DRAFT VERSION

This is a Man's World? Changes in Income Predict Sex Ratio at Birth

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Abstract

The human sex ratio at birth (SRB) is approximately 107 boys for every 100 girls. SRB was rising until the World War II and has been declining slightly after the 1950s in several industrial countries. Recent studies have shown that SRB varies according to exposure to disasters and socioeconomic conditions. However, it remains unknown whether changes in SRB can be explained by observable macro-level socioeconomic variables across multiple years and countries. Here we show that changes in disposable income at the macro level positively predict SRB in OECD countries. A one standard deviation increase in the change of disposable income is associated with an increase of 1.03 male births per 1000 female births. This is the first evidence to show that economic and social conditions influence SRB across countries at the macro level. This calls for further research on the effects of societal conditions on general characteristics at birth.

1. Introduction

The Trivers-Willard hypothesis (1) (henceforth TWH) predicts that natural selection favors a positive relationship between sex ratio at birth (SRB) and parents' ability to invest in offspring. This prediction stems from the assumption that a male in good condition at the end of the period of parental investment produces more offspring than a female in similar condition, and a female in bad condition produces more offspring than a male in similar condition. According to TWH we would expect SRB to vary with environmental factors. Indeed, sex ratio has been decreasing in several industrial countries in recent decades. Theories as to why have been put forth, but the proposed explanations are unable to fully account for the changes (2).

Previous studies have found statistically significant associations between SRB and multiple other factors. These studies can be roughly divided into three groups according to the explanatory variables used in them: studies concerning disasters (3–8), parental characteristics (9–15), and other country-level variables (16–18). Notably, there are also studies showing no significant association (19–22). Many studies give credence to TWH, but we see three caveats in the literature: the possibility of publication bias, narrow focus, and in some cases focus on the absolute levels instead of changes.

Our work fulfills all of these three important aspects. First, as some of the studies find no effect, the question remains: how many studies without significant results remained unpublished? We study the effects across a wide range of countries. This eliminates the possibility of publication bias almost necessarily involved in studies focusing on single events in a specific context. Second, we aim to study the effects of large-scale macro-level social phenomena, not those of a specific disaster or event. This has more relevance for

societies compared to narrow and specific individual-level determinants or country-level disasters. The fall in SRBs observed in multiple industrialized countries also requires an explanation that can be applied to a wide set of countries. Third, we focus on changes in disposable income – not levels. This is consistent with the idea that a sort of "hedonic adaptation" (23) renders gains of the distant past irrelevant to such sociobiological processes as SRB. As much of the literature finding significant results concerns disasters, it is likely that the shock to the status quo is the main mechanism behind the effects, and we expect SRB to adapt to new macro societal conditions quite rapidly.

2. Data and methods

We employ OECD (2014) data for annual growth rates of real household net disposable income deflated by final consumption of households between the years 1971 and 2013 for 23 countries, which we correct for population growth using mid-year estimates of total population from the World Bank (2015) to obtain per capita figures. We link this information with annual live birth data by sex obtained from the United Nations (2014), which is a dataset collected through questionnaires to national statistical offices since 1948.

This gives us an unbalanced panel of countries from 1971 onwards. In the analysis, we only included countries with more than 10 years of data (see S1 Table for included countries). We further excluded South Korea from the countries remaining after this selection. This was due to fear of possible sex-selective abortion and certain anomalies in the South Korean live birth data.

We employ fixed effects regression model of the following form to estimate SRB:

$$SRB_{i,t} = \alpha + \gamma_i + \delta_t + \beta \Delta Y_{i,t} + \varepsilon_{i,t}, \qquad \text{(S1)}$$

where i and t stand for the country and year indices, respectively. β is the estimated association between SRB ($SRB_{i,t}$) and change in disposable income $\Delta Y_{i,t}$. γ_i and δ_t are the country and year fixed effects, respectively. Descriptive information on the variables can be found in S2 Table.

3. Results

The timing of the change in disposable income and observed births is illustrated in (Fig 1). Lacking monthly data, we have tried to associate the income growth to the interval of births mostly affected by it. This imperfect modeling can be expected to result in more noise in the estimates, and thus it will attenuate the observed statistical associations.

***Fig 1. The timing of birth if conception happens at the time of income change from year t to year t+1.** When examining the income change at the time of conception at the macro level from t to t+1(presented in blue), the associated birth period with conception happening during the income change is presented in purple. From this period we have taken the only full year (t+1, presented in red) that corresponds to the period of income change when calculating the SRB.*

Figure 2 shows the association between the country-level SRB and the relative percent change in disposable income at the yearly level for an unbalanced panel of 23 OECD

countries for the years 1971–2012 controlled for year and country effects. The correlation between the two variables is significantly positive at 0.11.

Fig 2. Linear association between changes in disposable income per capita from previous year and SRB net of year and country fixed effects. The x-axis of the scatter plot is the relative per capita change of real household net disposable income deflated by final consumption of households expressed in percent as calculated by the OECD between the years 1971 and 2013 for 23 countries. The population growth numbers were obtained from the World Bank. The y-axis is SRB after controlling for year and country effects. SRB is calculated as the number of male births per 1000 female births from annual live birth data by sex obtained from the United Nations. The year and country effects are estimated with a fixed effects panel regression. The blue line represents the linear regression estimate. The dark gray area around the blue line is the 95% confidence interval. Only countries with more than 10 years of data are included in the unbalanced panel. In addition, South Korea was omitted due to fear of possible sex-selective abortion and certain anomalies in the South Korean live birth data.

To control for unobserved, time-invariant, country-level heterogeneity and common yearly shocks, we introduce a fixed effects regression model to estimate SRB (see S1 Fig and S2 Fig for the distributions of sex ratio by country and year). This simple analytical strategy leads to time- and country-independent effects of disposable income. The effect of Y on SRB is significant at the 5% level (Table 1). A coefficient of 0.391 means that a one percent growth in disposable income is associated with an increase of 0.39 male births per 1000 female births. A one standard deviation increase in the change of disposable income is associated with an increase of 1.03 male births per 1000 female births.

We also show that the GDP level per capita does not have a statistically significant relationship with SRB for the countries and years studied (see S3 Table in supplementary information, columns 2 and 3). Standard of living per se is unlikely to be a significant determinant, since SRBs have decreased in the industrialized world as living standards have risen (2). However, as the pace of change in living standards has slowed (24), SRBs have decreased as well (2).

Table 1. Association between changes in disposable income, GDP per capita, and changes in SRB.

	Dependent variable: SRB
Per capita annual proportional change in disposable income, per cent	0.391** (0.157)
Year fixed effects	Yes
Country fixed effects	Yes
N	490
R^2	0.014
Adj. R^2	0.013

*$p<0.1$; **$p<0.05$; ***$p<0.01$. The explanatory variable in the fixed effects panel regression is the relative per capita change of real household net disposable income deflated by final consumption of households expressed in percent as calculated by the OECD between the years 1971 and 2013 for 23 countries. The population growth numbers were obtained from the World Bank. The dependent variable is SRB. SRB is calculated as the number of male births per 1000 female births from annual live birth data by sex obtained from the United Nations. The year and country effects are controlled with a fixed effects panel regression. Only countries with more than 10 years of data are included in the unbalanced panel. In*

addition, South Korea was omitted due to fear of possible sex-selective abortion and certain anomalies in the South Korean live birth data.

4. Discussion

Our estimate shows a highly significant association between disposable income change and SRB and is thus consistent with the prediction of TWH. Also, consistent with the hedonic adaptation theory (23), changes in instead of levels of the standard of living exhibit a significant association. However, the result should be interpreted with caution. We control for country-level and yearly variation by using a fixed effects model, but change in income might simply act as a proxy for other social variables that in turn affect SRB. If those variables vary differently in countries over time, they still remain uncontrolled for. A reverse effect from SRB to income change is unlikely to play a role.

This is the first evidence of economic and social conditions influencing SRB at the macro level in a wide range of countries and underlines the significance of feedback loops between biological and social conditions. The results also offer a possible explanation to the puzzle of falling SRBs.

Acknowledgements

References

1. Trivers RL, Willard DE. Natural Selection of Parental Ability to Vary the Sex Ratio of Offspring. Science. 1973 Jan 5;179(4068):90–2.

2. Davis DL, Gottlieb MB, Stampnitzky JR. Reduced ratio of male to female births in several industrial countries. JAMA J Am Med Assoc. 1998;279(13):1018–23.

3. Catalano RA. Sex ratios in the two Germanies: a test of the economic stress hypothesis. Hum Reprod. 2003 Sep 1;18(9):1972–5.

4. Fukuda M, Fukuda K, Shimizu T, Møller H. Decline in sex ratio at birth after Kobe earthquake. Hum Reprod. 1998 Aug 1;13(8):2321–2.

5. Lyster WR. Altered Sex Ratio After the London Smog of 1952 and the Brisbane Flood of 1965. BJOG Int J Obstet Gynaecol. 1974 Aug 1;81(8):626–31.

6. Catalano R, Bruckner T, Marks AR, Eskenazi B. Exogenous shocks to the human sex ratio: the case of September 11, 2001 in New York City. Hum Reprod. 2006 Dec 1;21(12):3127–31.

7. Zorn B, Šučur V, Stare J, Meden-Vrtovec H. Decline in sex ratio at birth after 10-day war in Slovenia Brief communication. Hum Reprod. 2002 Dec 1;17(12):3173–7.

8. Graffelman J, Hoekstra RF. A Statistical Analysis of the Effect of Warfare on the Human Secondary Sex Ratio. Hum Biol. 2000 Jun 1;72(3):433–45.

9. Irgens Å, Irgens LM. Male proportion in offspring of military air pilots in Norway. Nor Epidemiol [Internet]. 1999 [cited 2015 Feb 20];9(1). Available from: http://www.ntnu.no/ojs/index.php/norepid/article/view/442

10. Almond D, Edlund L. Trivers–Willard at birth and one year: evidence from US natality data 1983–2001. Proc R Soc B Biol Sci. 2007 Oct 7;274(1624):2491–6.

11. Ruckstuhl KE, Colijn GP, Amiot V, Vinish E. Mother's occupation and sex ratio at birth. BMC Public Health. 2010 May 23;10(1):269.

12. Mealey L, Mackey W. Variation in offspring sex ratio in women of differing social status. Ethol Sociobiol. 1990;11(2):83–95.

13. Mathews F, Johnson PJ, Neil A. You are what your mother eats: evidence for maternal preconception diet influencing foetal sex in humans. Proc R Soc Lond B Biol Sci. 2008 Jul 22;275(1643):1661–8.

14. Johns SE. Subjective life expectancy predicts offspring sex in a contemporary British population. Proc R Soc Lond B Biol Sci. 2004 Dec 7;271(Suppl 6):S474–6.

15. Kanazawa S. Big and tall parents have more sons: Further generalizations of the Trivers–Willard hypothesis. J Theor Biol. 2005 Aug 21;235(4):583–90.

16. Catalano R, Bruckner T, Smith KR. Ambient temperature predicts sex ratios and male longevity. Proc Natl Acad Sci. 2008 Feb 12;105(6):2244–7.

17. Navara KJ. Humans at tropical latitudes produce more females. Biol Lett. 2009 Aug 23;5(4):524–7.

18. Williams RJ, Gloster SP. Human sex ratio as it relates to caloric availability. Biodemography Soc Biol. 1992;39(3-4):285–91.

19. Polasek O, Kolcic I, Kolaric B, Rudan I. Sex ratio at birth and war in Croatia (1991–1995). Hum Reprod. 2005 Sep 1;20(9):2489–91.

20. Rueness J, Vatten L, Eskild A. The human sex ratio: effects of maternal age. Hum Reprod. 2011 Oct 24;der347.

21. Khashan AS, Mortensen PB, McNamee R, Baker PN, Abel KM. Sex ratio at birth following prenatal maternal exposure to severe life events: a population-based cohort study. Hum Reprod. 2009 Apr 8;dep082.

22. Kolk M, Schnettler S. Socioeconomic status and sex ratios at birth in Sweden: No evidence for a trivers–willard effect for a wide range of status indicators. Am J Hum Biol. 2015 Jun 1;n/a – n/a.

23. Frederick S, Loewenstein G. Hedonic adaptation. In: Kahneman D, Diener E, Schwarz N, editors. Well-being: The foundations of hedonic psychology. New York, NY, US: Russell Sage Foundation; 1999. p. 302–29.

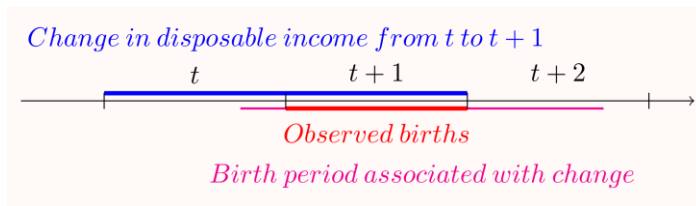24. Piketty T. Capital in the twenty-first century. Belknap Press; 2014.

Figures

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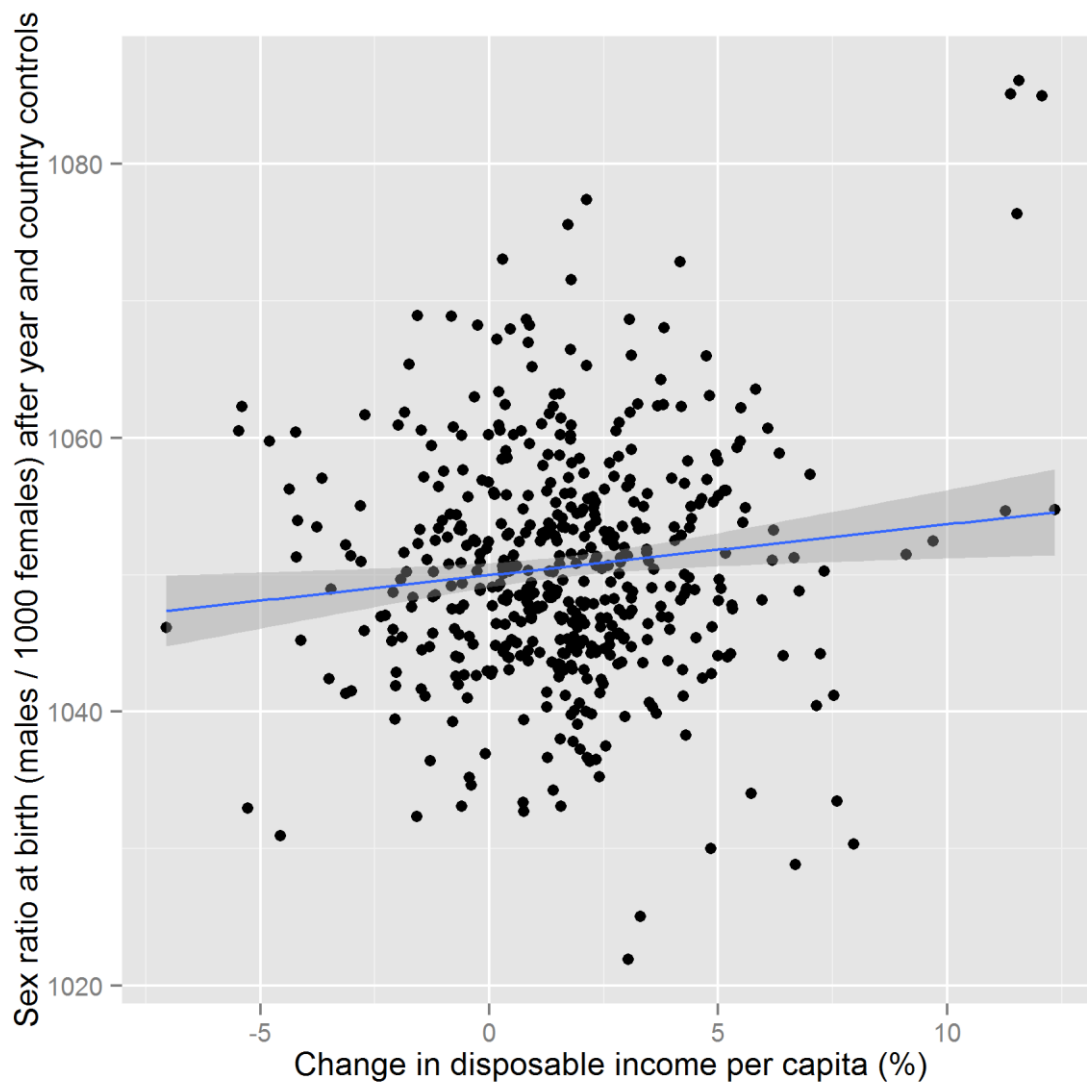
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