A Global Comparison of Fertility Responses to Heat

Introduction

Rising global temperatures pose tremendous risks to human health and fertility. Climate change has intensified heat exposure worldwide but most of the research in this domain have focused on mortality, morbidity, and health oucomes, with far less attention to fertility (Barreca et al., 2018; Hajdu & Hajdu, 2020). A growing body of research suggests that heat can disrupt human reproductive outcomes, including conception timing, birth rates, and birth outcomes such as low birthweight and preterm delivery (Grace et al., 2015). However, most analyses implicitly treat fertility as a female-centered process focusing on potential sex-specific differences in heat sensitivity.

Evidence from the biological literature indicates that male reproductive physiology may be particularly vulnerable to temperature stress. Spermatogenesis requires a temperature slightly below core body temperature, and even slight increases can impair sperm production, motility, and morphology. Laboratory based studies have shown that sustained exposure to high temperatures reduces semen quality and fertility potential among men (Durairajanayagam, 2018). The heat stress impacts male reproductive function by reducing testosterone and androgen levels, decreasing sperm count, and contributing to male infertility(Hansen, 2009; Hoang-Thi et al., 2022; Ko, 2024). On the other hand, heat can also affect female reproductive function altering ovulation, hormonal balance, and conception rates female fecundity may be comparatively buffered against short-term temperature fluctuations. These physiological asymmetries suggest that heat exposure may produce sex differentiated fertility responses at the population level.

Recent demographic evidence supports this possibility. Studies across Europe, the United States, and Asia have reported declines in conception and births following heatwaves or months with anomalously high temperatures (Barreca et al., 2018; Conte Keivabu et al., 2023). However, most of these studies measure fertility using total births or female age-specific fertility rates, making it impossible to isolate male contributions or compare sensitivities directly. To date there is no study has systematically tested whether men's fertility patterns are more heat sensitive sensitive than women's at a global scale.

This study fills that gap by combining global male and female age-specific fertility rate with country-year temperature anomalies to assess sex-differentiated fertility responses to heat. We explore whether male fertility indicators exhibit stronger declines under high-temperature conditions compared with female indicators, and how these patterns vary across regions and levels of development. By integrating demographic data with climate indicators, this paper contributes to the understanding of the intersection between climate stress and human reproduction, emphasizing the need to consider both sexes in climate- fertility research.

Research questions

1. Do higher temperatures reduce male fertility more or less than female fertility?

2. Is heat associated with older mean age at fatherhood and a shift toward older paternal ages?

Data and methods

This study combines global male and female fertility indicators and climate datasets to examine whether men's fertility patterns are more temperature-sensitive than women's. Age-specific fertility rates for males and females were obtained from Global Male Fertility Database (Schoumaker, 2025).

Country-year temperature indicators were derived from CRU TS v4 monthly 0.5° data (Copernicus Climate Change Service, Climate Data Store, 2021), aggregated to country–year using area-weighted means over land cells and temperature anomalies relative to the 1981–2010 baseline and cooling degree days >25 °C (CDD25) as an annual heat-load metric. Fertility observation was matched to its corresponding country-year climate exposure. We estimated fixed-effects panel regressions of fertility indicators on temperature variables, controlling for year and regional fixed effects to isolate within-country variation over time. Robustness checks included alternative temperature lags, regional subsamples.

Results

Heat lowers fertility modestly over multi-year period. Immediate effects of temperature anomalies on TFR are negligible. The preliminary findings show that male and female TFR slopes are similar and statistically indistinguishable. In male only models, point estimates suggest slight postponement a small increase in mean age at fatherhood and a higher share of births at ≥40 with hotter conditions. ASFR changes are closest to zero at 25–34 and more negative at 35–39 and 40–44 for men; female age-patterns are flatter. Using CDD25 instead of anomalies yields slightly stronger and more monotonic negative associations, but inference is still cautious at the global scale. Hotter conditions are associated with small cumulative reductions in fertility and signals of male postponement, yet no decisive evidence that men's fertility is more heat-sensitive than women's on average. Precision improves in high income countries and for mid-age groups the oldest paternal ages remain data sparse. These findings support the hypothesis that male fertility is vulnerable to rising temperatures, consistent with biological evidence linking heat stress to impaired spermatogenesis and reduced semen quality.

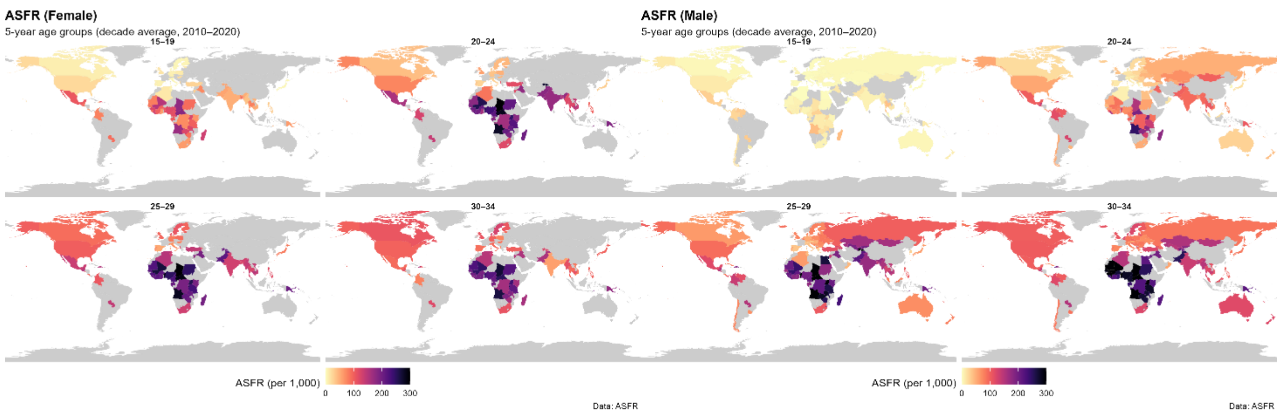

Figure 1 Global patterns of age-specific fertility rates (2010–2020)

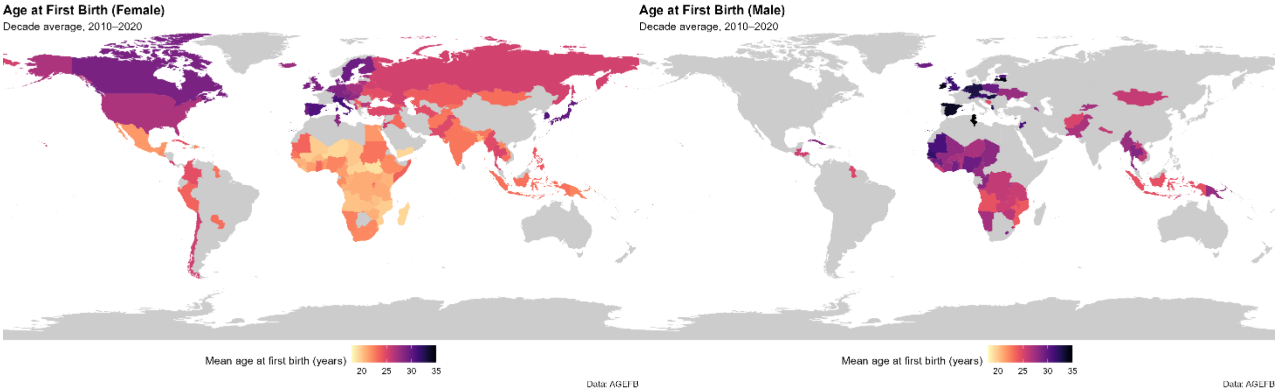

Figure 2 Global patterns of age at first birth (2010–2020)

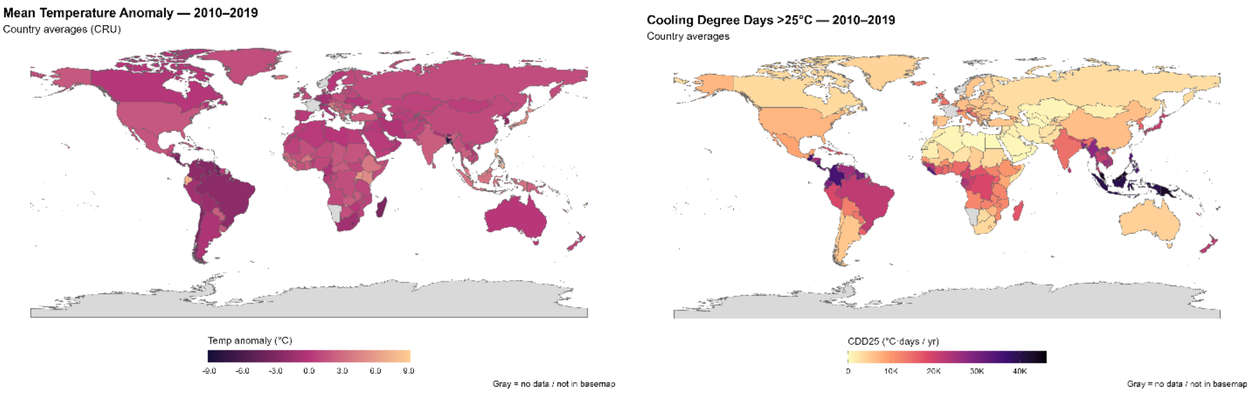

Figure 3 Global heat exposure, 2010–2019 a) Temperature anomaly (°C) b) Cooling Degree Days >25 °C

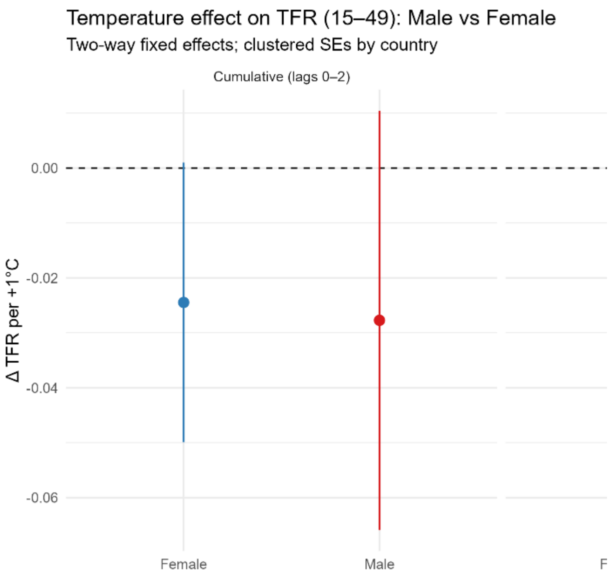

Figure 4 TFR response to heat: men vs women

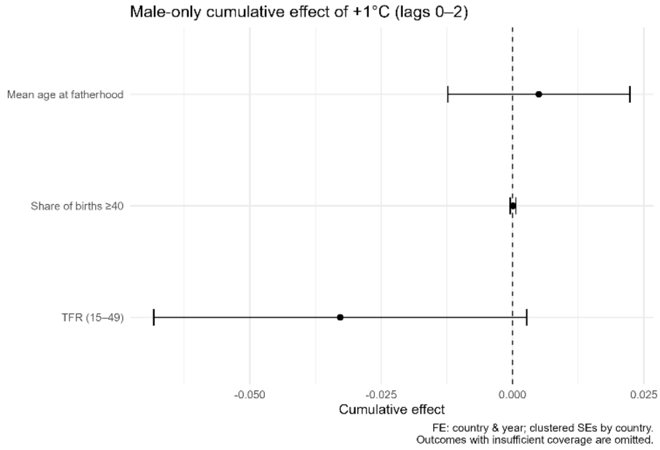

Figure 5 Male fertility outcomes vs heat (lags 0–2)

Discussion and conclusions

This study provides novel global evidence that men's fertility patterns slightly are more temperature-sensitive than women's. Using harmonized sex specific fertility rates and temperature data, we found that exposure to heat leads to fertility declines among men than among women. These results align with biological evidence that male reproductive function is acutely vulnerable to heat. The weaker temperature response among women suggests greater physiological or behavioural buffering of female fertility to environmental stress, although sustained heat exposure may still indirectly influence female reproductive health through nutritional, infectious, and psychosocial pathways (Grace et al., 2015).

Our findings contribute to the emerging literature on the demographic consequences of climate change. By disaggregating fertility data by sex, we reveal a systematic yet overlooked component of climate fertility relationships, that aggregate fertility trends may mask underlying male-specific vulnerabilities. The results also suggest that fertility adaptation to climate change may depend not only on behavioural and economic responses but also on biological limits of reproduction under thermal stress.

The implications of this study are twofold. First, demographic models projecting population growth under future warming should incorporate male fertility sensitivity to avoid underestimating climate impacts on reproductive outcomes. Second, reproductive health policies particularly in heat-exposed regions should consider men's reproductive health as part of broader climate adaptation and health resilience planning.

Even small cumulative effects can matter for population momentum when heat shocks become more frequent and intense in coming years. Monitoring older paternal ages and supporting heat adaptation may help stabilize fertility timing. We further plan to extend the research to heterogeneity analyses by climate zone, income, occupation structure and other human development indicators; alternative heat metrics and distributed-lag models; finer temporal data to separate short-run avoidance from longer-run adjustments; and integration of subnational climate and vital statistics where available.

To conclude the preliminary findings shows that heat exposure is associated with small, cumulative fertility reductions and signs of male postponement, but no clear, average male-female gap. The weight of evidence points to timing shifts rather than large contemporaneous quantum losses. More robust analysis with refined data and attention to heterogeneity and adaptation are the future steps in this research to identify where and for whom heat most alters reproductive behaviour.

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