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# Trivers-Willard at Birth and One Year

## Evidence from U.S. Natality Data 1983-2001


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Douglas Almond*and Lena Edlund†

**Abstract**

Trivers and Willard [1973] hypothesized that evolution would favor deviations from the population sex ratio to vary with maternal condition: mothers in good condition would have more sons and mothers in poor condition would have more daughters. We analyze the universe of U.S. births and infant deaths to White mothers 1983-2001, covering 48 million births and 310 thousand deaths. We find that: (i) married and better educated mothers bear more sons; (ii) infant deaths reinforce the pattern; and (iii) this reinforcing tendency is particularly strong during the post-neonatal period.

## 1 Introduction and Motivation

Trivers and Willard [1973] (TW) hypothesized that evolution would favor systematic deviations from the population sex ratio – mothers in good condition would have more sons and mothers in poor condition more daughters. The argument was based on the observation that while the average number of offspring to males and females equalize,[1] the reproductive success of a male offspring tend to be more resource sensitive. For instance, if each female bears two offspring, a daughter will yield two grand-children, while a son will yield two times his number of female partners. Assuming that the number of partners depends on his condition, and that this condition, in turn, is related to maternal condition, mothers in good condition will obtain more grand-children through sons. Conversely, for mothers in poor condition, daughters out-reproduce sons. TW further hypothesized that the mechanism would be parental control over offspring mortality.

We analyze U.S. natality data covering the period 1983-2001. This extends previous research in two ways. First, we compile the largest micro-data set of birth records yet analyzed in evaluating the TW hypothesis. Our analysis

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[1]At balanced breeding sex ratios.

confirms the presence of a TW effect at birth with respect to maternal marital status and education (but not age). Second, we investigate the gender differences in 310 thousand infant deaths, and how these relate to maternal characteristics. We find that infant deaths conform to the predictions of TW, thereby reinforcing the gender patterns observed at birth.

As mentioned, TW conjectured that the sex-choice mechanism involved parental control over offspring mortality. Obviously, the closer to conception, the lower the replacement cost of a terminated offspring. Mortality in-utero would therefore be more advantageous than mortality after birth and most studies have focussed on the sex ratio at birth. However, barring prenatal sex determination and elected abortions, the effects are small, see James [1987].[2] Greater parental discretion can be exercised once the child is born, and the empirical literature has mainly focussed on developing countries where a combination of high infant mortality and pronounced son preference can make for remarkably male sex ratios. For instance, a recent large scale Indian study found sex ratios to be substantially more male when mothers were better educated (Jha et al. 2006).[3] Whether infant mortality varies in a way predicted by TW in societies lacking a pronounced son preference is less well established.

The TW hypothesis has generated a substantial empirical literature outside the social sciences, see Cameron [2004]. Its relevance for human populations is, however, controversial, e.g., Freese and Powell [2001]. A priori, there are several reasons the TW prediction would be weaker or not hold. We are not only a species with high parental investment, but also unusually high *paternal* investment. A high level of paternal investment reduces if not eliminates the scope for TW, for it relies on effective polygyny, which high paternal investment may preclude.[4] Also, the low fertility and mortality of contemporary Western societies call into question the extent to which behavior is governed by fitness maximization. For instance, whether reproductive success increases with socioeconomic status (SES) is unclear. In addition, whereas there is evidence that parents vary aspects of parental investment such as length of breast feeding in accordance with TW, e.g., Gaulin and Robbins [1991] (the U.S.) and Koziel and Ulijaszek [2001] (Poland), the link to infant mortality is weak.

Abernethy and Yip [1990] and Norberg [2004] are the studies most closely related to ours. Abernethy and Yip [1990], using linked birth-death records 1976-1983 for the state of Tennessee, found postneotal infant deaths supportive of the TW hypothesis. Norberg [2004] focussed on maternal partnership status at the time of conception as a determinant of the sex ratio. She relied on survey data from the period 1959-1998. While she considered other markers of SES such as education and household income (in a multi-variate analysis), they were not consistently significant.

[2] For instance, dominant [Grant 1994] or aggressive [Kanazawa 2005] personality, stature [Kanazawa 2006] and nutritional status [Gibson 2003] have been associated with male sex ratios.

[3] Generalized daughter preference is more rare, for an example see Cronk [1989].

[4] Sequential, child-bearing female partners (e.g. "second marriages") may effectively constitute polygyny for TW purposes.

## 2 Data

We analyze National Center for Health Statistics (NCHS) Vital Statistics Birth Cohort Linked Birth/Infant Death Data, available for the years 1983-1991, 1995-2001. These data contain information extracted from the universe of birth certificates and in the case of an infant death, information from the corresponding death certificate such as cause of death. We restrict the analysis to singleton births to White mothers – about 80 percent of births.

Details about variable construction are in the Data Appendix.

## 3 Method

To investigate whether births and infant deaths lend support to the TW hypothesis we estimate the following regressions:

$$\texttt{male}_i = \alpha_0 + \alpha_1 x_i + \alpha_2 h_i + \epsilon_i, \quad (1)$$

and

$$\texttt{male}_i = \beta_0 + \beta_1 x_i + \beta_2 h_i + \beta_3 \texttt{dead}_i + \beta_4 \texttt{dead}_i \times x_i + \beta_5 \texttt{dead}_i \times h_i + \varepsilon_i, \quad (2)$$

where $\texttt{male}_i$ is a dummy which takes on the value one if infant $i$ is male; and $\texttt{dead}_i$ is a dummy which takes on the value one if the infant died. $x_i$ is a vector of socio-economic characteristics of the mother (marital status, age, race, education), $h_i$ is a vector of controls for the infant's health status at birth (dummies for gestation length and birth weight).

Gender at birth is commonly viewed as random implying that components of $\alpha_1$ and $\beta_1$ should be close to zero. Under the TW hypothesis, however, we expect these coefficients to be positive for variables signalling good condition, and negative for variables signalling poor condition. Moreover, if infant mortality operates in a way consistent with TW, we would expect the coefficients on the interaction terms in equation 2 to be negative if the variable signals good condition (and positive if the opposite). For instance, presuming that married mothers are in better condition than unmarried mothers, we expect the former to bear more male children and suffer fewer male infant deaths than the latter.

Males being more fragile – rendering male mortality more sensitive to the economic circumstances of the mother – may be one mechanism through which a TW effect is obtained. However, maternal age might be a factor for which the physiological and the social mechanisms may be distinguished because younger mothers are physiologically more fit but economically less so, while the converse may be true of older mothers. Thus, unless in their early teens, young mothers are biologically advantaged and a negative effect of young motherhood is likely to be due to the economic circumstances. Conversely, for older mothers, positive effects are unlikely to stem from a biological advantage.

The $h$ vector seeks to control for direct measures of the infant's health status at birth. Whether to include such variables, or view them as a result of maternal condition (possibly captured by the $x$ variables) is debatable. The compromise we strike is to include gestation length and birth weight (our results are not sensitive to their inclusion). These variables may be viewed merely as controls. For instance, boys are heavier than girls and may at a given birth weight suffer different mortality risk than girls. Alternatively, these variables may be picking up information about the condition of the mother not accounted for by the $x$ variables. For instance, mothers in poor condition may be more likely to deliver pre-term or low-birth-weight babies.

The tendency for more males to be born than females will be reflected in positive parameters $\alpha_0$ and $\beta_0$. Because males suffer higher infant mortality rates than females, we expect the coefficient on `dead`, $\beta_3$, to be positive. These three parameters – $\alpha_0$, $\beta_0$ and $\beta_3$ – fully capture the average differences in births and infant deaths by gender. We turn now to the empirical results.

## 3.1 Results

The results are generally supportive of the TW-hypothesis both with respect to the secondary sex ratio (at birth) and infant mortality. The one exception is maternal age. Consistent with TW, males born to younger mothers are more at risk, but contrary to TW, younger mothers are also more likely to bear sons than older mothers.

**TW and sex ratio at birth** Results from estimating 1 are in Table 1, column (1). Consistent with TW, married mothers are more likely to give birth to male offspring. The coefficients on the married dummy is positive and statistically significant at the 1 percent level. The other direct measure of the economic circumstances of the mother is her education level. We find that lower education is associated with a more female sex ratio. For instance, relative to a mother with some college, a mother without a high school degree is about 0.3 percent less likely to bear a boy.

With respect to maternal age, the pattern is contrary to the TW-hypothesis (marital status and educational attainment being lower for teenage mothers). We find that mothers 15-19 are more likely to give birth to sons and mothers older than 35 are more likely to give birth to daughters (compared to mothers in the age group 20-34). The negative gradient, however, is consistent with the observation (noted by TW) that sons are a more risky parental investment. Therefore, sons may be more beneficial to young mothers and daughters to old mothers. Thus, it seems that with respect to maternal age, it rather than its socio-economic correlates provides a better explanation for the sex-ratio-maternal-age pattern. These findings provide an interesting relief to the infant deaths patterns.

**TW and infant mortality** The results from estimating the effect of infant mortality are in Table 1, columns (2) - (4).

The estimates for the level terms (**survived infancy**) show the effects for those who survive infancy. Comparing across columns (1)-(3), it is clear that infant mortality reinforces the TW effect of marital status and education, and reduces the extent to which the age effects are contrary to TW.

The interaction terms (**died in infancy**) show whether the differences between decedents and survivors are statistically significant. Estimating 2 on the sample of infants who survive their first year and post-neonatal decdents, we find that the coefficient on `dead` × `married` is negative and statistically significant at the 1 percent level, columns (3)-(4). That is, married mothers were not only more likely to bear sons, marriage is associated with reduced risk for male children. There was, however, no reinforcing effect from neonatal deaths, column (2).

As for maternal age, interestingly, mothers younger than 20 years are more likely to lose infant sons. The effect applied to all infant deaths but was stronger for neonatal deaths, columns (2)-(4). Since young mothers are biologically predisposed to bear males, this suggests that early male mortality reflects young mothers being negatively selected with respect to social and economic circumstances. As for older mothers, despite a tendency to bear female offspring, sons fare better in the face of infant mortality. The greater survival chances of boys suggest that the biological disadvantage from being born to an older mother is countered by older mothers' being positively selected with respect to social characteristics (see Royer [2004]).[5]

We also estimated equations 1 and 2 for each year separately. Figures 1 and 2 plot the coefficient estimates for selected variables by year.

As a robustness check, we estimated regression models which included paternal information (age, race, education), but these neither altered the findings nor yielded results of independent interest. Obviously, this does not imply that paternal characteristics are not important, simply that they are sufficiently captured by information on the mother.

# 4 Discussion

Gender at birth is not random. A Trivers-Willard pattern is observed in the U.S. for the period 1983-2001. Mothers in "good condition" bear more sons than mothers in "poor condition," confirming a pattern noted by Darwin.[6] In addition to maternal marital status, we find that low education is associated with more female offspring, suggesting that the proximate mechanism for TW operates through low status in general rather than specifically through living conditions at the time of conception.

We also show that infant mortality reinforces the TW effect, i.e., in addition to the *in-utero* environment, the post-natal environment impacts the sex ratio

[5]Teen mothers are less likely to be married and have less education than older mothers in the 1983-2001 NCHS data. The 1988 U.S. Maternal and Infant Health Survey, which also records income, indicates that teen mothers have significantly lower household income and are more likely to receive welfare than older mothers (results available from authors).

[6]Darwin [1871]:281 noted as a "mysterious fact that...the excess of male to female births is less when they are illegitimate than legitimate" and hypothesized that males suffer disproportionately from adverse conditions.

in the way predicted by TW: males born to mothers in poor condition – as measured by maternal marital status and age – suffer higher infant mortality than males born to mothers in good condition.

Inherent male vulnerability can produce a TW effect if low socioeconomic status exposes the infant to greater environmental insults, as noted by e.g., Wells [2000]. Two findings, however, suggest that this mechanism may not be the only factor at play. First, only the post-neonatal deaths reinforce the TW pattern in marital status. The bulk of neonatal deaths takes place in the first week of life and can be linked to physiological factors such as congenital defects, low birth weight or gestation length. Many of these deaths take place in hospitals. Deaths in the post-neonatal period, by contrast, tend to be in an environment under greater parental control. Second, gender differences in infant deaths by maternal age are the polar opposite of what we would expect under the male vulnerability hypothesis. Advanced maternal age is recognized as a risk factor for a host of adverse pregnancy and birth outcomes. Nevertheless, advanced maternal age appears to benefit infant males.

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## Data Appendix

We construct the following dummy variables using information on mother and child.

**male** Indicates whether infant is male.

**dead** Indicates whether infant died.

**married** Indicates whether mother was married at the time of giving birth.

**sub15yr** Indicates whether mother was 14 years or younger at the time of giving birth.

**15to17yr** Dummy takes the value one if mother was 15 through 17 years old at the time of giving birth.

**18to19yr** Dummy takes the value one if mother was 18 or 19 years old at the time of giving birth.

**plus35yr** Indicates whether mother was 35 years or older at the time of giving birth.

**mEdMis** Indicates whether mother's education was missing.

**mEdLow** Indicates whether mother had 11 or fewer years of education.

**mEdHS** Indicates whether mother had 12 years of education, but not more.

Table 1: High status mothers bear more sons – pattern reinforced by post-neonatal mortality

| | | Dependent variable: infant is male<br>Sample: infancy survivors + deaths | | | |
|---|---|---|---|---|---|
| | | Infant | Neonatal | Postneonatal | |
| | mean | (1) | (2) | (3) | (4) |
| **survived infancy** | | | | | |
| married | 0.786 | 1.02*** | 1.12*** | 1.13*** | 0.65*** |
| | | [0.19] | [0.19] | [0.19] | [0.19] |
| sub15yr | 1.50E-03 | 4.93*** | 4.24** | 4.24** | 6.13*** |
| | | [1.87] | [1.88] | [1.88] | [1.88] |
| 15to17yr | 0.037 | 2.96*** | 2.68*** | 2.68*** | 3.18*** |
| | | [0.41] | [0.42] | [0.42] | [0.42] |
| 18to19yr | 0.072 | 1.28*** | 1.07*** | 1.08*** | 1.16*** |
| | | [0.29] | [0.29] | [0.29] | [0.29] |
| plus35yr | 0.100 | -1.61*** | -1.48*** | -1.48*** | -0.95*** |
| | | [0.24] | [0.24] | [0.24] | [0.24] |
| mEdMis | 0.104 | -2.09*** | -2.16*** | -2.14*** | -1.89*** |
| | | [0.27] | [0.27] | [0.27] | [0.27] |
| mEdLow | 0.18 | -3.06*** | -3.20*** | -3.20*** | -2.89*** |
| | | [0.23] | [0.23] | [0.23] | [0.23] |
| mEdHS | 0.324 | -1.07*** | -1.11*** | -1.11*** | -1.02*** |
| | | [0.18] | [0.18] | [0.18] | [0.18] |
| **died in infancy** | | | | | |
| dead | 6.48E-03 | | 42.45*** | 73.93*** | 75.0*** |
| | | | [3.69] | [4.26] | [4.17] |
| dead×married | | | 2.71 | -14.16*** | -14.4*** |
| | | | [2.69] | [3.26] | [3.26] |
| dead×sub15yr | | | 32.41* | 21.918 | 22.11 |
| | | | [17.64] | [23.58] | [23.55] |
| dead×15to17yr | | | 25.50*** | 16.69*** | 16.71*** |
| | | | [5.23] | [6.14] | [6.14] |
| dead×18to19yr | | | 14.81*** | 16.46*** | 16.34*** |
| | | | [4.07] | [4.61] | [4.61] |
| dead×plus35yr | | | -18.97*** | -28.92*** | -28.07*** |
| | | | [3.73] | [5.63] | [5.62] |
| dead×mEdMis | | | -1.45 | -2.98 | -2.93 |
| | | | [3.62] | [5.00] | [4.98] |
| dead×mEdLow | | | 3.60 | 3.19 | 3.07 |
| | | | [3.54] | [4.38] | [4.37] |
| dead×mEdHS | | | -1.92 | 6.10 | 6.06 |
| | | | [2.94] | [3.99] | [3.99] |
| Birth weight and gestation dummies | | yes | yes | yes | no |
| *N* | 48E+06 | 48E+06 | 47.9E+06 | 47.8E+06 | 47.8E+06 |

Notes: All regressions include a constant and year dummies. All explanatory variables are indicator variables and scaled by 1/1000.
*** indicates significance at the 1 percent level, ** at the 5 percent level and * at the 10 percent level.

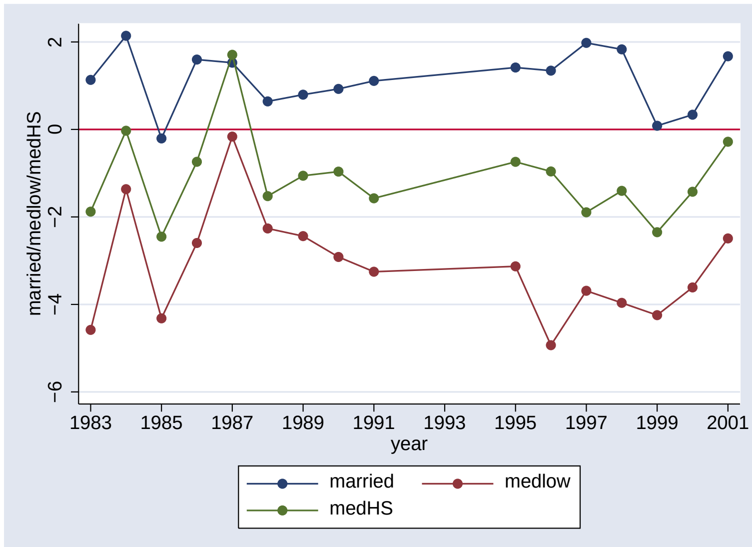


Figure 1: Maternal socio-economic status and maleness of offspring among infants surviving first birthday

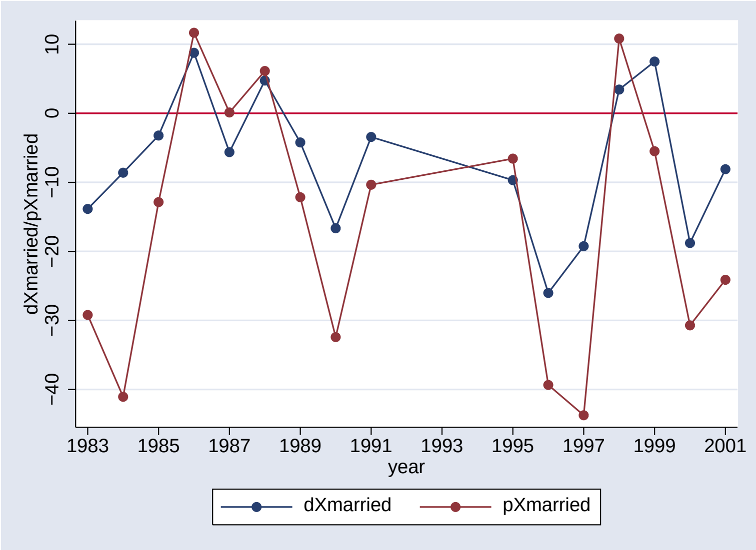


Figure 2: Reduced male mortality among married mothers: all infant deaths (dXmarried) and post-neonatal deaths (pXmarried)

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