Why Does Fertility Decline? Comparing Evolutionary Models of the Demographic Transition

1. Introduction

The demographic transition from high fertility and high mortality to low fertility and low mortality is a global phenomena which has progressively affected local populations since the late 18th century (Mason 1997). Although it is clear that the phenomenon is related to economic development, the exact mechanisms that produce it are still the subject of much research and debate (Caldwell et al 2006). Evolutionary anthropologists have given significant attention to the demographic transition, especially the remarkable decreases in fertility that characterize it (e.g. Boone & Kessler 1999, Borgerhoff Mulder 1998, Kaplan & Lancaster 2000, Low et al 2002, Luttbeg et al 2000).

The aim of this paper is to present rigorous, comparative evaluations of several influential evolutionary models of the demographic transition. The literature on this topic is crowded with competing theories and sub-theories, making comprehension difficult for academics and policymakers alike. Scholars working on the causes of the demographic transition often call for more comprehensive, better-controlled studies that will allow us to more easily distinguish between different theoretical explanations (e.g. Borgerhoff Mulder 1998, Caldwell et al 2006, Clarke & Low 2001). Yet to our knowledge only limited comparative work has previously been done (e.g. Kress 2008, Sanderson & Dubrow 2001, Shenk 2009). Such research, however, could be of great importance in disentangling the complex relationship between fertility and social change. In this paper we will work to address this gap in the literature by comparing multiple evolutionary models in order to determine which predictors or combinations thereof produce the most robust explanation of a rapid, recent demographic transition occurring in rural Bangladesh.

To compare models rigorously, we will use an evidence-based statistical approach employing model selection techniques derived from likelihood theory (Towner & Luttbeg 2007). This approach will allow us to quantify the relative degree of support the data give to alternative models, even when said models have overlapping predictions. Although model selection methods are ideal for comparative analysis, they are not frequently used in either anthropology or demography and have not been applied to the demographic transition. A prototype of this methodology has been published by Shenk (2009). The authors have recently completed NSF-funded field research in rural Bangladesh where we collected data specifically designed for this type of comparative analysis. This paper will represent the first set of results from our new survey.

2. Theoretical Perspective

Most evolutionary approaches to the demographic transition employ logic centered on one of three types of causal factors: (a) changes in mortality and extrinsic risk, (b) changes in the payoffs to parental investment or the costs of children, or (c) the transmission of low-fertility norms as part of a process of cultural evolution. Although not mutually exclusive, and perhaps even complementary, each perspective proposes a distinct causal mechanism based on evolutionary logic. Our goal is to assess the evidence for each model in comparison to the others, then determine which combination of causes provides the best explanation for fertility decline in Matlab, Bangladesh.

Risk-Related Theories Many evolutionary anthropologists have stressed the importance of decreasing risk, including but not limited to mortality risk, as a primary factor in decreasing optimal fertility. Risk here refers to mortality and/or stress imposed by factors such as disease load, nutritional deprivation, or interpersonal violence. Chisholm (1993) argues that human reproductive strategies may be contingent on local mortality rates. Individuals who experience a high mortality environment as children are more likely to reproduce early and often and invest less per child, while those who experience a lower mortality environment delay reproduction and pursue a strategy of lower fertility and high parental investment. Quinlan (2007) argues that when risk is extrinsic, i.e. offspring survival is not improved by parents' actions, reduced parental effort and higher fertility will result. By implication, if extrinsic risk decreases, then parental effort should increase and fertility should decrease with it. Leslie & Winterhalder (2002) stress the importance of risk sensitivity in shaping fertility behavior, with a special focus on variance and stochasticity in mortality patterns. Although predictions from their model are sensitive to social and economic context, they argue that in general lower or more predictable mortality would decrease variance in completed family size outcomes thus reducing the tendency of families to overcompensate by having numerous offspring.

Investment-Related Theories Kaplan (1996), drawing on the work of Becker (1991), argues that parents should optimize their allocations to children so as to maximize their children's own reproduction, i.e. the production of grandchildren. To do this, parents must optimally distribute their resources among investments in the number (quantity) and embodied capital (quality) of their children. Kaplan and colleagues contend that payoffs to investment in child quality determine parental decisions about the number of children to have. Expected returns on parental investment in traditional societies diminish rapidly due to high mortality or limited occupational options, while in contrast returns on investment in education-based wage-labor economies do not diminish until very high levels. Consequently, per-child investment is expected to increase and optimal fertility to decrease with economic development, producing a demographic transition.

Mace (1998) uses dynamic state variable modeling to compare the effects of several predictors on fertility. She finds that increasing the costs of raising children leads to a decrease in optimal fertility, and has the potential to reduce fertility to very low levels. In her model increasing wealth or decreasing risks to children do not have similar effects. In a similar vein, Luttbeg et al (2000) uses dynamic modeling to demonstrate that investment-related motivations may limit fertility even in highly pro-natal societies where wealth is strongly correlated with fertility. Their findings suggest that humans may be maximizing a combination of fertility and wealth per child rather than fertility per se. Finally, Low et al (2002) argue that the demographic transition is linked to increased investment in socioeconomic status through mediums such as education and work which increase ages at first reproduction and thus lower lifetime fertility.

Cultural Transmission Richerson & Boyd (2005) propose that the demographic transition is an effect of cultural transmission, a Darwinian but non-genetic mechanism of inheritance that can select for socially successful but genetically maladaptive traits. They argue that humans have evolved to preferentially imitate the behaviors of high status people within their social group, a pattern called *prestige bias*. In the past this would usually have led to increased fitness, but in modern industrial societies where social and reproductive success have become decoupled, the achievement of high status may entail a tradeoff between reproduction and the production of prestige. If high-status people have low fertility norms yet their behavior is preferentially imitated, widespread fertility reduction could result.

Another cultural transmission model is offered by Newson et al (2007), who argue that social influence from kin is key to encouraging fitness-enhancing behaviors like pronatalist social norms. The authors posit that in modernizing societies the widening of social networks to include more non-kin leads to an erosion of pro-natal norms and their replacement with social norms incompatible with (or even opposed to) high fertility. Low fertility is the result of this process.

Comparative Approaches to the Demographic Transition Many authors, especially those working from an evolutionary perspective, have called for comparative research on the demographic transition (e.g. Bock 2002, Borgerhoff Mulder 1998, Clarke & Low 2001, Low et al 2002) but such work has been limited. Comparative analyses can be challenging in terms of both data demands and analytical methodology. Models often use similar variables or do not produce unique predictions, making them difficult to distinguish using conventional hypothesis-testing methods. In addition, some alternative models are not mutually exclusive, leaving doubt as to the relative importance of the different causal mechanisms they posit. Another major hurdle to comparative work is that datasets often lack enough information to compare multiple models at once. Anthropologists usually collect their own data, but this limits sample size and consequently the kinds of tests which can be run. Demographers often work with large aggregate datasets which obscure the details needed to test evolutionary models (Clarke & Low 2001). Finally, the ubiquity of standard regression methods means that comparative testing often consists simply of putting in a key predictor variable from each model and basing the assessment of the model on how well that predictor performs (e.g. Heuveline 2001). While this method can be useful, model selection methods, which are becoming the standard in fields such as ecology, are more appropriate for these types of explicit comparisons (e.g. Towner & Luttbeg 2007).

The comparative work that has been done (e.g., Kress 2008, Sanderson and Dubrow 2000, Shenk 2009) shows these types of limitations: the studies utilize small datasets, only compare a small number of models, and/or use methods not well-suited to model comparison. In this paper we will seek to overcome these limitations by using data and methods chosen explicitly for comparative analyses.

3. Data & Methods

Study Population The data we will use for this paper comes from rural Matlab, Bangladesh, an area famous for long-term demographic and public health research conducted by the International Center for Diarrheal Disease Research, Bangladesh (ICDDR,B). The Matlab study area constitutes a complete sample of a population of 250,000 people. During the 40 years during which data has been collected, total fertility rates have fallen by more than 3.5 children per woman, mortality rates have decreased by 50-70% (ICDDR,B 2003, 2008), and significant social changes have impacted the local way of life. This paper will focus on survey data from a random subsample of the Matlab population collected by the authors as part of a project designed to advance evolutionary research on the demographic transition.

The primary economy of the Matlab area is subsistence farming of rice and jute, followed by fishing (Holman & O'Connor 2004). Most villagers participate in agriculture, though many own no land themselves. Income is generated from a variety of sources including agriculture, day labor, handicraft production, and remittances from family members in the city; average income is around $300 a year. Education levels vary considerably, but 30% of the population has no schooling (ICDDR,B 2008). Extended patrilocal families live together in a *bari* containing several small houses, and marriage is usually arranged. Women are subject to a limited form of *purdah* and usually stay at home and work domestically. Since the 1990s, however, education has become more widely available and accepted for women and some have entered the labor market .

Data Our survey sample comprises 944 women between the ages of 20 and 64 drawn randomly from the full ICDDR,B study population. Women were drawn in equal numbers from each of three 15-year age categories, allowing for better representation of women at older ages despite rapid population growth. Half of our sample was drawn from the ICDDR,B service area where many types of public health interventions have been conducted, while the other half was drawn from the Government Service Area which serves as a control area as it receives only basic services from the Bangladeshi government.

The survey focused on important correlates of fertility suggested by a broad review of the literature, including questions on education, occupation, income, land ownership, labor migration, marriage, mortality, health, contraception, exposure to modern cultural influences, and perceptions of social change. Data for each respondent are both familial and multi-generational; women were asked to answer questions on all members of their natal and marital families, including their children, siblings, parents and husband's parents. Thus our data provides intergenerational measures of many variables and over 50 years of time depth regarding fertility and its correlates. Our data contains sufficient information to allow for the simultaneous comparison of multiple models (often including multiple proxy measures of important variables), and has enough power to provide robust tests.

Analysis In order to productively compare models, we will use an evidence-based approach (reviewed in Towner & Luttbeg 2007). Traditional statistical analyses are based on null-hypothesis tests, but these entail a number of limitations. For example, there is an inherent asymmetry in the null and alternative hypotheses because only the null hypothesis is in a position to be rejected (Byers 2000). In addition, *p*-values are a poor and often misinterpreted indicator of the weight of evidence in the data for a particular hypothesis (Anderson et al 2000). In contrast, an evidence-based approach utilizes measures such as AIC (Akaike Information Criterion) values based on likelihoods to weigh the relative evidence for multiple alternative models (Burnham & Anderson 2002). An advantage of model selection criterion is that alternative models can be either nested (not mutually exclusive) or non-nested (mutually exclusive); both are the case for many models of the demographic transition.

For this paper we will conduct analyses comparing each of the major evolutionary models separately, then put strongly predictive elements of them together to determine which sets of predictor variables best explain fertility reduction in Matlab. We will focus on the outcome variables number of children born and number of surviving offspring; the predictor variables to be used for each model are outlined in the "Test Variables" column of Table 1. One of the key advantages of our dataset is that we often have multiple proxy measures for a particular variable of interest, improving the likelihood that null effects are not due to problems with the data or the particular variable chosen.

Table 1. Evolutionary Models of the Demographic Transition

TYPE	THEORY	FERTILITY REDUCES WITH:	TEST VARIABLES:
Risk Models	Childhood Environment (Chisholm 1993)	Decreases in local mortality rates; Decreases in chronic social stress	Infant/adult mortality rates by village; Child/adult deaths in household; Childhood illness & food insecurity
	Extrinsic Risk (Quinlan 2007)	Decreases in extrinsic risk and mortality, especially in infancy and childhood	Infant/adult mortality rates by village (extrinsic causes); Childhood illness & food insecurity
	Variance Compensation (Leslie & Winterhalder 2002)	Decreases in mortality rates; Decreases in variance of mortality	Infant /adult mortality rates by village, including variance; Child/adult deaths in natal/marital households
Investment Models	Embodied Capital (Kaplan 1996)	Increases in payoffs for investments in self and children in developing economies	Education of child, parent, grandparent; Occupation type; Access to national/international labor markets
	Costs of Children (Mace 1998)	Increased costs of raising children when wealth is heritable	Costs of education; Opportunity costs of delaying child productive work
	Status Competition (Low et al 2002)	Delayed childbearing due to status competition	Education of child, parent, grandparent; Mother's Occupation; Access to national/international labor markets

Cultural Transmission Models	Cultural Evolution (Boyd & Richerson 2005)	Large number of high prestige adopters of low fertility	Family/bari members living in cities or abroad; Access to and use of media; Frequency of travel to cities/abroad
	Kin Interaction (Newson et al 2007)	Decreased interactions with kin network	Size of natal/marital household/bari; Distance from natal to marital bari

5. Significance

The aim of this paper is to present a rigorous comparative test of several influential evolutionary models of the demographic transition using survey data newly collected for this purpose. Our goals are to determine how good the evidence is for each model, then which combinations of predictors provide the best explanation for fertility decline in Matlab, Bangladesh. We hope that by combining comparative work and novel methods, we can fill a gap in the literature and advance research on the demographic transition in terms of both theory and methodology.

Comparative work is especially needed when approaching the demographic transition because of the confusing multiplicity of theories in the literature. The lack of a generally accepted and satisfactory theory for the demographic transition is just one aspect of a broader problem – the lack of a generally accepted and viable theory of fertility (Bock 2002, Caldwell 2006). Insights into demographic transition theory produced by this research will also contribute to the more general endeavor of understanding fertility within multiple frameworks. Our hope is that this work will serve as a model for further research on the demographic transition and other complex demographic phenomena in other parts of the world.

6. References

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