

LOST DAUGHTERS AND FRAGILE SONS:
PATTERNS OF DIFFERENTIAL PARENTAL INVESTMENT
ACROSS THIRTY-FIVE COUNTRIES

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As members of the Dissertation Committee, we certify that we have read the dissertation prepared by Cordelia Barbara Ursula Guggenheim entitled *Lost daughters and fragile sons: Patterns of differential parental investment across thirty-five countries* and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy

_____ Date: 12/14/04
Aurelio J. Figueredo

_____ Date: 12/14/04
James E. King

_____ Date: 12/14/04
Judith V. Becker

_____ Date: 12/14/04
Melinda F. Davis

_____ Date:

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copies of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

_____ Date: 5/12/05
Dissertation Director: Aurelio J. Figueredo

STATEMENT BY AUTHOR

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SIGNED: Cordelia B. U. Guggenheim

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DEDICATION

With eternal and deepest gratitude, devotion, and love

this work is dedicated to my mothers:

Daniela, Manuela, and Ursula

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ABSTRACT

Survivorship of children is unsurprisingly dependent upon numerous variables, not least of which is the role that preferential treatment plays in biasing the birth and survival of sons and daughters across cultures. This study draws upon an evolutionary approach by examining the "Trivers-Willard hypothesis" concerning condition-dependent sex allocation and differential parental investment. The central idea is that within a polygynous social mating structure – where reproductive variance is higher for males than for females as an intrinsic function of polygyny – mothers in optimal condition (defined by high status, good health, and abundant resources) are more likely to produce and invest in male offspring whereas mothers in poor condition (defined by low status, poor health, and resource deprivation) are more likely to produce and invest in female offspring so as to maximize potential lifetime reproductive success. Previous research on humans concerning this hypothesis tends to be restricted to one cultural group and thereby limited in sample size. For this study, nationally representative household survey data collected by the Demographic and Health Surveys (*DHS+*) program across 35 countries was used to test biological, resource-oriented, and behavioral aspects affecting maternal condition, sex allocation, and parental investment in humans. Country samples ranged from 732 to 21,839 women interviewed within South Asia, Sub-Saharan Africa, the Caribbean/Latin America, and the Near East/North Africa. The units of analysis were the mothers and their lastborn child ($N = 128,039$ woman-child pairs). A sequence of hierarchical regressions theoretically pre-specified a causal model concerning four constructed scales measuring maternal socioeconomic resources, maternal biological

condition, prenatal care for the lastborn child, and health-seeking for the lastborn child. In startling contrast to the predictions of the original hypothesis, analysis of the overall model revealed small, yet stable, cross-regional main effects suggesting that – for all four regions – maternal biology predicts lastborn daughters while maternal resources predict lastborn daughters for each region, with the exception of Sub-Saharan Africa. Moreover, protective/preventative health-related behaviors predict lastborn sons within South Asia and the Near East/North Africa, while prenatal care and health-seeking are differentially attributed to the prediction of sons and daughters within Sub-Saharan Africa and the Caribbean/Latin America.

INTRODUCTION

“Once you’ve learned to think of a herring gull as an equal, the rest is easy.” – W. Drury

While there are academic endeavors that can wrap themselves neatly around a circle of concepts, sex ratio research is certainly not one of them. In fact, explorations of what drives any sexual species to produce one of merely two potential outcomes – a daughter or a son – has garnered remarkable attention for several centuries. And when the second sentence in a dissertation begins to reach back to the dawn of time, everyone starts to cringe. Nevertheless, responsibility for the determination of a daughter or a son has been assigned to anything from fantastical and mystical elements to biochemical ones. Apparently, almost anything short of shoe size could potentially influence whether a son or a daughter is born. Certainly, sex determination or adjustment has been attributed to timing of ovulation, maternal hormones, parental chromosomes, parental age, sexual positions, birth order, phases of the moon, mating opportunities, available nutritional resources, environmental stressors (e.g., drought, famine, flood), temperature changes (viz., across reptilian species), presence of kin and non-kin, the probability of infant survivorship, and when all else fails, stochastic variation (Andersson, 1994; Brewis, 1993; Brown & Silk, 2002; Cameron, 2004; Ciofi & Swingland, 1997; Clutton-Brock & Iason, 1986; Grant, 1998; Hamilton, 1967; Hardy, 1997, 2002; Hrdy, 1987, 1988; James, 1987). As if this were not enough of a picnic basket of predictors, the range of species that has been studied might not even fit on Noah's Ark anymore. At any rate, sex ratio differences – what causes them and what maintains them – have been studied in a wide

spectrum of species, ranging from spinach to whales (e.g., Freeman, Wachocki, Goldschlage, & Michaels, 1994; Wiley & Clapham, 1993).

Centuries of wondering "Is it a boy or a girl?" is not at issue here, though. That not all children – human or nonhuman – survive to adulthood on account of their sex, however, is. That they fail to do so on account of congenital, developmental, or insidious parenting is not news. And that parenting quality crawls across a continuum from here to the horizon is also confirmed, however woeful that may be. What is noteworthy, however, is the extent to which research has attempted to account for such variations in elements of gestation, survivorship, and parenting style. Such research has crossed the domains of anthropology, sociology, psychology, biology, and evolutionary theory. And some of that shall be reviewed here, with a focus on bringing commonalities across these domains into analytical cooperation toward assessing the extent to which one or more particular evolutionary theories may be able to account for variations in the birth of daughters and sons – both human and nonhuman.

That is to say, the evolutionary angle from which academics tend to approach the topics of conception, gestation, survivorship, and parenting is understandably from an evaluation of reproductive fitness and the adaptations that are predicted to come into play in order to maximize it. The heart of the central theory reviewed in this paper lies embedded in the notion that nonhuman and human animals actually do behave in a manner so as to optimize reproductive success (i.e., number of viable offspring produced), as measured not only in parity but also in their post-parturition investment in

the survivorship of offspring. How they do this and the proximate implications thereof are of no small significance in the face of survival disparities.

As Richard Alexander once wrote: “My own view of the optimal outcome would be for the significance of evolution to become so widely known and so thoroughly embedded in the understanding of all those working in human-oriented disciplines, that its tenets can be employed, without fanfare, when they are useful, and ignored or discarded when they are not” (1988, p. 339). This paper is an attempt to honor such a goal by evaluating a model concerning sex-biased parental investment while drawing upon both the evolutionary and cultural approaches in order to appreciate not only how evolutionary adaptations operate within cultures, but also how humans cross-culturally may be outrightly invoking an evolutionary strategy in the treatment of their children. That is, while there may be differences in the details of customs and traditions and even conscious explanations, an underlying evolutionary mechanism ought to be detectable, given that natural selection operates upon human and nonhuman animals, with reproduction and parenting as sources of biological and behavioral variation. As Cronin points out, the acceptance of natural selection and sexual selection as forces of evolution are thankfully, at this point, “...for modern Darwinism...a storm in a teacup” (1991, p. 236).

Theoretical framework

Therefore, this study focuses on a theory referred to as the “Trivers-Willard hypothesis” concerning condition-dependent sex allocation and differential parental investment in humans (Trivers & Willard, 1973). The central idea is that within a

polygynous social mating structure, where reproductive variance is higher for males than for females as an intrinsic function of polygyny, mothers in optimal condition (defined by high status, good health, and abundant resources) are more likely to produce and invest in male offspring whereas mothers in poor condition (defined by low status, poor health, and resource deprivation) are more likely to produce and invest in female offspring. Additional specifics shall be reviewed in the following chapter.

Although the Trivers-Willard hypothesis has been demonstrated in many animal species, its application and explanation for sex ratio determination across taxa have been notably inconsistent (Cockburn, Legge, & Double, 2002). At times, its effect has even been inconsistent within species (e.g., Cockburn, 1994). For example, animals that have been shown to exhibit condition-dependent sex allocation and differential parental investment include: fur seals, elephant seals, opossums, red deer, mule deer, zebras, spider monkeys, horses, humpbacked whales, chimpanzees, zebra finches, reindeer, hamsters, rats, coypus, mouse lemurs, and wood rats. Species where the theory has demonstrated less applicability include sea lions and chickens, with inconsistent support evident across studies on bison, lion tamarins, certain species of ungulates, pigs, mice, rhesus monkeys, and baboons.¹

Its applicability to humans is just as open to debate. While several studies on humans have found support for the Trivers-Willard hypothesis, some have provided

¹ For good reviews of studies addressing sex ratio variation and differential parental investment across various species (including humans) refer to any of the following: Anderson & Crawford (1993); Brown (2001); Clutton-Brock & Iason (1986); Caley & Nudds (1987); Cameron (2004); Carranza (2002); Cockburn, Legge, & Double (2002); Hamilton (1967); Hardy (1997); Hewison & Gaillard (1999); Hrdy, (1988); James (1987); Lazarus (2002); Pedersen (1991); Rosenfeld & Roberts (2004); Sheldon & West (2004); and van Hooff (1997).

inconclusive results on account of differences in measuring evidence of sex ratio biasing and parental resource allocation biasing (Keller, Nesse, & Hofferth, 2001). Indeed, ethologists seem to prefer pursuing tests for the Trivers-Willard hypothesis in all other species because the data required for such an analysis in humans has often been unavailable, limited in sample size, or problematic in its measurement. Furthermore, differences across cultures – for example, the practice of selective neglect and/or infanticide – may confound otherwise potentially ethologically comparative analyses, depending on how the theory is applied. As a result, there is a need for additional examination of condition-dependent sex allocation and differential parental investment in humans for both theoretical and practical purposes.

Objectives of current study

Every project should have a good purpose other than the pursuit of sheer academic joy; so too does this one. That is, the rationale for this study is that the field of evolutionary psychology can extend our knowledge of human behavior and survival by examining this phenomenon present in polygynous human social structures. Additionally, the main objective is to extend the application of the animal model to include human reproductive and parental behavior thereby revealing how humans produce and enhance the survival of their male and female offspring based on an evolutionary principle concerning reproductive success. A review of the comparative literature invites an empirical test of this theory in humans in that the assumptions and predictions of the Trivers-Willard hypothesis can be empirically examined, drawing upon certain criteria that will be discussed in the following chapter. Essentially, testable predictions

concerning facultative adjustment of species-specific sex ratios are not only fascinating in relation to the management of livestock, park animals, or free-ranging wildlife, but also to answering the ancient question of "Well, is it a boy or a girl?"

As such, the goal here is to look for patterns in the data, given the theoretical framework, thereby addressing not just whether the theory can be tested on humans, but what patterns may emerge in doing so. In essence, if selection of the measures is conservative and empirically-driven, potential sources of error are diminished, the variables used are comparative across vertebrates, the sample size is sufficiently large enough, and measures are standardized across samples...what might a cross-cultural test of the hypothesis yield for our species?

In brief, to accommodate such an objective, the research in the following chapters was conducted on data retrieved from the Demographic and Health Surveys (*DHS+*) program that provides nationally representative survey data from about 70 countries.² These data sets include household surveys sampled from thousands of women interviewed in households selected within South Asia, Sub-Saharan Africa, Latin America, the Caribbean, North Africa, and the Near East during phase II and III of the *DHS+* survey research (1988-1999). Data collected at the household level address education, employment, reproductive behavior, breast-feeding and healthcare practices, nutritional status, prenatal and postpartum care, and maternal health; in short, a rich source of information on which to test some of the parameters of the original hypothesis.

² The program itself was renamed MEASURE *DHS+* in 1997 to represent the additional content concerning measures of maternal and child health. Given that the program provides public domain data, access to the data sets can be initiated at the MEASURE *DHS+* website: <http://www.measuredhs.com/>

The field of evolutionary psychology has become more pronounced in understanding issues such as global and local incidences of violence against women and children. For example, female feticide, selective neglect, and infanticide are topics that primatologists can tackle from an evolutionary perspective but should not be limited to their colonies of langurs or rhesus macaques when insight into the human realm is readily apparent from our shared primate legacy. Similarities as well as differences to other species may inform our knowledge concerning the impact of maternal condition on infant survivorship. Most importantly, such research has the potential to identify possible risk factors that may only enhance some of the prevention and health-improving programs instituted by those supplying the data for this very paper. After all, the idea is to understand the “survival of those who survive” (Trivers, 2002, p. 64) and how or why their mothers let them live.

Research hypotheses

This study will test the Trivers-Willard hypothesis³ by pursuing two specific aims. For one, it will evaluate the significance of condition-dependent sex allocation of offspring among humans. The working hypothesis is that the sex of the child is predicted by maternal condition such that a mother who is “healthy and wealthy” will be more likely to have a son. A woman in sub-optimal condition regarding health and resources will, instead, more likely be the mother of a daughter. Secondly, the significance of

³ Note that, in the research literature, the central hypothesis is sometimes interchangeably referred to as the “Trivers-Willard model” or as the “Trivers-Willard hypothesis” and thus abbreviated as TWM or TWH, respectively. In some cases it is cited as the “Trivers-Willard effect” when referring to particular predictions of the hypothesis. For the sake of clarity in this paper, the guiding theoretical framework is referred to as the “TW hypothesis” while the term “model” will indicate the analytical approach used to test the hypothesis, as measured in this study.

differential parental investment among humans will be examined with the following working hypothesis in mind: Females of high status, abundant resources, and good health will be more likely to invest more resources in their male offspring than in their female offspring. Females at the other end of the condition continuum will tend to invest more in their female offspring. Details, however, concerning how these measures will be defined, follow later.

Analysis will include a system of hierarchical regressions of the following scales constructed as indexes from indicators available in the demographic survey data: maternal biological condition (MBC), maternal socioeconomic resources (MSR), prenatal care for the lastborn child (PCL), and health-seeking for the lastborn child (HSL). The first two scales – MBC and MSR – pertain to the prediction of the first working hypothesis concerning maternal condition and the sex of the child. The latter two scales – PCL and HSL – refer to the parental investment focus of the second working hypothesis. Refer to Figure 1 for an outline of the theoretical and empirical model to be discussed shortly in further detail in the method section.

Significance of research

The proposed study is innovative in that it involves a multi-sample analysis spanning 35 developing countries from four regions around the world. When research on this topic is conducted on humans, it is often limited in sample size by focusing on one cultural group. The task of tracing adaptive processes such as the phenomenon presented in this project, however, calls upon the need to not only use a large sample size but to investigate any patterns that may exist across various groups. Although any single

country used in the analysis of this research deserves extensive, individual attention – and most, if not all, have no doubt received such in other innumerable studies – there is not enough space to do so here without turning this into a history of humanity in place of a dissertation. For today, we shall focus on only 35 countries across South Asia, Sub-Saharan Africa, Latin America, the Caribbean, the Near East, and North Africa.

The focus on developing countries emerged from the idea that they serve as a stronger test of the relationship between maternal condition, sex allocation, and parental investment. This is because the disparity in what will be used to define *condition* – whether biological or social – is greater in developing countries; namely, the difference between being malnourished in Bangladesh and being malnourished in Tennessee is one of kind as well as degree when multiple socioeconomic indicators are taken into account. The contrast of what constitutes wealth and poverty is proportionally more striking in developing countries than within industrialized countries, although clearly varying degrees of poverty are present in the latter as well. Essentially, the survivorship uncertainties so much more prevalent in developing nations – especially as reflected in child mortality rates (World Health Organization [WHO], 2003) – are more comparable in intensity and impact to those faced by nonhuman animal populations in the wild; whereas industrialized nations are more comparable to captive animals in the challenges they confront. This may be, for some, an unsettling comparison to make. Indeed, this is a theoretical approach that is sometimes contested. However, it has been argued that relative, rather than absolute, differences regarding resources and status are more likely to trigger an adaptive mechanism concerning the TW hypothesis (see Keller, Nesse, &

Hofferth, 2001). As such, this approach should not be overlooked as a possibility given the reality of the resource and survival disparities between certain countries.

This study will present an analysis of the TW hypothesis in humans by testing variables that may predict the sex allocation of the lastborn child and the parental behaviors differentially directed toward that child, thereby comparing the human model to patterns found in other animals. The outcome of this research will be its contribution toward extending the use of the animal model and its inclusion of humans regarding an evolutionary principle significant in the survival and reproductive success of many other species. Furthermore, it may provide empirical justification for the notion that certain factors that place children at risk are being driven by evolutionary forces. In doing so, this analysis may be able to inform public health interventions that otherwise tend to focus on cultural explanations to the exclusion of potential human universals.

Summary

This research focuses on several elements of sex ratio and parental investment theory and will explore representative dimensions of maternal biology, resources, and behaviors. The following chapters will outline the relevant background literature and how the theory influenced the design of the current study. The methodology of the study will be presented, followed by the analyses used and what the results seem to indicate concerning support for maternal effects in determining sex ratios in humans and the role of differential parental investment. And, inspired by William Drury, as long as sea monkeys, oposums, carpenter ants, porpoises, herring gulls, and all the other lovely creatures are our equals, "...the rest is easy" (Trivers, 2002, p. 57).

LITERATURE REVIEW

“That variations in sex ratio as large as those observed in nature should be a matter of indifference to the individuals producing them seems most unlikely.” - Trivers and Willard (1973)

Central theory and assumptions

The Fisherian notion (1930) that a negative feedback system – as a function of frequency-dependent selection – ought to propel equalization of the sex ratio, was the initial impetus for a closer examination of an evolutionary mechanism apparently operating with some degree of predictive validity in certain species. Namely, Fisher argued that negative feedback pressures should stabilize at-birth male to female sex ratios at 1:1 (also often referred to as "at unity" or "at parity"). This approach, however, assumes equal costs and equal effects of investment in male and female offspring (Fisher, 1930). But when was anything ever equal, especially in nature? So, forty-two years later, Robert Trivers and Dan Willard presumed otherwise and postulated a tidy theory with their own assumptions; perhaps because things in nature rarely seem to gravitate toward equality or because natural selection obtains its power from variation.

Better yet, it stemmed mostly from empirical observation of the noticeable differences in sex ratios within species as much as across them; although, given specific limitations of the theory, it seems a bit unclear as to why their three-paged manifesto caused thirty years or more of excitement. That is to say, applying a cost-benefit assessment to parenting in the face of all the evolutionary forces operating upon parental expenditure became a favorite analytical toy among evolutionary biologists. And it still

is, with papers continually published on this theme, as noted by Hewison and Gaillard (1999).

At any rate, the cost-benefit element is built into the entire system in a meaningful way. In fact, it intersects at almost every level; from the assumption that, in sexually reproducing species, conception is not merely the origins of all origins, but is also the moment where deviations in sex ratios are initially produced (hence, referred to as the primary sex ratio). The next assumption posits that variation in condition – for example, among caribou, this would be body weight – impacts the reproductive success of males more so than females. That is to say, three central assumptions of this theory concerning natural deviations from a 50/50 sex ratio in nature are the following: (a) the condition of the mother during the period of parental investment serves as a predictor of the condition of the offspring at the end of the parental investment period; (b) differences in offspring condition at the end of the period of parental investment persist through adulthood; and (c) in species where males exhibit less parental investment than females, males are expected to exhibit higher variance in reproductive success. In summary, according to Trivers and Willard, "...under certain well-defined conditions, natural selection favors systematic deviations from a 50/50 sex ratio at conception....other things being equal, species showing especially high variance in male [reproductive success] (compared to variance in female RS) should show, as a function of differences in maternal condition, especially high variance in sex ratios produced" (1973, p. 90).

Interestingly, most tests of the TW hypothesis tend to focus on an abbreviated version without necessarily including – or at least, demonstrably excluding – some of the

underlying predictions that follow from the aforementioned assumptions. While many studies readily focus on the notion that "good-condition mothers invest in sons," it should not be overlooked that the following parameters were also included in the original argument: (a) the theory is expected to apply to species with small brood sizes, given cited empirical evidence – yet less so to species with larger litters; (b) compensatory growth, in response to malnutrition or maternal effects, for example, is deemed trivial in effect; (c) sex ratio at birth is assumed to be an indicator of parental investment; (d) and reproductive success of males is free to vary on account of "negligible" paternal care (Trivers & Willard, 1973, p. 91). Which is to say that several central assumptions must be met in order for analysis to address the actual Trivers-Willard hypothesis, as outlined in the original paper.

As such, the role of polygyny and minimal parental investment by males is central to the assumptions of the theory. Variance in reproductive success is explained as "all or nothing" for males within a polygynous mating system whereas the contrast in reproductive success for females is of smaller disparity in that a female is more likely than not to successfully secure mating opportunities at some point. Although she will never be able to produce as many potential grandchildren as a male could, it is at least more probable that she will at least have the opportunity to try. In truly socially polygynous mating systems – such as those seen among herding or harem species – not all males are so fortunate. Hence, the greater disparity between the males who are outcompeted by other males in their access to females.

Not surprisingly, then, research on the TW hypothesis tends to focus more on the role of reproductive variance among males and the subsequent investment females are expected to differentially provide to sons over daughters. It is necessary to keep in mind, however, that the theory is not so uni-directional and actually predicts *investment in the sex with the higher probability of reproductive success*, not in sons per se. As such, for various reasons, the true interpretation of the model is to focus on reproductive variance. In fact, numerous studies – and often those that are unclear as to the strength of their results – recommend that empirical analyses of the TW hypothesis must, by definition, involve measuring reproductive success of sons against that of daughters.

Take humans, for example. Whether maternal condition actually impacts the number of grandchildren a mother will ultimately have is one of the unanswered questions pertaining to the longterm outcome of initial facultative adjustments by mothers – whether these manipulations occur prenatally or later. And this is because a mere suggestion by Trivers and Willard, toward the conclusion of their paper, proposes that their model would fit humans in the case where the reproductive success of brothers belonging to higher socioeconomic groups would be expected to exceed that of their sisters', whereas lower socioeconomic sisters' reproductive success should exceed their brothers' (see Trivers & Willard, 1973, p. 91).

Moreover, this specific application of the theory is on account of paternal care not being as "negligible" in humans as it is in many other sexually reproducing species. Consequently, condition for humans is defined on a resource-related level pertaining to socioeconomics such that "...if the model is correct, natural selection favors deviations

away from 50/50 investment in the sexes, rather than deviations in sex ratios per se" (Trivers & Willard, 1973, p. 91). Apparently, tests of the model in humans should focus on postnatal parental investment whereby parents in "better" condition will bias their behavior toward sons.

So, careful reading of the theory would seem to indicate that maternal condition varies, in definition, according to the species; although Trivers and Willard also note that mammalian birth sex ratios reflect differential investment in the sexes produced. Which is to suggest that at least one starting point for the period at which parental investment occurs not only in utero, but at the moment of implantation. Naturally, this applies to humans as well. Which would be why they suggest that "...the earlier the adjustment, the better" (1973, p. 91). In fact, research on sex ratios reveals that mammalian reproduction involves male determination of sex (based on X and Y chromosomes) and yet female termination by sex (e.g., as evidenced by spontaneous abortions). For one, differential male mortality (in utero) is not explained by what has been referred to as the "unguarded X chromosome" in males (ibid.). But the observations, across species, that male fetuses outnumber female fetuses in spontaneous abortions has not gone unnoticed (Ono & Boness, 1991; Wells, 2000; Wilkinson, Nagoshi, Johnson, & Honbo, 1989; Williams & Gloster, 1992).

Deciphering specifics of the actual argument enhances understanding why so many studies yield inconsistent results. Given the variations and disparity in consistency across studies, if in fact the effect turns out to be random, van Hooff suggests this could be "a case of selective perception instead of a meaningful phenomenon" (1997, p. 301).

Indeed, that paternal care, for one, is nonexistent in some species and crucial in others is no small matter in testing the theory – regardless even of how small the father might be. For example, paternal care among giant waterbugs puts that of orangutan fathers to shame in comparison. But one might be tempted to think that the application of the theory to a fellow primate would befit humans more so than testing it on a hemipteran insect. The point is that a theory is constrained by the assumptions that define it and it should only be tested using measures that correspond to its predictions. For instance, a central component of the theory is the idea of condition. Studies testing for the TW hypothesis often employ measures of condition as a dichotomous state variable, rather than as a continuous trait. For sure, when discussing caribou condition, Trivers and Willard speak of "best condition" (1973, p. 90) but then shift to speaking of "better condition" when positing possibilities about the application of their model to humans (p. 91). This idea concerning the continuous nature of condition is significant in terms of the measures used in this study.

For now, we turn to the background literature that can address each assumption as they apply, while drawing upon a comparative perspective. And we shall do this with the understanding that, perhaps, Trivers and Willard best laid out their theory in the abstract by stating, "...natural selection should favor parental ability to adjust the sex ratio of offspring produced according to parental ability to invest" (1973, p. 90). All things considered, then, any one of the following phenomena could be impacting deviations in sex ratios, but what shall be reviewed here are those elements central to testing the maternal condition and differential parental investment predictions of the original theory:

namely, an overview of mating systems as the framework in which sexually reproducing species pursue specific reproductive strategies followed by a review of sources of facultative adjustment at the prenatal and postnatal levels. Where measurement issues are concerned, these too shall be discussed so that the empirical strategy employed in this paper – i.e., the choice of variables and the analytical model designed for this study – will be evident, relevant, and meaningful.

Comparisons across studies

Sex-ratio manipulation. For this, we shall begin at the beginning of beginnings – conception. An understanding of how species-specific mating systems drive the options available to males and females, respectively, might also assist. Namely, the contrast between the utility of a monogamous vs. a polygamous system, for example, lies in environmental – both physical and social – differences. And these differences manifest themselves in the physiological and behavioral domains. None of this is necessarily that interesting, unless of course, observations concerning the role of sexual dimorphism within species may play an important role in determining variance in condition, particularly for males. And species in which sexual dimorphism is predominant tend also towards mating systems that are more polygamous – whether polygynous or polyandrous. Moreover, if polygyny – or "reproductive inequality" (Betzig, 1992, p. 310) – is the driving element of the TW hypothesis, we ought to be riveted by anything related to it...or at least, riveted for the moment.

So, it is perhaps noteworthy that monogamy may be an artifact of male-biased sex ratios for some species (Hannon & Martin, 1996; Ligon, 1999). Or that across most

species, males are considered to be “cheaper” given that they require less care overall on account of higher mortality rates (Cartwright, 2000, p. 120). Or that when males disperse, upon reaching sexual maturity, a group of females are left to fight over everything that matters (i.e., resources, mates, and babies). Better yet, in female exogamous patriarchies (i.e., where the females saunter off), the males are left to worry about what males worry about most – status and procreating. Either way – or all at the same time – what seems to matter is whether enough potential mates are around and whether enough food is available for anyone mating and anyone born of such matings.

This is, of course, an abbreviated way of addressing concepts otherwise referred to as local mate competition (Hamilton, 1967) and local resource competition (Clark, 1978); although, as Maynard Smith (1980) denotes, the difference between these two is not always self-evident, depending on the data. At any rate, local resource competition is better known to parents as the situation when offspring who should be finally wandering off on their own, stay home, using up resources. Local mate competition is somewhat different in that the prospects of future mating opportunities influence who stays and who searches for happier hunting grounds, literally. And yet another is the theory of local resource enhancement (or "payback hypothesis" noted in Smith, 1995, p. 659) whereby weaned offspring remain with their natal group and contribute in a meaningful manner (Gowaty & Lennartz, 1985). Each of these and all of these matter when addressing sex ratio adjustments across species because they exemplify the levels at which cost-benefit calculations are concerned regarding ability and opportunity to invest differentially in male or female offspring.

For example, a recent study found that female ambrosia beetles apparently modify the number of males produced in response to outbreeding opportunities for their sons, in keeping with local mate competition theory (Peer & Taborsky, 2004). In contrast, another study, on female parasitoid wasps (foundresses), found that the constraints of lethal male-male competition confronted by their sons at birth actually drove the foundresses to produce female-biased sex ratios when facing increasing competition from clutches laid by other foundresses on the same host. In this way, the mating system is driving the sex ratio counter to local mate competition theory in that foundresses manipulated their sex ratios to decrease competitive risk to their sons, rather than enhance potential competition by producing more sons (Abe, Kamimura, & Shimada, 2004).

Low-ranking female bonnet macaques residing in matrilineal societies, on the other hand, assess the probability of infant survival and adjust the sex ratio in response to harassment by high-ranking females such that female fetuses are selectively aborted due to gestational maternal stress. Additionally, in this study Silk (1981) seems to suggest an "evolved response to local density-dependent mortality" (p. 1119) in that the proportion of sons and daughters produced in a given year was dependent on whether the highest proportion surviving in the previous year was made up of sons or daughters, respectively. These are merely some examples of facultative adjustment and its effect in nonhuman animals.

It is the temporal determination of sex, whether at the point of conception or during gestation, that we focus on now. And only for a moment before we should move on to specifics that were empirically addressed in the analyses of this study. Namely,

which variables impact sex ratios and how, depend, to a large extent, on which sex ratio is being discussed. In other words, variation can occur at the primary (zygote formation), secondary (at birth), and tertiary (sexual maturity) stages of sex ratios (Majerus, 2003, p. 47); most studies, however, concentrate on the primary and secondary. For example, James (1987) and Clutton-Brock and Iason (1986) provide two of the most cited overviews of factors that influence operational sex ratios within animal and human populations. That is to say, epiphenomena purported to impact sex ratios include maternal malnutrition, coital frequency and timing of fertilization, maternal and paternal dominance, hormones, stress, habitat type, season, litter size, parental parity/breeding success, and numerous others.

What is of interest here is not what has tickled the fancy of sex ratio research, but those effects that have either indicated or failed to connote potentially adaptive functions. While Clutton-Brock and Iason in fact pronounce that "...the firmest conclusion that can be drawn from the distribution of observed trends in the sex ratio is that the distribution does not conform to the predictions of any single adaptive hypothesis" (1986, p. 367), it is all the more reason to apply an empirical test of one such as that provided by the Trivers-Willard hypothesis. Essentially, the only way to find out which adaptive explanation might apply is, of course, to test each one. Nonetheless, the TW hypothesis is our central focus for this paper – bearing in mind that a variety of alternative explanations

have been proposed over the years in order to account for the variation in sex ratio patterns across species.⁴

Gestational cost and selective male affliction. But first, it is important to return to some of the specific research on facultative adjustments across species. For example, advantaged mothers such as fat, pregnant coypu abort females to produce mostly male litters; apparently, the mother coypu evaluates her own situation and differentially aborts as necessary so as to ultimately maximize the number of her grandchildren when fat reserves provide her with the energetic advantage to invest in sons over daughters (Gosling, 1986; Hrdy, 1999). This issue is meaningful in that numerous studies concerning mammalian gestation have demonstrated that male fetuses incur greater gestational costs on their mothers than do females. For example, in a study on grey seals, Anderson and Fedak (1987) found that the degree of maternal expenditure required to raise males to weaning cost 10% more than that required to raise females. Furthermore, they note that in utero, male grey seals incur a gestational cost on their mothers 7% over that of daughters in that placentas provisioning males are larger.

Another study found that maternal size in elephant seals was related to the sex ratio of offspring in that larger pups were born to the larger females. Furthermore, male pups were larger than the female pups – requiring more maternal physiological investment. Additionally, mothers over 380kg produced higher sex ratios whereby mothers weighing less than 380kg produced only female pups (Arnbom, Fedak, &

⁴ Refer to Cockburn, Legge, and Double (2002) for an overview of the following hypotheses: Fisher's, homeostasis, advantaged daughter, attractiveness, local mate competition (LMC), local resource competition (LRC), local resource enhancement (LRE), cost of reproduction, male exploitation, and brood reduction.

Rothery, 1994). Among Mongolian gerbils, Clark, Bone, and Galef (1990) also found that male pups were more costly than female pups while Derocher and Stirling (1998), in their study of polar bear mothers propose a threshold effect for maternal investment. That is, polar bear mothers do not seem to bias investment in general, but mothers may bias toward males in the case of triplets given the high mortality rate of one cub.

Differences in maternal expenditure based on fetal sex are also present in humans. For example, one study revealed an energy gradient across mothers in which women carrying a male rather than a female fetus had higher intakes of 8% for protein, 9.2% for carbohydrates, 10.9% for animal-based lipids, and 14.9% vegetable-based lipids with an overall 9.6% higher energy requirement than mothers carrying female fetuses (Tamimi et al., 2003). How such a gestational cost may impact human mothers should become more meaningful later in light of the prenatal care variables involved in this study and the predictions tested.

For now, though, the question then is: To what extent are females of various species actively manipulating the primary sex ratio or suffering fetal loss on another count? Indeed, one influence that causes some excitement in the sex ratio domain is that of differential male mortality in utero, purportedly as a function of anisogamy. Also referred to as selective male affliction or vulnerability (Gualtieri & Hicks, 1985), countless studies have focused on the extent to which genomic imprinting, gene selection forces (Wells, 2000), maternal stress (e.g., "nutritional insult"; Wells, 2000, p. 65), and malnutrition (Andersson & Bergstrom, 1998) cause "prenatal carnage" (Diamond, 1987, p. 487) that may impact males more significantly than females. According to Kraemer,

for example, the challenges of being male are intrinsically embedded within reproductive variance; that is, "many male mammals fail in their primary biological goal, which is to reproduce...[and] risk instead being excluded, wounded, or killed by rivals" (2000, p. 1611). But why males are more vulnerable from the start of life seems to be somewhat of a mystery.

Given the focus of this paper, of course, the question that comes to mind is whether the vulnerability of males is related to facultative adjustments concerning predicted reproductive outcomes. In humans, for example, chorionic gonadotropin (hCG) is the hormone by which embryos communicate their fitness to their mother, thereby generating the production of progesterone. Embryos that are unable to do this are aborted (Forbes, 1997; Haig, 1999). Indeed, human pregnancies exhibit a high attrition rate in the first two weeks post-ovulation whereby menstruation often serves as a form of spontaneous abortion (Haig, 1999). In fact, one study cited a pregnancy loss rate of 31% in human females (Wilcox et al., 1988). Provided a fetus survives gestation, it does not necessarily get any easier after birth. In fact, human and nonhuman animals seem to make postnatal decisions regarding sex ratio biasing (Hrdy, 1999) and this most often occurs during the period of parental investment following parturition. At least, this is the level at which differential adjustments have been easier to document in certain species.

Differential parental investment. Precisely when parental investment begins and ends can be a matter of opinion; most definitely, depending on the species in question. And what it is, to quote the one most credited with defining it, is "...any investment by the parent in an individual offspring that increases the offspring's chance of surviving

(and hence reproductive success) at the cost of the parent's ability to invest in other offspring" (Trivers, 1972, p. 139). To simplify matters for the moment, however, we turn first to the idea that parental investment differences are rooted inherently in the physiology of male and female sex differences.

Essentially, the extent to which any and all strategies concerning the gestation and nurturing of offspring are adaptive is dependent on constraints imposed by biology (e.g., gametic differences, gestational capacity, and parity) and environment (e.g., mating opportunities and predation pressures). Parent-offspring conflict and the role of competition between the two is presumed to begin at the moment of conception. And all kinds of additional characters come into play at this point regarding maternal and paternal effort (see Clutton-Brock, 1991; Gosden et al., 1999; Haig, 1999; Trivers, 1972, 1985). The focus here, however, is on the investment after birth.

While there are perfectly succinct scholarly definitions of what postnatal parental investment is, Sidney Poitier's character, in the 1967 movie *Guess who's coming to dinner*, makes parent-offspring conflict abundantly clear in his declarative speech to his father, portrayed by Roy E. Glenn, Senior:

"You listen to me. You say you don't want to tell me how to live my life. So what do you think you've been doing? You tell me what rights I've got or haven't got and what I owe to you for what you've done for me. Let me tell you something. I owe you nothing. If you carried that bag a million miles, you did what you were supposed to do. Because you brought me into this world and from that day, you owed me everything you could ever do for me like I will owe my son if I ever have another. But you don't own me...You've got to get off my back!"

In fact, the measure of a man lies in "...how well he provides his children" (Poitier, 2000, p. 181). The question, though, is whether parents actually do fulfill their obligations of providing everything they ever could. Research would suggest this is not necessarily always the case. That is, the ability to invest may be counterbalanced against a willingness to invest. What drives the difference is paramount. Enter, once again, cost-benefit analyses, not least of which is the notion that the principle of "diminishing returns" can apply to parental investment (viz., investment is so high already, any increments are either impossible or not meaningful; Teitelbaum & Mantel, 1971).

Despite all their efforts and intentions, or because of all the variance in parental behaviors, not all parents watch their children grow up and produce grandchildren; namely, there is also "the darker side of parenting" (Scheper-Hughes & Sargent, 1998, p. 21). Indeed, the impact of parental under-investment – or disinvestment – ranges from passive neglect to active infanticide (Scrimshaw, 1984). While 9% of all world cultures practice sex-selective infanticide (Hrды, 1999), most cases where human children do not survive would be more appropriately classified as selective neglect (Larme, 1997). Extensive research has accumulated in the last years addressing what adaptive mechanisms may be driving the practice of infanticide as well as how cultural sanctions may be merely providing the framework in which "evolved decision rules" can operate (Hrды, 1999). In fact, much of the research on infanticide seems to support the Trivers-Willard hypothesis in that infanticidal trends are most evident where females have the smaller chance of reproductive success comparable to males (Beise & Voland, 2002; Daly & Wilson, 1984; Dickemann, 1979; Gosden et al., 1999; Jeffery, Jeffery, & Lyon,

1984; Miller, 1987). As such, countries known to practice sex-selective infanticide were included in the analysis for this paper.

For example, Hrdy describes the role of the “daughter destroyers” within elite clans in India (1999, p. 326) and cites research revealing that among lower castes, genetic markers crossing caste boundaries serve as an indicator of females engaging in “marrying up” (i.e., hypergamy; Hrdy, 1999, p. 340) in that the lower caste females have higher reproductive variance than their male counterparts. Among the elites, however, daughters are at a distinct disadvantage. Additional factors that place children most at risk, particularly female infants, include: birth order, rural residence, and son preference (Hrdy, 1999).

That is to say, four purposes for which sons are valued over daughters in India include: economic, social, and for religious activities that only sons are able to perform (Arnold, Choe, & Roy, 1998), as well as variations in inheritance rules [e.g., partible (equal) inheritance vs. primogeniture (firstborn son inherits everything)]. In some cases, there is a preference for a daughter to assist as allomother to an impending son (Niraula & Morgan, 1992). Japan even has a special term for this – “ichihime nitarô” (Hrdy, 1999, p. 345) – as well as a specific term for infanticide – “mabiki” – which denotes “...‘thinning out [the rice plants] between the rows,’ a form of good domestic policy” (Picone, 1998, p. 38). Furthermore, reasons for infanticide, as summarized by Picone (1998), suggest that infants have been killed as a form of family planning not just to limit family size overall but also in order to control inter-birth intervals and total number of children. In yet other instances, what may seem to be indicative of a preference for sons

is rather a "strong non-preference for daughters" (Basu, 1999, p. 252). And still other studies – whether examining humans or nonhuman animals – seem to indicate that sometimes daughters are the preferred investment.

Advantaged daughters vs. male quality. The matrilineal organization of cercopithecine society, for example, places the emphasis of reproductive success with the dominant females and, as such, high-ranking females should produce daughters whereas low-ranking females produce sons when resources are scarce. This pattern reverses when resources become abundant and competition is less severe (Hrdy, 1999; Small & Hrdy, 1986). This phenomenon is referred to as the "advantaged daughter hypothesis" (Altmann & Altmann, 1991) whereby daughters inherit their mother's social rank. In turn, the Trivers-Willard hypothesis is sometimes referred to as the "male quality hypothesis" whereby maternal effects influence the reproductive success of males (van Hooff, 1997, p. 293).

As indicated earlier on, support for the TW hypothesis has been variable across mammalian species. For example, food-restricted hamster mothers produced smaller, female-biased litters and by the 15th day of a particular study, they had reduced their litters by half, whereas no such mortality pattern was present in the other food conditions (Huck, Labov, & Lisk, 1986). Moreover, of the food-restricted pups, males and females weighed less than all others by the 25th day of the study. Similar tests of maternal condition and its impact on the sex ratio of litters have yielded moderate support for the TW hypothesis (e.g., coypu; Gosling, 1986). In the wild boar, for example, mothers apparently adjust their litter size and sex ratio in that maternal condition, as measured by

weight and size, was associated with litter size (Fernández-Llario, Carranza, & Mateos-Quesada, 1999). A study on house mice by Krackow (1993) examined fitness differentials based on body weight variation and found a positive effect for males but not for females. Yet in others, support is absent on account of social variables purported to influence the sex ratio (e.g., yellow-bellied marmots; Armitage, 1987; spotted hyaenas; Hofer & East, 1997).

Nonetheless, several studies seem to suggest that the TW hypothesis finds its strongest support in ungulates such as reindeer and red deer (Kojola, 1997). For example, Kucera (1991) demonstrated that heavier and fatter (as measured by kidney-fat index) female mule deer produced male-biased litters. In fact, Hewison and Gaillard (1999) argue that the predictions are supported in species such as red deer, reindeer, bighorn sheep, and fallow deer because these species most satisfy the assumptions of the theory.

In turn, an examination of advantaged daughters or quality males across humans yields several studies that have indicated a weak to moderate Trivers-Willard effect for lower status groups but no real effect in the higher status groups, regardless of how status (or maternal condition) was actually measured (e.g., Borgerhoff Mulder, 1998; Chacon-Puignau & Jaffe, 1996; Webster, 2004). On the other hand, Freese and Powell (1999), were not able to support the TW hypothesis in humans in that sex-biased differences in socioeconomic investment were absent in their study while Mealey and Mackey (1990) showed that, among 19th century Mormons, higher order wives produced higher sex ratios. Interestingly, they also make note that a threshold effect may exist in humans in that the TW hypothesis "cannot by itself predict which species will exhibit sex ratio

biases under which conditions, or whether sex ratios will exhibit continuous variations or respond to some environmental threshold" (1990, p. 92).

Measurement issues

Maternal condition. This notion of a threshold effect is significant in that measurement of maternal condition – a central component of the TW hypothesis – is paramount to interpreting results as a fair test of the theory. That is to say, variations in the definition of maternal condition have encompassed physical, social, environmental, and nutritional covariates to the detriment of consistency across studies and species. It would seem that maternal effects may have static and dynamic elements. As is the case with elephant seals, there is a threshold effect concerning the minimum maternal body mass/size required to produce sons. Interestingly, human mothers characterized by low pre-pregnancy weight yielded lower sex ratios at conception in one study (Cagnacci, Renzi, Arangino, Alessandrini, & Volpe, 2004). Additionally, increased weight gain during pregnancy apparently produced lower sex ratios leaving the authors to conclude that maternal body weight is significant in human reproduction and secondary sex ratios. Furthermore, Andersson and Bergstrom (1998) demonstrated that shorter and more obese women had lower secondary sex ratios while Gibson and Mace (2003) showed that the most recent child born to women with muscle mass (as assessed by mid-upper arm muscle area) were boys. However, Stein, Zybert, and Lumey (2004) argue that, given a potential difference between acute and chronic undernutrition, selective fertilization or selective attrition of a fetus is required for undernutrition to significantly impact the sex ratio.

Maternal condition in humans has also been measured by maternal educational level, with higher levels of education predicting heavier birthweights in newborns, after controlling for confounds such as occupation, marital status, and pre-pregnancy weight (Grjibovski, Bygren, Svartbo, & Magnus, 2003). While some studies have incorporated income as a measure of condition, measuring household wealth and resources among poor people is relatively a Western idea in that social capital – i.e., access to resources rather than ownership – is fundamental to survival. That is, notions of income and ownership exclude the impact of cashflow, debt, and burdens imposed by others (i.e., people within the household as well as family being supported at a distance). Furthermore, occupation is more dynamic and therefore variable, in contrast to years of schooling that can serve as a more static indicator of condition (see Macassa, Ghilagaber, Bernhardt, Diderichsen, & Burström, 2003).

Parental investment. Determining the period of parental investment in humans is problematic in that the endpoints are nebulous, yet not so in other animals – especially in dispersing species where the period of parental investment can be discretely observed. Capturing information concerning parental behavior is likewise challenging. Nonetheless, previous research on the TW hypothesis in humans tends to document parental investment through breast-feeding measures. Indeed, this is a popular measure of parental investment across all mammalian studies of the TW hypothesis.

For this study, though, the variables selected measure parental behavior on dimensions that are less likely to be directly or indirectly influenced by the child; that is, certain parenting behaviors operate in response to bi-directional interactions in the case of

behaviors that are child-initiated and parent-soliciting (Clutton-Brock, 1991). Breast-feeding is one such behavior, as any mother who has ever had to wean a child can probably confirm. Despite its popularity in parental investment research, however, it is beset with complications concerning variations in its practices. For example, the very poor and the very educated are more likely to breast-feed for varying reasons (Barros, Victora, Vaughan, & Smith, 1986). Additional potential covariates include differences in urban/rural residences, maternal age, birth order, and religion (Hinde & Mturi, 1996).

Moreover, breast-feeding is not limited to confounding only human studies. In fact, a study of the Antarctic fur seal demonstrated that milk consumption is differentially allocated to lean tissue and body lipid reserves by males and females, respectively, even though no sex differences were found for overall milk consumption. Furthermore, sexual dimorphism of the pups was already apparent within one day of birth thereby establishing that measuring maternal investment by pup growth (i.e., mass and mass change) may be confounded by sex-specific birth mass and growth rates of pups. Essentially, if sex-specific differences are already present, maternal investment may appear to be biased when, in fact, physiology has pre-established the bias (Arnould, Boyd, & Socha, 1996). Furthermore, in a study on Antarctic fur seals, Goldsworthy (1995) found that maternal attendance behavior duration (i.e., foraging trips) predicted sons' weight whereas maternal attendance duration predicted daughters' weight. While males received more attention from mothers, it was unclear whether this was due to "maternal discrimination"

or "differential extraction" by offspring on account of sucking differences or sex-related energy needs (p. 227).⁵

Essentially, arguing against the use of breast-feeding as a measure of parental investment may seem counter-intuitive at first, particularly in light of its popularity. However, the strength of a test of the TW hypothesis is only as reliable as the measures used to examine it. As such, breast-feeding was not used as a measure of parental investment in this study both for empirical reasons drawn from previous research as well as systematic variation inherent in the data for this study. The selection of variables that were used, however, will be outlined in the following chapter.

Summary

To reiterate from before, the first prediction in this study concerning condition-dependent sex ratios states that: The sex of the lastborn child is predicted by maternal condition such that a woman who has abundant resources and good health will more likely be the mother of a son. Conversely, women in sub-optimal condition are more likely to be the mothers of daughters. The second prediction concerning parental investment states that: Mothers in good condition will preferentially invest more resources in their lastborn sons than in their lastborn daughters. Mothers at the other end of the condition continuum will tend to invest more in their lastborn daughters. Bearing in mind the present review of the relevant literature, these predictions shall be operationalized in the following chapter.

⁵ Additional discussion of complications provided by breast-feeding as a measure of parental investment across species can be found in the following: Gaulin & Robbins (1991); Mendl & Paul (1989); Nemeth & Bowling (1985); Quinlan, Quinlan, & Flinn (2003); and Raphael & Davis (1985).

METHOD

Research design

Instrumentation by DHS+. The data for this research was provided by the Demographic and Health Surveys (*DHS+*) program. Funded by the United States Agency for International Development (USAID), the project collects nationally representative samples on issues pertaining to maternal and child health for the purposes of informing policy makers and in order to enhance the international practice and use of demographic survey methodology within the countries involved in data collection. Over the past 20 years, *DHS+* has conducted over 70 household surveys across more than 50 countries, employing standardized techniques that make cross-cultural comparisons feasible and even encouraged.

As such, the surveys yield data on women of reproductive age (i.e., ages 15-49 years⁶) concerning the following: household demographics and characteristics, nutritional status of the women interviewed and of children living with them, information concerning education and employment, reproductive knowledge and behavior, prenatal and postpartum care, breast-feeding practices, medical histories, women's status, and background information on male partners (when present). In some countries only ever-married women may be surveyed (Macro International Inc., 1996).⁷

Sampling by DHS+. The sampling techniques employed are designed to maximize the retrieval of information representing 100% of the population surveyed. *DHS+* emphasizes the use of nonzero probability sampling. When this is not the case and

⁶ Although the standard protocol for sampling only includes women in this age group, the data collected for Bangladesh includes female interviewees as young as 10 years old.

a sample is not self-weighting, calculation of sample weights should be included in any inferential analyses of *DHS+* data (Macro International Inc., 1996). That is, individual weights in almost all of the surveys are normalized so that if all of the women within a sample are included, the weighted and unweighted numbers of women should be equal. If selecting a sub-sample, then the weighted and unweighted sample sizes will differ. In order to ensure that analysis is representative of the entire population – and not just of the sample population – sample weights are provided with all data sets for proper parameter estimation; their significance being that they "...are often interpreted as the number of population units represented by each unit of the sample" (Häder & Gabler, 2003, p. 124).

Selection of countries. The initial data set included 40 countries from four regions: South Asia, Sub-Saharan Africa, Latin America/Caribbean, and the Near East/North Africa and thus included 148,112 women and 185,660 children. Of these, 5 countries were eliminated based on a lack of data for maternal nutritional status as measured by indicators for body mass index (BMI). Excluded countries were: Pakistan, Nigeria, Rwanda, Paraguay, and Yemen. Dropping 13,855 cases of women for which maternal BMI was missing constituted losing 9.4% of the original available data set.

Theoretical considerations, as discussed in the previous chapter, justified the inclusion of countries pre-established to have culturally-instituted biased sex ratios. For example, precluding countries such as India and Nepal would have presumed an articulated anthropological approach and bypassed the utility of an evolutionary analysis, thereby defeating one of the central purposes of this research. All countries with

⁷ Relevant countries for which this is the case are: Bangladesh, India, Nepal, Egypt, and Turkey.

information pertaining to maternal nutritional status, socioeconomic resources, and parental investment were therefore retained for analysis with the assumption that sex ratios biased for only cultural reasons will differ from those biased on account of adaptive cost-benefit calculations concerning reproductive variance. That is to say, if such proximate cultural mechanisms are in place, to the exclusion of an evolutionary account, they should be revealed by an overall lack of fit with the model. The underlying expectation, however, is that such cultural practices as those that may be skewing sex ratios are potentially doing so in the directions predicted by an ultimate explanatory approach.

Of the 35 countries, Sub-Saharan Africa is represented by 21 countries whereas South Asia and the Near East/North Africa each consist of three countries, and the Caribbean/Latin America is represented by eight countries. Essentially, these four regions capture countries where 67% of the South Asian sample are classified as “least developed” (i.e., Bangladesh and Nepal). For the Sub-Saharan African region, 57% are representative of “least developed” countries (i.e., Benin, Burkina Faso, Central African Republic, Chad, Comoros, Madagascar, Malawi, Mali, Mozambique, Niger, Togo, and Zambia) and from the Caribbean/Latin America, Haiti (13%) is classified as “least developed” (UNICEF, 2001, p. 106). The remaining countries fall into the “developing country” category. A list of all countries selected for this study – as well as dates surveys were collected – is presented, by region, in Table 1.

Selection of cases. The initial sample size across the 35 countries for all potential variables of interest included 134,257 women and 166,294 children. Within this sample

of children, 22.7% were the firstborn and youngest child – and therefore, only child. While 104,995 women reported information for only one child (of which 76.7% were later-born children), 21.8% of the women in this sample reported information for more than one child.

Given that *DHS+* methodology by default records information for the youngest child first, it was assumed that all cases with only one child were, more likely than not, providing information for the lastborn child. Thus, all 104,995 single-child cases were retained as well as lastborn children from cases including siblings. For several reasons, it was determined that the focus of this study would be on data recorded for the lastborn child of each woman with more than one child in the data set.⁸ Determining the unit of analysis in terms of the focal child can be complicated, given the research on infanticidal risk. For various reasons, however, many studies seem to focus on the youngest child; for example, for his study on the Mukogodo, Cronk selected the most recent child because it tends to be the one "most dependent upon parental care and hence potentially the most vulnerable to variations in its quality and quantity" (2000, p. 208). Consequently, 32,037 older siblings (19.3%) were dropped from the sample for analysis.

In fact, analyzing the model across all children would introduce several potential confounds. For one, each woman's information would be weighted by the number of children she had, thereby inflating her representation in the analyses and placing women

⁸ It was considered to be semantically more accurate to use the term "lastborn" since an only child is the lastborn child as well as the firstborn. In contrast, the term "firstborn" is more likely to imply that more than one child exists. Of course, what this means is that the firstborn and lastborn child may be one and the same – and for 104,995 women in this data, they actually are. As such, the term "lastborn child" will be used throughout this paper to denote the youngest and/or only reported child for each woman in the data.

with only one child at a statistical disadvantage in terms of the units of analyses. Furthermore, parametrics aside, the differences in parental investment across children belonging to the same mother is an entirely separate area, drawing upon theory related to parent-offspring conflict and sibling competition (e.g., Clutton-Brock, 1991; Trivers, 1972, 1974). Selecting the youngest of several siblings would also decrease the potential influence of reporting error more likely to be characteristic of memory recall concerning the care of the older children. In addition, research has indicated that later-born children and girls with older sisters are often more at risk of infanticide for reasons central to this study (Arnold, Choe, & Roy, 1998; Betzig, 1997; Hrdy, 1999).

Despite the expectation that information for older children would be less reliable, certain variables were equally unreliable across the youngest and/or only reported child. Although the sample at this point included 134,257 woman-child pairs across all four regions, the final data set used in the analyses included only those woman-child cases that provided complete data across all variables examined. As such, 4.6% of these cases were excluded from the analyses leaving a final sample size of 128,039 woman-child pairs (weighted $N = 124,371$). An overview of the final sample used in the analyses is presented in Table 2 (unweighted and weighted by sample weight for the sake of parametric comparison across countries).

Research procedures

Rationale for use of scales. Following a principle of *e pluribus unum*, multiple indicators of real-world phenomena can serve as composite measures against which mathematical manipulations can test theoretical relationships. Combining variables in this

manner involves producing for each set of relationships, a scale that represents a particular construct based on those manifest indicators (i.e., observable phenomena). Whether the scale is representative of a systematic association between such manifest indicators is determined by the degree of internal consistency – a measure of scale reliability – that ultimately serves as evidence of construct validity. Furthermore, as a measure of discriminant validity, each scale should be uncorrelated from other scales used, and therefore differentiated from one another on account of indicators involved (Nunnally, 1978; Pedhazur & Schmelkin, 1991). Thus, while the real-world does not necessarily provide us with a distinct mold for what, say, maternal condition or parental investment might be, it is nonetheless possible to combine meaningful, observable indicators of such information together and thereby apply a theoretical framework to such composite measures. And this is precisely what was utilized for this study.

Construction of measures. As described above, initial analyses required evaluating the absence of information as well as the presence of extreme values across variables of potential interest. Items that were conditional or logically dependent were collapsed into single indicators whenever possible. Items for which data was scattered across cases, at best, were excluded from consideration for analyses given the possibility of nonrandom missing data and confounds implicit therein. For example, most problematic, unfortunately, were the variables concerning breast-feeding – of which 60% of the initial 134,257 woman-child pairs were missing information for breast-feeding duration (measured in months). Additional reasons for why breast-feeding was problematic are reviewed later on in the final chapter of this paper.

For the purposes of this study, four central scales were constructed relating to the *biological*, *resource-oriented*, and *behavioral* aspects affecting maternal condition, sex allocation, and parental investment in humans. Each scale was rigorously designed to capture the salient, empirical, and reliable indicators of maternal condition and parental investment as befits the original Trivers-Willard hypothesis – to the exclusion of potential confounds and sources of error whenever possible. Selection of the final set of variables are presented in Table 3, along with brief descriptions and coding schemes. In order to present a model that could be compared to those addressed in some of the nonhuman animal research, stringent decision rules were applied so as to enhance the cross-species comparative focus of this study. These are briefly reviewed here.

Maternal socioeconomic resources (MSR). Based on prior research reviewed in the preceding chapter, a measure of socioeconomic status was required as well as a physiological measure of maternal condition. For the socioeconomic indicators, the four dimensions of household economic status are based on a needs assessment determination per household and serve as relative measures of household socioeconomic status in place of the typically popular measure of income. These were drawn from a previous study by Smith, Ramakrishnan, Ndiaye, Haddad, and Martorell (2003). Economic status was therefore defined by level of basic needs met involving household investment and number of cheap and/or expensive assets owned. The former is measured by whether the household has a finished floor, a toilet facility of some kind, and access to piped or bottled water. Cheap assets include a radio, a television, or a bicycle whereas expensive assets include a refrigerator, a motorcycle, or a car.

As such, households classified as “destitute” are either meeting none or only one of the basic needs but possess none of the measured assets. Households classified as “poor” are satisfying two of the basic needs but lack ownership of any assets or such households own some cheap assets but are either meeting only one basic need or none at all. Households determined to be in the “middle” category are either meeting two to three of the basic needs and only own cheap assets or they own, at minimum, one expensive asset but are meeting, at most, one basic need. Lastly, “rich” households are meeting two to three of their basic needs and are, at a minimum, in possession of one expensive asset.

An additional measure of access to resources was indicated by location of residence within an urban area. As detailed in Table 3, an urban residence received a higher score than a rural residence given that urban life tends to provide women with more efficient and potential access to resources. Noted, of course, is the reality that urban life may increase the exposure level to toxins – particularly public waste in certain regions – as well as crowding. The overriding element that determined an urban residence as more indicative of optimal resources, however, is the importance of access to the fulfillment of basic needs, education, health services, and community support that tend to increase female health and quality of life, rather than decrease it (Madzingira, 1993).

While previous studies have included measuring female status by the presence or absence of a male partner, this project measured male contribution not by presence alone, but by a male’s value as deferred upon him through number of years of education. Given that *DHS+* sampling methods involve interviewing only “ever married women” within four of the countries involved in this study – and the small number of unpartnered women

represented in the data for those countries as well as throughout all countries selected overall – it was necessary to establish a comparable measure of male contribution for all women. Indeed, the assumption of previous studies that the presence of a male partner is uniformly positive and contributory may be inaccurate (e.g., impact of stepfathers; Flinn, Leone, & Quinlan, 1999). For example, a male with no education may actually have just as negative an impact on a woman’s biology and behavior as no man at all, though the sources of the disadvantage may differ. In fact, in some cases it could be argued that it is better to have no man present at all than an uneducated one who may actually be draining resources from her and the rest of the household. Most importantly, given that educational level is usually associated with a better socioeconomic situation, improved access to resources, and informed decision-making, it serves as an honest indicator of several correlated variables that may enhance a male’s value as a partner overall (Kozziel & Ulijaszek, 2001). For these latter reasons concerning the colinearity of situation, access, and decision-making, a woman’s level of education (as represented by number of years of schooling) was also included in the maternal socioeconomic resources scale.

Maternal biological condition (MBC). Body mass index (BMI) was selected as an indicator of the continuum of maternal condition and is measured as a woman’s weight in kilograms/(woman’s height in meters)². Note that BMI measurements less than 18.5 reveal “chronic energy deficiency” whereas a value greater than 25 suggests “excess energy reserves” (WHO, 1995 cited in Smith et al., 2003, p. 61). Obesity is notably rampant in certain regions, such as Latin America and the Caribbean, and has been viewed to represent malnutrition; however, it has been shown to outrightly influence sex

ratios in nonhuman animals, as reviewed in the preceding chapter, and this is of paramount interest here. While an overweight woman may be considered unhealthy by modern standards, the role that fat has played in evolutionary history suggests that excess energy reserves are an indicator of good condition within the mammalian female reproductive life cycle. Therefore, all women of all BMI measurements were retained for analysis. A measure classifying each woman as under-nourished, healthy, or overweight was also included so as to assign a score to differentiate women among three potentially significant categories of body mass index.

Additionally, current pregnancy and breast-feeding status were selected in order to differentiate between women on two important elements that constitute the mammalian female reproductive life cycle. While breast-feeding was predicted to have a negative effect on a mother's condition by placing a drain on her energy and nutrient intake (Brown, 2001), length of pregnancy (as opposed to pregnancy status by itself) was predicted to represent a positive indicator of maternal condition. Although any pregnancy naturally deprives a woman of necessary energy reserves (i.e., maternal depletion; Ellison, 2001), the very fact that she is able to be pregnant and especially to be able to maintain a pregnancy for any length of time are considered indicators of good condition (Haig, 1999), especially given that malnourished and/or stressed women may be more likely to miscarry (Kerr, 1971). For this reason, current pregnancy duration was selected for the maternal health scale whereby women who were not pregnant were coded as zero for pregnancy duration.

Prenatal care for lastborn child (PCL). This scale was designed to capture information concerning parental investment in that it includes protective, risk-avoidance behaviors. Though the number of prenatal visits could potentially be correlated with a woman's health-related needs to seek prenatal care in the first place, what matters is that she actually was able to obtain care. For example, a woman who did not receive prenatal care is not necessarily lacking the need for it, while a woman who received prenatal care on numerous occasions may be no more at risk of a difficult pregnancy than the first woman. What is central here is that a woman not only sought care but was able to access it. As such, this is a measure not of health status – since the health status of women unable to obtain care would be otherwise unmeasured – but rather a measure of access and initial parental effort directed toward the maintenance of maternal and child health. Furthermore, type of prenatal care received was measured by whether none was received at all, whether the woman received prenatal care from someone other than a medically trained person, or whether she received care from a medically trained person.

Additionally, two measures for birth assistance were also included: (a) a variable for whether a mother delivered her lastborn child at a medical facility and (b) whether she delivered without any assistance, whether she received assistance during delivery from a non-medically trained person, or whether she received assistance from a medically trained person. Note that, although place of delivery and type of delivery were highly correlated ($r = .759, p < .01$) in this study, it was still possible for a woman to receive assistance from a medically trained person but to have delivered at home or somewhere other than at a medical facility.

Health-seeking for lastborn child (HSL). Given the previously reviewed complexities of breast-feeding measures across studies, the health-seeking information in the demographic survey data was more of interest for the measurement of parental investment than the scattered, problematic breast-feeding data. This was for two reasons: previous research has documented sex biases in treatment seeking, particularly among diarrhea clinics in the developing world (Makhlouf Obermeyer, 1996). Secondly, diarrhea in the developing world is particularly dangerous for children and the risk of dehydration cannot be underplayed (Hoque et al., 1999). Consequently, the scale including the diarrhea treatment was coded to emphasize the treatment-seeking aspect of that variable whereby the higher score was assigned to children who received treatment and the lowest score assigned to those children who did not receive treatment for a reported case of diarrhea.

Furthermore, the other variables included were prevention-oriented in that they were designed to capture any differences in immunization health-seeking as reflected by a dose of Bacillus Calmette-Guerin (BCG) for the prevention of tuberculosis, a vaccination against measles, and three doses of DPT to prevent diphtheria, pertussis, and tetanus as well as three doses of the polio vaccine to prevent poliomyelitis. A measure to indicate age-relative compliance with immunization completion was also included to provide each child with a score comparable to all other children, regardless of age. Note, though, that all eight vaccinations should ideally be given before the first birthday has been reached such that by the time they are 4 months old, children should have received five of the eight vaccinations (Smith et al., 2003).

The overall HSL scale is not a measure of the child's health, but rather the parental response and prevention strategy experienced by the child. It serves as a direct measure of parental-initiated investment per lastborn child in that seeking medical assistance is less likely to be initiated by a child; as such, this scale is less likely to be documenting individual differences across children in place of parental strategies.

Scale construction. The variables of practical and theoretical interest were standardized across cases and evaluated for each scale using Cronbach's inter-item reliability analysis. Final determination of scales was based on a Cronbach's alpha $> .60$ which would indicate that 60% of the variance in a given scale is nonrandom (Pedhazur & Schmelkin, 1991). Although an alpha as low as .60 is not ideal (v. Nunnally, 1978), obtaining much higher than that for the maternal biological condition scale could not be achieved without the incorporation of redundant information concerning pregnancy status. Since each scale consisted of variables that provided a score to each woman and each child when the relevant information was available, final determination and construction of the scales was based on the 134,257 sample size using listwise deletion of cases given missing data on any of the constructed variables. This was a conservative approach but feasible given the extensive sample size. The inter-item reliabilities for each of the four scales, along with descriptions of the relevant indicators, are presented in Table 4.

For scale confirmation, indicators were then correlated with the scales. The results of these correlations are presented in Table 5. It should be noted that, although the diarrhea treatment variable did not correlate strongly with the scale to which it was

assigned ($r = .243, p < .01$), it was nonetheless significantly correlated (albeit, weakly) with all the other items, excluding the indicator for measles vaccination received ($r = .005, p = .064$). More importantly, though, it was necessary to include a measurement for diarrhea treatment-seeking behavior given that diarrhea is one of the main causes of mortality in children in developing countries (WHO, 2003). In this case, theoretical considerations overrode the weaker statistical justification for retaining that variable in the health-seeking behavior scale. Furthermore, to assess the extent of collinearity among the four scales, a correlation matrix yielded the highest correlation between maternal socioeconomic resources and prenatal care ($r = .59, p < .01$) with other correlations ranging from $r = .21, p < .01$ (for maternal biological condition and prenatal care) to $r = .37, p < .01$ (for prenatal care and health-seeking for the lastborn child; see Table 6).

Statistical analyses

A series of hierarchical regressions in SPSS (drawing upon the mixed general linear model for categorical and continuous variables) was used to examine the particular hypotheses of the study. The purpose of hierarchical regressions is to elucidate the proportion of variance in the dependent variable(s) that can be explained by the independent variables. Given that much of the research in the behavioral sciences seeks to assess relationships among multiple variables, most of which are meaningfully correlated in the real-world, the overall purpose of this type of analysis is to isolate the effects between variables to the closest approximation possible, in spite of such naturally-occurring, interdependent relationships. That is, this methodology identifies any direct effects of the independent variable(s) on the dependent variables while controlling for all

other variables as well as any conditional relationships on account of interactions between predictors.

It is a particularly useful analytical tool because it involves a multivariate analysis of the data in that the variance is partitioned hierarchically by entering variables into the model in a certain, pre-specified sequence. The order of such a sequence is determined by hypothesized causal priority of each predictor, while controlling for the effect of any previously included dependent variables. In this way, the effect of each variable is partialled out (or residualized) so as to identify its contribution over and above the effect of all the other variables in the equation, including any interaction terms (i.e., conditional associations) that may have been addressed in the model as well (Gorsuch & Figueredo, 1991). Interaction terms are included so as to partial out the additive effect of any given predictor variable changing as a function of any other predictor variable. According to Cohen and Cohen (1983), not all possible combinations of variables need be entered as interaction terms; only those that examine potential and meaningfully conditional associations between predictors.

Furthermore, when a fully specified model can be achieved – defined as lacking “reciprocal causation, feedback loops, or unmeasured common causes” – the hierarchical nature of this method lends itself well to the estimation of causal effects (Cohen & Cohen, 1983, p. 121). For example, Type I sum of squares indicates the extent of error reduction with the sequential addition of any given predictor. Standardizing the scale scores prior to entering them into the model ensures that the beta-coefficients provided will be standardized regression coefficients (β) and are thus interpretable as regression

weights in the calculation of the best-fitting line appropriate to the model. In the case where such regression weights are estimated using simultaneous analysis, as opposed to hierarchical, they serve to isolate the direction of an effect but less so the magnitude thereof. Yet in this situation, the hierarchical nature of the forthcoming analyses produced standardized regression coefficients that render the direction and magnitude of each effect measured.

The proportions of variance (also known as the coefficient of determination) produced with each regression essentially represent effect sizes for each predictor, thereby isolating and identifying the impact of any variables believed to influence the dependent variable in a systematic and meaningful manner. As such, the coefficient of determination (denoted as R^2) for each predictor provides a measure of the strength of the relationship between a given predictor and the dependent variable, holding constant all other variables in the regression. This is because R^2 measures the proportional reduction in error within a given model; namely, it represents a ratio that provides the proportion of error that is reduced in the prediction of the dependent variable by the inclusion of a given predictor variable (Wilkinson, Blank, & Gruber, 1996, p. 152).

For this study, the causal priority assigned to the variables of interest are laid out in Figure 1 whereby standardized scores for maternal socioeconomic resources (MSR) were entered first, given the prediction that they precede the measure for maternal health (MBC) in explanatory power. That is, socioeconomic factors are predicted to be region and country-specific. Resources available to each mother are, in turn, predicted to influence her biological condition (as measured by MBC). The next relationship

examined is the effect of MSR and MBC in influencing levels of prenatal care for each lastborn child (PCL). The frequency and type of prenatal care are, in turn, predicted to determine the sex of that same child (SEX). Lastly, degree of health-seeking for the lastborn child (HSL) is hypothesized to be predicted by the sex of that child.

Interaction terms, where relevant, were included to measure whether the effect of any of the central predictors (MSR, MBC, PCL, SEX, and HSL) on the dependent variable of any given regression was mediated by REGION or COUNTRY. For example, if an interaction between REGION and MSR was significant and large in predicting PCL, this would indicate that the manner in which maternal resources impacts prenatal care varies as a function of regional or country differences; such that, whatever the relationship between maternal resources and prenatal care is, it is conditional upon whichever region or country is being examined by which the very nature of how resources predict prenatal care is being driven by something unique to specific regions or particular countries. For this study, conditional associations – as measured by the interaction terms – are crucial in determining to what extent cultural variance is at play here in addressing an evolutionary theory that has been difficult to demonstrate reliably in human populations. In essence, if the Trivers-Willard hypothesis applies to humans over and above what cultural differences may exist, then results from interaction terms in the forthcoming analyses should be nonsignificant or minimal.

Consequently, three sets of multiple regressions were run to test the main effects and interactions between predictors across and within all four regions. The first set of analyses involved using an *interaction model* across all countries, thereby revealing the

proportion of variance in each dependent variable explained by the independent variables as well as any relevant interactions between the predictors for all countries. The second set of analyses used a *main effects model* across all countries to examine the proportion of variance in each dependent variable explained by the independent variables to the exclusion of the interaction terms. Given a comparison of the results from these two analyses, the third set of regressions examined the *interaction model within each region* to identify any unique regional effects across all variables and relevant interactions.

Summary

The focus of this study was on 35 countries from four regions and involved the construction of four scales relating to the *biological*, *resource-oriented*, and *behavioral* aspects affecting maternal condition, sex allocation, and parental investment in humans. Data analysis required a sequence of hierarchical regressions theoretically-derived and pre-specifying the order of the variables entered into each model, thereby isolating their individual effects on the dependent variables.

RESEARCH FINDINGS

Part I: Descriptive statistics of study sample

Overall profile. Thirty-five countries were sampled representing four regions of the world: South Asia, Sub-Saharan Africa, the Caribbean/Latin America, and the Near East/North Africa. Refer to Figure 2 for an overview of the regional representation within the current survey data sets examined for this study. Not surprisingly, preliminary analyses revealed regional differences across demographic and scale variables. As such, Table 7A provides comparisons of household, parental, and child demographics by region. Table 7B presents descriptive statistics by region for the variables included in the scales. Although regional differences are likely to be more informative than any given single mean representing all four regions, both are presented in each table for the sake of comparing each region against the entire sample.

As such, descriptive analyses⁹ of the study sample overall revealed that, for the mothers across all four regions: 91% reported a male partner present, 13% were living in female-headed households at the time of the interview, 14% were malnourished, 10% were pregnant at the time of sampling, and 63% were breast-feeding. The mean age of the women across all regions was 27.8 years, with the average age at first marriage being 17.7 years and education averaging 3.8 years.

A comparison of pregnancy status and maternal weight status across regions indicates that within South Asia and the Latin American/Caribbean regions, 9% of all

women were currently pregnant; of which 9.1% of the overweight mothers in South Asia were pregnant while 10.9% of the overweight women within Latin America/Caribbean were currently pregnant at the time of their interview. Furthermore, 11% of the Sub-Saharan African and Near East/North African samples were pregnant; of which 14.8% of overweight women within the Sub-Saharan African region and 12.3% within the Near East/North African samples were pregnant. Noteworthy, also, is that 4.3% of the pregnant women within South Asia were also currently breast-feeding – the highest rate across all regions, with the next highest within the Near East/North African region (2%). Moreover, of all breast-feeding mothers (whether pregnant or not) within South Asia, 38.5% were malnourished. This is in noticeable contrast to the prevalence of a body mass index measuring less than 18 among other breast-feeding mothers within Sub-Saharan Africa (13%), Latin America/Caribbean (3.9%), and the Near East/North Africa (3%).

Within the 21.8% of the sample reporting information for more than one child, the maximum number of children currently residing at home with the mother and under the age of five years was 4. Of the children across all regions: 1% were from multiple births with a mean birth order number of 3.6. The mean age of the lastborn child across all women was 19.7 months. While 99% of the children were reported to have been breast-fed at some point, 83% were breast-fed within one day of birth. Additionally, 79% received the BCG vaccination, 53% received the measles vaccination, and the average number of DPT vaccinations received was 1.98 whereas the average number of polio

⁹ Descriptive statistics presented here are based on unweighted analyses of the data used in the regressions. However, comparisons concerning the four scales across countries and regions are based on the inferential analyses from the regressions (i.e., weighted by sampleweight for each country).

vaccinations was only a bit higher, at 2.03. Overall, the mean percent of age-recommended vaccinations received was 72%.

South Asia. Women interviewed within South Asia had, on average, 7.3 household members living with them at the time of their participation in the survey. Among the households, 7% were female-headed and only 24% of the mothers were living in an urban area, representing the highest percentage of rural residences across all regions. This sample was also, on average, the youngest group in the data ($M = 25.8$ years) with male partners also younger ($M = 31.8$ years) than the male partners within the other three regions. Additionally, age at first marriage for these women was the youngest across all regions ($M = 17.1$ years). Consistent with previous demographic research (Smith et al., 2003), mothers in South Asia were on the lower end of the BMI spectrum ($M = 19.7$) whereby this region had the highest number of malnourished mothers (36%). Additionally, 73.5% of the households sampled were either destitute or poor.

The lastborn children in this sample were also, on average, the youngest ($M = 17.4$ months) of all children in the current data, with a mean birth order number of 2.9. Within this group, 82% of the South Asian mothers were breast-feeding – the highest percentage for all four regions as well. Concerning health-seeking behaviors for their children, however, South Asian women had the second lowest average number of prenatal care visits ($M = 2.65$) and delivered at a medical facility only 30% of the time. Completion of BCG and measles vaccinations were also lowest in this region with 71% and 43% compliance, respectively. As such, South Asian women had the lowest mean scores for the maternal biological condition, prenatal care, and health-seeking scales, with

Bangladesh averaging the lowest of all countries overall in maternal condition and prenatal care.¹⁰

Sub-Saharan Africa. This group had the highest mean number of household members ($M = 8.1$) and the highest percentage of females per household (53.1%), with 15% being female-headed throughout the region. Similar to the South Asian sample, 72.1% of the households were either destitute or poor, with 29% of the mothers living in urban areas. In contrast to South Asia, though, 12% of the mothers sampled were malnourished. Additionally, male partner's age was, on average, highest for this sample ($M = 37.7$ years) yet average years of education for both the mothers and their partners were the lowest across all regions; namely, maternal mean years of education was 2.9 while partners' mean education was 4.1 years. As such, this region averaged lowest of the four regions on the maternal socioeconomic resources scale, with Burkina Faso averaging the lowest across all countries. Furthermore, within this group, 69% of the mothers were breast-feeding – the second-highest proportion across all regions.

Completion of all three DPT and polio vaccinations was lowest in this region with 49% and 48% compliance, respectively. On the other hand, 23% of children with diarrhea in the two weeks prior to the household survey received treatment. This was the highest rate across all regions. It should also be noted that the percentage of children with diarrhea left untreated was 3% – the lowest rate across all regions; bearing in mind,

¹⁰ Given that the scales analyzed in this study were based on standardized scores that were then standardized again for the purposes of the hierarchical regressions, as discussed earlier, the specific means (M) and standard deviations (SD) for each country and each region should, by definition, tend towards a mean of zero and a standard deviation of 1. As such, means and standard deviations are not that informative but are provided nonetheless in the presentation of the regression analyses to demonstrate differences between regions and countries when appropriate.

however, that only 74% of the children in this sample did not have diarrhea in the two weeks prior to the survey. This is meaningful because all other regions ranged from 79-81% pertaining to absence of diarrhea. Furthermore, while prevalence of diarrhea was highest within this region, it was highest for sons (27.1%), treated or untreated. Among the daughters, 24.8% had treated or untreated diarrhea. Lastly, although South Asia had the lowest mean for health-seeking across all regions, Chad had the lowest mean across all countries on that scale.

Caribbean & Latin America. Women interviewed within this region had the lowest mean number of household members living with them ($M = 6.4$). A little more than half of all mothers were living in an urban area at the time of their interview – the highest proportion of urban residences (52%) across all regions in this data, with only 4% of the women measured as malnourished. Of the households, 55.6% were classified as middle or rich. In addition to the proportion of urban residences, the presence of female-headed households was also highest in this region (16%), albeit exceeding Sub-Saharan Africa in this demographic by merely 1%. Furthermore, 13% of the women in this sample were without male partners, in comparison to Sub-Saharan Africa's proportion of 12% on the same demographic. Within this group, mothers had an average of 5.3 years of education – the highest average across all regions. Additionally, these mothers had more prenatal care visits ($M = 4.64$) than any other region and 56% of their lastborn children were delivered at a medical facility and assisted by a medically trained person – again, the highest across all four regions examined. Accordingly, this region was the highest in maternal socioeconomic resources and prenatal care, with the Dominican Republic

representing the highest average for resources and prenatal care across all countries. Furthermore, across all countries, Nicaragua had the highest average for health-seeking overall.

Near East & North Africa. Mothers interviewed within Egypt, Morocco, and Turkey were the least malnourished of the entire sample, with only 2% having a body mass index less than 18. What is more, Turkey had the highest average maternal condition for all countries. Furthermore, 71.7% of their households were classified as middle or rich in terms of relative household resource availability and access – the highest percentage of the top brackets concerning socioeconomic status. Mothers in this region were, on average, a year older than women in the Caribbean/Latin America region and were thus the oldest across all regions ($M = 29.6$ years). Additionally, the age of their lastborn child was, on average, older than the lastborn child within the other three regions ($M = 24.8$ months). Furthermore, this group had the lowest breast-feeding rate (39%) across all regions.

Regarding health-seeking behaviors, mothers in this region had the highest rates for all vaccination variables (see Table 7B) but the lowest treatment rate for children with diarrhea (13.9%) and the highest rate of children with untreated cases of diarrhea (4.8%) – as well as the highest proportion of children who did not have diarrhea (81%) in the two weeks prior to the household survey. In contrast to the Sub-Saharan African region, this yields the lowest prevalence of diarrhea as characteristic of this region but demonstrates a similar pattern of sex differences as seen in the Sub-Saharan African region; namely, 19.7% of sons and 17.4% of daughters had treated or untreated diarrhea

in the two weeks prior to the survey (i.e., 2.3% difference between sons and daughters) regardless of overall prevalence. Lastly, this region had the highest overall average for maternal condition as well as the highest average for health-seeking for the lastborn child.

Part II: Sex ratio of lastborn children

Patterns in the data. The number of males (65,190) to females (62,849) across all regions in the final sample selected for analysis yields a sex ratio of 1.037 (51% boys, 49% girls). Categorizing these numbers according to sex ratio across individual countries for the entire sample shows 37% to be female-biased and 60% as male-biased with only one country (Brazil) represented by an equal sex ratio regarding number of lastborn boys and girls under the age of 5 years and living with their mothers. Among children less than 1 month old ($n = 1,260$) and thus the closest approximation to the birth sex ratio for this particular sample, the sex ratio bias across countries is 19% equal, 63% male-biased, and 18% female-biased. For the children aged 2 months old ($n = 4,190$), the distribution of equal sex ratios across countries is still 19% but male-biased is represented by 65% and female-biased sex ratios have dropped to 16% in comparison. For a list of sex ratios by sampled country, see Table 8.

The change in sex ratios per age groups within this sample required further elaboration given that the data in this study includes all lastborn children under the age of five years; namely, the sex ratio for each country at the time of sampling may indicate survivorship patterns for children under five across the thirty-five cultures. In that case, for an additional comparison, the sex ratio for the data from each sampled country was compared to the estimated national sex ratio at birth for each country. Although obtaining

reliable secondary sex ratio information is often difficult, for some of the reasons cited earlier concerning sex-selective infanticide (particularly in rural areas), estimates provided by the CIA (as recommended by P. Rushton, personal communication, February 21, 2003) were used to examine the presence of a pattern in the change of the estimated sex ratio at birth and the actual sex ratio of the sample used in this study. While the numbers provided by the CIA are estimates and are subject to similar confounds as other sex ratio estimates, it was considered better to use estimates that vary as a function of each population than to compare all countries against one single expected number; namely, the estimate of a secondary sex ratio of 1.06 males to females in humans (Cartwright, 2000), that is often used in comparisons with the sex ratios of other species.

Cluster analysis. Preliminary interpretation of the discrepancy in the national at-birth sex ratios from the sex ratios of the current data was suggestive of interesting trends. That is, plotting percent change in sex ratio by country revealed a distinct pattern (see Figure 3) that required further elaboration in that certain countries apparently deviate from the secondary sex ratio by becoming unusually female-biased (e.g., Uganda) while others deviate by becoming unusually male-biased (e.g., Turkey). Noteworthy, also, is that all three Near Eastern/North African countries yield male-biased trends as well as India; notwithstanding, the countries with prevalent son preference and significantly high female infanticide rates (Freed & Freed, 1989; George, 1997; Hrdy, 1999; Oomman & Ganatra, 2002; Venkatesan, 2001).

Thus, a hierarchical cluster analysis involving Ward's linkage method was used to determine the pattern of association between cases based on discrepancies between the

national at-birth sex ratio and the sex ratios within the current data. This method of cluster analysis is similar to an ANOVA in that it minimizes the within-cluster sum of squares in relation to each between-cluster sum of squares. And it does so at each juncture where group membership is determined based on a Euclidean distance measure that serves as the break-off point for identifying each group. Euclidean distance is defined as "...the root mean square discrepancy between objects across attributes" (Wilkinson, Blank, & Gruber, 1996, p. 609). A cluster analysis is likely to present a pattern of information across cases on a given variable when the branches in the cluster tree are drawn close and tightly together. When the majority of the branches exist further out along the Euclidean distance, and therefore farther away from zero, they tend to represent uniform randomness within the data (Wilkinson et al.).

In this case, a cluster analysis was created utilizing a composite score for each country from the CIA data and the survey research so as to measure similarities and differences in individual countries' deviation from their estimated at-birth sex ratio among children under five years of age. Results reveal a distinctive pattern of three clusters, with the first break (Euclidean distance = 0.593) across two groups separating countries by those that decreased (or remained unchanged) in the number of males relative to females and those that decreased in the number of females relative to males within the under-five age group. The former group contains countries with male and female-biased sex ratios while the latter contains only male-biased countries. The second break (Euclidean distance = .343) distinguishes between a group that decreased in the number of males proportional to females, thereby producing female-biased sex ratios, and

a group that either decreased or did not decrease in the number of males relative to females, thereby producing male-biased sex ratios.

As such, the cluster tree yields three distinctive groups (see Figure 4). The top cluster, in italics, includes the female-biased countries that reflect a loss of males relative to females within the under-five age group. The center of the tree identifies the male-biased countries that did or did not decrease in number of males relative to females. And the bottom group, in bold, contains the countries that demonstrate a loss of females relative to males. The cluster analysis implies a proportional decrease over time from the estimated at-birth sex ratio in almost all countries. The comparative framework of the cluster analysis is useful for placing country patterns into perspective concerning forces – both evolutionary and cultural – that may be driving the sex-ratio changes, as shall be addressed in the following chapter.

Part III: Hierarchical regression analyses

Overview of modeling. As stated earlier, analyses involved a system of hierarchical regressions testing initially for the interaction and main effects of region, country, and the four scales: maternal socioeconomic resources, maternal biological condition, prenatal care for lastborn child, sex of lastborn child, and health-seeking for lastborn child. Causal priority of each variable was theoretically-based and determined the sequence of the variables entered into the regressions (refer again to Figure 1 for the theoretical and empirical model used in this section of the analyses). Also, as outlined earlier, the first set of regressions – Model 1 – analyzed the model across all 35 countries. The second set of regressions examined the model for main effects only, so as to compare

against the results of Model 1 and to determine the significance of the conditional relationships (i.e., interaction terms). The third set of analyses – Model 3 – served as a follow-up to Model 1 by testing the model within each of the four regions.

Note, however, that testing the model within each country is not included here for several reasons. For one, results from Model 1 yielded trivial interactions such that conditional relationships between the scales and region and country as predictors, respectively, were not indicative of varying differences requiring further elaboration at the country-level. Results concerning the prediction of the sex of the lastborn child, however, did suggest that regressions within regions would be meaningful. Furthermore, analyses within countries would be more prone to sampling error and non-random biases; namely, the significance of any within-country variation would lie in a given country's individual deviation from their respective regional pattern. Without additional variables to explain such variation, country-level regressions invite the problem of omitted variable bias thereby running the risk of a misspecified model, especially since the scales were constructed using all 35 countries. Ultimately, testing the model to see when it cannot possibly fit as opposed to testing when it fits – particularly across so many samples – defeats the purpose of involving such a large dataset in the first place for addressing a theory that inherently ought to apply across countries. Therefore, only regional comparisons were deemed meaningful for an examination of the TW hypothesis. These are reviewed below in Model 3.

Results from the regressions across all countries revealed overall significant effects at the .01 alpha level, albeit trivial in magnitude on several counts – as

demonstrated by the standardized regression coefficients (β). These findings shall be discussed by comparing regional differences and similarities at each step of the series of regressions. In other words, results are presented for each dependent variable as it is predicted by each set of independent variables, following the stepwise sequence depicted in Figure 1. Moreover, results for Model 1 will be presented based on the order of entry of the variables. However, results for Model 3 will be presented as comparisons between regions for each predictor – not according to their order of entry in the regressions but rather, as comparisons of their explanatory power.

Model 1: Interaction effects across countries

Maternal socioeconomic resources. In the first regression, region and country together accounted for 22.6% of the variance in maternal socioeconomic resources, $F(35, 124336) = 1037.49, p < .01$, as indicated by $R^2 = .226$ for the overall model (see Table 9). In fact, region accounted for 13.8% while country accounted for almost 12%, as indicated by R^2 for each variable. Additionally, Sub-Saharan Africa had the lowest mean for the maternal socioeconomic resources scale ($M = -.32, SD = .82$), with Burkina Faso as the lowest ($M = -.84, SD = .31$) of all countries; while the Dominican Republic was the highest ($M = .97, SD = .99$), with its region overall highest in maternal socioeconomic resources ($M = .50, SD = 1.05$).

Maternal biological condition. In the second regression, maternal socioeconomic resources accounts for 11% of the variance in maternal biological condition. In fact, across all regions, increasing maternal socioeconomic resources contributes toward increased maternal biological condition but not all that powerfully, as indicated by the

small, positive standardized regression coefficient for the maternal socioeconomic resources scale ($\beta = .066$) in this regression. Furthermore, region accounts for 17.7% of the variance in maternal biological condition while country only accounts for 1.1% across all four regions (see Table 10). As such, the overall regression testing the effects of maternal socioeconomic resources, region, country, and interactions accounts for 26.2% of the variance in maternal biological condition, $F(70, 124301) = 629.05, p < .01$.

Although significant, the interaction between maternal socioeconomic resources and region, as well as the interaction between maternal socioeconomic resources and country, are trivial in effect. That is to say, maternal socioeconomic resources by region accounts for 0.1% of the variance in maternal biological condition, while the interaction of country with maternal socioeconomic resources accounts for 0.3% of the variance in maternal biological condition. This, of course, means that the predictive contribution of the interaction terms is minimal. Small interactions such as these merely demonstrate, for example, that the effect of maternal resources in explaining maternal biological condition does not vary much – if at all – as a function of regional or country differences but that in this case, some degree of conditional variation by country and region is present for this scale. This trend of trivial explanatory power is evident throughout almost all of the conditional relationships tested within the sequence of regressions in Model 1. Moreover, that the main effect for region is so large, in comparison, indicates that almost 18% of the variance in maternal biological condition is explained by systematic differences between regions regarding maternal condition.

What is interesting, on the other hand, is that South Asia ($\beta = -.566$) differs from the other three regions in the direction of its coefficient in this regression: Sub-Saharan Africa ($\beta = .097$), Latin America/Caribbean ($\beta = .461$), and the Near East/North Africa ($\beta = .768$). In fact, Bangladesh ranks the lowest ($M = -.72$, $SD = .85$) in maternal biological condition while Turkey has the highest mean ($M = .82$, $SD = .94$) on that scale. Furthermore, of all the regions, South Asia has the lowest mean maternal biological condition ($M = -.67$, $SD = .83$) while the Near East/North African region has the highest ($M = .73$, $SD = 1.0$).

Prenatal care for lastborn child. Table 11 reveals that maternal biological condition accounts for 9% of the variance in prenatal care with a small, yet positive, effect ($\beta = .061$). Maternal socioeconomic resources has the largest effect (37.1%) in predicting prenatal care for the lastborn child. Indeed, increased maternal socioeconomic resources predicts increased prenatal care ($\beta = .706$) across all countries. Region, on the other hand, only predicts 5.5% of prenatal care, while country is the second strongest predictor by explaining 13% of the variance. Here it should be noted that the interaction of country with maternal socioeconomic resources represents the largest proportion – with only 2.2% predictive power – of all the interactions in the entire set of regressions for the interaction model, thereby demonstrating their minimal explanatory contribution overall. Hence, 2.2% of the variance in prenatal care is explained by maternal socioeconomic resources varying as a function of country differences.

Nonetheless, in its entirety, the model testing the effects of maternal condition, resources, region, and country captures 47.9% of the variance in prenatal care for the

lastborn child, $F(105, 124266) = 1090.17, p < .01$. Across the four regions, South Asia has the lowest mean prenatal care for the lastborn child ($M = -.28, SD = 1.0$) with Bangladesh having the lowest ($M = -.96, SD = .63$) of all countries; while the Latin American/Caribbean region has the highest ($M = .44, SD = 1.0$), as demonstrated by the Dominican Republic with the highest mean ($M = 1.18, SD = .44$) across all countries once again. Note, however, that the Near East/North African region is similar ($M = -.27, SD = 1.0$) to South Asia concerning mean levels of prenatal care.

Sex of lastborn child. The subsequent regression in this series tests for the effect of country, region, maternal socioeconomic resources, maternal biological condition, and prenatal care in predicting the sex of the lastborn child. As Table 12 shows, the overall model accounts for 49.2% of the variance with almost all of the predictive power being explained by region, $F(140, 124231) = 859.31, p < .01$. In fact, maternal socioeconomic resources only accounts for 0.1% of the variance in predicting the sex of the lastborn child while region explains 49.1% of the variance. Yet, the former predictor has a small, positive effect such that higher levels of resources predict lastborn daughters across all regions ($\beta = .040$). Furthermore, this regression reveals that prenatal care is not significant in predicting the sex of the lastborn child, $F(1, 124231) = 2.17, p = .14$. This is the only nonsignificant main effect in Model 1 and is the first of only two throughout all main effects examined in the models of this study. Moreover, maternal biological condition does not contribute any detectable predictive power to the sex of the lastborn child, given that R^2 equals zero for this predictor as well.

Health-seeking for lastborn child. The final regression in this set of tests examines the effect of region, country, the three scales, and the sex of the lastborn child in determining health-seeking for that child. Results show that male lastborn children are more likely to receive treatment and immunizations; however, this effect is very small both in explanatory power ($R^2 = .1\%$) and magnitude ($\beta = -.081$). The largest contribution (16.7%) in predicting health-seeking across all four regions lies in prenatal care for the lastborn child ($\beta = .085$), suggesting that higher rates of prenatal care for the mother predict higher rates of health-seeking for the lastborn child. Furthermore, maternal biological condition has a small, yet significant, positive predictive effect ($\beta = .236$) in explaining 4.2% of the variance in health-seeking behaviors. Maternal socioeconomic resources account for only 1.1% of the variance in health-seeking ($\beta = .215$); such that, as resources increase, health-seeking for the lastborn child increases. Region accounts for 0.8% of the variance in health-seeking whereby the second strongest predictor is country, accounting for 7.2% of the variance.

Note also that the conditional relationships between prenatal care with region (1.6%) and prenatal care with country (1.7%) are significant, albeit also small, indicating that a small proportion of explanatory power in predicting health-seeking is contingent upon variations in how country- and region-specific differences determine prenatal care. Conditional relationships between maternal biological condition and maternal socioeconomic resources with country and region are even smaller (ranging from .1 to .5%).

The entire model here accounts for 27.8% of the variance in health-seeking for the lastborn child, $F(175, 124196) = 273.37, p < .01$. What is more, South Asia has the lowest average level of investment in health-seeking behaviors ($M = -.19, SD = 1.05$) whereas the Near East/North Africa ($M = .30, SD = .85$) demonstrates, on average, higher levels of preventative behaviors towards their lastborn children. However, among all the countries, Chad has the lowest mean ($M = -.99, SD = 1.03$) whereas Nicaragua has the highest mean ($M = .48, SD = .67$) for health-seeking behavior.

Model 2: Main effects across countries

To test for the effect of the interaction terms, a set of regressions including only main effects across all regions was used. The main effects model revealed minimal differences from the interaction analyses. In fact, for all tests, the main effects model showed less explanatory power. For example, the overall predictive power of the first regression of region and country on maternal socioeconomic indicators without interaction terms is the same as the model already presented above for the interaction model. As such, it is not repeated here.

Prediction of maternal condition, on the other hand, yielded a model fit of 25.9% across the three predictors. That is, maternal resources, region, and country accounted for 25.9% of the variance in maternal biological condition, $F(36, 124335) = 1205.15, p < .01$. The interaction model discussed above (cf. Model 1) exceeded this by only .3%. Furthermore, the main effects model testing prenatal care for the lastborn child accounted for 46.6% of the variance in the dependent variable, $F(37, 124334) = 2937.19, p < .01$, whereas Model 1 accounted for 47.9% - a difference of 1.3%. Sex of the lastborn child

was even less noticeable with 49.1% explained in the main effects model, $F(38, 124333) = 3160.96$, $p < .01$, and thus a mere difference of 0.1% from the interaction model. Finally, health-seeking for the lastborn child accounted for 24.7% of the variance in the main effects model, $F(39, 124332) = 1043.43$, $p < .01$. As stated before, the interaction model accounted for 27.8% of the variance in health-seeking and thus exceeded the explanatory contributions of the main effects model by 3.1%.

The extent to which these are minor differences indicates that the conditional relationships tested in Model 1 have better explanatory power than the main effects model, albeit not by much. Essentially, a main effects model would suffice in terms of parsimony, given the nonsignificant contributions of the interaction terms overall. However, in order to draw upon the most parsimonious and best-fitting model, interaction terms were included in the additional regression analyses for the sake of testing effects across regions. These are presented next.

Model 3: Interaction effects across regions

Maternal socioeconomic resources. For the first regression testing for maternal socioeconomic resources, several trends were revealed. In Table 24 it is apparent that country accounts for 30% of the variance in maternal socioeconomic resources within the Latin American/Caribbean region, $F(8, 33519) = 1812.373$, $p < .01$. Likewise, in Table 19, country predicts almost 25% of the variance in maternal resources within Sub-Saharan Africa, $F(21, 52626) = 830.907$, $p < .01$. This is in contrast to 17% for the Near East, $F(3, 9910) = 669.903$, $p < .01$ and 9% for South Asia, $F(3, 28281) = 955.129$, $p < .01$ (see Tables 29 & 14, respectively). These results are meaningful to the extent that

they reveal how maternal resources vary as a function of country differences within each region. As such, 30% of the resources within the Latin American/Caribbean region are predicted by country-level variables whereas only 9% of the variation in resources within South Asia is determined by elements unique to the three countries representing that region. Note then, that the two regions with the greatest disparity in maternal socioeconomic resources relative to one another – Latin America/Caribbean and Sub-Saharan Africa – are also the ones in which country-level differences carry the highest levels of explanatory power.

Moreover, within the Latin American/Caribbean region, Haiti has the lowest average maternal resources ($M = -.318$, $SD = .946$) in contrast to the Dominican Republic, which was previously established as the country with the highest average level of maternal resources ($M = .973$, $SD = .989$) within that region as well as across all thirty-five countries. Also as stated earlier, Burkina Faso has, on average, the least maternal resources ($M = -.844$, $SD = .313$) available across all countries and thus, of course, the least within Sub-Saharan Africa as well. Zimbabwe, on the other hand, has the highest average maternal socioeconomic resources within Sub-Saharan Africa ($M = .206$, $SD = .884$), according to the measures used in this model. Within South Asia, Nepal had the lowest average for maternal resources ($M = -.671$, $SD = .639$), with Bangladesh slightly higher ($M = -.525$, $SD = .816$), leaving India with the highest average maternal resources ($M = -.063$, $SD = .996$) for that region. And within the Near East/North African region, Morocco had the lowest average maternal resources ($M = -.166$, $SD =$

.933) in contrast to Turkey, which had the highest ($M = .796$, $SD = .755$) of the three countries and second to the Dominican Republic for that measure across all countries.

Maternal biological condition. Regional differences for maternal biological condition are also demonstrated in that socioeconomic resources and country account for approximately 43% of the variance in maternal condition within South Asia, $F(6, 28278) = 3500.66$, $p < .01$, and almost 39% in the Near East/North African region, $F(6, 9907) = 1047.35$, $p < .01$ (see Tables 15 & 30, respectively). Within Latin America/Caribbean, the model accounts for 27.1% of the variance in maternal biological condition, $F(16, 33511) = 779.76$, $p < .01$, whereas the model has the least predictive power (8.1%) in explaining maternal biological condition within Sub-Saharan Africa, $F(42, 52605) = 110.37$, $p < .01$ (see Tables 25 & 20, respectively). Across all regions, increases in resources predict higher levels of maternal condition, as demonstrated by positive regression coefficients (in increasing order) for the Near East/North Africa ($\beta = .066$), South Asia ($\beta = .105$), Latin America/Caribbean ($\beta = .140$), and Sub-Saharan Africa ($\beta = .214$).

Interestingly, though, for both South Asia and the Near East/North Africa – the regions with the lowest and highest maternal condition, respectively – most of the variance captured by the model is explained by country; namely, 37% for South Asia and 31% for the Near East/North African region. Maternal resources, on the other hand, account for about 15% of maternal biological condition within the Latin American/Caribbean and the Near East/North African regions, while 13.4% of the explanatory power is provided by maternal resources within South Asia. In Sub-Saharan Africa, on the other hand, while the degree of explanatory power provided by maternal

socioeconomic resources is considerably smaller than that of any of the other regions, 6.4% of the variance in maternal biological condition of Sub-Saharan African mothers is explained by socioeconomic resources available to them – thereby representing 79% of the overall predictive fit of that regression model. Lastly, conditional relationships between country and maternal resources are significant but essentially trivial in effect size (ranging from .1 – .4%); suggesting, overall, that differences in maternal condition vary by country – not surprisingly – but that the relationship between how resources within country impact maternal condition is relatively consistent across regions.

Prenatal care for the lastborn child. Results from the third regression in Model 3 revealed that, for most of the regions, maternal socioeconomic resources explains about one-third of the variance in prenatal care for the lastborn child. Essentially, this pattern is repeated across regions to varying degrees with one noticeable exception for the region with the highest average of prenatal care; namely, within Latin American/Caribbean countries, maternal socioeconomic resources account for 45.7% of the variance in prenatal care while maternal biological condition accounts for 18.2% of the variance in the same measure. The entire model (as shown in Table 26) explains 55.5% of the variance in prenatal care, $F(24, 33503) = 1743.91, p < .01$. South Asia, the region with the lowest average level of prenatal care, follows a similar pattern of explanatory power in that maternal resources account for 35.5% and maternal condition accounts for 12.2% of prenatal care, whereby the entire model explains 44.7% of prenatal care in that region, $F(9, 28275) = 2543.11, p < .01$ (see Table 16).

Although only 5.6% of maternal biological condition within Sub-Saharan Africa accounts for prenatal care, the same measure carries no explanatory power within the Near East/North African region ($R^2 = 0$, $p = .318$). That is to say, country differences are more apparent within these two regions, with 20.3% and 23.3% of the variance in prenatal care, respectively, accounted for by the country variable. However, 30.6% of the variation in prenatal care within Sub-Saharan Africa is explained by maternal socioeconomic resources; likewise, 36% for the Near East/North African region. As such, the effect of country differences within Latin America/Caribbean and South Asia are smaller than those of the other two regions; namely, 11.9% and 10.5%, respectively. Nonetheless, the entire model for Sub-Saharan Africa, presented in Table 21, accounts for 43.7% of the variance in prenatal care for that region, $F(63, 52584) = 649.18$, $p < .01$. Moreover, the entire model for the Near East/North African region captures 46.9% of the variance in prenatal care across those countries, $F(9, 9904) = 971.73$, $p < .01$ (see Table 31).

Furthermore, across all regions, increasing maternal socioeconomic resources predicts increased levels of prenatal care, as determined by the following regression coefficients (in ascending magnitude): Sub-Saharan Africa ($\beta = .375$), South Asia ($\beta = .643$), the Near East/North Africa ($\beta = .706$), and Latin America/Caribbean ($\beta = .739$). Likewise, higher levels of maternal biological condition also predict higher levels of prenatal care within Sub-Saharan Africa ($\beta = .019$), Latin America/Caribbean ($\beta = .041$), and the Near East/North Africa ($\beta = .061$). Once again, though, South Asia falls away

from the cross-regional pattern here by demonstrating that lower levels of maternal condition predict higher levels of prenatal care ($\beta = -.017$) within that region.

Sex of lastborn child. Given that the aforementioned regression of Model 1 revealed only a meaningful effect for regional differences, testing the effect of maternal socioeconomic resources, maternal biological condition, and prenatal care within each region yielded interesting findings in the prediction of lastborn sons and daughters. For one, the model was significant for each region. Moreover, it carried the greatest explanatory power for Sub-Saharan Africa (see Table 22) by accounting for 49.9% of the variance in the sex of the lastborn child, $F(84, 52563) = 624.00, p < .01$ with 49.6% explained for the Latin American/Caribbean region, $F(32, 33495) = 1030.15, p < .01$ (see Table 27). The model for South Asia (see Table 17) accounts for 48% of the variance in predicting the sex of the lastborn child, $F(12, 28272) = 2173.30, p < .01$. Lastly, maternal resources and condition, prenatal care, and country differences account for 47.2% of the variation in predicting sons or daughters within the Near East/North African region, $F(12, 9901) = 736.59, p < .01$ (see Table 32).

Discrepancies in the extent to which each variable contributes toward predicting sons or daughters is where the regional differences become meaningfully apparent. For example, maternal socioeconomic resources account for 11.2% of the variance in sex of the lastborn child within Sub-Saharan Africa – again, the region with the lowest level of resources. Conversely, resources only account for 0.2% of the variance in sex within South Asia while the Latin American/Caribbean and the Near East/North African regions fall somewhere inbetween regarding predictive capacity (2.0 to 5.2%, respectively).

Parameter estimates for this predictor reveal that maternal socioeconomic resources predict lastborn daughters – as indicated by small, yet positive, regression coefficients – within South Asia ($\beta = .004$), Latin America/Caribbean ($\beta = .010$), and the Near East/North Africa ($\beta = .040$). The region that differs from this pattern is Sub-Saharan Africa, with a small effect for resources predicting sons ($\beta = -.003$).

Of all predictors for this regression tested within each region, maternal biological condition demonstrated the widest range; explaining between 1.8% to 24.7% of the variance in whether a mother's lastborn child was male or female. Specifically, maternal condition was least explanatory within Sub-Saharan Africa ($R^2 = .018$, $p < .01$) and yet contributed the most predictive power within the Near East/North African region ($R^2 = .247$, $p < .01$). Note again, that the latter region averaged the highest level of maternal condition for all regions as well. Additionally, the region with the lowest average level of maternal condition – namely, South Asia – demonstrated that 22% of the variance in sons or daughters was accounted for by the mother's biological condition. For Latin American/Caribbean mothers, 11.8% of the variance in sex for their lastborn children is explained by their biological condition. Furthermore, maternal biological condition shows a trend toward predicting daughters within all four regions: Sub-Saharan Africa ($\beta = .005$), the Near East/North Africa ($\beta = .008$), Latin America/Caribbean ($\beta = .011$), and South Asia ($\beta = .012$).

Regarding the last predictor in this regression, prenatal care accounts for 13.3% of the variance in sex within Latin America/Caribbean but only 0.8% within Sub-Saharan Africa. Again, Latin America/Caribbean had the highest average for prenatal care across

all regions. Moreover, prenatal care explains 6.7% of the variance in sex within South Asia (the region with the lowest average in prenatal care) and 5.5% within the Near East/North Africa. Finally, prenatal care yields a weak trend toward predicting lastborn sons – as indicated by negative parameter estimates – in three of the four regions: Latin America/Caribbean ($\beta = -.004$), Near East/North Africa ($\beta = -.004$), and South Asia ($\beta = -.006$). In contrast, to a very small degree, prenatal care predicts daughters within Sub-Saharan Africa ($\beta = .001$).

Health-seeking for lastborn child. The parental investment scale of health-seeking, as measured by immunizations and treatment for diarrhea, fit differentially across regions as well. Again, the model was the best fit for the Sub-Saharan African region, whereby maternal resources and condition, prenatal care, and sex of the lastborn child accounted for 33.4% of the variance in health-seeking behaviors, $F(105, 52542) = 251.29, p < .01$ (see Table 23). And again, the second best fit (i.e., 24.5%) was produced by testing the model within the Latin America/Caribbean region, $F(40, 33487) = 271.69, p < .01$ (see Table 28). The region with the highest average level of health-seeking – the Near East/North Africa – yielded a fit of 21.9% variance explained, $F(15, 9898) = 185.18, p < .01$ (see Table 33). Lastly, 21.4% of the variance in health-seeking was accounted for by the predictors within the region with the lowest average of health-seeking; namely, South Asia, $F(15, 28269) = 513.46, p < .01$ (see Table 18).

Examining the individual effect of each predictor reveals that maternal resources contribute between 0.8% (Latin America/Caribbean) to 1.9% (Near East/North Africa) explanatory power in determining health-seeking levels, whereby the model accounts for

1.4% of the variance in both Sub-Saharan Africa and South Asia. What is more, increases in maternal socioeconomic resources predict increases in health-seeking behaviors across Latin America/Caribbean ($\beta = .044$), the Near East/North Africa ($\beta = .215$), and South Asia ($\beta = .28$), with the exception of Sub-Saharan Africa ($\beta = -.082$).

Maternal biological condition once again reveals a wide distribution in effect size. That is, the region with the highest average maternal condition – the Near East/North Africa – demonstrated that 12.4% of the variance in health-seeking is explained by maternal condition whereas the region with the lowest average for this measure – South Asia – yields only 0.8% explanatory power for maternal condition. Sub-Saharan Africa and Latin America/Caribbean produced intermediate effect sizes for this variable (i.e., 3.0% and 5.4%, respectively). However, increasing maternal biological condition predicts higher levels of health-seeking behaviors across all four regions: South Asia ($\beta = .03$), Latin America/Caribbean ($\beta = .100$), Sub-Saharan Africa ($\beta = .148$), and the Near East/North Africa ($\beta = .236$).

Testing for the effect of prenatal care, Sub-Saharan Africa yielded the highest proportion of variance accounted for in health-seeking; namely, 24.3%. In contrast, the Near East/North African region produced the lowest with only 2.0% of the variance in health-seeking accounted for by prenatal care. Additionally, within the Latin American/Caribbean region, prenatal care explains 10.6% of the variance in health-seeking and 13.9% within South Asia. Here too, higher levels of prenatal care predict higher levels of health-seeking within the Near East/North Africa ($\beta = .085$), Latin America/Caribbean ($\beta = .092$), Sub-Saharan Africa ($\beta = .299$), and South Asia ($\beta = .33$).

Lastly, sex of the lastborn child accounted for 5.4% of the variance in health-seeking within the Near East/North Africa, 4.8% within Latin America/Caribbean, 2.7% within South Asia, and 1.4% within Sub-Saharan Africa. Furthermore, health-seeking behaviors were differentially allocated to sons over daughters within the Near East/North Africa ($\beta = -.081$), Sub-Saharan Africa ($\beta = -.033$), and South Asia ($\beta = -.12$). Conversely, lastborn daughters were receiving more health-seeking attention ($\beta = .028$) within the Latin American/Caribbean region.

Summary

That there are demographic differences between regions is not at all surprising. By contrast, the extent to which the overall model fits, despite the demographic variation, is noteworthy. In summary, the overall model across all countries (Model 1) yielded small, but significant, cross-regional effects; namely, parametric variation in the regressions indicates that the effect of each predictor is stable but that the exact magnitude of each effect varies by region, as a mere matter of degree. Furthermore, the difference between the interaction and main effects models (i.e., Model 1 and 2) suggests that the more informative test involves an interaction model – even though the main effects were rather robust on account of trivial, but significant, interactions. Additionally, given the fit of Model 1 in terms of overall significance, yet lacking explanatory power for the sex of the lastborn child, subsequent analyses testing the model within each region (Model 3) produced more interpretable, stable, and meaningful patterns – albeit, small effects on several counts.

In brief, South Asia yielded the lowest levels of maternal biological condition, prenatal care, and health-seeking whereas the Near East/North Africa demonstrated the highest levels of maternal biological condition and health-seeking. Moreover, while Sub-Saharan Africa is characterized by low maternal socioeconomic resources, the Latin American/Caribbean region is characterized by high maternal socioeconomic resources as well as high prenatal care levels. These differences notwithstanding, the regression analyses testing for the Trivers-Willard hypothesis reveal stable, yet varying, patterns across and within regions. For some regions, these effects are very small – indeed, tiny (e.g., maternal resources explains only 0.2% of the variance in daughters within South Asia).

Despite some of the small effects – or, in fact, because of them – these results reveal some interesting conclusions nonetheless. In other words, given the design of this study – from the selection of the variables for the scales, based on theory and previous comparative research, to the analytical strategy employed – the extent to which the model fit the data across regions is salient towards addressing the relevance of testing the Trivers-Willard hypothesis in humans. And to the extent that previous research can place these differences in context in terms of understanding how differential parental investment is expressed in humans across several cultures shall be discussed in the following chapter.

DISCUSSION

“Each man carries the vestiges of his birth – the slime and eggshells of his primeval past – with him to the end of his days. Some never become human, remaining frog, lizard, ant. Some are human above the waist, fish below. Each represents a gamble on the part of nature in creation of the human. We all share the same origin, our mothers; all of us came in at the same door.” - Herman Hesse, Demian.

Interpretation of findings

As established by previous research, males are born at a higher frequency, with the average sex ratio in humans estimated to be 1.06 males born for every female. However, variations across countries exist and a comparison of the current sample sex ratio with national estimates thereof, yielded three evident patterns: one where there is a drop in the number of males but they continue to outnumber females; one where males decrease so drastically within the first five years of life, that the sex ratio becomes female-biased; and one where males initially predominate in number and increase, due to what can only be attributed to a loss of female children.

All things considered, though, while the descriptive characteristics initially presented confirm foreseeable demographic differences, the system of regressions used in this research places those differences and similarities into perspective regarding an evolutionary framework as provided by the Trivers-Willard hypothesis. That is to say, both sons and daughters are being impacted, in part, by pre- and post-parturitional events. However, for three out of four regions, the expression of these maternal effects differs – for daughters, it is in the mother’s physical condition and status, and for sons, in her health-related behaviors. Interestingly, the strongest effects in this model are those of maternal biological condition predicting daughters for the countries with the highest sex

ratios...and not just the highest sex ratios – but specifically those countries where the sharpest decline in daughters appears to be most evident (refer again to Figures 3 & 4, i.e., Turkey, Egypt, Morocco, and India).

Analyses within regions revealed that maternal biology is predicting lastborn daughters in all four regions and maternal resources are predicting lastborn daughters in three of the four regions. Specifically, the two regions with the highest and lowest average maternal biological condition – the Near East/North Africa and South Asia – also yielded the strongest effect for maternal condition; namely, 22 to 24.7% of the variance in sex, respectively, is predicted by maternal biological condition. And evidently, maternal condition predicts female lastborn children in those regions. This is particularly interesting given that these are the regions that are also the most male-biased in terms of the sex ratio for this study sample. It would seem then, that despite the disparity in maternal condition, mothers in countries with high sex ratios are producing female children when in good condition, as defined for this study.

Furthermore, maternal biological condition predicts 11.8% of the sex of the lastborn child among mothers within Latin America/Caribbean – the region with the highest average maternal resources. Here also, daughters are predicted by better condition. Note, also that the greatest regional disparity across the measures for maternal condition and resources yielded the most variance explained by country-level differences. Yet interactions were small enough to indicate that the relationship between maternal condition and resources within countries is consistent across regions. Moreover, while maternal resources predict daughters in three of the four regions, the strongest effect for

resources was in predicting sons in Africa. Note also, however, that while Africa had the lowest level of resources relative to the other regions, the effect for predicting sons was remarkably weak.

Conversely, protective and preventative elements, as demonstrated by the prenatal care and health-seeking dimensions in this model, indicate that lastborn sons are being maintained through maternal behavior in three of the four regions as well, albeit also weakly. In other words, while daughters in Sub-Saharan Africa are barely predicted by prenatal care (i.e., 0.8%), for the other three regions, prenatal care predicts sons – with the strongest effect for Latin America/Caribbean prenatal care (13.3%). And while health-seeking within the Latin American/Caribbean region predicts daughters, for the other three regions, higher levels of health-seeking predict sons. In fact, the strongest effect for health-seeking was in the Near East/North African region in predicting sons. Figure 5 is provided as an overview of the regional findings from Model 3.

That prenatal care predicts sons, although weakly, in Latin America/Caribbean, South Asia, and the Near East/North Africa suggests that survival of boys is enhanced by improved access to prenatal care and is indicative of the research on differential male mortality, whether in utero or postnatally (Beise & Volland, 2002; Wells, 2000; Williams & Gloster, 1992). Additionally, these results support preferential treatment in health-seeking as documented by previous studies (e.g., Basu, 1989; Hossain & Glass, 1988).

Essentially, results yield a pattern whereby maternal condition predicts daughters and behavior predicts sons; with Sub-Saharan Africa deviating the most from this pattern and Latin America/Caribbean deviating only by showing more health-seeking for

daughters. In fact, perhaps the latter can be attributed to the results of another study on women and children in the Caribbean that found a "partiality for female children" (Sargent & Harris, 1998, p. 202) which might explain why these mothers contrast with all other regions on this particular scale. Furthermore, the lack of significant differential mortality patterns within Africa may be due to the "economic value of children in many African groups" (Lazarus, 2002, p. 294).

As can be understood from the descriptive analyses, the picture that emerges across these four regions is one of discrepant characteristics across the given parameters examined, with a remarkable pattern of female loss in those countries where up to 25% of maternal condition accounts for the presence of lastborn daughters. And, as mentioned at the beginning of this paper, given the interest in applying evolutionary theory to humans, there is the need to identify indicators for at-risk populations. Although Nepal is the only country to have a higher infant mortality rate for its females than its males, it is evident that females are "disappearing," as numerous accounts have documented selective infanticide across South Asian and Near Eastern countries (see Croll, 2000; Freed & Freed, 1989; George, 1997; Jeffery, Jeffery, & Lyon, 1984; Krishnaswamy, 1984; Miller, 1987). The data here seem to confirm this phenomenon for these regions.

Returning to the topic of mating systems so central to the TW hypothesis, one element that seems clear is that male-biased mating systems tend to move towards monogamy – as opposed to polyandry – with the exception of some avian reproductive strategies. As such, it has recently been predicted that countries where particularly high sex ratios predominate will be faced with severe constraints on mating opportunities and

this will exact itself in higher rates of male aggression (Pedersen, 1991), with even a higher risk of terrorism proposed (Hudson & den Boer, 2002, 2004). Research on primates even demonstrates that social systems become unstable if high-ranking mothers produce too many sons (Altmann & Altmann, 1991). Furthermore, females may become more valued in that the sex ratio imbalance in some countries risks establishing a significant dearth of wives which, in turn, may "...enhance the social value of daughters, reversing their vulnerability and the force of male dominance" within those countries (Dickens, 2002, p. 336). On the other hand, in a study on infanticide and amniocentesis in North India, Jeffery, Jeffery, and Lyon (1984) remark that "...there is no evidence that women are an economic commodity for which scarcity will raise their value...rather, their scarcity is symptomatic of their low value" (p. 1211).

Interpreting these findings in terms of the Trivers-Willard hypothesis, then, leaves us with several points of contrast. For one, if the measures used in this study capture the original concepts of maternal condition and parental investment – by focusing on manifest indicators that seem to represent the most reliable piece of information regarding these concepts – then indeed, it would seem that the Trivers-Willard effect is either particularly weak in humans or altogether absent. As was the case in another study that found only mild support for the TW hypothesis at extreme levels of paternal education, the authors argue that "...given the large sample size of this study, this raises the possibilities that the T-W effect may be either elusive or immeasurable in modern societies" (Koziel & Ulijaszek, 2001, p. 77).

Similarly, Teitelbaum and Mantel propose that "...detection of small or moderate effects on the sex ratio requires very substantial sample sizes" (1971, p. 25). In their study they found that the human sex ratio was significantly associated with socioeconomic variables (i.e., social stratification, income, position, education) but that the strongest effect was for an increase in the sex ratio from the lowest to moderate socioeconomic groups whereas the moderate to highest status groups yielded nonsignificant changes. Essentially, they found the strongest effect within the most adverse condition (i.e., lowest status group). Likewise, Webster (2004) also found that the TW effect was strongest among poorer families while applying the Bounded Risk Distribution (BRD) model to a sample of British Columbian wills.

Other studies on animals have found the biggest difference within the lowest condition group; for example, in red deer and macaques the "differences in relative fitness of sons and daughters and differences in the relative costs of rearing male and female offspring can favour variation in the sex ratio" (Gomendio, Clutton-Brock, Albon, Guinness, & Simpson, 1990, p. 261) denoted as the cost of reproduction hypothesis. Joshi (2000) proposes a similar effect of diminishing returns in that a ceiling effect of resource availability would render the "Triversian" strategy not optimal once resources exhibit less disparity across conditions. A good question becomes "What, then, is the range of validity of the Trivers-Willard hypothesis?" (ibid., p. 2). In that case, the question then becomes: Are humans adjusting their sex ratios in some other way, for some other purpose, or even perhaps not at all?

Sargent and Gross (1985) review two principles that seem relevant here: the Concorde fallacy and the Williams principle. The former pertains to the role of expected benefits in future investment. Essentially, they argue that when animals determine the level of risk of investment based on what has already been invested and act so as to minimize the loss thereof, this commits the Concorde fallacy. Furthermore, the Williams principle states "...that at any point in time an animal invests in its brood so as to maximize its remaining lifetime reproductive success, subject to a tradeoff between present and future reproduction" (ibid., p. 45). For example, in insects, when reviewing patterns of maternal care, Tallamy and Brown (1999) found that some insect mothers care only because they can, i.e., the costs are few. Furthermore, insect mothers limited in reproductive success during one breeding season "...gain considerably from continuing to invest in the offspring they have already succeeded in producing" (p. 729).

What if, for example, the mammalian secondary sex ratio is *not* an outright measure of differential investment, per one of the initial assumptions of the Trivers-Willard theory? Is it accurate to "assume" investment when chances of one sex against the other are 50/50 at baseline anyway? Given results of other studies, i.e., numerous factors that potentially mediate sex ratios, perhaps sex selection at conception in humans should not assume parental investment. While coypu and mice may be capable of spontaneously aborting, no research to date has demonstrated such a systematic manner of sex ratio manipulation in humans. In fact, what seems paramount in humans is not merely parental ability to invest, but willingness to do so. A test of differential parental investment should therefore include assessment not only of whether parents *can* care and

to what extent they do, but whether there are certain parameters that might influence that they care at all.

For example, the research on son preference often approaches the question of preference from the assumption that parents in many countries outrightly favor males. While this may be true, the benefit of the timeframe for the data collection used in this study suggests – in contrast to the recent upsurge in the use of amniocentesis for in utero detection of neonates' sex – that whatever adjustments might have been made to the secondary sex ratios of the respective countries, they were more likely than not uniformly committed postnatally. However, there are variations in the costs and benefits of daughters and sons in developing countries. That is, sons are costlier, as evidenced by higher levels of investment in health-seeking behaviors across all four regions. And the research on infant mortality of these "fragile sons" confirms their cost.

The fact that Sub-Saharan Africa deviates somewhat from the pattern found for the other three regions is potentially explained by the degree of polygyny across those countries. That is, polygyny may afford more autonomy to wives than monogamy does and the husband's influence is even more denounced the higher the woman's education is (Dodoo, 1998). Indeed, there is substantial variation in the degree of polygyny across these countries. For example, according to *DHS+* information from the surveys used in this study, almost 51% of women in Burkina Faso report having two or more co-wives present and 46% of women from Senegal report having one other wife present. In contrast, 96% of women in Madagascar are not in a polygynous union and the same for 75% of women in Comoros. Furthermore, of those 25% who have a co-wife, 71% only

had one co-wife, according to another study (Althaus, 1997). An additional point of interest in that research was the degree of marital rate differences between men and women, i.e., 48% of the men were unmarried in contrast to 39% of the women.

Namely, it would seem that polygyny can leave almost half of its male population without a mate. As such, the trend for the African countries in this data would suggest a mild Trivers-Willard effect in that if mothers have the resources, they produce sons. Otherwise, even when in good physical condition, they invest in producing daughters. Note, however, that the effect for the resources was somewhat greater than that of the effect for physical condition. As such, this is the closest this analysis seems to come in supporting the Trivers-Willard hypothesis across the thirty-five countries examined herein – and even then, merely establishes a weak effect.

Given that there seems to be a weak effect concerning the relationship between condition and differential investment, the central question then is whether this might indicate a pattern that is either currently adaptive or an ancient vestige from an earlier evolutionary adaptation. In fact, where there seems to be consistency across studies focusing on the TW hypothesis in humans is in how authors often propose numerous alternative explanations to account for the weak and inconsistent results found in humans. For example, the TW hypothesis may not fit our species for any number of reasons such as the variation in levels of paternal care, degrees of polygyny, and relative resource levels that may be driving some of the differences (Keller et al., 2001; Webster, 2004). Additionally, the reproductive value of offspring – instead of reproductive success – may be based on maternal phenotypic quality to the extent that fitness has not been reliably

documented across human and non-human studies (Hewison & Gaillard, 1999; Sheldon & West, 2004). Moreover, parental investment in humans is complicated by at least three variables, according to the differential payback hypothesis, in that fitness returns are influenced by raising costs, parent-offspring conflict and other familial interactions, in addition to offspring reproductive success (Smith & Smith, 1994).

Furthermore, life history strategies across species – even if only focusing on mammalian reproductive ones – may be too variable to produce a one-size-fits-all model (Cockburn et al., 2002). Perhaps reproductive success of human males is not impacted by maternal effects (cf. Hrdy, 1999) or the reproductive success of men in male-biased countries is so low that women favor producing daughters (e.g., cost of reproduction hypothesis; Gomendio et al., 1990; Myers, 1978). Better yet, status and reproductive success are not related in humans the same way that they seem to impact other animals (Freese & Powell, 1999; Lazarus, 2002).

Indeed, given all these concerns, Mealey and Mackey (1990) propose a threshold effect may be present in humans in that the TW hypothesis “cannot by itself predict which species will exhibit sex ratio biases under which conditions, or whether sex ratios will exhibit continuous variations or respond to some environmental threshold” (p. 92). That analyses across such a large sample should produce such remarkably weak results implies that a threshold effect may be evident. Results here are, to some degree, another example of support for the conditional extreme values of the TW hypothesis, as demonstrated in previous studies on humans (e.g., Teitelbaum & Mantel, 1971; Webster, 2004).

In fact, what is noticeable in the results of this study is that women in good condition within male-biased regions are investing in the rarer sex – namely, daughters – while the more female-biased countries within Sub-Saharan Africa seem to be investing in sons (given the weak effect for maternal condition in predicting daughters in this region). In short, these results seem to support Fisher’s hypothesis – particularly the homeostasis element – whereby parents are predicted to “respond to a low number of one sex by producing that rare sex” (Cockburn et al., 2002, p. 269). Other studies on humans have tried to assess the extent to which frequency-dependent selection could be driving the sex ratios (e.g., Lummaa, Merilä, & Kause, 1998; Schmitt, in press).

Assumptions and limitations

Anderson and Crawford (1993) as well as Carranza (2002) provide critical reviews of how the TW predictions beg modification in order to be appropriately applied to humans. For example, Freese and Powell (1999) did not find support for the TW hypothesis in humans in that they showed no sex-biased differences in socioeconomic investment. On the other hand, they failed to mention paternal care as a potential confound. They conclude with: "...the evidentiary burden would now seem to fall upon those who might attribute our findings to the exceptional character of American society rather than to the more fundamental limitations of the theory" (p. 1737), citing sociologists' "professional obligation...to test [sociobiological] hypotheses fairly and rigorously" (p. 1738).

It is hoped that was accomplished here. Although, it should be recognized that all that was done here was information analysis using a specific framework that allowed for

empirical testing. And given that information is stored in points of contrast, the observation that good condition mothers in male-biased countries show a tendency toward producing daughters and that there are not enough daughters in these regions to account for this pattern, is indeed an important point of contrast. Despite all attempts, however, to be thorough and to minimize error, something somewhere is always flawed in some way. To the extent, however, that these results do not reflect some "exceptional character" of the four regions examined, it is necessary to outline potential sources of error.

Potential measurement error. For example, while the overall sample size of this study bodes well for the statistical power in the analyses, such a multi-sample approach by default enhances the possibility of variation in sampling across so many countries. Furthermore, while selection of the lastborn child, as opposed to selection of the oldest child, may capitalize on the idea that memory recall for the youngest will be better and therefore more likely to be accurate, focusing on the oldest child might serve as a better source for measuring parental investment since the oldest child exemplifies the longest period of investment provided by a given mother to date. However, identifying whether a child in the data is the oldest child or not is difficult since the children reported are more likely to be the ones still living at home and thus, count among a woman's younger children, especially when birth order numbers run as high as 18 for some women. Not to complicate matters, but according to previous studies on birth order, the selection of the lastborn child is also confounded by the possibility that the favored child was being studied (Rohde et al., 2003). This is reminiscent of a suggestion posed by Trivers that the

ultimate confound in sex ratio research overall is the idea that such research may be confounded by the sex most likely to get caught for observation, as opposed to the “true” sex ratio within a given species (2002, p. 62).

Naturally, there are numerous problems associated with survey data in general. Standardization, whether in technique or measurement, limits the possibilities of responses. The very nature of defining something as a “problem” invites people to wonder whether they actually have one. The role of demand characteristics, for example, is not limited to a laboratory setting either. McCombie and Anarfi (2002) show that the sex of an interviewer can affect differences in responses to surveys and points out that response biases may occur despite systematic methodological precautions. While observational data has been the methodology of choice for several other studies, both human and nonhuman, this research focused on self-report data as provided by the surveys and is prone to any of the typical errors common to such methodologies.

Furthermore, the issue of reporting error endemic to survey research is such that, although no noticeable sex-biased differences were apparent across diarrhea treatment-seeking behaviors, this could in fact be an effect of reporting error alone. That is, numbers that indicate a child did not have diarrhea could, essentially, be numbers that reflect neglect rather than accuracy. Given that these household surveys rely on the mother’s memory – both in terms of accuracy and honesty – some of the data could be actually reflecting perceptions of what a “sick” child looks like as well as the error inherent in a parent’s preference for noticing, let alone treating, an ill child. While this study attempted to rely on information that was as empirical and as removed from

reporting error as possible, it nonetheless requires self-report. One safety mechanism is that *DHS+* attempts to verify parental report by asking for medical records whenever appropriate. Given the current data here, fortunately, at least respondent resistance tends to be lower in developing countries than within industrialized countries (Macro International Inc., 1996).

Problematic data. Several variables were excluded from analysis because their inclusion would have required dropping a meaningfully significant number of cases (e.g., 50%) from the entire sample across countries. For example, some of the breast-feeding data could have been incorporated into the parental investment measures; however, there are numerous theoretical justifications for why this might have actually weakened the scale, as mentioned earlier. Additionally, there is the potential confound of HIV prevalence and its effect on lowering breast-feeding rates in certain countries that have concentrated on discouraging women from breast-feeding so as to reduce the risk of HIV transmission to infants.

Specifically related to this study, however, information concerning breast-feeding duration was missing for 61% of the children. For example, a large proportion of the missing data cases involved children who were unweaned at the time of the interview, as indicated by reports that the child was being breast-fed. While breast-feeding duration was recorded for some of the weaned children, in cases where the mother was reported as currently breast-feeding, then breast-feeding duration was not recorded for that child. This may have indicated, of course, that the child was still being breast-fed. However, this could not be assumed given the following issue; namely, although some of the

children ($n = 709$) were reported as never having been breast-fed, their mothers were reported as currently breast-feeding at the time of data collection. As such, it is possible that they were wet-nursing for other children. This would suggest systematically missing data. On the other hand, there could be random error in the data.

Either way, this allowed for too many assumptions about the breast-feeding duration information whereby attempting to construct a parental investment measure using the breast-feeding information would have required imputing too much for 61% of the sample of lastborn children, thereby skewing the final analyses. Even if reliable breast-feeding duration information had been available, it would have been complicated by the fact that clearly some of these children were still being breast-fed and so the comparison of unweaned to weaned would have involved several confounds as well, one of which would have been questionable accuracy in recall for weaned children.

To appreciate the variation in breast-feeding duration which may be attributable to cultural, socioeconomic, or reporting error, see Figure 6 (for regional variation in the current data) and Table 34 (for comparisons of median breast-feeding duration). The conservative analytical approach used in this research made it necessary to exclude the breast-feeding information even though prior studies have relied on it as a measure of parental investment (e.g., Gaulin & Robbins, 1991). That is to say, breast-feeding information is otherwise uniquely problematic as a measure of parental investment, regardless of the measurement issues involved in the data for this study; not least of which are the variations in breast-feeding practices across countries. An additional issue concerns a mother's inability to provide breastmilk – i.e., there were no indicators in the

data for whether a mother could even breast-feed in cases where the child had not been, or was not being, breast-fed.

Furthermore, concerning pregnancy status – if maternal condition includes current pregnancy, as measured in this study, this may be correlated with birth order effects given cultural preferences, in that the lastborn child examined may be a female because she is the firstborn – and was retained for her expected household "assistance" purposes. On the other hand, only 10% of the current sample was pregnant so that such cultural effects might not contribute too significantly to the overall model.

Of course, with a sample this large, it can be a challenge to identify "bad" data, extreme values, and significant outliers given that for almost any indicator, there are bound to be multiple cases that fall outside the expected ranges. And the question then is, what decides the outer limits of a potential indicator? For example, although household composition variables were not included in the analyses, six households in Senegal were listed as having 80 members. This was initially strange until it was revealed that the composition of households within Niger and Cote d'Ivoire was almost as high. Given polygyny rates in some areas, without further information, it was difficult to determine what exactly a "household" was...and as such, this issue could be a valuable aspect included in additional research on this topic. That is, incorporating information concerning households would provide an interesting test of the local resource competition or enhancement hypotheses.

Additionally, particularly relevant information concerning polygynous pairings was missing from the data at hand. As stated before, given that the samples in this study

certainly cover countries where polygyny is common, and given that previous studies on humans have focused on the role of polygyny in determining sex ratios and differential parental investment, it would have been informative to have included that in the measure. At the same time, measuring the direct and indirect endogenous effects of polygynous households is a challenge and beset with confounds pertaining to measurements of the division of labor, caregiving, and attention that might make such an analysis even more difficult. Furthermore, degrees of polygyny would represent the mating system and thus address mostly the overarching assumption of the theory, not the predictors (maternal condition and parental investment) nor the differential outcome (sex of the lastborn child). Lastly, definitions of parenthood – while varying across monogamous social structures as well – can be even more conflated within households where alloparenting is not only normative but inherent within the very structure of the social situation.

Suggestions for future research

Questions that remain. The foremost issue is the notion of condition – what exactly did Trivers and Willard mean by it? And why have so many different interpretations been applied to it? If they meant weight and body size for polygynous animals where paternal care is trivial, then the theory can be tested on those species and probably should not be expected to fit others. Which is to say, with so many constraints involved in terms of "well-defined conditions," is it really that surprising that there is so much variation not only in the results that have been revealed across species but in the extent to which this theory has been applied?

To the extent that other studies recommend that a true analysis of the TW hypothesis would have to test for whether maternal condition predicts offspring reproductive success and then examine the variance of reproductive success between siblings, it is slightly odd that more studies have not actually done this; that is to say, on species where reproductive success can be tracked. To test for sex of offspring alone, in the absence of the predicted covariates, actually omits significant components of the theory. Indeed, with the exception of a study by Borgerhoff Mulder (1998), an interactive effect between status and differential reproductive success between human siblings has not been thoroughly established nor even examined (Lazarus, 2002).

For now, one has to wonder about the findings of the model examined here. After all, why would better-condition mothers be more likely to produce daughters in countries with high sex ratios? And what is happening to the lastborn daughters? That is, if 49% of the women in the Near East and North Africa are overweight and this seems to account for 25% of the sex of lastborn children, with heavier women more likely to produce daughters...where are the daughters? These results could indicate that high sex ratio environments – particularly as extreme as those of the South Asian and the Near Eastern/North African regions – might cue mothers in good condition to produce daughters in much the same way that the ambrosia beetle modifies her sex ratio based on local mating possibilities for her children. Of course, given the specific results of the model, that still leaves about 75% of the variance in offspring sex unaccounted for and what happens post-parturition to the human daughters is not explicitly addressed in this model. One can only presume other postnatal adjustments taking place because, certainly,

postnatal health-seeking is more likely to be directed at maintaining sons. So, in accordance with Gadagkar's comment, "...it is today's speculation that will guide tomorrow's research" (2000, p. 380), the following is an outline of tentative ideas for possible further exploration on this topic.

Model modifications. As such, the following include some recommendations for examining differential parental investment in humans. For example, future analyses should include variables concerning child nutritional status as a measure of parental investment – such as height-for-age, weight-for-height, weight-for-age, and birthweights. These would better inform the model concerning maternal effects – whether short- or long-term – upon offspring condition. As previously suggested, analysis of the reproductive success of offspring, as well as reproductive value, would enable a more representative test of the original theory.

Also, measurement of maternal effects should consider the inherent properties of each predictor (i.e., whether static or dynamic measures are used). For example, one potential problem with the current study is that mothers were measured for BMI postnatally for the child being studied. Other studies have documented the same concern (e.g., Andersson & Bergstrom, 1998) while one study suggests that BMI may not be the best measure of maternal condition since it does not distinguish between obese and muscular women (Gibson & Mace, 2003). Although the issue of prediction here is that a mother in good condition is more likely to be parent to one sex over the other, it has been recommended by other studies that maternal condition at preconception would serve as a better test of the presence of facultative adjustment (Cameron, 2004; Sheldon & West,

2004). For example, it would be interesting to test the sex ratio against expected averages at the primary and secondary levels; namely, 3 months post-conception (1.2:1) vs. at birth (1.06:1) sex ratios (from Cartwright, 2000) to examine the juncture at which sex ratio manipulation might be occurring.

Furthermore, although some previous research has indicated that birth order does not appear to directly determine sex ratios, there is still the question of whether birth order – or even sex of the child – affects maternal condition (Stein, Barnett, & Sellen, 2004). As such, applying the model using the oldest child as the unit of analysis and comparing against the lastborn child in cases of sibship and partialing out the difference, while holding other variables constant, might assess the impact of previous births on maternal condition. However, a limitation in the current data set is that only children under five years of age were included. As such, information for the oldest child of all mothers was not available. Moreover, an additional variable that may impact maternal condition involves the age difference between mothers and fathers. Finally, sex ratios by age group should be examined. If this yields a specific pattern of sex ratios across age groups, this might elucidate differential mortality of males or a pattern of female infanticide.

Conclusions

There is something inherently poetic in the original theory of Trivers and Willard. That is, the idea that maternal effects are retained from development into adulthood is reminiscent of a comment by the poet Rainer Maria Rilke: “Perhaps we are our childhood still, for as St. Augustine said, ‘Whither should it have gone?’” This would seem to apply

across all cultures; at least, an evolutionary model such as the one used herein naturally presupposes that all of us carry the past with us, at all times. And, given the geographic and cultural expansiveness of this study and the conservative fit of the model, these patterns indicate the application of the evolutionary approach to human biology and behavior as clearly salient – not so much because the Trivers-Willard hypothesis is only weakly expressed in our species, but because it was demonstrated here to be consistently weak across a sample involving thousands of mothers and their lastborn sons and daughters.

Which is to say, that while the African countries deviated somewhat from the pattern found in the other regions, these differences are not necessarily all that striking. Essentially, in testing for adaptive facultative sex ratio adjustment in humans, it was found that human mothers may be investing in their sons not out of lack of preference for their daughters, but because they have to – given higher rates of male mortality. Hence, we see the preponderance of prenatal care and health-seeking directed toward last-born sons. Furthermore, in those countries that have noticeably high sex ratios (e.g., India, Nepal, Egypt, Morocco, and Turkey), mothers in good condition are investing in daughters while mothers in the more female-biased African countries (e.g., Mali, Mozambique, Senegal, Uganda, Zambia, and Zimbabwe) are investing in sons.

Surprisingly, both of these patterns provide more support for the frequency-dependent homeostasis element of Fisher's (1930) original theory. Thus, at the end of the day, the specific relevance of the Trivers and Willard hypothesis to humans may be, after all, just another storm in the teacup. Either way, though, while we may differ from

opossums, red deer, and wood rats on this topic, we are still in good company with many of the other animals.

Figure 1. Theoretical & empirical model of the study

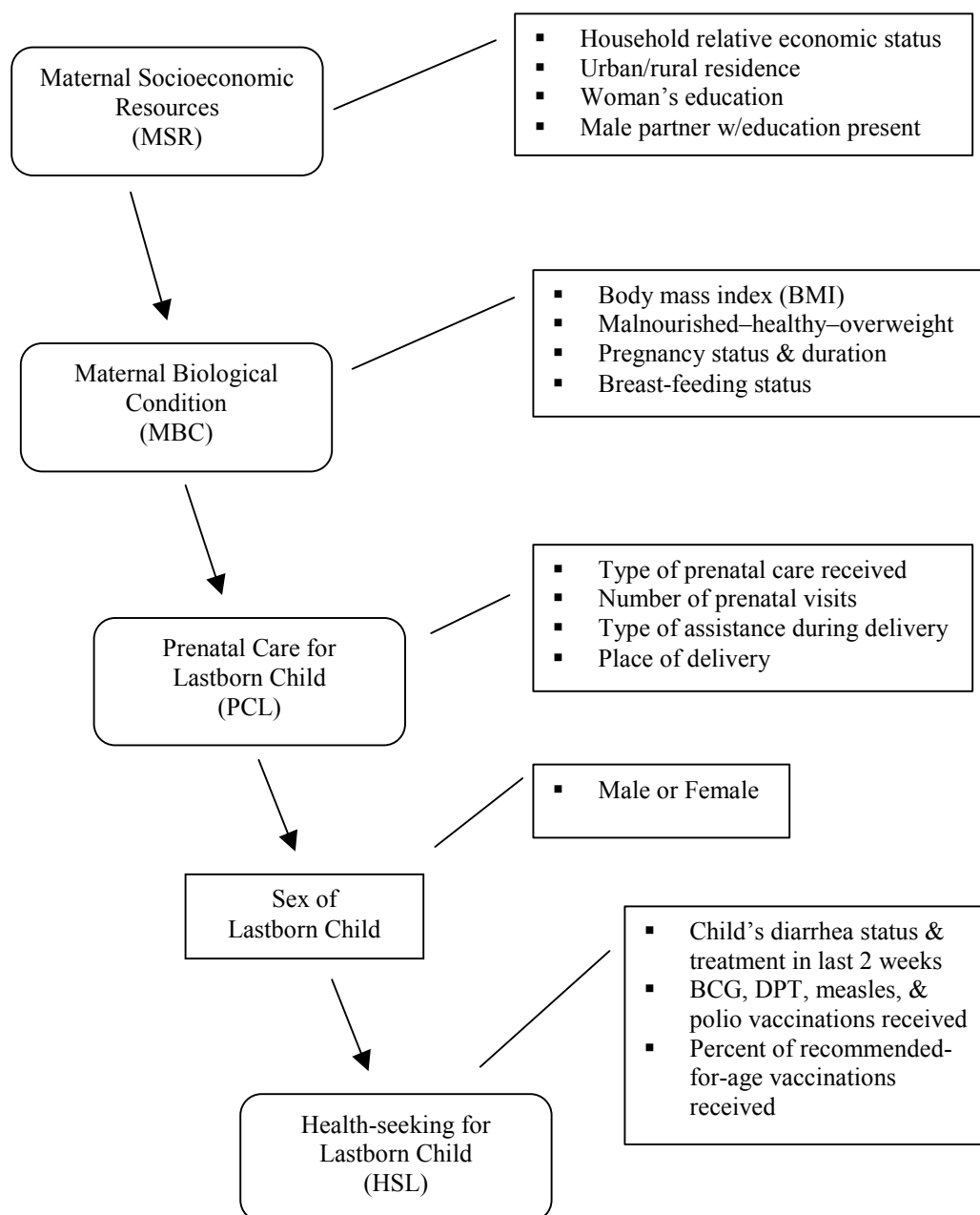


Figure 2. Representation by region

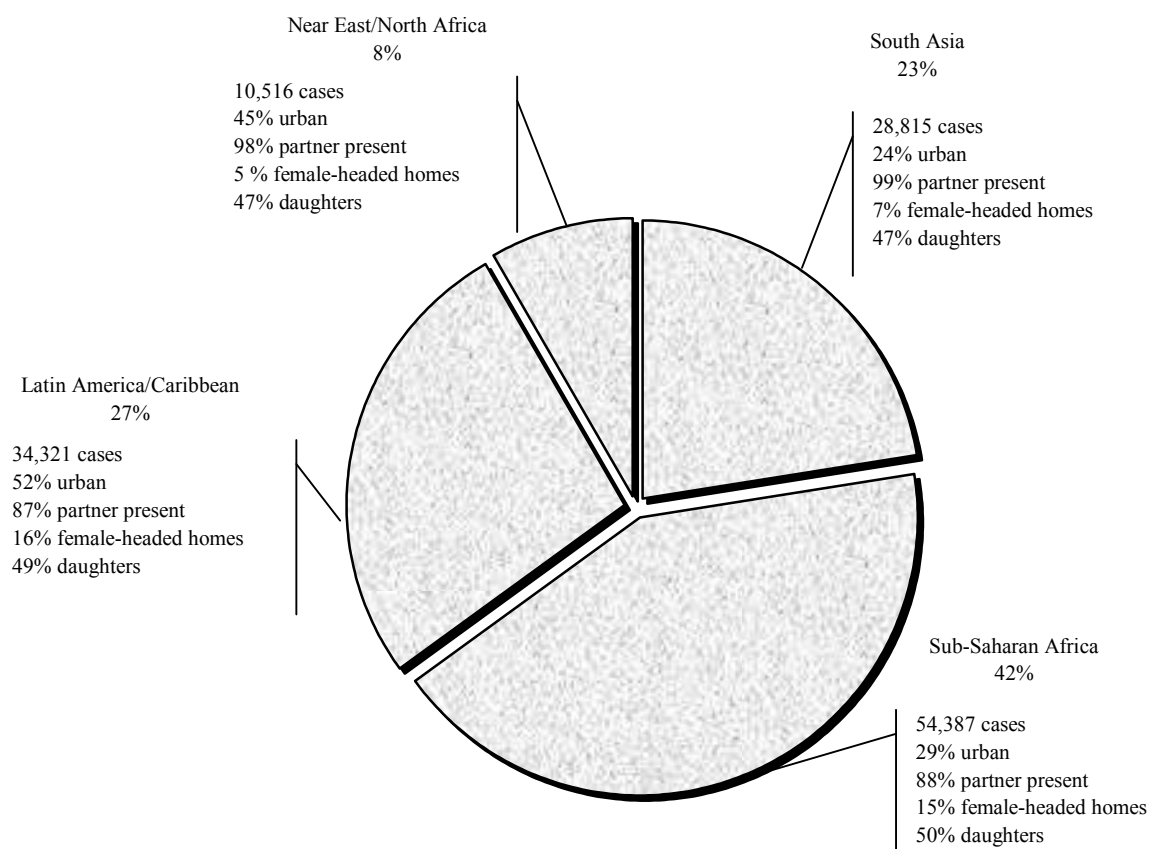


Figure 3. Cross-national percent change in sex ratios

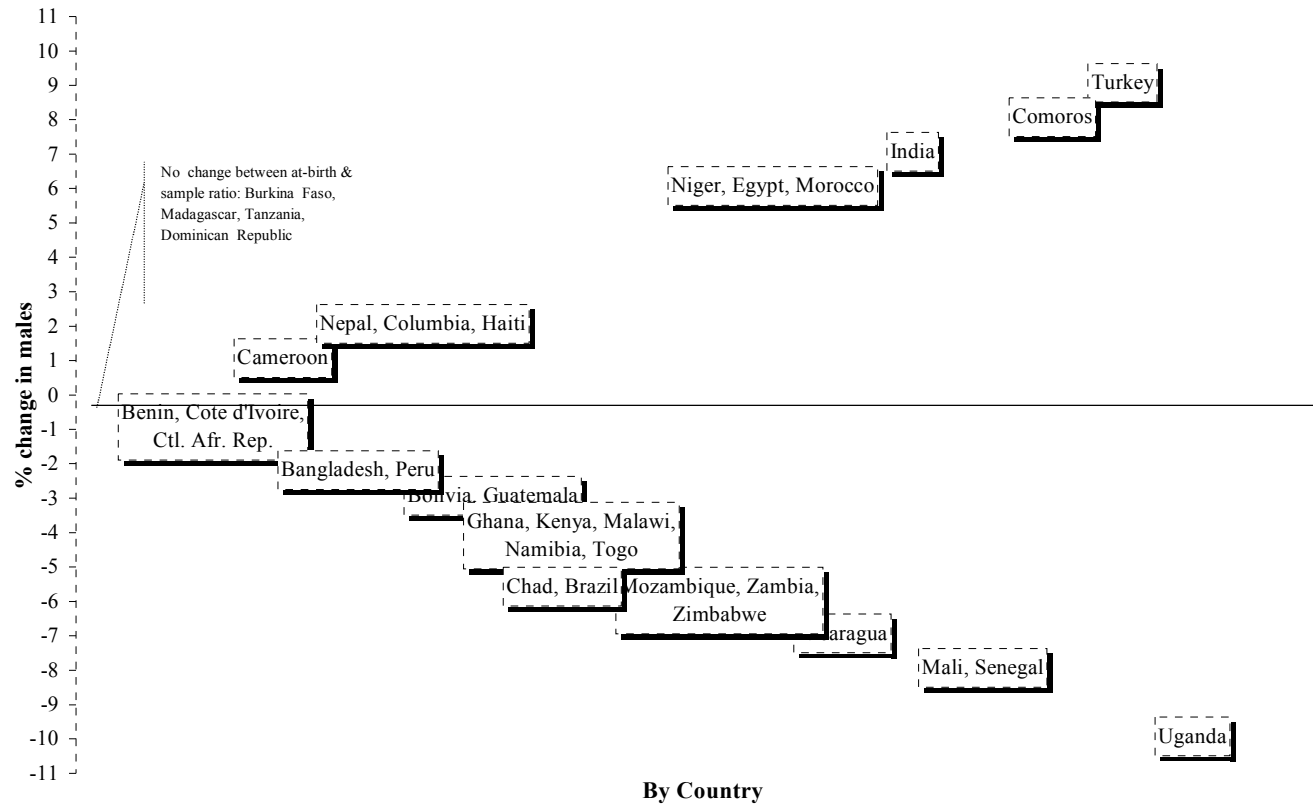


Figure 4. Cluster tree of country sex ratio comparisons

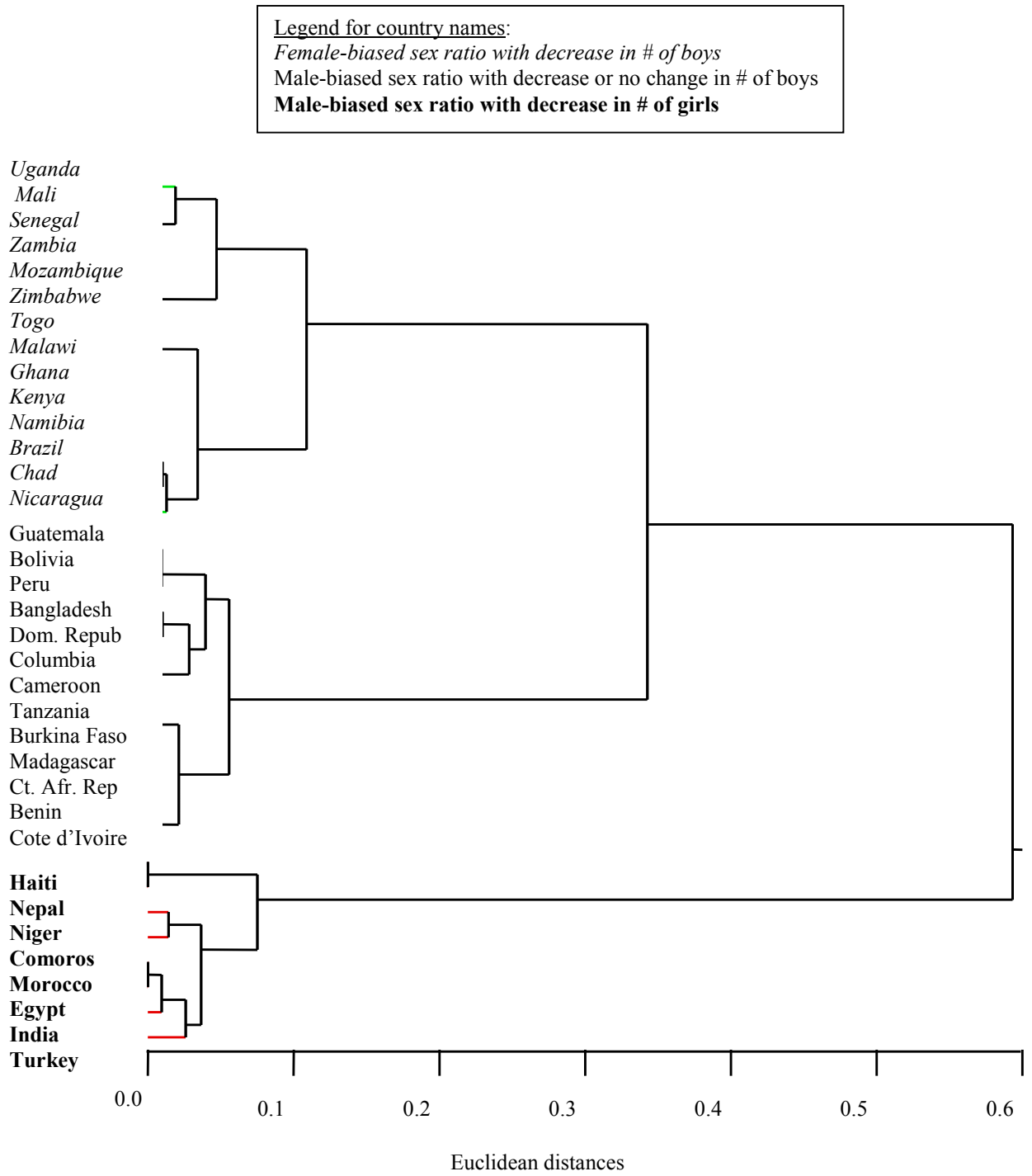


Figure 5. Overview of regional findings

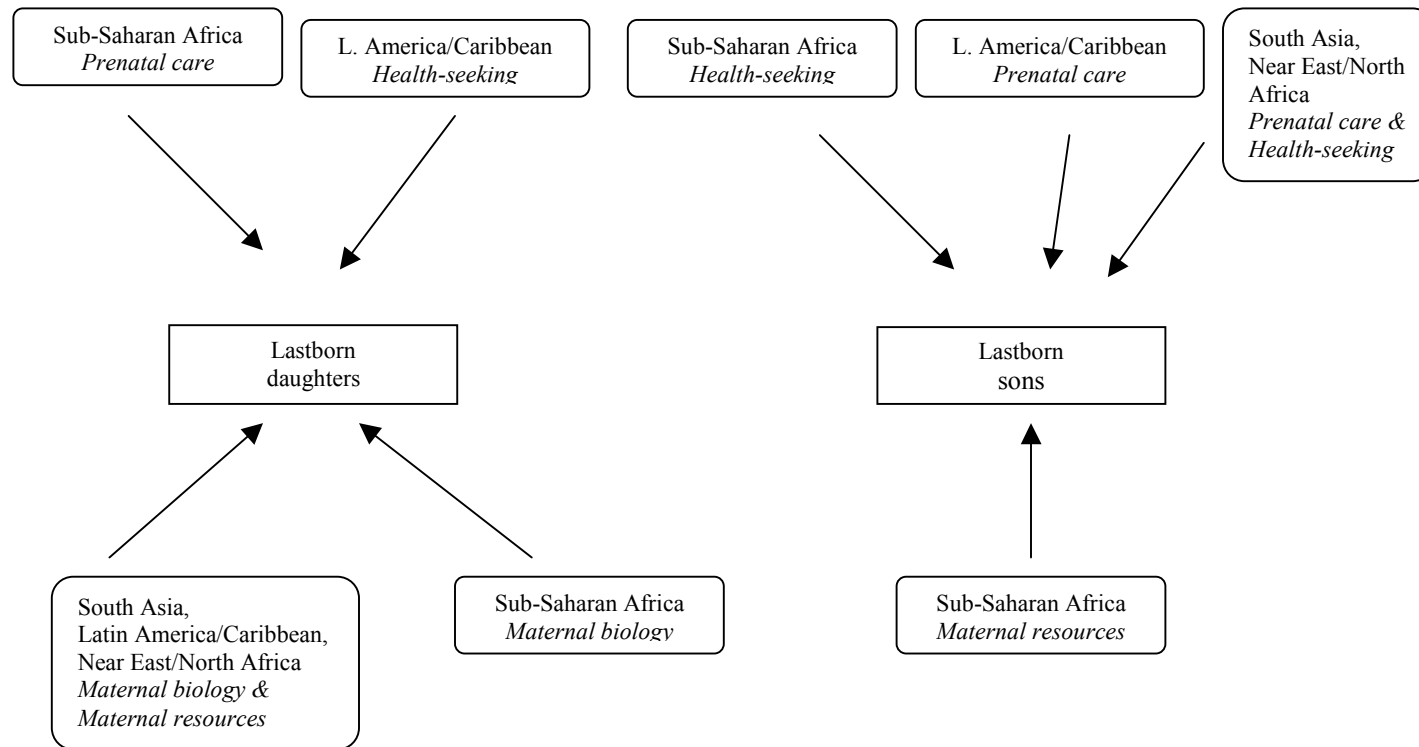


Figure 6. Mean breast-feeding duration (unweighted) by region

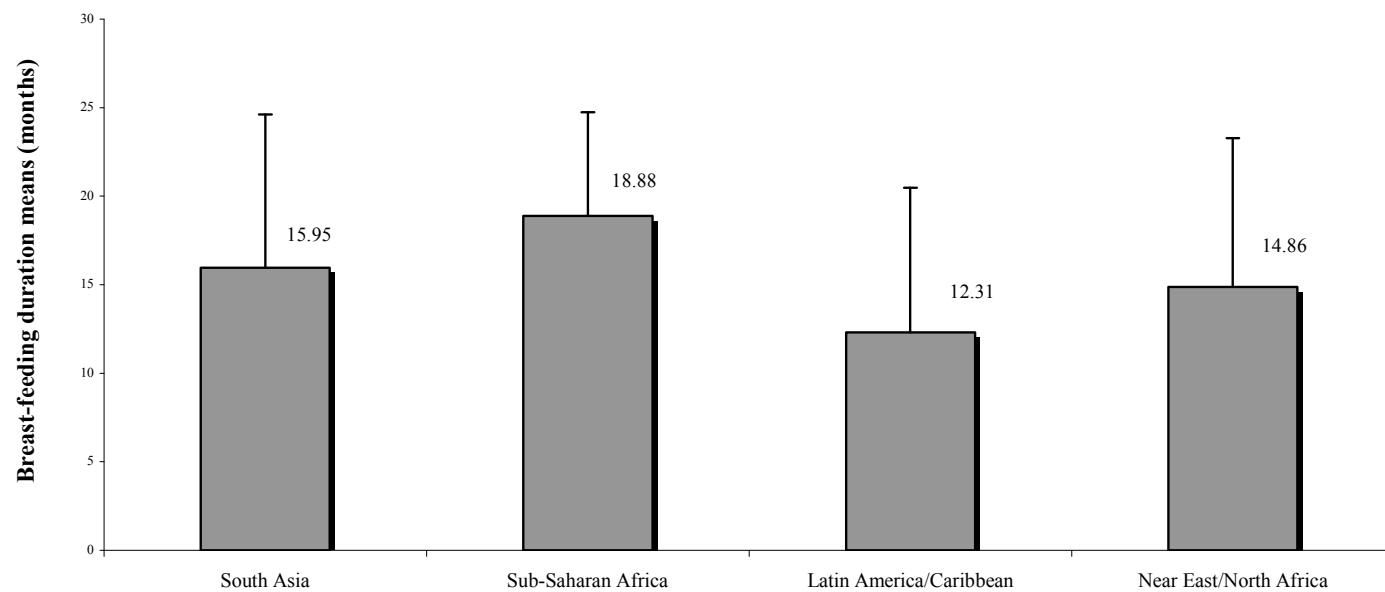


Table 1. Initial unweighted sample size by region and country (N = 134,257 mother-child pairs)

		Year of collection	Initial sample size
South Asia	Bangladesh	1997	3,852
	India	1998	22,729
	Nepal	1996	3,384
			Total for region = 29,965
Sub-Saharan Africa	Benin	1996	2,137
	Burkina Faso	1993	3,061
	Cameroon	1998	1,516
	Central African Republic	1995	2,052
	Chad	1996	3,892
	Comoros	1996	792
	Cote d'Ivoire	1994	3,087
	Ghana	1998	1,540
	Kenya	1998	2,575
	Madagascar	1997	2,624
	Malawi	1992	2,321
	Mali	1996	4,251
	Mozambique	1997	2,851
	Namibia	1992	1,940
	Niger	1998	3,542
	Senegal	1997	2,809
	Tanzania	1996	3,865
	Togo	1998	3,206
	Uganda	1995	3,413
Zambia	1996	3,950	
Zimbabwe	1994	1,929	
			Total for region = 57,353
Latin America & Caribbean	Bolivia	1998	3,208
	Brazil	1996	3,214
	Columbia	1995	3,465
	Dominican Republic	1996	2,664
	Guatemala	1995	5,550
	Haiti	1995	1,908
	Nicaragua	1998	4,985
	Peru	1996	11,076
			Total for region = 36,070
Near East & North Africa	Egypt	1995	5,203
	Morocco	1992	3,190
	Turkey	1993	2,476
			Total for region = 10,869

Table 2. Final sample size by region and country

		Unweighted	Weighted (by sample weight)
South Asia	Bangladesh	3,730	3,505
	India	21,839	21,487
	Nepal	3,246	3,292
		<u>Total = 28,815</u>	<u>Total = 28,284</u>
Sub-Saharan Africa	Benin	2,037	2,037
	Burkina Faso	2,887	1,831
	Cameroon	1,411	1,411
	Central African Republic	1,967	1,967
	Chad	3,789	3,789
	Comoros	732	732
	Cote d'Ivoire	3,025	3,025
	Ghana	1,467	1,356
	Kenya	2,474	2,386
	Madagascar	2,510	2,431
	Malawi	2,230	1,953
	Mali	3,933	3,619
	Mozambique	2,539	2,218
	Namibia	1,750	1,543
	Niger	3,443	3,762
	Senegal	2,615	2,615
	Tanzania	3,518	3,820
	Togo	3,076	3,249
	Uganda	3,290	3,079
Zambia	3,834	3,827	
Zimbabwe	1,860	1,997	
		<u>Total = 54,387</u>	<u>Total = 52,647</u>
Latin America & Caribbean	Bolivia	3,073	2,874
	Brazil	3,034	2,873
	Columbia	3,368	3,517
	Dominican Republic	2,211	1,890
	Guatemala	5,361	5,471
	Haiti	1,805	1,805
	Nicaragua	4,728	5,137
	Peru	10,741	9,960
		<u>Total = 34,321</u>	<u>Total = 33,527</u>
Near East & North Africa	Egypt	5,049	4,371
	Morocco	3,116	3,116
	Turkey	2,351	2,426
		<u>Total = 10,516</u>	<u>Total = 9,913</u>

Table 3. List of variables used in scales

Scale name & code	Description of variables & coding scheme
Maternal Socioeconomic Resources (MSR)	<ul style="list-style-type: none"> ▪ Whether woman lives in urban/rural residence - rural=0, urban=1 ▪ Household economic status - destitute=0, poor=1, middle=2, rich=3 ▪ Woman's years of education ▪ Male partner's educational value - measured in years if partner present, otherwise equals 0 if no male partner present or if male partner has 0 years of education
Maternal Biological Condition (MBC)	<ul style="list-style-type: none"> ▪ Woman's body mass index (BMI) - weight in kg/square of height in meters ▪ Whether woman is malnourished, healthy, or overweight - malnourished=0, healthy=1, overweight=2 ▪ Duration of current pregnancy (if pregnant) - not pregnant=0, otherwise recorded as months (max=10) ▪ Whether woman is currently breast-feeding - not breast-feeding=0, currently breastfeeding=1 - note: reverse-coded for predicted negative effect
Prenatal Care for Lastborn Child (PCL)	<ul style="list-style-type: none"> ▪ Whether woman received prenatal care & type of care - did not receive prenatal care=0, received prenatal care but not from medically trained person=1, received prenatal care from medically trained person=2 ▪ Number of prenatal care visits - no visits=0, otherwise equals number of visits recorded ▪ Whether delivery was assisted & type of assistance - delivery was not assisted=0, delivery was assisted=1, delivery was assisted by medically trained person=2 ▪ Whether delivery took place at a medical facility - delivery not at medical facility=0, delivery at medical facility=1
Health-seeking for Lastborn Child (HSL)	<ul style="list-style-type: none"> ▪ Child's diarrhea in last 2 weeks - child had diarrhea and was not treated=0, no diarrhea=1, had diarrhea and was treated=2 ▪ Whether child received BCG vaccination - no=0, yes=1 ▪ Whether child received measles vaccination - no=0, yes=1 ▪ Total number of DPT vaccinations - ranges from none=0 to max=3 ▪ Total number of polio vaccinations - ranges from none=0 to max=3 ▪ Percent of age-recommended vaccinations child received - ranges from 0 to 100

Table 4. Cronbach's alphas for scales

Scale name & code	α	Description of measure	Number of items/scale
Maternal Socioeconomic Resources (MSR)	.75	Urban/rural, household wealth, woman's education & partner's education (if present)	4
Maternal Biological Condition (MBC)	.63	Woman's BMI, malnourished vs. healthy/overweight, duration of current pregnancy, breast-feeding status	4
Prenatal Care for Lastborn Child (PCL)	.81	Type of prenatal care received, number of prenatal visits, type & place of delivery assistance	4
Health-seeking for Lastborn Child (HSL)	.85	Diarrhea treatment and immunizations (measles, polio, BCG, & DPT)	6

Table 5. Pearson correlations between scales and indicators

	Maternal Socioeconomic Resources	Maternal Biological Condition	Prenatal Care for Lastborn Child	Health-seeking for Lastborn Child
Whether woman lives in urban area	.715			
Household economic status	.778			
Woman's education	.802			
Male's educational value	.738			
Woman's BMI		.785		
Woman is malnourished/healthy/overweight		.775		
Duration of current pregnancy, if pregnant		.544		
Woman currently breast-feeding (reversed)		.655		
Whether prenatal care received & care type			.770	
Number of prenatal care visits			.788	
Delivery assistance			.808	
Delivery took place at a medical facility			.824	
Child's diarrhea: untreated/absent/treated				.243
Whether child received BCG vaccination				.799
Whether child received measles vaccination				.742
Total number of DPT vaccinations received				.916
Total number of polio vaccinations received				.894
Percent recommended vaccinations received				.922

Note: All correlations are significant at $p < 0.01$, two-tailed. Listwise $N=128,039$.

Table 6. Pearson correlations between scales

	Maternal Biological Condition	Maternal Socioeconomic Resources	Prenatal Care for Lastborn Child
Maternal Socioeconomic Resources	.28		
Prenatal Care for Lastborn Child	.21	.59	
Health-seeking for Lastborn Child	.25	.33	.37

Note: All correlations are significant at $p < 0.01$, two-tailed. Listwise $N=128,039$.

Table 7A. Household, maternal, and child demographics by region

	South Asia	Sub-Saharan Africa	Latin America & Caribbean	Near East & North Africa	All regions
Household size	7.3	8.1	6.4	7.5	7.4
Female-headed household	7%	15%	16%	5%	13%
% of females in household	50.7	53.1	51.7	50.2	51.9
% of males in household	49.3	46.9	48.3	49.8	48.1
Male partner present	99%	88%	87%	98%	91%
Male partner's age (years)	31.8	37.7	33.3	34.4	34.8
Woman's age (years)	25.8	28.0	28.6	29.6	27.8
Woman's education (years)	3.6	2.9	5.3	3.6	3.8
Woman's age at first marriage	17.1	17.2	18.7	18.8	17.7
Woman works for cash	16%	46%	29%	16%	31%
Birth order of lastborn child	2.9	4.0	3.5	3.8	3.6
Age of lastborn child (months)	17.4	17.5	23.6	24.8	19.7

Note: Sample means are unweighted. Listwise $N=128,039$.

Table 7B. Descriptive statistics of indicators by region

	South Asia	Sub-Saharan Africa	Latin America & Caribbean	Near East & North Africa
Whether woman lives in urban area	24%	29%	52%	45%
Woman's education (years)	3.6	2.9	5.3	3.6
Male partner's education, if partner present	6.0	4.1	6.0	5.3
Woman's BMI	19.7	21.7	24.3	25.9
% BMI in healthy range	59%	76%	59%	48%
% BMI in overweight range	5%	12%	38%	49%
Duration of current pregnancy, if pregnant	5.23	5.20	5.30	5.51
Woman currently breast-feeding	82%	69%	45%	39%
% received prenatal care from MTP	63%	64%	72%	54%
Average number of prenatal care visits	2.65	3.40	4.64	2.27
Delivery assisted by MTP	38%	35%	56%	48%
Delivery took place at a medical facility	30%	45%	56%	38%
Child had diarrhea & received treatment	17%	23%	17%	14%
Child received BCG vaccination	71%	77%	87%	88%
Child received measles vaccination	43%	46%	66%	68%
Child received all 3 DPT vaccinations	51%	49%	63%	72%
Child received all 3 polio vaccinations	52%	48%	59%	73%
% recommended vaccinations received	66%	67%	80%	84%

Note: Sample means are unweighted. Listwise $N=128,039$.

Table 8. Sex ratios by region and country

		National est. sex ratio (at birth)	Current sample (last-born child < 5 yrs)
South Asia	Bangladesh	1.06	1.04
	India	1.05	1.12
	Nepal*	1.05	1.07
Sub-Saharan Africa	Benin	1.03	1.02
	Burkina Faso	1.03	1.03
	Cameroon	1.03	1.04
	Central African Republic	1.03	1.02
	Chad	1.04	.99
	Comoros	1.03	1.11
	Cote d'Ivoire	1.03	1.02
	Ghana	1.03	.99
	Kenya	1.03	.99
	Madagascar	1.03	1.03
	Malawi	1.03	.99
	Mali	1.03	.95
	Mozambique	1.03	.97
	Namibia	1.03	.99
	Niger	1.03	1.09
	Senegal	1.03	.95
	Tanzania	1.03	1.03
Togo	1.03	.99	
Uganda	1.03	.93	
Zambia	1.03	.97	
Zimbabwe	1.03	.97	
Latin America & Caribbean	Bolivia	1.05	1.02
	Brazil	1.05	1.00
	Columbia	1.03	1.05
	Dominican Republic	1.05	1.05
	Guatemala	1.05	1.02
	Haiti	1.05	1.07
	Nicaragua	1.05	.98
	Peru	1.05	1.03
Near East & North Africa	Egypt	1.05	1.11
	Morocco	1.05	1.11
	Turkey	1.05	1.14

* Indicates the only country where female infant mortality exceeds male infant mortality (72.27 deaths/1,000 live births to 68.95 deaths/1,000 live births).

Note: Information for sex ratios based on 2003 estimates posted at CIA website for "Worldbook of Facts."

Table 9. Across All Regions – Dependent Variable: Maternal Socioeconomic Resources

Source	Type I Sum of Squares	df	Mean Square	F	p	R ²
REGION	15648.599	4	3912.150	4983.647	.000	.138
COUNTRY	12856.464	31	414.725	528.313	.000	.116
Model	28505.063	35	814.430	1037.494	.000	.226
Error	97603.431	124336	.785			
Total	126108.494	124371				

Table 10. Across All Regions – Dependent Variable: Maternal Biological Condition

Source	Type I Sum of Squares	df	Mean Square	F	p	R ²
MSR	11489.346	1	11489.346	15391.319	.000	.110
REGION	19997.305	4	4999.326	6697.180	.000	.177
COUNTRY	1018.233	31	32.846	44.001	.000	.011
REGION *MSR	115.399	3	38.466	51.530	.000	.001
COUNTRY *MSR	249.704	31	8.055	10.791	.000	.003
Model	32869.987	70	469.571	629.045	.000	.262
Error	92788.490	124301	.746			
Total	125658.477	124371				

Table 11. Across All Regions – Dependent Variable: Prenatal Care for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	F	p	R ²
MBC	6501.180	1	6501.180	12222.630	.000	.090
MSR	38992.211	1	38992.211	73307.830	.000	.371
REGION	3834.375	4	958.594	1802.217	.000	.055
COUNTRY	9896.666	31	319.247	600.205	.000	.130
REGION *MBC	4.469	3	1.490	2.800	.038	.000
COUNTRY *MBC	103.604	31	3.342	6.283	.000	.002
REGION *MSR	35.392	3	11.797	22.180	.000	.001
COUNTRY *MSR	1517.322	31	48.946	92.021	.000	.022
Model	60885.219	105	579.859	1090.172	.000	.479
Error	66096.706	124266	.532			
Total	126981.925	124371				

Table 12. Across All Regions – Dependent Variable: Sex of Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
PCL	.542	1	.542	2.171	.141	.000
MBC	2.903	1	2.903	11.626	.001	.000
MSR	21.054	1	21.054	84.313	.000	.001
REGION	29970.562	4	7492.641	30004.757	.000	.491
COUNTRY	10.302	31	.332	1.331	.103	.000
REGION *PCL	.564	3	.188	.752	.521	.000
COUNTRY *PCL	9.506	31	.307	1.228	.179	.000
REGION *MBC	4.207	3	1.402	5.616	.001	.000
COUNTRY *MBC	13.628	31	.440	1.760	.006	.000
REGION *MSR	.699	3	.233	.933	.424	.000
COUNTRY *MSR	7.677	31	.248	.992	.479	.000
Model	30041.644	140	214.583	859.312	.000	.492
Error	31022.356	124231	.250			
Total	61064.000	124371				

Table 13. Across All Regions – Dependent Variable: Health-seeking for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
SEX	49.869	1	49.869	68.441	.000	.001
PCL	18173.990	1	18173.990	24942.148	.000	.167
MBC	3918.634	1	3918.634	5377.969	.000	.042
MSR	1040.638	1	1040.638	1428.181	.000	.011
REGION	749.793	4	187.448	257.256	.000	.008
COUNTRY	6978.130	31	225.101	308.931	.000	.072
REGION *SEX	30.761	3	10.254	14.072	.000	.000
COUNTRY *SEX	40.613	31	1.310	1.798	.004	.000
REGION *PCL	1505.353	3	501.784	688.653	.000	.016
COUNTRY *PCL	1545.970	31	49.870	68.442	.000	.017
REGION *MBC	146.949	3	48.983	67.225	.000	.002
COUNTRY *MBC	119.643	31	3.859	5.297	.000	.001
REGION *MSR	105.400	3	35.133	48.217	.000	.001
COUNTRY *MSR	453.032	31	14.614	20.056	.000	.005
Model	34858.774	175	199.193	273.374	.000	.278
Error	90494.885	124196	.729			
Total	125353.660	124371				

Table 14. South Asia – Dependent Variable: Maternal Socioeconomic Resources

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
COUNTRY	2532.173	3	844.058	955.129	.000	.092
Model	2532.173	3	844.058	955.129	.000	.092
Error	24992.228	28281	.884			
Total	27524.401	28284				

Table 15. South Asia – Dependent Variable: Maternal Biological Condition

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
MSR	2872.989	1	2872.989	4378.386	.000	.134
COUNTRY	10893.331	3	3631.110	5533.750	.000	.370
COUNTRY *MSR	15.971	2	7.985	12.170	.000	.001
Model	13782.291	6	2297.048	3500.662	.000	.426
Error	18555.327	28278	.656			
Total	32337.617	28284				

Table 16. South Asia – Dependent Variable: Prenatal Care for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
MBC	2334.187	1	2334.187	3936.331	.000	.122
MSR	9236.264	1	9236.264	15575.870	.000	.355
COUNTRY	1957.771	3	652.590	1100.516	.000	.105
COUNTRY *MBC	2.702	2	1.351	2.279	.102	.000
COUNTRY *MSR	41.292	2	20.646	34.817	.000	.002
Model	13572.216	9	1508.024	2543.105	.000	.447
Error	16766.664	28275	.593			
Total	30338.879	28284				

Table 17. South Asia – Dependent Variable: Sex of Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
PCL	504.487	1	504.487	2022.398	.000	.067
MBC	1989.250	1	1989.250	7974.545	.000	.220
MSR	17.001	1	17.001	68.152	.000	.002
COUNTRY	3994.046	3	1331.349	5337.137	.000	.362
COUNTRY *PCL	.037	2	.018	.074	.929	.000
COUNTRY *MBC	.607	2	.303	1.216	.296	.000
COUNTRY *MSR	.122	2	.061	.245	.783	.000
Model	6505.550	12	542.129	2173.298	.000	.480
Error	7052.450	28272	.249			
Total	13558.000	28284				

Table 18. South Asia – Dependent Variable: Health-seeking for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
SEX	705.506	1	705.506	787.333	.000	.027
PCL	4105.462	1	4105.462	4581.629	.000	.139
MBC	205.457	1	205.457	229.287	.000	.008
MSR	362.633	1	362.633	404.692	.000	.014
COUNTRY	1401.360	3	467.120	521.298	.000	.052
COUNTRY *SEX	2.994	2	1.497	1.670	.188	.000
COUNTRY *PCL	97.016	2	48.508	54.134	.000	.004
COUNTRY *MBC	2.370	2	1.185	1.322	.267	.000
COUNTRY *MSR	18.601	2	9.301	10.379	.000	.001
Model	6901.398	15	460.093	513.457	.000	.214
Error	25331.016	28269	.896			
Total	32232.414	28284				

Table 19. Sub-Saharan Africa – Dependent Variable: Maternal Socioeconomic Resources

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
COUNTRY	10157.370	21	483.684	830.907	.000	.249
Model	10157.370	21	483.684	830.907	.000	.249
Error	30634.446	52626	.582			
Total	40791.816	52647				

Table 20. Sub-Saharan Africa – Dependent Variable: Maternal Biological Condition

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
MSR	2632.098	1	2632.098	3577.865	.000	.064
COUNTRY	691.301	21	32.919	44.748	.000	.018
COUNTRY *MSR	86.809	20	4.340	5.900	.000	.002
Model	3410.208	42	81.195	110.371	.000	.081
Error	38699.484	52605	.736			
Total	42109.692	52647				

Table 21. Sub-Saharan Africa – Dependent Variable: Prenatal Care for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
MBC	1551.375	1	1551.375	3138.987	.000	.056
MSR	11462.249	1	11462.249	23192.234	.000	.306
COUNTRY	6602.640	21	314.411	636.167	.000	.203
COUNTRY *MBC	49.331	20	2.467	4.991	.000	.002
COUNTRY *MSR	547.617	20	27.381	55.401	.000	.021
Model	20213.211	63	320.845	649.184	.000	.437
Error	25988.479	52584	.494			
Total	46201.690	52647				

Table 22. Sub-Saharan Africa – Dependent Variable: Sex of Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
PCL	110.520	1	110.520	442.243	.000	.008
MBC	236.954	1	236.954	948.166	.000	.018
MSR	1652.046	1	1652.046	6610.610	.000	.112
COUNTRY	11081.471	21	527.689	2111.532	.000	.458
COUNTRY *PCL	5.842	20	.292	1.169	.271	.000
COUNTRY *MBC	8.054	20	.403	1.611	.041	.001
COUNTRY *MSR	4.187	20	.209	.838	.669	.000
Model	13099.075	84	155.941	623.995	.000	.499
Error	13135.925	52563	.250			
Total	26235.000	52647				

Table 23. Sub-Saharan Africa – Dependent Variable: Health-seeking for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
SEX	583.276	1	583.276	768.187	.000	.014
PCL	12804.006	1	12804.006	16863.146	.000	.243
MBC	1239.151	1	1239.151	1631.988	.000	.030
MSR	568.522	1	568.522	748.756	.000	.014
COUNTRY	3055.718	21	145.510	191.640	.000	.071
COUNTRY *SEX	31.182	20	1.559	2.053	.004	.001
COUNTRY *PCL	1266.552	20	63.328	83.404	.000	.031
COUNTRY *MBC	83.222	20	4.161	5.480	.000	.002
COUNTRY *MSR	402.519	20	20.126	26.506	.000	.010
Model	20034.149	105	190.801	251.289	.000	.334
Error	39894.577	52542	.759			
Total	59928.725	52647				

Table 24. Latin America/Caribbean – Dependent Variable: Maternal Socioeconomic Resources

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
COUNTRY	13748.448	8	1718.556	1812.373	.000	.302
Model	13748.448	8	1718.556	1812.373	.000	.302
Error	31783.904	33519	.948			
Total	45532.352	33527				

Table 25. Latin America/Caribbean – Dependent Variable: Maternal Biological Condition

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
MSR	4489.558	1	4489.558	5744.685	.000	.146
COUNTRY	5152.897	8	644.112	824.184	.000	.164
COUNTRY *MSR	107.841	7	15.406	19.713	.000	.004
Model	9750.296	16	609.394	779.759	.000	.271
Error	26189.354	33511	.782			
Total	35939.651	33527				

Table 26. Latin America/Caribbean – Dependent Variable: Prenatal Care for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
MBC	3943.110	1	3943.110	7456.426	.000	.182
MSR	14917.154	1	14917.154	28208.355	.000	.457
COUNTRY	2395.595	8	299.449	566.259	.000	.119
COUNTRY *MBC	48.889	7	6.984	13.207	.000	.003
COUNTRY *MSR	828.410	7	118.344	223.789	.000	.045
Model	22133.158	24	922.215	1743.909	.000	.555
Error	17717.071	33503	.529			
Total	39850.229	33527				

Table 27. Latin America/Caribbean – Dependent Variable: Sex of Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
PCL	1281.145	1	1281.145	5128.272	.000	.133
MBC	1119.308	1	1119.308	4480.456	.000	.118
MSR	172.737	1	172.737	691.445	.000	.020
COUNTRY	5651.975	8	706.497	2828.022	.000	.403
COUNTRY *PCL	3.236	7	.462	1.851	.073	.000
COUNTRY *MBC	4.944	7	.706	2.827	.006	.001
COUNTRY *MSR	1.929	7	.276	1.103	.358	.000
Model	8235.275	32	257.352	1030.151	.000	.496
Error	8367.725	33495	.250			
Total	16603.000	33527				

Table 28. Latin America/Caribbean – Dependent Variable: Health-seeking for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
SEX	946.180	1	946.180	1671.847	.000	.048
PCL	2247.168	1	2247.168	3970.617	.000	.106
MBC	1085.504	1	1085.504	1918.024	.000	.054
MSR	158.947	1	158.947	280.850	.000	.008
COUNTRY	1500.315	8	187.539	331.371	.000	.073
COUNTRY *SEX	5.036	7	.719	1.271	.260	.000
COUNTRY *PCL	150.371	7	21.482	37.957	.000	.008
COUNTRY *MBC	33.517	7	4.788	8.460	.000	.002
COUNTRY *MSR	23.370	7	3.339	5.899	.000	.001
Model	6150.408	40	153.760	271.686	.000	.245
Error	18951.941	33487	.566			
Total	25102.349	33527				

Table 29. Near East/North Africa – Dependent Variable: Maternal Socioeconomic Resources

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
COUNTRY	2067.071	3	689.024	669.903	.000	.169
Model	2067.071	3	689.024	669.903	.000	.169
Error	10192.854	9910	1.029			
Total	12259.924	9913				

Table 30. Near East/North Africa – Dependent Variable: Maternal Biological Condition

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
MSR	1660.926	1	1660.926	1760.940	.000	.151
COUNTRY	4227.183	3	1409.061	1493.909	.000	.311
COUNTRY *MSR	39.083	2	19.541	20.718	.000	.004
Model	5927.192	6	987.865	1047.350	.000	.388
Error	9344.325	9907	.943			
Total	15271.517	9913				

Table 31. Near East/North Africa – Dependent Variable: Prenatal Care for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
MBC	.567	1	.567	.998	.318	.000
MSR	3160.375	1	3160.375	5565.008	.000	.360
COUNTRY	1704.549	3	568.183	1000.497	.000	.233
COUNTRY *MBC	1.140	2	.570	1.004	.367	.000
COUNTRY *MSR	100.004	2	50.002	88.047	.000	.017
Model	4966.634	9	551.848	971.733	.000	.469
Error	5624.493	9904	.568			
Total	10591.127	9913				

Table 32. Near East/North Africa – Dependent Variable: Sex of Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
PCL	144.157	1	144.157	578.729	.000	.055
MBC	808.361	1	808.361	3245.235	.000	.247
MSR	134.715	1	134.715	540.824	.000	.052
COUNTRY	1112.564	3	370.855	1488.829	.000	.311
COUNTRY *PCL	.482	2	.241	.968	.380	.000
COUNTRY *MBC	.028	2	.014	.057	.945	.000
COUNTRY *MSR	1.438	2	.719	2.886	.056	.001
Model	2201.744	12	183.479	736.591	.000	.472
Error	2466.256	9901	.249			
Total	4668.000	9913				

Table 33. Near East/North Africa – Dependent Variable: Health-seeking for Lastborn Child

Source	Type I Sum of Squares	df	Mean Square	<i>F</i>	<i>p</i>	R ²
SEX	359.822	1	359.822	563.767	.000	.054
PCL	127.093	1	127.093	199.128	.000	.020
MBC	895.398	1	895.398	1402.906	.000	.124
MSR	123.021	1	123.021	192.749	.000	.019
COUNTRY	239.932	3	79.977	125.308	.000	.037
COUNTRY *SEX	2.829	2	1.415	2.216	.109	.000
COUNTRY *PCL	12.950	2	6.475	10.145	.000	.002
COUNTRY *MBC	3.232	2	1.616	2.532	.080	.001
COUNTRY *MSR	8.542	2	4.271	6.692	.001	.001
Model	1772.819	15	118.188	185.176	.000	.219
Error	6317.352	9898	.638			
Total	8090.171	9913				

Table 34. Median breast-feeding duration (months) by country

		From DHS surveys	From current study
South Asia	Bangladesh	30.5	24.0
	India	25.4	12.0
	Nepal	31.0	21.0
Sub-saharan Africa	Benin	22.8	19.0
	Burkina Faso	25.2	24.0
	Cameroon	18.1	16.0
	Central African Republic	20.6	18.0
	Chad	21.4	19.0
	Comoros	20.1	14.0
	Cote d'Ivoire	20.3	18.0
	Ghana	21.5	18.0
	Kenya	20.9	18.0
	Madagascar	20.7	17.0
	Malawi	21.2	20.0
	Mali	21.6	19.0
	Mozambique	22.0	18.0
	Namibia	17.3	14.0
	Niger	20.6	20.0
	Senegal	20.9	18.0
	Tanzania	21.5	24.0
	Togo	24.4	21.0
	Uganda	19.5	18.0
Zambia	20.0	20.0	
Zimbabwe	18.5	18.0	
Latin America/ Caribbean	Bolivia	17.5	14.0
	Brazil	7.0	5.0
	Columbia	11.3	8.0
	Dominican Republic	7.6	6.0
	Guatemala	19.8	12.0
	Haiti	17.5	16.0
	Nicaragua	12.2	9.0
	Peru	19.5	14.0
North Africa	Egypt	18.9	18.0
	Morocco	15.5	13.0
	Turkey	11.9	10.0

Note: Medians from current study are unweighted and based on 47,295 cases for which data was available.

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