

**Fertility Determinants on the Frontier:
Longitudinal Evidence from the Ecuadorian Amazon¹**

David L. Carr² (david_carr@unc.edu)
and William Pan³ (wpan@bios.unc.edu)

Association of American Geographers Annual Meeting
Population Specialty Group Student Paper Award, First Place
Los Angeles, March, 2002

I. Introduction

1. Fertility Determinants in the Developing World

Reflecting the demographic dynamics of Western European nations in the late 19th and early 20th centuries, much of the developing world is experiencing rapidly falling fertility and mortality rates (Davis 1963; Coale 1973; Teitelbaum 1975). With some revisions to this demographic transition framework, researcher suggests that families today are having fewer children where certain enabling conditions are gaining purchase on rapidly changing cultural mores.

For example, ascending socio-economic levels and increasing women's employment associated with urbanization raise the costs of child-rearing (Knodel, Chamrathirong et al. 1987; Hirschman and Guest 1990; Singh 1994; Martine 1996; Agadjanian 2001). These twin trends are placing women in propinquity to further fertility suppressing factors, including greater access to contraception—which helps to meet latent demand for contraceptive use and to create new demand (Easterlin and Crimmins 1982; Bulatao and RD Lee eds. 1983; Ross and Mauldin 1996; Freedman 1997; Guilkey and Jayne 1997); improved sanitation and health care—which lowers infant mortality, obviating the demand for “insurance” births (Davis 1963; Hirschman and Guest 1990; Singh 1994); and superior access to education—which helps to postpone marriage, to empower women to meet their demand for smaller families (Caldwell 1980; Easterlin and Crimmins 1982; United Nations 1987; Weinberger 1987; Cleland and Rodriguez 1988; Hirschman and Guest 1990; United Nations 1995; Diamond, Newby et al. 1999; Kravdal 2000; Dreze and Murthi 2001), and to adopt “western” values towards smaller families (Caldwell 1980; Caldwell and Caldwell 1987; Lesthaeghe and Surkyn 1988; Kohler, Behrman et al. 2001). Each of these processes ultimately operate through proximate behavioral factors regulating fertility: contraceptive use, childbearing postponement and child spacing (Davis 1963; United Nations 1987; Warren 1987).

¹ Carr and Pan are advised at the Carolina Population Center by Richard E. Bilborrow (richard_bilborrow@unc.edu). The data in this paper come from a study conducted with funding from a NASA research grant (RE Bilborrow and S. Walsh co-PIs) [Bilborrow, 1997 #1958].

² Department of Geography and Carolina Population Center, University of North Carolina, Chapel Hill.

³ Department of Biostatistics and Carolina Population Center, University of North Carolina, Chapel Hill.

2. Fertility Determinants on the Agricultural Frontier

Despite a well-developed literature regarding the determinants of fertility in the developing world in general, we are unaware of published research explicitly examining fertility determinants in rural agricultural frontiers. This is peculiar given that: 1) most deforestation on the earth occurs in such environments (Myers 1994; Geist and Lambdin 2001); 2) household size has been linked to deforestation at the farm level in numerous studies (e.g., Pichon 1997; Carr 2002), including a study derived from this data (Pan, Murphy et al. 2001); and 3) fertility is exceptionally high on the frontier. Indeed, although most of the rapid growth characteristics of frontier environments is due to in-migration, evidence suggests that frontier migrants experience higher fertility than their cohorts in migration origin areas (e.g., Weil 1981; Rundquist and Brown 1989; Murphy, Marquette et al. 1999). For example, the total fertility rate (TFR) for a 1990 sample of settlers in the Ecuadorian Amazon was 8.0 children per women, comparable to rates for Brazilian (8.3) and Peruvian (8.4) frontiers, and considerably higher than urban and “non-frontier” rural fertility rates (Murphy, Marquette et al. 1999).

There are certain characteristics about an agricultural frontier that we believe mitigate incentives to reduce fertility. First, abundant land but scarce capital, infrastructure, and labor resources, mean that investment in the land is inefficient relative to investments in labor and, hence, in reproduction (Caldwell and Caldwell 1987). Second, since access to health care is poor, mortality is high, inducing compensatory births, and the means to contraception are non-existent or prohibitively expensive (e.g., Henriques 1988; Marquette 1995; Pichón and Bilsborrow 1999). The exceptional scarcity of wage-labor employment and schooling for women on the frontier may also decrease the economic value of women's time relative to that of children, further increasing fertility (Singh, Casterline et al. 1985; Singh 1994).⁴

Following the first point above, a core population-environment interface in frontier environments turns on the direct relationship between people and land. The scant research on land-fertility relationships generally (though inconclusively) supports the hypothesis that: 1) where access to land is expanded, fertility rises; and, conversely, 2) land ownership suppresses fertility. Both the demand for labor on a larger farm and the desire to expand landholdings as the family grows are considered the two primary interpretations for the first relation (Chayanov 1986; Binswanger and McIntire 1987; Clay and Johnson 1992; Ellis 1993). The latter is explained by the economic security imparted by land in lieu of children (Schutjer, Stokes et al. 1981; Schutjer, Stokes et al. 1983). Perhaps the most striking study positively relating fertility and farm size was the Philippine Rural Survey of 1952 (Hawley, 1955) in which average total fertility varied from 4.8 to 7.0 (per woman in her last decade of childbearing) as plot size increased from under 1 hectare to over 4 hectares. Stokes, Schutjer, and Bulatao (1984) cite more recent evidence from among the diverse environments of Bangladesh, Philippines, India,

⁴ Further, the increased education and literacy help women to acquire, and take advantage of, information about family planning facilities and contraceptives. A large literature exists on the topic (Bongaarts 1978; Easterlin 1978; Caldwell 1980; Lesthaege, Shah et al. 1981; Easterlin and Crimmins 1982; Singh, Casterline et al. 1985; Newman 1986; United Nations 1987; Weinberger 1987; Cleland and Rodriguez 1988; Singh 1994; McDevitt 1996).

Mexico, and Brazil. Similarly, Cain (1984) found a positive correlation between farm size and fertility in Egypt and Thailand. Nevertheless, some studies show only insignificant differentials in family size relative to land access (e.g. Tuladhar *et al.* 1982). Nevertheless, the effect of resource access on fertility is hypothesized by some to be reversed when secure tenure of resources is established (Schutjer, Stokes et al. 1981; Schutjer, Stokes et al. 1983). Yet since most of these studies were conducted in settled agricultural areas of relatively high population density, one must be cautious in extrapolating to frontier environments of relatively great land availability (Cain 1984).⁵

The smattering of studies that have examined this land-fertility relation in rural frontier environments agree that higher land availability is associated with higher fertility. Such findings are reported for Thailand (VanLandingham and Hirschman 1995) Brazil (Merrick 1978; Molyneaux 1986), and the western agricultural frontier in the US during the 19th century (Easterlin 1971; Anderton and Bean 1985). Preliminary findings from multi-temporal data derived from a modest sample from the Peruvian Amazon suggests that fertility can both drive land size and *vice versa* (Coomes, Grimard et al. 2001). But the relation between frontier land ownership and fertility is unclear (Molyneaux 1985).

Lastly, a topic that has gone virtually unnoticed in the frontier literature is the potential relation between migration and fertility. The quite modest literature written on fertility-migration links focuses on fertility changes among rural-urban migrants (Hollos and Larsen 1992; Lerman 1992; Lee and Pol 1993; Zeng 1996) or on fertility differentials among international migrants versus origin cohorts (Gorwaney, van Arsdol et al. 1991; Fennelly, Cornwell et al. 1992; Burke 1995; Driscoll and Upchurch 1995; Landale and Hauan 1996). However, modest evidence from India suggests that women from rural households with migrants may have lower fertility than women in households with no migrants (Yadava and Yadava 1993).

To our knowledge, no published research has examined the determinants of fertility using longitudinal household data in an agricultural frontier. This paper attempts to do so, by taking advantage of a subset of longitudinal data collected in 1990 and 1999 in the Ecuadorian Amazon. We will examine descriptive statistics and develop logistic and Poisson regression models from this rich data set to explore the underlying mechanisms potentially related to fertility.

Based on the discussion above, our research questions are twofold:

- 1) What factors predict childbirth during the period 1990 to 1999?**
- 2) What factors are related to number of children born during the period 1990 to 1999?**

We anticipate the same fertility determinants discussed for the developing world in general (e.g., women with better access to health care, contraception, jobs, and

⁵ There are further critiques of the relationship between resource access and fertility. First, a larger farm may lead to high fertility not because more children help on the farm, or that a large farm supports more children, but rather because a large farm allows for greater resource security and thus, for more surviving children (Clay and Johnson 1992). A host of other studies find insignificant differences in family size relative to resource access (Firebaugh 1982; Tuladhar *et al.* 1982; Nagarajan and Krishnamoorthy 1992).

education will have fewer children) to pertain to the frontier as well. But a frontier population is unique in that we expect lower variability within these factors given the relative homogeneity of socio-economic and physical characteristics compared to longer settled regions. Indeed as examining fertility determinants in a frontier environment is an exploratory endeavor, we are therefore uncertain if sufficient variability will exist in our data to yield statistically significant results. Controlling for women's age and previous parity, we expect the following factors to be negatively related to both fertility outcomes: women's educational achievement, contraceptive use, having land title, asset accumulation, and access to electricity. Conversely, we anticipate the following variables to be positively associated with childbearing: desire for more children, number of infant deaths, number of household out-migrants, and increased land access.

II. The Ecuadorian Amazon

Ecuador comprises three distinct regions: the western coastal lowlands, the central highland Sierra, and the eastern Amazon lowlands (the "*Oriente*"), most of which are contained in the provinces of Napo, Sucumbios, and Orellana. The *Oriente*, the westernmost extension of the Amazon basin, is perhaps the most biologically diverse region on the planet (Myers 2000). This rich ecology has been diminished by rapid population growth and deforestation. The population more than doubled from 1950 to 1990, to over 400,000 (INEC 1992). In-migration to the *Oriente* began in earnest in the late 1970s, averaging 5.0% per annum during the last inter-censal period (1982-90). Also contributing to increasing population density is the high total fertility rate (TFR). The most recent "national" demographic survey indicates that the Amazon region has a far higher TFR than elsewhere in the country - 5.5 vs. 3.4 for the country as a whole (Centro de Estudios sobre Poblacion y Desarrollo Social (CEPAR) 2000). Although a decrease in TFR over time (8.0 in 1990 to 5.0 in 1999) has been estimated for the samples collected based upon the P/F ratio method (United Nations 1983), these rates continued to exceed national and other regional averages.

Settlers living in Ecuador's northern Amazon (Figure 1) are comprised primarily of agricultural families who migrated from other rural areas of Ecuador. Their arrival was predicated on the expansion of the oil industry. Since oil was discovered in the region in 1967, petro-dollars have generated over half of Ecuador's export earnings. This oil boom has resulted in road construction penetrating lowland regions, opening vast forest tracts to migrant settlers and leading to an estimated deforestation rate of (according to our longitudinal data set) 4% per year.

III. Methods

1. Household, Community and Satellite Data

To help understand the intricacies involved between environmental and population change, CPC conducted surveys in 1990 and 1999 on a representative sample of farm plots in the northeast region of the Ecuadorian Amazon. A brief description of the sampling procedure and data is provided below, with more detailed exposition provided by Pichón (1997), Pan and colleagues (2001), and Messina and Walsh (2001). The sample of plots surveyed was selected in 1990 via a two-stage approach that selected sectors and *fincas* (government-defined agricultural units). Two questionnaires per household farm were administered separately to the household head and spouse to

acquire information regarding land use, livestock, off-farm work, hired labor, credit, household composition and migration history, fertility and contraceptive use, health, and household assets. A follow-up survey was administered in 1999, with the addition of two components to better understand the biophysical changes occurring. First, a community sample was selected and surveyed in 2000 based upon household responses to specific questions regarding interaction between the household and community (e.g. market location, health care availability, etc.). Second, satellite images were acquired from NASA to depict changes in land cover over time and geographic position systems (GPS) were used to locate surveyed households, roads, community and health centers, markets, and schools to assist in the production of maps and development of spatial analyses.

Creation of the longitudinal data set for this analysis was a two-step process. First, family households that were interviewed in 1990 and 1999 were identified and merged (N=252 of 418 households in 1990). Second, the data set was limited to households with the same women responding to the female questionnaire in both years and who were of childbearing age (15-49) in 1990. The final sample consisted of 165 women.

2. Variables and Statistical Model

The primary research questions require outcome variables to be defined for both the occurrence of childbirth and the total number of births reported for each woman between 1990 and 1999. Demographic and socioeconomic factors were identified based upon their theoretical importance in the literature as well as their availability in the data and are listed in Table 1. In addition to the cross-tabulations shown in the table, three-way contingency tables (cross-breaks) were examined to control for variables such as woman's age and parity.

Since we are examining occurrence of childbirth *and* the total number of births between 1990 and 1999, the most plausible statistical models are the logistic and Poisson. Logistic regression is appropriate for categorical outcome variables and models the log odds of birth occurrence given a set of explanatory variables. The logistic regression model equation, also referred to as the *logit*, is shown in Equation 1:

$$\log\left\{\frac{\theta_{hi}}{1-\theta_{hi}}\right\} = \alpha + \sum_{k=1}^t \beta_k x_{hik} \quad (1)$$

The expression in the brackets represents the odds of a birth versus no birth for the hi^{th} group, α is the intercept, and $\beta_k x_{hik}$ represent the fixed parameters and set of explanatory variables. If one exponentiates the α and β coefficients, one can interpret the estimates as the odds of a birth for a given explanatory variable (see results section).

Poisson regression assumes that the number of births reported for each woman has a Poisson distribution given the independent explanatory background covariates and risk factors. The Poisson model used for this paper was the loglinear model shown in Equation 2:

$$\mu_i = N_i \lambda_i = N_i \exp\left(\alpha + \sum_{k=1}^t \beta_k x_{ik}\right) \quad (2)$$

Where μ_i represents the incidence or the expected number of total births for each woman (note – since age will serve as one of the explanatory variables and N_i is approximately

the same for each woman, an offset was not included in the model) and λ_i is referred to as the incidence density. Each $\exp(\beta_k)$ are incidence density ratios for unit changes in their associated explanatory variable x_{ik} .

Both models estimated parameters using maximum likelihood in SAS V8.1. Goodness of fit for the logistic model was assessed using Pearson residuals and statistics, while the Poisson model utilized Deviance statistics. Overdispersion for the Poisson model was examined by modeling the scale parameter in separate models. For more details of logistic and Poisson models see Stokes, Davis, and Koch (1996) or Hosmer and Lemeshow (1989).

IV. Results

1. Descriptive data

a. Demographic factors

The mean number of births for women between 1990 and 1999 was approximately two for those with two or fewer live births prior to 1990 (see Table 1). However, among the vast majority with three or more children prior to 1990, the mean number of births from 1990 to 1999 was slightly less than one. Most women did not desire more children in 1990. Desire appears to have a strong relation to the number of births between 1990 and 1999; those who wished to have no children averaged under one birth between 1990 and 1999 while women hoping to have more than two children averaged three births during the period. Infant mortality also appeared to be strongly related to fertility, but in an unanticipated direction: women with no infants dying prior to 1990 had more than double the number of children and were more likely to report a birth during the time period as did those experiencing child mortality. However, three-way tables that controlled for age revealed that the relationship was not significant. Also unexpected was the higher number of births reported among women who had ever used contraceptives, yet this relationship was also mitigated when controlling for age. Age in 1990 was, as expected, strongly related in a negative direction with fertility. Nevertheless, higher educational achievement was notably and consistently related to higher fertility, again contradicting theory. Lastly, it was unexpected that women in households with two or fewer out-migrants during the period had more than double the number of children between 1990 and 1999 than women in households with three or more out-migrants. It should be noted that all of these variables are likely to be strongly related to women's age (as with infant mortality and contraceptive use), which is why multivariate regression analyses are appropriate to control for this key variable (as we will see in Section IV.2).

b. Socio-economic factors

The majority of women came from households with legal title to their farm (see Table 1). These women had over 50% fewer children than women from squatter households. Nearly a third of the sample pertained to households that lost more than five hectares of land between 1990 and 1999. These women had notably fewer children than women from households that acquired at least five hectares during the period. The majority of women came from households whose assets remained relatively unchanged. These women had more children than women from households with greater asset changes during the period (whether plus or minus). Access to electricity in the home, a proxy for infrastructure and material development, was associated with notably fewer children born

to women from 1990 to 1999. This was especially the case among the small minority with such access throughout the period of study (only a quarter of these women had children during the period). Lastly, the mean road distance to a market for all households in the sample was 21.4 kilometers. For women reporting a birth during the period 24.3 compared to 18.9 for women reporting no birth during the period. Distance to road appears to particularly increase number of births among women in the most remote households. In households over thirty kilometers to a market, 65% of women reported a birth compared to under 50% in all other categories. These women also had more than double the mean number of births during the period as any other group.

2. Regression results

a. Logistic regression

Model diagnostics for the logistic model identified two outliers among the 165 observations in the original data set that were subsequently removed. Model 1 was an inadequate fit to the logistic model (Pearson, $p=0.001$), therefore 1999 contraceptive use, assets, distance to a community center, access to electricity and duration were removed from the model using a backward selection technique to identify the best model fit. Model 2 diagnostics indicate a good fit to the data with all variables significant at the 0.05 level. Estimates for β are interpreted as the log odds for the occurrence of a birth between 1990 and 1999. Odds ratios are calculated by exponentiating the estimates and are interpreted as the increase (or decrease) in odds of a birth occurring (e.g. absence of land title in 1990 increases the odds of a birth by $e^{0.58} = 1.79$ over those households with title). Model variables are described in Table 2.

In regards to demographic factors, as control variables, the number of infant deaths prior to 1990 and women's age in 1990 and were negatively related to the odds of giving birth during from 1990 to 1999 (Table 3). As anticipated, the desire for more children in 1990, was positively related to childbearing in from 1990 to 1999. Again as expected, contraceptive use in 1990 (use in 1999 was insignificant) and number of household out-migrants from 1990 to 1999 was negatively related to giving birth from 1990 to 1999. Finally, women's education and the total number of live births prior to 1990, were unexpectedly positively related to the odds for childbirth during 1990 to 1999.

Relative to socio-economic variables, land title and increase in land availability were positively related to childbirth from 1990 to 1999 at the 0.01 level; both relations were anticipated. Again as expected, increase in assets over the time period was also significantly and negatively related to childbearing. Access to electricity was only marginally related to childbearing and was removed from Model 2. And duration living in the *Oriente* was insignificant.⁶

b. Poisson multivariate regression

No outliers or influential observations were identified for the Poisson regression, thus 165 women contributed to the estimation of the parameters. Model 1 provides

⁶ An important note is that a decrease in land and a decrease in assets from 1990 to 1999 are negatively related with the reporting of a birth.

estimates for the maximum model. Model 2 was fit to attain a more parsimonious model by excluding variables using a backward selection technique. To calculate the predicted number of births one would sum the appropriate parameters and compute the exponent of the sum (e.g. a 20-year old woman that desires children with zero live births prior to 1990, no contraceptive use, no change in land or assets, and electricity only in 1999 would have $e^{3.60-20*.12+- .28} = 2.50$ predicted births from 1990-99).

Demographic factors that were significantly associated with decreasing the number of births reported were number of infant deaths prior to 1990, 1990 values for contraceptive use, and woman's age (Table 4). These are all anticipated results. Unexpectedly, the total number of live births prior to 1990 strongly predicted an increase in the number births between 1990 and 1999. Surprisingly, women's education and desire for more children were not significantly related to the number of births during the time period when controlling for all other factors.

No socio-economic factors were significant and positively related to the number of births reported. Access to electricity was negatively related to the number of births when compared to the reference category of no electricity. Therefore, a household with electricity in 1990 and 1999 had significantly fewer births than a household with no electricity in either year.⁷

V. Conclusion and Discussion

In this paper we used a longitudinal data set (from surveys administered in 1990 and 1999) to examine the determinants of household fertility among women in an agricultural frontier in the Ecuadorian Amazon. The results were more revealing than we anticipated. Even with highly significant control variables such as women's age and previous parity taken into account, it appears that many fertility determinants enumerated in the demographic literature in reference to the developing world in general were largely applicable to this frontier environment. For example, women wanting more children were more likely to give birth, while higher educational achievement, contraceptive use, and increased assets decreased the odds of a birth during the time period 1990 to 1999.⁸ Improved infrastructure, in the form of access to electricity in the home had no significant effect in decreasing the odds of birth but was strongly related in the negative direction to number of children born from 1990-99.⁹ Consistent with the land-fertility hypothesis, increased access to land increased the probability of childbirth but was not

⁷ When adjusted for age, parity and infant mortality relations to the outcome variables are sensible. Further, additional models were fit that omitted them in the analysis. However, omitting these variables did not affect the direction or significance of the remaining variables in either model.

⁸ Increased asset ownership was not significant in predicting the number of births in the Poisson model. In other words, assets predict the occurrence of a single birth but does not predict number of births per woman, suggesting a threshold in the demand for labor.

⁹ We believe that this measure may be capturing much of the error terms expressed in distance to a community center. This would explain why the former variable, apparently significant in the descriptive analysis, was insignificant in the regression models. In future research we plan to establish distance to the nearest health center from our GIS data. This would provide the most pertinent locational measure for this study.

significantly related to the number of children born during the period. Further, those without land title were more likely to report a birth (but not significantly more births than those with land title).

One result was unexpected, yet potentially informative: women who came from households with out-migrants were less likely to have a child in 1990 to 1999. We expected that out-migration would induce further births to compensate for decreased labor availability on the farm. However, perhaps a more cogent argument is that out-migration results from a perceived household population surplus (or the absence of labor demand). Further, since some migrant households likely receive remittances, these households may be more exposed to the mitigating fertility effects associated with enhanced socio-economic status.

This paper is an attempt to begin to understand fertility determinants in an agricultural frontier environment in the Latin American tropics. We feel that this is an important topic for humanitarian and ecological concerns. Relative to the first concern, fertility is exceptionally high on the frontier, and this paper suggests that poor infrastructure, child and maternal health care availability, scarce educational opportunities, and a virtual absence of wage employment for women are some of the potential causes. These factors are placed in stark relief to the extraordinary finding that most women wanted no more children, suggesting very strong, and largely unmet, demand for reproductive health services. Regarding the ecological importance of the research, agricultural expansion in the tropics is the primary proximate cause of deforestation on the planet. Most forest conversion for agriculture is accomplished by small farm families and household size has been consistently linked as a key determinant of deforestation in such environments (both on the farm and due to second-generation out-migration to new forest frontiers). The results of this study support the notion that improving certain aspects of women's intellectual and material wellbeing may decrease fertility on the frontier, a laudable objective for human development and environmental conservation.

Table 1.

Descriptive Variables	N	% reporting at least one birth: 1990-99	Mean no. of births: 1990-99
ALL	165	50%	1.17
Demographic factors			
<i>Age in 1990</i>			
15-29	48	81%	2.21
30-39	66	58%	1.20
40-49	51	12%	0.16
Total No. of live births prior to 1990			
Zero	8	63%	1.88
One	7	57%	2.29
Two	19	84%	2.32
Three or more	131	44%	0.90
Total No. of infants died prior to 1990			
Zero	85	64%	1.66
One	34	41%	0.74
Two	23	35%	0.57
Three or more	23	30%	0.61
Desired No. of children in 1990			
Zero	137	44%	0.94
One	16	88%	1.75
Two or more	12	75%	3.00
Ever used contraception			
No	65	34%	0.82
Yes	100	61%	1.40
Education level as of 1990			
None	13	38%	0.62
Primary incomplete	72	44%	1.06
Primary complete	71	54%	1.28
Secondary or more	9	89%	2.00
No. of household out-migrants prior to 1990			
Zero	108	54%	1.34
One	33	42%	0.88
Two or more	24	46%	0.79
No. of household out-migrants 1990-99			
One	62	71%	1.76
Two	28	54%	1.39
Three	33	30%	0.45
Three or more	42	33%	0.71
Socio-economic factors			
Type of Land Title in 1990			
Title	81	38%	0.77
Certificate of Possession	68	57%	1.44
None	16	81%	2.06
1990 Landholdings (Ha)			
0 - 19	13	54%	2.00
20 - 39	36	53%	1.22
40 - 59	90	53%	1.18
60 +	26	35%	0.65
Change in farmland			
Lost more than 5 ha.	49	37%	0.82
Lost 5 ha. to gained 5 ha.	71	59%	1.30
Gained at least 5 hectares	45	51%	1.36
Change in Assets from 1990 to 1999*			
Lost at least 2	34	41%	1.06
Lost 1 to gained 1	93	53%	1.29
Gained at least 1	38	53%	0.97
Access to electricity			
None 1990-99	83	59%	1.49
1999 only	63	46%	1.00
1990 and 1999	19	26%	0.32
Walking distance to road/river in 1990 (km.)			
Located on road (0 km)	96	44%	0.94
0.5 - 5	35	49%	1.29
6 +	34	71%	1.71
Distance to a community center in 1999 (km.)			
0-10	47	43%	0.96
11-20	45	49%	1.04
21-30	41	49%	1.1
31+	32	65%	2.25

*The female questionnaires in 1990 and 1999 contained a listing of household assets from which an overlapping set of 14 variables was tabulated for each time point. The change in the number of assets represents the change in possession of these specific assets only – not all the assets in the household.

Table 2.

<i>Variables</i>	<i>Description</i>
<u>Demographic factors</u>	
AGE90 * ❖	Woman's age in 1990
TOTLB90 *	Total no. of live births prior to 1990
TOTDIE90 *	Total no. of infants died prior to 1990
DESIRE	Desired more children in 1990 (Yes / No)
CONTRA *	Contraceptive use: 0=never, 1=1990 only, 2=1999 only, 3=Both 1990 and 1999
EDUC *	Woman's education: 0=Primary School or less, 1=Secondary School or More
MIGMAL99	Male out-migrant from 1990-99 (1=Yes; 0=No)
MIGFML99	Female out-migrant from 1990-99 (1=Yes; 0=No)
MIGMAL90	Male out-migrant prior to 1990 (1=Yes; 0=No)
MIGFML90	Female out-migrant prior to 1990 (1=Yes; 0=No)
<u>Socio-economic factors</u>	
TENURE *	Type of Land Tenure in 1990 (None, Certificate of Possession, Full Title)
LABOR	Index of female labor in 1990 (Range: 0-10)
TOTAREA90 *	1990 Landholdings (Ha): 0-19, 20-39, 40-59, 60+
LANDCHANGE * ❖	Change in land from 1990-1999
ASSETS90 *	1990 Assets owned (Range: 0-14)
ASSETS99 *	1999 Assets owned (Range: 0-14)
ROAD90 * ❖	Road distance to Community in 1990 (km)
WALKED *	Walking distance to Road in 1990 (km)
POWER	Electricity access: None, Access in 1999 only, Access in 1990 and 1999
DUR90	Years living in Oriente prior to 1990

❖ These variables were centered and scaled prior to running the regressions

* These variables constituted the minimum model for the Logistic Regression

Table 3. Logistic Regression Model

<i>Variables</i>	<i>β - Estimate</i>	<i>Odds Ratio</i>
Intercept	-3.15 *	0.04
<u>Demographic factors</u>		
AGE90	-2.99 ***	0.05
TOTLB90	0.43 ***	1.54
TOTDIE90	-0.76 ***	0.47
CONTRA		
None vs. Used in 1990 and 1999	1.28 *	3.60
1990 Only vs. Used in 1990 and 1999	2.11 ***	8.25
1999 Only vs. Used in 1990 and 1999	3.21 ***	24.78
EDUC	0.99	2.69
MIGFML99	0.704	2.02
MIGMAL90	-1.07 *	0.34
<u>Socio-economic factors</u>		
TENURE		
Certificate of Possession vs. Full Title	1.23 **	3.42
Nothing vs. Full Title	2.38 **	10.80
LABOR90	0.28 **	1.32
LANDCHANGE	0.94 ***	2.56
ASSETS90	-0.33 ***	0.72
WALKED	0.19 **	1.21
R-Square	0.54	
Pearson GOF Statistic (p – value)	0.88 (0.86)	

*** = Significant at the 0.01 level, ** = Significant at the 0.05 level, * = Significant at the 0.1 level

Two observations were identified as outliers and deleted

Table 4. Poisson Regression Models

<i>Variables</i>	<i>Model 1</i>	<i>Model 2</i>
Intercept	11.6 ***	11.69 ***
<u>Demographic factors</u>		
Woman's age in 1990	-0.11 ***	-0.12 ***
Total no. of live births prior to 1990	0.16 ***	0.14 ***
Total no. of infants died prior to 1990	-0.24 ***	-0.22 ***
Desired more children in 1990 (Yes / No)	0.27	
Contraceptive use in 1990 (Yes / No)	-0.28	-0.36 *
Contraceptive use in 1999 (Yes / No)	-0.12	
Woman's education ✚	0.29 *	0.24
<u>Socio-economic factors</u>		
Land title in 1990 (no title vs. title)	0.09	
Change in land from 1990-1999^	0.005 *	0.004
1990 Assets owned	-0.04	-0.05
1999 Assets owned	0.02	
Distance to community center (KM)	0.002	
Electricity access		
Electricity in 1990 and 1999	-0.69	-0.87 **
Scale	1.09	1.08

References Cited

- Agadjanian, V. (2001). "Women's work and fertility in a sub-Saharan urban setting: a social environment approach." Journal of Biosocial Science **32**(1): 17-35.
- Anderton, D. and L. Bean (1985). "Birth spacing and fertility limitation: a behavioral analysis of a nineteenth century frontier population." Demography **22**(2): 169-83.
- Binswanger, H. and J. McIntire (1987). "Behavioral and material determinants of production relations in land-abundant tropical agriculture." Economic Development and Cultural Change **36**(1): 73-99.
- Bongaarts, J. (1978). "A framework for analyzing the proximate determinants of fertility." Population and Development Review **4**(1 (March)): 105-132.
- Boserup, E. (1984). Technical Change and Human Fertility in Rural Areas of Developing Nations. Rural Development and Human Fertility. W. Schutjer and C. Stokes. London and New York: MacMillan: 23-33.
- Bulatao, R. and RD Lee eds. (1983). Determinants of fertility in developing countries. New York, Academic Press.
- Burke, B. (1995). "Mexican immigrants shape California's fertility future." Population Today **23**(9): 4-6.
- Cain, M. (1984). On the relationship between landholding and fertility. New York, New York Center for Policy Study.
- Caldwell, J. C. (1980). "Mass education as a determinant of the timing of fertility decline." Population and Development Review **6**(2): 225-255.
- Caldwell, J. C. and P. Caldwell (1987). "The cultural context of high fertility in sub-Saharan Africa." Population and Development Review **13**(3): 409-437.
- Carr, D. L. (2002). Rural-frontier migration and deforestation in the Sierra de Lacandón National Park, Guatemala. Ph.D. dissertation. Department of Geography. University of North Carolina. Chapel Hill, NC.
- Centro de Estudios sobre Poblacion y Desarrollo Social (CEPAR) (2000). Encuesta Demografica y de Salud Materna e Infantil. ENDEMAIN III.. Quito, CEPAR and US Centers for Disease Control.
- Chayanov, A. V. (1986). The Theory of Peasant Economy. Madison, University of Wisconsin Press.
- Clay, D. and N. E. Johnson (1992). "Size of the farm or size of the family: Which comes first?" Population Studies **46**: 491-505.
- Cleland, J. and G. Rodriguez (1988). "The effect of parental education on marital fertility in developing countries." Population Studies **42**(3): 419-442.
- Coale, A. (1973). The demographic transition. International Population Conference, Leige: International Union for the Scientific Study of Population.
- Coomes, O., F. Grimard, et al. (2001). Peasant farm size and family size: A causality analysis from the Peruvian Amazon. NEUDC Conference, Boston University.
- Davis, K. (1963). "The theory of change and response in modern demographic history." Population Index **29**(4): 345-366.
- Demeny, P. (1992). "Policies seeking a reduction of high fertility: A case for the demand side." Population and Development Review **18**(2): 321.

- Diamond, I., M. Newby, et al. (1999). Female education and fertility: examining the links. Critical perspectives on schooling and fertility in the developing world. C. H. Bledsoe, J. B. Casterline, J. A. Johnson-Kuhn and J. G. Haaga. Washington, D.C., National Academy Press: 23-48.
- Dreze, J. and M. Murthi (2001). "Fertility, education, and development: evidence from India." Population and Development Review **27**(1): 33-63.
- Driscoll, A. and D. Upchurch (1995). Post-immigration childbearing patterns of Mexican women in the United States. Annual Meeting of the Population Association of America, San Francisco, California.
- Easterlin, R. A. (1971). "Does human fertility adjust to the environment?" American Economic Review **61**: 399-407.
- Easterlin, R. A. (1978). The economics and sociology of fertility: A synthesis. Historical Studies of Changing Fertility. C. Tilly. Princeton, NJ, Princeton University Press: 57-133.
- Easterlin, R. A. and E. M. Crimmins (1982). An exploratory study of the "synthesis framework" of fertility determination with world fertility survey data. Voorburg, The Netherlands: International Statistical Institute, World Fertility Survey Scientific Report.
- Ellis, F. (1993). Peasant economics: Farm households and agrarian development. Cambridge, Cambridge University Press.
- FAO (2001). The global forest resources assessment 2000 summary report. Rome, Committee on Forestry.
- Fennelly, K., G. Cornwell, et al. (1992). "A comparison of the fertility of Dominican, Puerto Rican and mainland Puerto Rican adolescents." Family Planning Perspectives **3**: 107-10.
- Firebaugh, G. (1982). "Population density and fertility in 22 Indian villages." Demography **19**(4).
- Freedman, R. (1997). "Do family planning programs affect fertility preferences? A literature review." Studies in Family Planning **28**(1): 1-13.
- Geist, H. J. and E. F. Lambdin (2001). What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. Louvain-la-Neuve, Belgium, LUCC International Project Office: 116.
- Gorwaney, N., M. van Arsdol, et al. (1991). "Migration from Latin American countries to the United States: the economic, social and reproductive lives of Hispanic female immigrants, 1980." International Migration **29**(4): 573-99.
- Guilkey, D. and S. Jayne (1997). "Fertility transition in Zimbabwe: determinants of contraceptive use and method choice." Population Studies **51**(2): 173-89.
- Henriques, M. (1988). The colonization experience in Brazil. Land Settlement Policies and Population Redistribution in Developing Countries: Achievements, Problems, & Prospects. A. Oberai. New York, Westport, and London, Praeger: 317-354.
- Hirschman, C. and P. Guest (1990). "Multilevel models of fertility determination in four Southeast Asian countries: 1970 and 1980." Demography **27**(3): 369-395.

- Hollos, M. and U. Larsen (1992). "Fertility differentials among the Ijo in southern Nigeria: does urban residence make a difference?" Social Science and Medicine **35**(9): 1199-210.
- INEC (1992). V Censo de Poblacion y IV de Vivienda; Resultados Definitivos. Quito, INEC.
- Knodel, J., A. Chamrathirong, et al. (1987). Thailand's Reproductive Revolution: Rapid Fertility Decline in a Third-World Setting. Madison, University of Wisconsin Press.
- Kohler, H., J. Behrman, et al. (2001). "The density of social networks and fertility decisions: evidence from South Nyanza District, Kenya." Demography **38**(1): 43-58.
- Kravdal, O. (2000). "A search for aggregate-level effects of education on fertility, using data from Zimbabwe." Demographic Research **4**(3): 35.
- Landale, N. and S. Huan (1996). "Migration and premarital childbearing among Puerto Rican women." Demography **33**(4): 429-42.
- Lee, B. and L. Pol (1993). "The influence of rural-urban migration on migrants' fertility in Korea, Mexico and Cameroon." Population Research and Policy Review **12**(1): 3-26.
- Leet, D. R. (1977). "Interrelations of population density, urbanization, literacy, and fertility." Explorations in Economic History **14**: 388-401.
- Lerman, C. (1992). The effect of migration on contraceptive usage and service point choice in Indonesia. Fertility transitions, family structure, and population policy. C. Goldscheider. Boulder, Colorado/Oxford, England, Westview Press: 137-54.
- Lesthaeghe, R., I. H. Shah, et al., Eds. (1981). Compensating changes in intermediate fertility variables and the onset of marital fertility transition. Proceedings of the IUSSP World Conference in Manila, Philippines, 6-9 December 1981. Liege, Belgium, Ordina Press.
- Lesthaeghe, R. and J. Surkyn (1988). "Cultural dynamics and economic theories of fertility change." Population and Development Review **14**(1): 1-43.
- Marquette, C. (1995). Household demographic characteristics, consumption, labor and land use on the northeastern Ecuadorian Amazon frontier. Ph.D. dissertation, Fordham University, New York.
- Martine, G. (1996). "Brazil's fertility decline, 1965-95: a fresh look at key factors." Population and Development Review **22**(1): 47-75.
- McDevitt, e. a. T. (1996). Trends in adolescent fertility and contraceptive use in the developing world. IPC/95-1. Washington, DC, US Bureau of the Census: 1-53.
- Merrick, T. W. (1978). "Fertility and land availability in Brazil." Demography **15**: 321-336.
- Messina, J. and S. J. Walsh (2000). Analysis of land change across spatial scales using geographic techniques: A comparison of deforestation in Ecuador and Thailand. Latin American Studies Association (LASA), Miami, FL.
- Messina, J. and S. J. Walsh (2001). "Morphogenesis: modeling landuse and landcover dynamics in the Ecuadorian Amazon." Plant Ecology **156**: 75-88.
- Molyneaux, J. (1985). Community input and product markets, land availability and fertility in the Amazon frontier. Paper presented at the Population Association of American Annual Meeting, Boston, Massachusetts, March 28-30.

- Molyneaux, J. (1986). Determinants of fertility in frontier Brazil: measures of the values of children. Ann Arbor, Michigan, University Microfilms International, 1986. 164 p., doctoral dissertation at the University of North Carolina at Chapel Hill.
- Murphy, L. L., C. Marquette, et al. (1999). Land use, household composition, and economic status of settlers in Ecuador's Amazon: A review and synthesis of research findings, 1990-1999. University of Florida, Center for Latin American Studies 48th Annual Conference: "Patterns and Processes of Land Use and Forest Change in the Amazon," March 23-26, 1999, Gainesville, FL.
- Myers, N. (1994). Tropical deforestation rates and patterns. The causes of tropical deforestation. K. Brown and P. D.
- Myers, N. (2000). "Biodiversity hotspots for conservation priorities." Nature **403**(6772): 853-858.
- Nagarajan, R. and S. Krishnamoorthy, Eds. (1992). Landholding and fertility relationships in a low-fertility agricultural community in Tamil Nadu. Population Transition in South Asia. Delhi, B.R. Publishing Corporation.
- Newman, J. L. (1986). "Fertility and transition." Focus **Spring**.
- Pan, W., L. Murphy, et al. (2001). Population and land use in Ecuador's northern Amazon in 1999: Intensification and growth in the frontier. Population Association of America annual meeting, Washington, D.C.
- Pichón, F. and R. Bilsborrow (1999). Land use systems, deforestation, and demographic factors in the humid tropics: Farm-level evidence from Ecuador. Population and Deforestation in the Humid Tropics. R. Bilsborrow and D. Hogan. Liege, Belgium, IUSSP: 175-207.
- Pichon, F. J. (1997). "Settler Households and land-use patterns in the Amazon frontier: farm-level evidence from Ecuador." World Development **25**(1): 67-91.
- Robinson, W. and W. Schutjer (1984). "Agricultural development and demographic change: A generalization of the Boserup model." Economic Development and Cultural Change.
- Rosero-Bixby, L. and A. Palloni (1998). "Population and deforestation in Costa Rica." Population and Environment **20**(2): 149-78.
- Ross, J. A. and P. W. Mauldin (1996). "Family planning programs: Efforts and results, 1972-94." Studies in Family Planning **27**(3): 137-147.
- Rudel, T. and B. Horowitz (1993). Tropical deforestation: Small farmers and land clearing in the Ecuadorian Amazon. New York, Colombia University Press.
- Rundquist, F.-M. and L. A. Brown (1989). "Migrant fertility differentials in Ecuador." Geografiska Annaler, Series B **71**(2): 109-123.
- Schutjer, W. A., C. S. Stokes, et al. (1981). "Relationships among land, tenancy, and fertility: A study of Philippine barrios." The Journal of Developing Areas **15**(October): 83-96.
- Schutjer, W. A., C. S. Stokes, et al. (1983). "Farm size, land ownership, and fertility in rural Egypt." Land Economics **59**(54).
- Singh, K. P. (1986). Correlates of fertility behaviour: A study of rural communities in Punjab and Haryana, New Delhi, Concept Publishers.
- Singh, R. D. (1994). "Fertility-mortality variations across LDCs: Women's education, labor force participation, and contraceptive use." Kyklos **47**(2): 2,209-229.

- Singh, S., J. B. Casterline, et al. (1985). "The proximate determinants of fertility: subnational variations." Population Studies **39**(1 (March)): 113-135.
- Teitelbaum, M. S. (1975). "Relevance of demographic transition theory for developing countries." Science **188**: 420-425.
- Tuladhar *et al.*, J. M. (1982). "Differential fertility in rural Nepal." Population Studies **36**(1).
- United Nations (1983). Manual X: Indirect techniques for demographic estimation. New York, United Nations.
- United Nations (1987). Fertility behavior in the context of development: Evidence from the World Fertility Survey. New York, UN.
- United Nations (1995). Women's education and fertility behaviour: Recent evidence from the Demographic and Health Surveys. New York, United Nations.
- VanLandingham, M. and C. Hirschman (1995). Adaptations to resource constraints during the pretransitional era: fertility differentials arising from the peopling of the Thai Frontier. Seattle Population Research Center Working Paper No. 96-2: 11.
- Warren, C. (1987). "Fertility determinants in Puerto Rico." Studies in Family Planning **18**(1): 42-48.
- Weil, C. (1981). "Health problems associated with agricultural colonization in Latin America." Social Science & Medicine **15D**: 449-461.
- Weinberger, M. B. (1987). "The relationship between women's education and fertility: selected findings from the World Fertility Surveys." International Family Planning Perspectives **13**(2 (June)): 35-46.
- World Bank (1991). Forest Sector Review. Washington DC, The World Bank.
- Yadava, K. and G. Yadava (1993). "Estimation of fecundability of migrated couples in the process of rural out-migration in India." Janasamkhya **11**(1): 41-9.
- Zeng, Y. (1996). "Latent possibility for a change of the fertility behaviors of rural-urban migrants." China Population Today **13**(5-6): 16.