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Declining fertility on the frontier: the Ecuadorian Amazon

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Abstract

This paper examines farm and household characteristics associated with a rapid fertility decline in a forest frontier of the Ecuadorian Amazon. The Amazon basin and other rainforests in the tropics are among the last frontiers in the ongoing global fertility transition. The pace of this transition along agricultural frontiers will likely have major implications for future forest transitions, rural development, and ultimately urbanization in frontier areas. The study here is based upon data from a probability sample of 172 women who lived on the same farm in 1990 and 1999. These data are from perhaps the first region-wide longitudinal survey of fertility in an agricultural frontier. Descriptive analyses indicate that fertility has plummeted in the region, which is surprising since it had remained high and unchanging among migrant colonists up to 1990. Thus only half of the women in our sample reported having a birth during the 1990-1999 time period, and most women report in 1999 that they do not want to have any more children. Analyses, controlling for women's age, corroborate hypotheses about land-fertility relations. For example, women from households with a legal land title had fewer than half as many children as those from households without a title. Large cattle (pasture) holdings and hiring laborers to work on the farm (which may replace household labor) are both related to socio-economic status that is traditionally associated with lower fertility. Similarly, distance to the nearest community center is positively related to fertility. Factors negatively related to fertility include increasing temporary out-migration of adult men or women from the household, asset accumulation, and access to electricity.

Keywords

Population; Environment; Fertility; Agricultural frontier; Amazon; Latin America; Ecuador

Introduction

Although population growth in forest frontiers[1] is generally attributed primarily to in-migration, high fertility is also important and can result in increasing population pressures on

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[1]We refer to the"frontier" as a rapidly changing region experiencing population growth and land appropriation, characterized by plentiful land and scarcity of labor and capital (Almeida, 1992).

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the land. High individual fertility may be a key motivating factor underlying out-migration from areas of origin to the forest frontier. Fertility is often extraordinarily high among migrant settler women in frontier regions and is typically higher than among women in areas of origin (see Murphy, Marquette, Pichdn, & Bilsborrow, 1999;Rundquist & Brown, 1989;Weil, 1981). During the 1990s, total fertility rates (TFR) were 7-8 births per woman in frontier areas throughout the Amazon (Murphy et al., 1999).

Despite the well-developed literature regarding the determinants of fertility in the developing world in general, there is little published research explicitly examining fertility determinants in rural agricultural frontiers. The international conservation and development community has largely turned a blind eye to the issue of population dynamics on the frontier. Indeed, despite efforts of the Global Science Panel of population scholars, population was conspicuously absent among the major themes at the 2002 Johannesburg World Summit on Sustainable Development (Meyerson, 2002).

The lack of attention given to population dynamics in this context is startling given its obvious importance for human development and environmental conservation. Specifically, in relation to human development, high frontier fertility may be linked to poor socio-economic infrastructure, lack of child and maternal health care, scarce educational opportunities, and a virtual absence of wage employment for women. Regarding environmental conservation, the world's ecological “hot spots” also coincide with areas of high population growth (Cincotta, Wisnewski, & Engelman, 2000). Along agricultural frontiers within these regions both population and environmental change are most dynamic and, in fact, most ongoing deforestation on the planet is occurring in these environments (Geist & Lambin, 2001; Myers, 1994). Further emphasizing the importance of population dynamics regarding development, household size has been linked to deforestation at the farm level in numerous studies (e.g., Carr, 2005; Pichón, 1997), including studies using the same data used here (e.g., Pan et al., 2004).

This article represents a first step in exploring demographic, socio-economic, and ecological factors potentially related to fertility in a sample of colonist households in the Ecuadorian Amazon. Although fertility has fallen significantly nearly everywhere in the developing world since the 1970s, it has remained high in frontier regions. The analysis here, however, indicates rapidly falling fertility in the context of frontier development. Lessons learned from this analysis can help us in understanding which factors sustain fertility at high levels as well as which factors contribute to reducing fertility in frontier settings. The data are unique in that (to the best of our knowledge) they are the first statistically representative longitudinal survey of fertility in a frontier context.

In the following section, we briefly review the current state of knowledge on fertility determinants in the developing world and in agricultural frontier settings. Section “Survey site, sample design, and data description” presents an overview of the study site and a description of the sample design and data collection. In Section “Description of the sample population: 1990 and 1999” we describe the study population in terms of its demographic, socio-economic, and ecological conditions. Section “Conclusion” concludes with a discussion of the implications of the results for future research and policy interventions.

Fertility determinants in the developing world

Following on the demographic transition that began in Western Europe and spread to other developed nations in the 19th and early 20th centuries, most of the developing world has been experiencing its own rapid decline in fertility and mortality rates beginning in the latter third of the twentieth century (Coale, 1973; Teitelbaum, 1975). Major factors involved in the transition in developing countries are increasing women's education, socio-economic

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development, increasing women's employment, and urbanization, which provide women with alternative roles to child-raising and also raise the costs of child-rearing (Agadjanian, 2001; Hirschman & Guest, 1990; Knodel, Chamratrithirong, & Debavalya 1987; Martine, 1996; Singh, 1994). A second set of factors which were not relevant to the onset of the demographic transition in developed countries relate specifically to access to methods for controlling fertility, including modern methods of contraception, female sterilization and safe abortion (Bulatao & Lee, 1983; Easterlin & Crimmins, 1982; Freedman, 1997; Guilkey & Jayne, 1997; Pritchett, 1994; Ross & Mauldin, 1996). Improved sanitation and health care have also been important developments as they lower infant mortality, obviating the demand for "insurance" births (Davis, 1963; Hirschman & Guest, 1990; Singh, 1994). Perhaps most important, however, are the effects of the vast expansion of school systems on female education, which has led to marriage postponement, empowerment of women to adopt "western" values of smaller families, and improved use of fertilityregulating methods (Caldwell, 1980; Diamond, Clements, Stone, & Ingham 1999; Dreze & Murthi, 2001; Easterlin & Crimmins, 1982; Hirschman & Guest, 1990; Kravdal, 2000; United Nations, 1995a, b, c). Each of these processes operates through proximate behavioral and biological factors regulating fertility: fecundity or potential fertility, fertility preferences, and the implementation of those preferences through formation of unions, use of contraceptives, and birth spacing (Bertrand, Salazar, Mazariegos, Salanic, Rice, & Sow, 1999; Davis, 1963; United Nations, 1987, 1995a, b, c; Warren, 1987).

Fertility determinants at the agricultural frontier

The absence at the frontier of some of the fertility suppressing factors enumerated above, as well as other factors, contributes to the usual high levels of fertility in these remote regions. First, abundant land but scarce capital, lack of infrastructure, and labor scarcity all imply that the economic returns to land are low relative to labor, contributing to high desired family sizes and hence reproduction (Caldwell & Caldwell, 1987). However, the demand for children is also predicated on labor demands, which change over the household lifecycle. In a frontier environment, a typical lifecycle begins with migration to a new farm plot where risk aversion, modest prior farming experience, and survival needs dictate the sowing of annual crops. As the household matures, financial stability and an increased labor supply from growing children contribute to new farming endeavors on the frontier, such as perennial crops and cattle (Walker et al., 2002). Nevertheless, these land uses may be adopted at any stage in the life cycle and affect the demand for labor. Little is known about the effects of different forms of land use on fertility in a frontier environment. For example, controlling for the stage of the family lifecycle (women's age is a good proxy), raising annual crops requires more labor and may therefore promote higher fertility than raising cattle. However, the literature on rural fertility and child labor requirements indicates complex relationships, and high fertility may not be economically beneficial overall to rural households even under circumstances of high labor demand (Lee, 2001; Lee & Kramer, 2002; Stecklov, 1999; Turke, 1989).

A second characteristic of remote agricultural regions is the lack of health infrastructure that has inherently limited access to family planning resources, tending to keep fertility high (e.g., Entwisle, Hermalin, Kamnuansilpa, & Chamratrithirong, 1984; Henriques, 1988; Marquette, 1995; Pichón & Bilsborrow, 1999). The lack of health care infrastructure also contributes to high mortality along the frontier, which encourages compensatory births.

A third important characteristic of the frontier is the limited access to wagelabor employment and schooling for women, which decrease the economic value of women's time relative to that of children, increasing desired family sizes (Singh 1994; Singh, Casterline, & Cleland, 1985).[2] For example, more educated women have considerably lower fertility in agricultural frontiers

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in countries as diverse as Guatemala (Grandia, Corzo, Obando, & Ochoa, 2001) and South Africa (Mencarini, 2000).

A core population-environment interface in rural environments is the relation between people and farm size and farm tenure (Doveri, 2000). The existing scant research on land-fertility relationships generally (though inconclusively) supports the hypothesis that: (1) when access to land increases, fertility tends to rise; and, conversely, (2) land ownership suppresses fertility. Both the demand for labor on larger farms and the desire to expand landholdings as the family grows are the two primary hypotheses for the first relation (Binswanger & McIntire, 1987; Chayanov, 1986; Clay & Johnson, 1992; Ellis, 1993). Perhaps the most striking study finding a positive relationship between fertility and farm size is based on the Philippine Rural Survey of 1952 (Hawley, 1955), in which the mean total fertility varied from 4.8 to 7.0 births per woman aged 40-49 (nearing the end of childbearing) as plot size increased from under 1 ha to over 4 ha. Stokes, Schutjer, and Bulatao, (1986) cite more similar evidence from Bangladesh, Philippines, India, Mexico, and Brazil. Similarly, Cain (1984) found a positive correlation (but not quite significant at the .05 level) between farm size and fertility in Egypt and Thailand. Nevertheless, other studies show only insignificant differentials in family size relative to land access (e.g. Tuladhar, Stoeckel, & Fisher, 1982).

With regard to the second point above, the effect of resource access on fertility is hypothesized to be reversed with secure tenure of resources, as the economic security provided by children is replaced by the security of land ownership (Schutjer, Stokes, & Cornwell, 1981; Schutjer, Stokes, & Poindexter, 1983)[3] However, owning only small amounts of land can lead to concerns about how much land will be available for children following future farm subdivision among adult children, which encourages having fewer children (Carr, 2003; Desai & Alva, 1998). The effect of land security on fertility is thought to be stronger than that of land availability itself (Thomas, 1991).

Data on the relation between fertility and land (farm) size and land tenure are hampered by methodological shortcomings, including the lack of longitudinal data, which has confounded the direction of causation. Further, existing studies lack key control variables, such as age of woman, contraception use, education, or infrastructure. Lastly, most studies were conducted in settled agricultural areas of relatively high population density, rendering suspect extrapolation to frontier environments of abundant land and low population density (Cain, 1984).[4] However, hypotheses regarding linkages between land and fertility assume that labor is used on the farm, which is more reasonable in a frontier environment (Lakshmanasamy, 1988; Thomas, 1991).

The smattering of studies that have examined this land-fertility relation in rural frontier environments generally find higher land availability associated with higher fertility. Such findings are reported for Thailand (Van Landingham & Hirschman, 1995), Brazil (Merrick, 1978; Molyneaux, 1986), and the western agricultural frontier in the US during the 19th century (Anderton & Bean 1985; Easterlin, 1971). Preliminary findings from multi-temporal data from a modest sample in the Peruvian Amazon suggest that fertility can drive farm size and vice versa (Coomes, Grimard, & Diaz, 2001). In any case, the relation between frontier land and

[2]Further, 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; Caldwell, 1980; Cleland & Rodriguez, 1988; Easterlin, 1978; Easterlin & Crimmins, 1982; Lesthaege et al., 1981; Mc Devitt, 1996; Newman, 1986; Singh, 1994; Singh, Casterline, & Cleland, 1985; United Nations, 1987; Weinberger, 1987) good, but perhaps integrate in text?

[3]However, one study from Bangladesh showed this relation only when land is pooled among extended families (Saha, 1993).

[4]There are further critiques of the relation between resource access and fertility. First, a larger farm may lead to higher fertility not because more children help on the farm, or because it can support more children but rather because a larger farm allows for greater resource security, and thus for more surviving children (Clay and Johnson, 1992). Many other studies finds insignificant differences in family size relative to resource access (e.g., Firebaugh, 1982; Nagarajan & Krishnamoorthy, 1992; Tuladhar et al., 1982).

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fertility remains unclear. While we anticipate that the relation will be positive in our study region in Ecuador, as in other agricultural regions, we qualify this with the caveat that land titles may themselves be important since they may affect forms of land uses that benefit from credit. This credit may be available mainly to those with land titles, such as pasture for cattle. These land uses may, in turn, mediate demands for children's labor and, possibly, fertility and family size. Finally, land title and farm size are associated with higher socio-economic status that is universally associated with lower fertility.

A related topic that has gone virtually unnoticed in the frontier literature is the potential relation between migration and fertility in that setting (Thomas, 1991). Agricultural frontiers are characterized by high in-migration rates but may also have high out-migration. As the frontier develops, with increasing land consolidation and decreasing land availability for growing populations, these migration frontiers may become migration fonts even within a generation of initial settlement. The quite modest literature on fertility-migration links focuses on fertility changes among rural-to-urban migrants (e.g., Hollos & Larsen, 1992; Lee & Pol, 1993; Lerman, 1992; Zeng, 1996) or on fertility differentials of international migrants, those individuals who remain behind, and natives in the destination country (Burke, 1995; Driscoll & Upchurch, 1995; Fennelly, Cornwell, & Casper, 1992; Gorwaney, van Arsdol, Heer, & Schuerman, 1991; Landale & Hauan, 1996). The micro-level evidence is ambiguous since households with high fertility may experience more pressures to have a family member out-migrate, while alternatively, those families with outmigrating members may experience attitudinal changes due to information transfers that lead to fertility declines. For example, some evidence from India suggests that women from rural households with out-migrants have lower fertility than those in households with no migrants (Yadava & Yadava, 1993).

A further question we explore is whether out-migration of individuals affects childbearing among women remaining on the farm. This seems plausible for several reasons and we anticipate the relation to be negative. Ability to migrate is related to higher socio-economic status and, therefore, to greater exposure to, and perhaps desire for, contraception. Following the initial cost of migration, this relation would theoretically be strengthened by remittances sent by the migrant to the origin household. The desire to migrate may also imply a less conservative attitude in general, which is consistent with use of contraception. Migration may also result from land or other resource constraints, which could, at least theoretically, constrain fertility. Further, migration *out of* the Amazon will usually be to an area of lower fertility, where values encouraging smaller family size may be internalized by the migrant. Finally, a decrease in the frequency of intercourse results when the household head migrates. This decrease in coital activity will, most likely, supercede other effects on fertility.

Forest frontiers are the last major frontier in the global fertility transition. Despite the importance of fertility change in these agricultural frontiers, where population interfaces directly with biologically rich environments, we are not aware of research exploring the determinants of fertility using longitudinal data from a statistically representative sample of households in an agricultural frontier. This paper is based on such an analysis and data set, from data collected in 1990 and 1999 in the Ecuadorian Amazon.

Survey site, sample design, and data description

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) (Map 1). The extraordinarily rich biodiversity of this region has been diminished significantly

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by rapid population growth and land clearing by migrant agricultural colonists. The population has more than doubled from 1950 to 1990, to over 371,000 (INEC, 1992), and to almost 550,000 according to the most recent census in 2001 (INEC, 2001). Heavy in-migration to the *Oriente* began in the 1970s, averaging 5.0% per annum (of growth relative to native population) from 1982 to 1990 and 3.5% from 1990 to 2001 (all three rates are more than double the national intercensal growth rates). Besides in-migration, high fertility contributed to rising population density in the region. 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 Población y Desarrollo Social (CEPAR) 2000). Although a dramatic decrease in TFR over time (8.0 in 1990 to 5.0 in 1999) has been estimated for the samples, these rates continued to exceed national and other regional averages.

Settlers living in Ecuador's northern Amazon (Map 2) are comprised primarily of poor agricultural families who migrated from other rural areas of Ecuador, especially from the Sierra. Their arrival was facilitated by the discovery of oil in the northern part of the study area near Lago Agrio in 1967. Since the early 1970s, petro-dollars have generated over half of Ecuador's export earnings. Roads built by petroleum companies opened up the Amazon lowland forests to migrant settlers, leading to rapid deforestation (Pan, Murphy, Sullivan, Pichdn, & Bilsborrow, 2001).

In contrast to the Brazilian Amazon, settlement in Ecuador has been spontaneous, rather than government-directed (Hecht & Cockburn 1989; Moran, 1984; Stewart, 1994). Migrants settled along the oil roads, with successive arrivals claiming land behind farms along the roads, forming parallel lines of farms known as *respaldos*. Settlers arranged for the surveying and titling of their property through the formation of *precooperativas*, through which they applied to the government Land Reform and Colonization Agency (IERAC), and since 1994, to the National Institute for Agricultural Development (INDA). These institutions survey plot boundaries, as the first step towards a land title. Two further steps are the purchasing of a temporary title (*certificado de posesión*) and finally, the purchase of a permanent legal title, called an *escritura*.

Again unlike Brazil, large-scale commercial agriculture, ranching and logging have not played major roles in the Ecuadorian Amazon, where forest clearing is driven by small-farm agriculture. Furthermore, the regions differ in ecological characteristics: Ecuador's Amazon has a year-round growing season, requiring the use of slash and mulch agriculture, with little burning, and possesses pockets of more fertile soils related to its proximity to volcanic Andean slopes.

Household and community data

To understand environmental and population change in the region, a team from the Carolina Population Center conducted detailed household and community-level surveys in 1990 and 1999 on a representative sample of farm plots and communities in the northern Ecuadorian Amazon. A brief description of the sampling procedures and data is provided below, with more detail in Pichón (1997) and Pan and Bilsborrow (2005). The sample of plots surveyed was selected in 1990 via a two-stage procedure in which first settlement areas or sectors were selected and then farms or *fincas* (governmentdefined agricultural units within which farm households are located) were selected from each sample sector. Two questionnaires were administered in each farm household, one to the household head and one to the spouse, to acquire information on location, land acquisition and title, land use, technology, 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.

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Creation of the longitudinal data set for this analysis involved a two-step process. First, family households that were interviewed in 1990 and 1999 were identified and merged (N = 252 of the 418 households from 1990 that remained in 1999). 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 172 women.

Description of the sample population: 1990 and 1999

Demographic characteristics

Fertility on the Amazonian frontier in Ecuador has been very high, with average household size for our study population exceeding seven. Most children were born since settlement in the Amazon, typically within the previous dozen years. The sex ratio slightly favors males: high labor demands on the farm encourage the retention of males. Households in this particular sub-sample of the 1999 data—i.e., those first interviewed in 1990 that remained on sample plots to 1999, differ from those that appear only in either the 1990 or the 1999 surveys, being smaller and more extended (more than just spouses and children) than the other households. Households in this sample have the same head and spouse for the entire 10 years (1990-1999). Children tend to remain in the house until they decide to migrate, marry, or the head decides to provide them with a portion of the farm plot.

Reflecting falling fertility in the region, only 51% of all women in our sample reported a birth between 1990 and 1999, with the mean number of births slightly higher than 1. Age is an important control variable as it sets a biological limit to childbearing and is related to fecundity and childbearing in all populations. Beyond the effect of age, number of prior births is an important indicator of where a woman is situated in her childbearing trajectory. For example, the mean number of births during the period 1990-1999 among women who have already had three or more births by 1990 is approximately half the number of women with two or fewer births prior to 1990. Theory also supports a positive relation between prior infant mortality and subsequent (compensatory) births. Partial correlation coefficients were examined and confirmed that logits should be examined while controlling for women's age.

Most women in 1990 reported desiring no more children (Table 1). This is striking, given the exceptionally high fertility typical of frontiers, and suggests an extraordinarily high latent demand for contraception. The desire for more children in 1990 was clearly related to number of births between 1990 and 1999. Those who wished to have no more children averaged under one birth between 1990 and 1999 (with only 40% reporting a birth), while women hoping to have more children averaged three births during the period and were nearly three times as likely to have a birth. A counterintuitive finding here is the higher number of births reported by women who had ever used contraceptives. This surely relates to the fact that women with more births were more concerned about avoiding more pregnancies (so that the causation is the reverse), and may also relate to fecundity (i.e., infecund women would not need to use contraception); however, when controlling for women's age, (sounds misogynistic to use sterilized for women and vasectomy for men) -women who had undergone tubal ligation or whose spouses had a vasectomy were significantly more likely to have fewer births (and only slightly so). Further, our data refer only to contraceptive use at any point during the time period and do not distinguish quality or frequency of use (factors that clearly effect the likelihood of a birth).

Socio-economic factors

Having more household assets may raise the costs of child-rearing (Agadjanian, 2001; Hirschman & Guest, 1990; Knodel et al., 1987; Martine, 1996; Singh, 1994), to the extent that an increase in material household possessions reflects more modern tastes for goods (higher consumption aspirations). Thus we observe that women in households with the lowest number

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of assets had three times as many births and more than four times the probability of a birth as women in households with the highest number of assets at the beginning of the interval (Table 2). Women in the middle assets group were more than six times more likely to have a birth than women of the highest asset group. This finding corroborates the presence of a subtle inverse-u-shaped relation between economic security and fertility whereby the very poorest minority may be less able to have children, with modest increases in financial security, childbearing is facilitated, and at the highest levels it declines substantially as families choose to invest in land, labor, or physical and human capital rather than in more children. Table 2 also shows the relationship between change in assets and fertility, indicating only a possible slight relationship, with women in households losing assets having lower fertility, perhaps because of economic difficulties. Access to electricity in the home, a proxy for infrastructure, income and access to information, was associated with notably fewer children being born in the interval. This was especially pronounced among the small minority with such access in both 1990 and 1999 (only a quarter of these women had children during the period). Similarly, the small number of houses with the most expensive roof materials had fewer than one-quarter the number of births and the probability of having a birth as those with the least durable roof material (thatch). This relation remained significant despite the theoretical association to women's age: asset accumulation over time enables home improvements as the household life-cycle progresses.

An unexpected relationship is the positive (though not statistically signifi-cant) relation of women's education to fertility. While this is contrary to the usual situation, there are some similar relations found in the literature. At very low levels of education, slightly more education tends to be associated with increased childbearing (Lesthaege et al., 1981; United Nations, 1995a, b, c). Further, following Bongaarts (1978) and Singh et al. (1985), early in the demographic transition, more education may raise fertility as it enables women to follow through on high desired family size.

Spatial variables were related to fertility as expected. The mean road distance to the nearest market for all households in the sample was 21.4 km. Women reporting a birth during the period were located further from a community center (24.3 km.) compared to women reporting no birth (18.9 km.). In households over 30 km to a market, 64% of women reported a birth compared to 43-50% for the remaining women. The former also had nearly double the mean number of births during the interval of women less than 20 km from a market. Walking distance to the nearest road or river in 1990 or to a community center in 1999 also had positive associations with fertility but were not statistically significant.

Migration effects

Based on the small body of literature on the subject, we speculate that women in households with out-migrants may have lower fertility due to the effects of greater exposure to outside information and resulting greater desires to use contraception, as well as perhaps decreased intercourse frequency. While we do observe notable differences among household fertility relative to migration factors, none remained significant when controlling for women's age (Table 2).[5] The likelihood of a birth in the interval is also strikingly different: 70% for women in households with one or fewer out-migrants, falling to 33% for those in households with three or more migrants. A similar relation is found for the effects of earlier out-migration from the household prior to 1990, as seen in Table 2. The migration-fertility hypothesis here is also consistent with the fact that women born outside the Amazon have lower fertility. However, the small size of Amazonian-born women is insufficient for the relation to be statistically

[5]In this sample, none of the migrants are husbands; virtually all are older sons and daughters migrating off the plot to find work. Further, only 21 household reported having received remittances.

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significant. Most households engaging in off-farm employment migrate temporarily. Months of off-farm employment is a proxy for time spent in another location. Women whose off-farm employment increased by more than 12 h during the decade were significantly less likely to have a birth.

Farm factors

The data provide support for theories postulating a negative association between land tenure and fertility, and contradict the usual hypotheses of a positive relationship between farm size and fertility. Nearly half the women in the sample are in households with legal title to their farm (Table 3); they are more likely to have a birth and have less than half the mean number of births of women without firm titles. This relation was robust when controlled for women's age.

Results examining relations between changes in land size and fertility are mixed. Farm size in 1990 was negatively related to childbearing during the subsequent decade: Women on the smallest farms had more than double the number of births as women on the largest farms. However this relation was not significant when controlling for women's age as older women tend to live on larger farms due to capital accumulation and the benefit of having arrived earlier on the frontier and thus, the ability to select preferential land.

It is intriguing that despite the apparent negative relationship between land size and fertility, *changes* in farm size have a threshold positive relation with fertility. Approximately the same numbers gained as lost land between 1990 and 1999. The positive relationship with fertility exists only among households that did not lose more than 10 ha of land. All other groups had substantially higher fertility than the control group of households that lost more than 10 ha. This may suggest that households expand farmland as a response to or in preparation of a birth in order to have more land in the future for children. However, only substantial decreases in land prompt a fertility reduction response.

Land use factors

Data are presented in Table 3 also on changes in cleared land, perennials, and cattle pasture, agricultural, capital, labor, and technical inputs, and the relationships with fertility in 1990-1999. The results appear to support the life cycle and peasant labor allocation frameworks relating labor to fertility in the frontier. In the evolution of the farm life cycle on the frontier, the areas in pasture and perennials may be expected to rise compared to areas in annual crops (not shown) as childbearing declines in middle age and eventually as children leave the natal home. At any point in the life cycle, crops are substantially more labor demanding than pasture and may therefore encourage higher fertility. As anticipated, controlling for women's age, less pasture is related to significantly greater birth probabilities. Conversely, disintensification, as measured through afforestation, is related to significantly lower fertility, but this relation no longer remains significant when controlling for women's age.

Relative to agricultural inputs, such as herbicides, pesticides, and fertilizers, usage is related slightly to lower fertility (though the relation is not statistically significant). Although use of inputs may imply a greater demand for labor through land intensification, their usage also requires capital for their purchase. And, as observed earlier in Table 2, fertility appears negatively related to wealth as measured by asset accumulation. As expected from the discussion of the literature on land use and fertility, capital and technical inputs are associated with notably lower fertility, but the sample size is inadequate to yield statistically significant results. Last, hired labor is significantly and negatively related to fertility. This is expected since families that hire labor are relatively well-off and thus at risk of exposure to key variables related to fertility reduction.

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Conclusion

In this paper we have explored the relationships between fertility and a number of potentially relevant socio-economic, demographic, and land factors in a forest frontier context in the Ecuadorian Amazon. The analysis is based on a probability sample of 172 women who remained on the same farm in 1990 and 1999, perhaps the first statistically representative longitudinal survey containing fertility data in a frontier setting. A striking finding is that fertility fell rapidly in the region during the 1990s. Thus, only half of all women in the sample report having a birth during the time period. This makes sense as most women in 1990 stated that they did not want to have any more children. That in itself is surprising in a land-abundant frontier environment, but the data appear reliable given that the desire to not have any more children is strongly and positively related to the number of births women already had in 1990.

Despite many shared traits characteristic of frontier regions, the Ecuadorian Oriente also has a unique history that will influence the outcomes of social variables. Political and economic instability during the 1990s and the dominance of oil extraction economy are two primary differences. With this geographical caveat in mind, most of the empirical data here provide evidence in support of the existing literature on demographic and socio-economic links to fertility. For example, women in households with the most assets had a fraction the births in the interval of those in the lowest asset category. Similarly, access to electricity and quality of home construction, proxies for modernization and wealth, respectively, were also associated with fewer children being born. These findings would suggest that general development policies could also help improve contraceptive use and maternal and child health in the region.

However, some expectations inherited from the literature are not supported here. Education is statistically unrelated to fertility outcomes. Some of this may be explained by the fact that younger women in the sample are less likely to have completed their schooling (and this explains the statistical insignificance of the association when controlling for women's age). We also speculate that a generational difference is emerging in which younger women with more education are more likely to desire smaller families and more able to act on those desires than those few older women who have more than a primary education and who may have more traditional views of childbearing. In future studies we hope to test this hypothesis by examining the links between age, education, family size desire, and fertility in a multivariate model. Nevertheless, studies from around the world resoundingly agree that at higher education levels fertility falls and any policy relating to maternal and child health in the region should certainly benefit from investing in the education of girls at the primary level and beyond.

Finally, a number of other factors have the expected effects on fertility in the interval, including spatial variables such as distance to the nearest road, market, or community center. The latter is significantly associated with lower fertility, indicating that the other measures ultimately serve merely as proxies for access to health facilities, which in the context of the northeast Ecuadorian Amazon are located only in major community centers. Only sterilization or vasectomy was statistically related to lower fertility, though all households using some contraception had more births than those who did not. This suggests that the mere presence of a quality health facility may in itself be enough to help lower fertility levels as latent demand becomes satisfied and new contraceptive demand is stimulated.

The out-migration of adult men and women from the household is negatively related to fertility —probably due to migration exposing household members remaining behind to attitudinal changes (e.g., higher consumption aspirations and lower family size aspirations, and possibly also lower frequency of intercourse). However, when controlling for women's age, none of these variables remains significant. A substantial increase in temporary labor migration, on the other hand, is significantly related to lower fertility, suggesting that women are choosing to

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invest in their own labor rather than in childbearing during such shifts in the allocation of household labor resources. This finding corroborates research on international migration and suggests that migration may increase development not only through near-term allocation of financial and labor resources but also through decisions regarding future household labor investments.

The data suggest that some of the assumptions in standard hypotheses regarding the relationships between land and fertility should be reconsidered. Women in households with legal land titles had nearly two-thirds fewer births in the 9 year period and less than half the probability of a birth than women in households without a title. In this frontier region of precarious land claims, a provisional land title—certificate of possession—appears to not provide couples with sufficient security to reduce fertility. Only with a full land title is fertility attenuated. Indeed, some researchers hypothesize that land security trumps land availability in relation to fertility (Thomas, 1991). Thus findings were mixed on the relations between size of farm and fertility: Women on the smallest farms had more than four times the number of births in the interval of women on the largest farms. Yet, at the same time, those women living on farms that increased in land size over time had more births in the interval. The first relationship is anticipated as children and land are substitute goods. The second is more puzzling and may indicate that additional land is often acquired in anticipation of having a larger family. This is consistent with the finding that women in households that lost at least 5 ha of land had very low fertility, suggesting that these women were dubious of their economic prospects in 1990 and had their fears confirmed. A clear relation emerging from the analysis is the strongly negative association between hired labor and fertility. This negative association suggests hired labor as a proxy for household wealth and related fertility suppressing variables as well as the importance of the ability and desire to replace household labor with hired labor. In sum, farm size-fertility relations are more complex than the simple notion that bigger farms lead to higher fertility and vice versa.

We do not reject the theory that larger farms tend to be associated with higher fertility among subsistence peasants largely removed from cash economies. Larger producers, consistent with a socio-economic argument rather than a labor argument, tend to have fewer children than those with smaller farms. However, in this case study, larger farm size is *also* associated with a shift from annual and perennial crops to cattle ranching, since it reflects higher socio-economic status. Both socio-economic status and raising cattle (which requires little labor) are associated with lower fertility, though this is only evident for large farms of 60 or more hectares and farms with at least 5 ha in pasture in 1990, perhaps indicating threshold effects.

In examining fertility determinants it is key to control for women's age. Since fertility has only recently begun to fall in this frontier setting, and has fallen sharply, younger women must be the pioneers in fertility reduction, and are therefore more likely to change fertility behavior based on socio-economic and farm changes. More case studies are desirable to address how fertility change in frontier environments may differ (and why) from patterns in other, more traditional urban and rural environments in the developing world as well as with historical patterns in developed nations. Further research on factors associated with fertility and fertility decline at the frontier would also be useful for understanding an underlying driver of migration, a major contributor to population growth in current frontier contexts.

Frontier fertility is a little understood yet important topic for ecological and human development: most deforestation on the earth occurs in such environments and household size has been linked to deforestation on the frontier. Further, data suggest that high frontier fertility may be linked to poor infrastructure, lack of access to child and maternal health care or family planning, insecurity of land tenure, scarce educational opportunities, and a virtual absence of wage employment for women. Improving our understanding of these links is necessary to

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developed informed policies to reduce frontier fertility, improve the quality of life of farm families, and ameliorate environmental impacts.

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Map. 1.
Ecuador and the Northern Oriente Study Area

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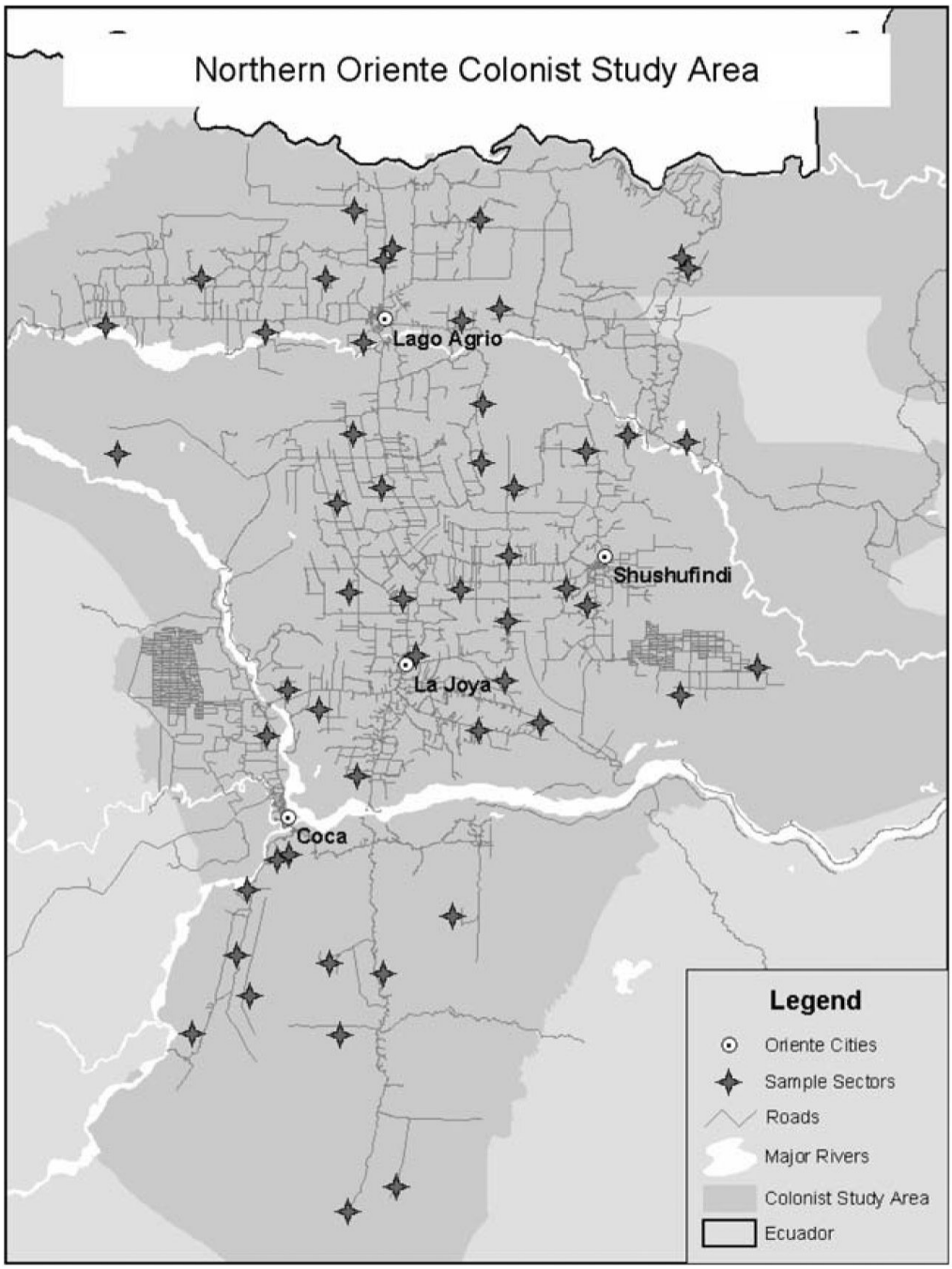

Map. 2.
Northern Oriente Colonist Study Area

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Table 1

Household demographic factors

	N	% Reporting at least one birth: 1990-99	Mean no. of births: 1990-1999
All	172	51%	1.20
Age in 1990			
15-29	52	79%	2.25
30-39	64	59%	1.25
40-49	56	14%	0.18
Age of Head in 1990			
15-29	23	91%	2.78
30-39	62	56%	1.31
40-49	52	46%	0.98
50+	35	20%	0.31
Total no. of live births prior to 1990			
0	11	45%	1.36
1	6	67%	2.83
2	21	76%	2.19
3 or more	134	46%	0.96
Total no. of infants died prior to 1990			
0	90	61%	1.66
1	35	49%	0.80
2	23	35%	0.65
3 or more	24	29%	0.63
Desired more			
No	137	40%	0.93
Yes	35	89%	2.31
Used			
1990	56	41%	0.77
1999	64	64%	1.50
Ever	101	60%	1.43
Method used, 1990			
Rhythm	20	55%	1.15
Female sterilization	15	7%	0.13
Pill	12	75%	1.33
IUD	8	13%	0.17
Other	1	100%	1.00
None	116	54%	1.43

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Table 2

Migration and socio-economic factors affecting birth outcomes by women's age in 1990

	Women 15-29			Women 30-39		
	%		Mean no. birth	%		Mean no. birth
	N	≥1		N	≥1	
Household out-migrants 1990-1999						
0	32	78%	2.31	27	74%	1.52*
1 or more	30	60%	1.89	42	48%	1.02
Household out-migrants prior to 1990						
0	53	70%	2.30	46	54%	1.13**
1 or more	9	67%	1.89	23	65%	1.35
Woman's education level as of 1990						
Primary incomplete	13	62%	2.07	39	69%	1.59
Primary complete or more	49	71%	1.97	30	43%	0.733**
Assets in 1990						
0-3	10	70%	2.10	8	63%	1.13
4-8	46	74%	2.15	47	68%	1.44*
≥9	6	33%	0.67	14	21%	0.50
*Change in assets from 1990 to 1999**						
Lost at least 2	14	64%	1.93	12	42%	0.92
Lost 1 to gained 1	23	65%	2.88	28	64%	2.07
Gained at least 1	25	76%	2.04	29	59%	1.07**
Access to electricity						
None	42	69%	2.10	33	70%	1.43
1999	18	72%	1.94	26	54%	1.27
1990 and 1999	2	50%	0.50	10	30%	0.40

t-tests based on differences between the number of births reported between the two age groups

*Significant at the .10 level

**significant at the .05 level, significant at the .01 level

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Table 3

Farm and land use factors affecting birth outcomes by women's age in 1990

	Women 15-29			Women 30-39		
	%		Mean no. birth	%		Mean no. birth
	N	≥1		N	≥1	
1990 Landholdings						
0-19	6	100	3.83	1	100	2.00
20-39	13	62%	1.85	14	64%	1.57
40-59	38	68%	1.84	42	57%	1.1*
60+	5	60%	1.40	12	50%	1.17
Change in						
Lost more than 5 ha	17	59%	1.65	20	55%	1.15
Lost 5 ha to gained 5 ha	28	75%	2.14	29	62%	1.34
Gained at least 5 ha	17	71%	2.12	20	55%	1.1*
Type of land tenure in						
Title	26	54%	1.42	41	49%	0.95
Certificate of Possession	28	75%	2.39	25	68%	1.48
None	8	100	2.50	3	100	2.67
Pasture allocation in						
0 ha	12	83%	2.75	12	75%	1.67
0-5 ha	26	85%	2.12	23	65%	1.22
>5	24	46%	1.50	34	47%	1.06
Coffee allocation in						
0 ha	4	75%	2.75	4	75%	1.50
0-5 ha	44	75%	2.11	40	58%	1.175**
>5	14	50%	1.43	25	56%	1.24

t-tests based on differences between the number of births reported between the two age groups

*Significant at the .10 level

**significant at the .05 level, significant at the .01 level