Available to order from www.statssa.gov.za.

Titiunik, Rocio, Sebastian Martinez, Paul J. Gertler, Sebastian Galiano, and Matias D. Cattaneo. 2007. "Housing, Health, and Happiness." The World Bank, Policy Research Working Paper 4214.

Vink, Nick, and Stefan Schirmer. 2002. "The Decline of the South African Economy: Agriculture, 1970–2000." In *The Decline of the South African Economy*, ed. S. Jones 51–67. Northampton, MA: Elgar

West, Nicola, Barry Dwolatzky, and Alan Meyer. 1997. "Terrain-Based Routing Of Distribution Cables." *IEEE Computer Applications in Power*, 10(1): 42–46.

World Bank. 1994. *World Development Report 1994: Infrastructure for Development*. Washington, DC: The World Bank.

World Bank 2007. "Clean Energy for Development Investment Framework: The World Bank Group Action Plan." Washington, DC: The World Bank. http://siteresources.worldbank.org/DEVCOMMINT/Documentation/21289621/DC2007-0002%28E%29-CleanEnergy.pdf (accessed June 2007).

This article has been cited by:

1. Dave Donaldson, Adam Storeygard. 2016. The View from Above: Applications of Satellite Data in Economics. *Journal of Economic Perspectives* **30**:4, 171-198. [Abstract] [View PDF article] [PDF with links]
2. Paul J. Gertler, Orie Shelef, Catherine D. Wolfram, Alan Fuchs. 2016. The Demand for Energy-Using Assets among the World's Rising Middle Classes. *American Economic Review* **106**:6, 1366-1401. [Abstract] [View PDF article] [PDF with links]
3. Hunt Allcott, Allan Collard-Wexler, Stephen D. O'Connell. 2016. How Do Electricity Shortages Affect Industry? Evidence from India. *American Economic Review* **106**:3, 587-624. [Abstract] [View PDF article] [PDF with links]
4. B. Kelsey Jack, Grant Smith. 2015. Pay as You Go: Prepaid Metering and Electricity Expenditures in South Africa. *American Economic Review* **105**:5, 237-241. [Abstract] [View PDF article] [PDF with links]
5. Rema Hanna, Paulina Oliva. 2015. Moving up the Energy Ladder: The Effect of an Increase in Economic Well-Being on the Fuel Consumption Choices of the Poor in India. *American Economic Review* **105**:5, 242-246. [Abstract] [View PDF article] [PDF with links]
6. Clément Imbert, John Papp. 2015. Labor Market Effects of Social Programs: Evidence from India's Employment Guarantee. *American Economic Journal: Applied Economics* **7**:2, 233-263. [Abstract] [View PDF article] [PDF with links]
7. Michael Greenstone, B. Kelsey Jack. 2015. Envirodevonomics: A Research Agenda for an Emerging Field. *Journal of Economic Literature* **53**:1, 5-42. [Abstract] [View PDF article] [PDF with links]
8. Shaun McRae. 2015. Infrastructure Quality and the Subsidy Trap. *American Economic Review* **105**:1, 35-66. [Abstract] [View PDF article] [PDF with links]
9. Molly Lipscomb,, A. Mushfiq Mobarak,, Tania Barham. 2013. Development Effects of Electrification: Evidence from the Topographic Placement of Hydropower Plants in Brazil. *American Economic Journal: Applied Economics* **5**:2, 200-231. [Abstract] [View PDF article] [PDF with links]
10. Catherine Wolfram,, Orie Shelef,, Paul Gertler. 2012. How Will Energy Demand Develop in the Developing World?. *Journal of Economic Perspectives* **26**:1, 119-138. [Abstract] [View PDF article] [PDF with links]