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Rural Electrification and Fertility

Evidence from Côte d'Ivoire

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Jörg Peters and Colin Vance[1]

Rural Electrification and Fertility – Evidence from Côte d'Ivoire

Abstract

Using household-level survey data from Côte d'Ivoire, this paper investigates the determinants of fertility with a particular focus on the effect of electrification. Based on count data regression models, our analysis suggests a highly significant relationship between fertility and electricity, but one that is only revealed when the model distinguishes between rural and urban areas. Specifically, we find a positive association between electricity and fertility for urban households, contrasted by a negative relationship for rural households. This dichotomy is suggested to reflect the influences of electricity in facilitating child care, offset by its modernizing impacts through the provision of information.

JEL Classification: O 12, O 33, J 13

Keywords: Rural development; energy access; demography; count data

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1. Introduction

It is widely acknowledged that economic growth contributes to decreasing fertility. At the same time, declining birth rates are also believed to foster development in the developing world. Eastwood and Lipton (1999) find evidence for a negative impact of fertility on both income equality and growth.[1] They argue that negative externalities associated with having many children call for active population policy such as female education or sensitization campaigns. In discussions among both academics and practitioners, rural electrification is frequently mentioned as a negative determinant of fertility. Academic contributions on the linkage between electrification and fertility stress the importance of attitude changes and their implications for contraceptive usage (Harbison and Robinson 1985). Practitioners, on the other hand, emphasise the more direct role of better access to information technology and lighting services in reducing the frequency of intercourse (IEG 2008).

Based on these considerations, this paper investigates empirically the relationship between fertility and electrification. Our theoretical framework is rooted in classical fertility economics but adapted to the African context by introducing insights from anthropology. Caldwell and Caldwell (1987) suggest that notwithstanding certain life-cycle constraints such as marriage, postpartum abstinence, and grandmotherhood, the demand for children of rural West African couples is essentially unlimited. The number of children is thus the product of a stochastic process (Heckman and

Willis, 1974) consisting of biological aspects as well as behavioural factors that are not determined strategically. One of the latter is the frequency of intercourse, as many couples do not treat this as a choice variable in the long run. We assume that such behavioural factors are largely a function of cultural patterns. To the extent that these patterns differ substantially between urban and rural Africa, our empirical analysis distinguishes between rural and urban impacts of access to electricity on fertility.

The data used in this study draws on the Côte d'Ivoire Living Standards Survey (CILSS) of 1,600 households conducted annually between 1985 and 1988. As rural Côte d'Ivoire underwent a spate of electrification projects in the 1970s that terminated abruptly by the end of the decade, we investigate the associated implications for fertility in a country where today some 40% of the population still lacks electricity. Based on the estimation of a Poisson regression model, our analysis suggests a highly significant relationship between the number of children born and access to electricity, but one that is only revealed when the model allows for differential impacts of electrification according to rural and urban households. Specifically, we find a positive association between electricity and fertility for urban households, contrasted by a negative relationship for rural households. This dichotomy is suggested to reflect the countervailing influences of electricity in creating leisure time and lowering the costs of child care, which dominate in the city, and its modernizing impacts primarily through the provision of information, which dominate in rural areas.

The remainder of this paper is organised as follows. Section 2 summarises the impacts of electrification cited in the literature, particularly with regards to fertility, and sketches the theoretical framework of our analysis. Section 3 presents the utilised data and the applied empirical models. Section 4 elaborates on the results before section 5 concludes.

2. Literature and Theoretical Background

2.1 The Impacts of Electrification

Rural electrification is widely believed to contribute to development and increased well-being, and access to electricity is recognised to be an important condition for achieving the Millennium Development Goals (UN, 2005; UNDP, 2005). Comprehensive studies on the impacts of electrification have been conducted by the World Bank in the Philippines (ESMAP, 2003), Indonesia (EnPoGen, 2003a) and Sri Lanka (EnPoGen, 2003b). Among the most commonly cited impacts are income generation effects via the productive use of electricity (Gouvello and Durix, 2008). Khandker, Barnes and Samad (2009), for example, find positive effects of electrification on income and educational outcomes using data from Bangladesh. Based on panel data, Khandker et al. (2009) confirm similar findings for Vietnam.

Furthermore, reference is often made to the health related benefits from rural electrification induced by the reduction of indoor air pollution or access to improved medical services (IEG, 2008; Bensch and Peters, 2010). Fouquet and Pearson (2007) investigate the very long term effects of access to improved lighting services and suggest strong psychological effects of light and electricity, in particular. Access to modern lighting sources is said to change people's perception of the world, which has positive consequences for well-being.

In addition to these effects, IEG (2008) points to the relationship between rural electrification and fertility. They find a negative correlation in several country studies and refer to an indirect channel via improved access to information technologies as the major source for this outcome. La Ferrara, Chong and Duryea (2008) provide evidence from Brazil supporting the idea that television soap operas and the role models they portray have a negative effect on fertility. Jensen and Oster (2009) also highlight the impact of television on woman's status and fertility. Using data from India, they investigate the roll-out of cable TV as treatment and find that women's acceptance of domestic violence decreases as well as fertility.

In a review of some earlier research, Harbison and Robinson (1985) find that most studies reveal a positive correlation between electrification on the village level and contraceptive usage, but only some of them identify a negative correlation for electrification and fertility. These studies typically use regional data to compare mean values in regions with and without electricity or for households with and without a connection (Harbison and Robinson, 1985). In general, there have been few studies investigating the relationship between electrification and fertility that employ multivariate methods.

2.2 The Economics of Fertility in Rural Africa

Starting with Malthus' work some two centuries ago linking food availability with population growth, social scientists have been studying the determinants of fertility. Malthus assumed that population grows primarily in response to biological impulses – "the passion between the sexes" (Malthus, 1798) – subject to exogenously given constraints on land and technological capacity. Elements of Malthus' biological determinism have been carried forward in subsequent theorizing. According to the Theory of the Demographic Transition, demographic change is part of a larger process of economic development that culminates in the stabilization of population growth following a period of rapid expansion. This stabilization occurs when birth rates fall to reach a lower level of mortality already achieved from improved diet and health care. Falling under the rubric of "modernization," several explanations may be forwarded for fertility declines, including increases in female education and participation in the labour force, a diminishing influence of religious belief, and urbanization. While this theory has served as an organizing framework for explaining population variations throughout the centuries, particularly in Europe, it is ultimately based on a series of ad hoc causal assertions that provide little insight into the underlying mechanisms driving fertility (Leibenstein, 1974).

In attempting to fill this theoretical void, Becker's so-called classical fertility model (1981) focuses on demand-side determinants. Couples weigh the marginal costs and benefits of each additional child and determine the total number according to utility maximization. In these models, parents determine the number of children strategically at a certain stage in life, often simultaneously with other decisions pertaining to education, place to live, or labour supply. Schultz (1997) transfers the classical fertility model to developing countries and Benefo and Schultz (1996) use it to analyze fertility and mortality in Côte d'Ivoire and Ghana. One shortcoming of the model is that the supply side and potentially related constraints like biological limitations or random effects such as contraceptive failures are not taken into account (Rosenzweig and Schultz, 1985).

Indeed, successfully equating desired fertility with actual fertility is heavily dependent on the availability of reliable contraceptive instruments. It is widely acknowledged, however, that such instruments are rarely used in Africa, especially in rural areas. Frank and Bongaarts (1991) report rates below 1 % for usage of effective contraceptives for Côte d'Ivoire, with comparable rates observed for most other African countries. In the absence of effective contraceptive usage, targeting a certain number of children is not likely to be successful.

In line with these considerations, Caldwell and Caldwell (1987) argue that, effectively, rural African couples do not limit the number of children to a certain optimal level, as suggested by classical fertility economics models. The only limiting factors are rules that are applied in order to sustain social stability: Women do not have sex before marriage, after a birth and after becoming a grandmother. While such rules differ to some extent across regions – Caldwell and Caldwell (1987) report mainly on rural areas in Nigeria and Benin – Ainsworth (1989) confirms the absence of family planning for Côte d'Ivoire. These observations suggest that fertility is strongly correlated with the frequency of intercourse.

This absence of planning notwithstanding, the reasons for bearing many children are explainable economically. First, children serve as a social insurance system. This effect is enhanced by social institutions that assure that wealth is transferred from the bottom up in the age pyramid. Furthermore, the effect of traditional religion, which mostly coexists with monotheistic beliefs, on the number of children is substantial. New generations are closely linked to their ancestors and the latter are commonly assumed to be reborn in the same lineage. Therefore, "high fertility is associated with joy, the right life, divine approval, and approbation by both living and dead ancestors" (Caldwell and Caldwell, 1987). Not least, children are frequently needed for agricultural work.

These considerations are reflected in fertility rates in Côte d'Ivoire ranging from 6.77 in the 1950s to 7.31 in the first half of the 1980s, when the data used in the present analysis was collected. As pointed out by Heckman and Willis (1974), such high rates suggest that the number of children is the product of a stochastic process, whereby couples cannot determine the exact number and timing of births.[2] In each month, a fertile woman has some probability of conception that can be influenced by contraceptive and coital behaviour.

Without explicitly referring to a stochastic process, Frank and Bongaarts (1991) distinguish between biological and behavioural factors affecting the probability of conception. Biological factors are sterility or susceptibility to intrauterine mortality, which are generally beyond an individual's sphere of influence. Behavioural factors, on the other hand, are chosen by the couple and include breastfeeding, postpartum abstinence, contraception usage, and frequency of intercourse.

For the purpose of this paper, we hypothesise that electrification is one of a suite of variables that determines the conception probability and thereby the number of children born in a given period. One channel through which electrification may influence fertility is direct, whereby couples either increase or reduce the frequency of intercourse in the face of time-saving appliances or alternatives to having sex such as television.[3] Such influences can be regarded as impacting an underlying spontaneous momentum of conception, one that is absent of planning. At the same time, the influence of electrification may operate over an indirect channel through modernization, which may include the diffusion of information on contraceptive practices, venereal diseases or women's rights. It may also include changes in the costs of caring for children, which tends to influence fertility negatively. Unlike the direct channel, the indirect channel is reflective of and may even foster strategic behaviour in decisions about intercourse and fertility.

3. Data and Empirical Approach

3.1 Data Description

The data used in this paper is drawn from the CILSS, which was conducted by the World Bank and Institut National de la Statistique, Côte d'Ivoire. Between 1985 and 1988, roughly 1,600 households were interviewed annually and on a representative and nation-wide basis. Approximately half of the households were revisited in the following year; the other half was replaced by new households. Specific information on children was collected for one fertile woman per household. If more than one fertile woman was living in the dwelling, the woman selected for the interview was drawn randomly. In total, the sample contains information on women from 3,376 households, 1,817 of whom were interviewed one time and the remaining 1,559 of whom were interviewed twice over two consecutive survey years.

We are particularly interested in how fertility changes in the wake of electrification. Although the CILSS data do not contain information about when the respective household was electrified, there is a high likelihood that this occurred in the late 1970s, when a wave of electrification projects was implemented in Côte d'Ivoire's rural areas. In 1970, only 90 rural communities were covered by the electricity grid, a figure that increased to 454 by 1980, whereafter the process was decelerated substantially (SOPIE, 2002). Therefore, we can assume that an electricity-using rural household in the data had been connected in the late 1970s so that – if electrification has an impact on fertility in rural areas – the number of children born after 1980 should be particularly affected.

Table 1 describes the individual- and household-level characteristics of electrified and non-electrified households that are included in the econometric model, separated by location in rural and urban areas. In line with expectations, the connection rate is higher in urban areas (79%) than in rural areas (12%). Non-electrified households in both urban and rural areas have, in total, more children than electrified ones. With respect to children born after 1980 the picture is confirmed for rural areas, where non-electrified households have more newly born children. Non-electrified households in urban areas, though, have fewer children that were born after 1980 than electrified urban households.

Several other differences are notable. Non-electrified households in urban areas exhibit lower income than rural households, suggesting that in urban areas only the poorest abstain from getting connected. At the same time, electrified rural households earn nearly 1.6 times more than their non-electrified counterparts. Turning to education, the incidence of holding a diploma is higher for individuals in electrified households in both rural and urban areas. While other variables such as breast feeding behaviour and age do not differ markedly between the two groups, the substantial dissimilarities in terms of education and income suggests the inclusion of interaction terms in the model specification to allow for differential effects of these variables by urban and rural location.

Table 1: Descriptive statistics

	Urban		Rural	
	Electrified	Non-electrified	Electrified	Non-electrified
Household-level variables				
Total children	3.10	3.69	4.17	4.37
Children born after 1980	1.62	1.54	1.67	1.80
Household size	6.24	4.85	7.53	5.83
Income (in FCFA)	209.67	90.25	142.48	91.48
Number of wives	1.04	1.03	1.36	1.32
Individual-level variables				
Age of woman	27.06	29.53	30.44	30.70
Age of head	41.75	44.88	48.30	48.40
Diploma head (1,0)	0.55	0.16	0.22	0.07
Primary school diploma(1,0)	0.39	0.11	0.11	0.04
Married	0.64	0.73	0.73	0.81
Months breastfeeding	12.84	14.71	14.93	15.02
Number of observations	1245	336	212	1583

3.2 Econometric Model

The outcome variable to examine the effect of electrification on fertility is the number of kids born after 1980. Accordingly, our econometric model regresses this outcome variable on a dummy variable indicating whether the household uses electricity or not, E_i and a vector of control variables $\mathbf{X}_i$. In order to account for differences between rural and urban areas we include a dummy variable R_i that takes the value 1 if the household is located in rural areas and interact it with E_i as well as with those control variables, for which a different effect can be expected in urban and rural regions.

$$K_i = \alpha + \alpha_E E_i + \alpha_R R_i + \alpha_{ER} E_i R_i + \alpha_X \mathbf{X}_i + \varepsilon_i$$

As the dependent variable modelled in this paper is a count of the number of children born following a household's connection to the electric grid, our empirical methodology employs the Poisson model as the principal model. In addition, we use further count data models to check the robustness of the results. Unlike linear regression, which is apt to produce inefficient, inconsistent, and biased estimates when applied to count variables (Long and Freese, 2006:249), the Poisson model assumes that the errors follow a Poisson rather than normal distribution. Moreover, rather than modelling the dependent variable as a linear function of the regression coefficients, it models the natural log of the response variable as a linear function of the coefficients.

These features, the latter of which assures non-negative predictions generated by the model, suggest that the Poisson is a more appropriate estimator than linear regression for modelling fertility behaviour (Ainsworth 1989).

The structural equation of the Poisson model is written as:

$$E(y_i \mid \mathbf{x_i}) = \exp(\mathbf{x_i}\boldsymbol{\beta})$$

where *y* denotes the dependent variable, ***x*** a vector of explanatory variables, and β the coefficient estimates. The principal assumption of the Poisson model is that the mean of the dependent variable is equal to its standard error, referred to as equidispersion. While a simple inspection of the descriptive statistics confirms this, we will further scrutinize the equidispersion assumption by applying state-of-the-art tests in Section 4.

In interpreting the results, we present both the regression coefficients as well as the corresponding marginal effects, which are derived by taking the derivative of the above equation with respect to the explanatory variable of interest:

$$\frac{\partial E(y \mid \mathbf{x})}{\partial x_k} = \beta_k \exp(\mathbf{x}\boldsymbol{\beta})$$

The marginal effects are conventionally calculated at the mean of the independent variables and can be requested in the output of most statistical software packages, though some care must be taken in their interpretation when interaction terms are involved. As Ai and Norton (2003) discuss for the case of logit and probit models, the interaction effect for two variables requires computing the cross derivative $\frac{\partial^2 E(y \mid \mathbf{x})}{\partial x_{i1} \partial x_{i2}}$, whereas standard computer software typically displays the effect equal to $\frac{\partial E(y \mid \mathbf{x})}{\partial (x_{i1} x_{i2})}$. They show that this latter calculation often results in false inferences with respect to both the sign and significance of the interaction term. As their analysis applies to non-linear models generally, including the Poisson, we follow their recommendation to calculate the interaction effects as given by the cross-derivative. We derive the formulas used for these calculations in the appendix.

To correct for the non-independence of repeat observations from pooling the data, the regression disturbance terms are clustered at the level of the individual interviewee, and the presented measures of statistical significance are robust to this survey design feature. In addition, the specification includes year dummies to control for the effects of macro-level influences that affect the sample as a whole.

Before turning to the results, a potential caveat in ascribing a causal interpretation to the effect of electricity on fertility is the possibility that other relevant variables have been omitted from the model, which, if correlated with electrification, could induce biases in the estimated coefficient. In this regard, it is noted that the selection process underpinning whether a household decides to connect is largely driven by its income, wealth, and education level, all of which are observable variables captured by the measures of income, the number of wives, and the two dummies indicating whether the woman or the household head received at least a primary school diploma. Thus, although the possibility of omitted variable bias can never be completely ruled out, the variables included in Table 1 afford reasonably broad coverage of those determinants of fertility that are potentially correlated with electrification.

4. Results

Table 2 catalogues the coefficient estimates and corresponding marginal effects from two specifications of the Poisson model of fertility. The second model is distinguished from the first by its inclusion of interaction terms allowing for differential coefficients on electricity, education, and income according to whether the household is located in a rural area. This increased flexibility significantly improves the fit of the model. The likelihood-ratio chi-square statistic is 15.49, which, at four degrees of freedom, provides clear evidence that Model 2 has a superior fit to Model 1. In addition, we tested for the appropriateness of the Poisson model. For this purpose, we first conducted a goodness-of-fit test on the quality of the fit of the Poisson model. The chi squared distributed Pearson statistic takes the value 3398.5 and has 4,918 degrees of freedom, so that the test fails to reject the null hypothesis that the Poisson model is appropriate with a P-value of 0.99. In addition, we did a likelihood ratio test of the negative binomial model against the Poisson at 1 degree of freedom that also clearly fails to reject the null hypothesis that the overdispersion parameter from the former model equals zero (P=0.999), providing further confirmation that the data are Poisson distributed.

With the exception of the dummy indicating electricity access and the age of the household head, all of the variables in Model 1 are statistically significant, mostly at 1% or 5% level, and have signs that are consistent with intuition. Confirming the descriptive analysis, residence in a rural area and marital status are positively associated with fertility, while household size has a negative coefficient. The age of the interviewed women, which is specified as a quadratic function, has a nonlinear effect on the number of children born after 1980, peaking at an age of around 28 and falling thereafter. This is in line with intuition, as younger women give birth to more children – either due to higher sexual activity or because younger and competing wives enter the polygamous household as the women get older. Household income and the dummies indicating the completion of grammar school all have negative coefficients, likely reflecting an underlying calculation that incorporates the higher opportunity costs of childbearing among the more educated and those with a higher income. Conversely, the number of wives, which serves as a proxy for household wealth, has a positive coefficient. Finally, the duration of breastfeeding, a determinant of post-partum infertility, has a negative coefficient.

These findings generally hold upon introducing the interaction terms in Model 2, though some notable distinctions also emerge. Of particular interest are the coefficients on the electricity dummy and on its interaction with the rural dummy. The former coefficient is positive while the latter is negative, suggesting that urban couples with electricity have significantly more children than rural couples. Further insight into this pattern can be gleaned from breaking the interaction effect into its constituent parts to examine the effect of electricity among rural and urban dwellers:

$$\frac{\Delta E}{\Delta electricity}|_{rural=1} = E[y \mid electricity = 1, rural = 1, x] - E[y \mid electricity = 0, rural = 1, x] = -0.133$$

and

$$\frac{\Delta E}{\Delta electricity}|_{rural=0} = E[y \mid electricity = 1, rural = 0, x] - E[y \mid electricity = 0, rural = 0, x] = 0.121$$

The corresponding breakdowns for the other marginal effects are presented in Table 3. According to these marginal calculations, those in rural areas with electricity have 0.133 (P=0.066) less children than rural residents without electricity. By contrast, urban residents with electricity have 0.121 (P=0.035) more children than city dwellers lacking electricity. While the significance of these estimates confirms the hypothesis that electrification matters in the determination of fertility, their opposing signs complicates a straightforward appraisal of the underlying mechanism. The negative effect of electricity in rural areas is consistent with both direct influences (e.g. reduced privacy and alternatives to intercourse) and indirect influences (e.g. diffusion of information) on fertility. The positive effect in urban areas, however, is unexpected. One explanation may be the influence of electricity in creating more leisure time. Related to this, it may be that the increased costs of having children in an urban environment are mitigated by the availability of work-saving appliances that an electricity connection affords. It is of interest to note that the finding of opposing effects of electricity by geography is not unprecedented.

Table 2: Poisson regression of births since 1980

	Model 1		Model 2	
	Coefficient	Marginal effect	Coefficient	Marginal effect
Household-level variables				
Electricity	0.0104	0.0161	0.0835**	0.1295**
	(0.728)	(0.728)	(0.039)	(0.040)
Rural	0.1040	0.1602	0.0978**	0.1505**
	(0.000)	(0.000)	(0.017)	(0.016)
Electricity*Rural			-0.1651***	-0.2543***
			(0.007)	(0.006)
Income	-0.0002**	-0.0003**	-0.0002**	-0.0003**
	(0.033)	(0.032)	(0.017)	(0.017)
Income*Rural			0.0003*	0.0004*
			(0.079)	(0.099)
Household size	-0.0058*	-0.0089*	-0.0068*	-0.0104*
	(0.056)	(0.056)	(0.028)	(0.028)
Age of head	-0.0004	-0.0007	-0.0004	-0.0006
	(0.635)	(0.635)	(0.692)	(0.692)
Diploma head	-0.0646**	-0.0983**	-0.1081***	-0.1627***
	(0.026)	(0.024)	(0.002)	(0.001)
Diploma head*Rural			0.1322**	0.1920**
			(0.019)	(0.030)
Number of wives	0.0436***	0.0673***	0.0385**	0.0593**
	(0.007)	(0.007)	(0.019)	(0.019)
Individual-level variables				
Age of woman	0.1531***	0.2364***	0.1531***	0.2361***
	(0.000)	(0.000)	(0.000)	(0.000)
Age of woman2	-0.0027***	-0.0042***	-0.0027***	-0.0042***
	(0.000)	(0.000)	(0.000)	(0.000)
Diploma	-0.1029***	-0.1538***	-0.1276***	-0.1890***
	(0.001)	(0.001)	(0.000)	(0.000)
Diploma*Rural			0.1325**	0.1848**
			(0.026)	(0.044)
Married	0.2379***	0.3478***	0.2391***	0.3491***
	(0.000)	(0.000)	(0.000)	(0.000)
Months breastfeeding	-0.0240***	-0.0370***	-0.0240***	-0.0371***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-1.5864***		-1.6023***	
	(0.000)		(0.000)	
Log-likelihood	-7158.8		-7166.5	
Number of observations	4935		4935	

p-values are in parentheses. ***,** and * indicate significance levels of 1%, 5% and 10%, respectively. Year dummies, not presented, are jointly significant at the 1% level.

Cornwell and Robinson (1988) uncover a similar pattern in their analysis of farm women in the US during a period of electrification between 1930 and 1950, with a negative association between electrification and fertility for Southern counties and a positive association for non-Southern counties.

Table 3: Breakdown of Marginal Effects for interacted Variables (Model 2)

	Rural	Urban
Electricity	-0.133*	0.121**
	(0.066)	(0.035)
Income	0.0002	-0.003**
	(0.545)	(0.017)
Diploma Woman	0.008	-0.177***
	(0.919)	(0.000)
Diploma Head	-0.039	-0.152***
	(0.607)	(0.001)

p-values are in parentheses. ***,** and * indicate significance levels of 1%, 5% and 10%, respectively.

Rural-urban distinctions are also seen with respect to the coefficients on income, diploma, and diploma head. In all three cases, the negative effect of the variable is offset by a positive coefficient on the rural-interaction that has roughly the same magnitude. In the case of diploma, for example, the negative effect for urban dwellers is essentially reduced to zero, both for females in rural areas who hold a diploma themselves and for those whose household head owns a diploma. Likewise, the effect of income, which is negative in the city, is approximately zero in the countryside. Taken together, these findings confirm the intuition that the educated and those with more income incur a higher opportunity cost from children in the city than in rural areas.

To test the robust of these results, we also explored the estimation of the Zero-Inflated Poisson (ZIP) model. Whereas the Poisson and Negative Binomial models rest on the assumption that the probability of a positive value of the dependent variable is non-zero for every observation, the ZIP models assumes that there is a substantial share of individuals for which this probability is zero. Based on maximum likelihood estimation, the model involves simultaneous estimation of the positive count outcome and of membership in the null-count group using either the probit or logit procedure. In the context of reproductive behaviour, the ZIP would be appropriate if we believed that structural constraints, such as infertility, were the primary source of zeros in the data. While our reliance on the Poisson model reflects our belief that the majority of women in the data have a positive probability of bearing children, this has little practical relevance for the empirical findings. As seen in Appendix 2, the estimated marginal effects from the ZIP model are only slightly different from those of the Poisson.

The two-part model, which involves separate estimation of a probit model followed by an OLS on the positive counts, affords another method for accommodating zeros in the data that yielded very similar marginal effects.

5. Discussion and Conclusion

With electrification rates below 50 percent in most African countries, electricity provision will remain a critical component of efforts to modernise Africa's economy for the foreseeable future. Against the backdrop of increasing population pressure and the challenges posed by rural to urban migration, an important consideration in gauging the impact of these efforts will be the effect of rural electrification on fertility. This paper has investigated this issue by drawing on elements of both the classical model of fertility economics as well as anthropological considerations. We argue that the notion of family planning being exclusively based on strategic considerations is inconsistent with the cultural practices of and structural constraints faced by rural families in Africa. Fertility is better understood as a process that is driven by a mix of calculating behaviour, biological determinants, and stochastic influences.

Our empirical results, generated from the estimation of a Poisson regression of the number of births using household level data, support this assessment. In addition to the dummy indicating electricity access, we identify several statistically significant determinants of fertility, including age, the duration of breastfeeding, income, and education. Moreover, the interaction of several of these variables with the rural dummy variable throws into stark relief the importance of location as a potentially important intervening factor on the determinants of fertility. Absent the interactions, the significantly weaker influence of income and education in rural areas would have gone undetected, while the coefficient of electrification would have been falsely ascribed a magnitude not different from zero.

Instead, we find that electrification has opposing effects on fertility in urban and rural areas, positive in the former and negative in the latter. As this is one of the few studies to be conducted on this issue using econometric analysis of micro-level data, it would be of interest to see whether the findings presented here are corroborated by studies using data sets from other African countries. It would be particularly interesting to conduct a comparative analysis of fertility by drawing data from countries that have different rates of urbanization and electrification. Baseline surveys from electrification projects in Benin, Mozambique, Rwanda and Senegal have recently been completed that will be followed up with ex-post surveys (Bensch and Peters, 2010, Bensch, Peters, and Schraml, 2010, Peters and Harsdorff, 2010), thereby allowing the observation of fertility behaviour directly following an intervention. These data sets will afford a promising opportunity for further pursuing this line of inquiry in future research.

Presuming that the findings here can be replicated, one policy implication is to enhance efforts to improve access to electricity in rural areas. Such interventions should include impacts on fertility in their monitoring system and, if effects are confirmed, incorporate them into cost-benefit analysis. For this purpose, it is not important whether the direct or the indirect channel prevails in translating electricity usage into lower fertility rates. Nevertheless, it would be helpful for the concrete design of electrification projects to understand if electrification first contributes to modernisation and then to a strategic change of reproductive behaviour, or if it is a direct and rather spontaneous change in the frequency of intercourse. Answers to this question would allow policy-makers to assess, for example, whether television-based campaigns advocating contraception could complement electrification programs in fostering population control. Future research should thus be focused on the collection of detailed data on sexual and reproductive behaviour. Not only could this complement research on HIV/AIDS (Cogneau and Grimm, 2006), but also provide further evidence on the relation between electricity access and fertility. In particular, before-and-after data surrounding an electrification intervention would help in isolating the effect of electrification on sexual behaviour.

Appendix 1: Derivation of marginal effects

The following presents the derivation for the marginal effects of the interaction terms in the Poisson model. Departing from the expected value of the model,

$E[y \mid x_1, x_2, \mathbf{x}] = \exp(\beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \mathbf{x}\boldsymbol{\beta})$,

the marginal effect when x_1 and x_2 are continuous (a case not included in the model but presented here for completeness), the marginal effect is:

$$\frac{\partial^2 y}{\partial x_1 \partial x_2} = \frac{\partial}{\partial x_1}\left(\frac{\partial y}{\partial x_2}\right)$$

$$= \exp(\beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_2 + \mathbf{x}\boldsymbol{\beta})\left[\beta_{12} + (\beta_1 + \beta_{12} x_2)(\beta_2 + \beta_{12} x_1)\right]$$

If x_2 is a dummy and x_1 is continuous, then the marginal effect is given by:

$$\frac{\Delta}{\Delta x_2}\left(\frac{\partial E}{\partial x_1}\right) = \frac{\partial E[y \mid x_1, x_2 = 1, \mathbf{x}]}{\partial x_1} - \frac{\partial E[y \mid x_1, x_2 = 0, \mathbf{x}]}{\partial x_1}$$

$$= (\beta_1 + \beta_{12})\exp(\beta_1 x_1 + \beta_2 + \beta_{12} x_1 + \mathbf{x}\boldsymbol{\beta}) - \beta_1 \exp(\beta_1 + \mathbf{x}\boldsymbol{\beta}) .$$

Finally, the marginal effect when x_1 and x_2 are dummies is given by:

$$\frac{\Delta^2 E[y]}{\Delta x_1 \Delta x_2} = E[y \mid x_1 = 1, x_2 = 1, \mathbf{x}\boldsymbol{\beta}] - E[y \mid x_1 = 0, x_2 = 1, \mathbf{x}\boldsymbol{\beta}] -$$

$$\left(E[y \mid x_1 = 1, x_2 = 0, \mathbf{x}\boldsymbol{\beta}] - E[y \mid x_1 = 0, x_2 = 0, \mathbf{x}\boldsymbol{\beta}]\right)$$

$$= \exp(\beta_1 + \beta_2 + \beta_{12} + \mathbf{x}\boldsymbol{\beta}) - \exp(\beta_1 + \mathbf{x}\boldsymbol{\beta}) - \exp(\beta_2 + \mathbf{x}\boldsymbol{\beta}) + \exp(\mathbf{x}\boldsymbol{\beta}) .$$

Given that the interaction effects are comprised of multiple parameters that make analytical computation of the variance impossible, the standard errors are calculated by applying the Delta method, which uses a first-order Taylor expansion to create a linear approximation of a non-linear function.

Appendix 2: Zero Inflated Poisson Model

Table A1: Zero Inflated Poisson regression of births since 1980

	Coefficient	Marginal effect
Household Level Variables		
Electricity	0.0970**	0.1608**
	(0.015)	(0.015)
Rural	0.1037**	0.1705***
	(0.011)	(0.010)
Electricity*Rural	-0.1734***	-0.2653***
	(0.003)	(0.001)
Income	-2.51e-08***	-4.13e-08***
	(0.005)	(0.006)
Income*Rural	3.07e-08*	5.07e-08*
	(0.070)	(0.070)
Household size	-0.0073**	-0.0122*
	(0.017)	(0.017)
Age of head	-0.0001	-0.0002
	(0.872)	(0.892)
Diploma head	-0.769**	-0.1267**
	(0.022)	(0.018)
Diploma head*Rural	0.1205**	0.2111**
	(0.027)	(0.035)
Number of wives	0.0435**	0.0717***
	(0.007)	(0.007)
Individual Level Variables		
Age of woman	0.1119***	0.1837***
	(0.000)	(0.000)
Age of woman2	-0.0018***	-0.0031***
	(0.000)	(0.000)
Diploma	-0.1372***	-0.2170***
	(0.000)	(0.000)
Diploma*Rural	0.1360**	0.2411**
	(0.021)	(0.034)
Married	0.2154***	0.3411***
	(0.000)	(0.000)
Months breastfeeding	-0.0241***	-0.0397***
	(0.000)	(0.000)
Constant	-1.1368***	
	(0.000)	
Wald Chi Squared	1081.0	
Number of observations	4935	

p-values are in parentheses. ***,** and * indicate significance levels of 1%, 5% and 10%, respectively. Year dummies, not presented, are jointly significant at the 1% level.

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[1] Fertility is also considered as a factor that negatively affects the health status of children. See, for example, Baten and Böhm (2010).

[2] Heckman and Willis (1974) develop their model as an extension to the classical fertility model, which posits that the number of children is limited and determined at one point in life. They argue that fertility is rather a sequential process exhibiting random characteristics. Couples that decide rationally not to limit their number of children therefore represent an extreme case of the more general conventional fertility model.

[3] While the LSMS data do not contain information on the usage of radio and television, in other survey work conducted in Mozambique, we find that more than 65 % of men in grid connected households declare watching television to be their principal activity during evening hours; almost 75 % watch television or listen to the radio. In Rwanda, 45 % of men in connected households in the sample name listening to the radio or watching television as major activity during evening hours (the surveys are described in Bensch, Peters, and Schraml, 2010; Bensch and Peters, 2010). Harsdorff and Peters (2010) report for Benin that 65 % of men in connected households watch television in the evenings.

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