This is the published version of a paper published in *Evolution and human behavior*.

Citation for the original published paper (version of record):


Access to the published version may require subscription.

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http://urn.kb.se/resolve?urn=urn:nbn:se:hig:diva-34207
Are skewed sex ratios associated with violent crime? A longitudinal analysis using Swedish register data

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ABSTRACT

Keywords: Sex ratio Violent crime Mating market Sweden

There is widespread concern in both the popular and academic literature that a surplus of men in a population intensifies mating competition between men, particularly unpartnered men, resulting in increased violence towards both men and women. Recent contributions challenge this perspective and argue that male mating competition and levels of violence will be higher when sex ratios are female-skewed. Existng empirical evidence remains inconclusive. We argue that this empirical ambiguity results from analyses of aggregate-level data, which put inferences at risk of ecological fallacies. Our analysis circumvents such problems by using individual-level, longitudinal demographic register and police data for the Stockholm metropolitan area, Sweden (1990–2003, n = 758,498). These data allow us to investigate the association between municipality-level sex ratios and violent offending (homicide, assault, threat, and sexual crimes) while adjusting for sociodemographic factors. Results suggest that aggregated offending rates are negatively associated with male-skewed sex ratios, whereas individual-level violent offending correlates positively with male-skews. We find that the more-men-more-violence association holds particularly for male violence against other men, but is insignificant for violence against women. Moreover, the association is significant among childless men, but not among fathers. However, robustness checks question the causality of these associations. Female violent offending is positively, albeit due to a low number of cases, insignificantly associated with male-skews. Moreover, both male and female non-violent offending is higher in male-skewed municipalities. We discuss the implications with regard to the theoretical debate and problems of unobserved heterogeneity in the sex ratio literature.

1. Introduction

There is widespread concern in both the popular and academic literature that a surplus of men in a population is associated with an increase in a variety of social problems, particularly the incidence of violence (Brooks, 2012; Hudson & Den Boer, 2004; Hvistendahl, 2011; Messner & Sampson, 1991). Some scholars argue that male-skewed sex ratios will leave more men without a partner, thus increasing the share of single men, the demographic group that is responsible for a large share of violent offending (Daly & Wilson, 1988; Pedersen, 1991). However, recent contributions contest this prediction and argue that the incidence of violence should decrease as sex ratios become increasingly male-skewed (e.g. Barber, 2009b; Schacht, Tharp, & Smith, 2016). In this reformulated sexual selection framework (Kokko & Jennions, 2008), men are predicted to be more willing to comply with female long-term mating preferences and to avoid repeated antagonistic mating competition when women are scarce. Consequently, violent male-male rivalry is expected to be less frequent when men are abundant.

Existing empirical evidence remains inconclusive (see Schacht, Rauch, & Borgerhoff Mulder, 2014; Schnettler & Filser, 2015, 2020 for reviews), partially due to methodological and data shortcomings. In particular, past studies mainly rely on cross-sectional and aggregate level data, leaving findings vulnerable to the ecological fallacy, i.e. making inadequate inferences on individual-level behavior based on associations in population level data (cf. Pollet, Stoebenbelt, & Kuppens, 2017 for a review). Unobserved heterogeneity is also likely to contribute...
to inconsistencies in previous empirical findings. In particular, associations between sex ratios and violent crime might be driven by sex-skewed migration patterns. Given that young women are more likely to migrate to more prosperous regions (cf. Leibert, 2016), the correlation between regional prosperity and violent crime (cf. Hoogh, Vanhoutte, Hardyns, & Bircan, 2011) may be a crucial source of heterogeneity in previous studies.

In this paper, we address these shortcomings by using Swedish longitudinal register data for the Stockholm metropolitan area to study the potential association between local sex ratios and violent offending at the individual level. Specifically, we explore whether municipality-level sex ratios are associated with male and female violent offending. Our data allow us not only to avoid the ecological fallacy, but also to examine whether any association between sex ratios and violent offending differs by offender and victim sex. Furthermore, our individual-level analysis allows us to examine the extent to which various individual-level characteristics moderate the sex ratio-crime link — a subject of much previous speculation, but little empirical testing. Finally, by controlling for absolute and relative socioeconomic conditions both on the individual- and context-level, we aim to adjust for one obvious potential candidate driving a potentially spurious sex-ratio-crime link.

1.1. More men, more violence?

Predictions of increased violence in male-skewed populations emphasize that a male oversupply diminishes men’s prospects to find a partner, increasing male-male mating competition (Dyson, 2012; Hesketh & Xing, 2006; Hudson & Den Boer, 2004; Hvidstendahl, 2011). Propositions of this notion that male abundance exacerbates male tendencies towards violence build on sexual selection and parental investment theory (Bateman, 1948; Darwin, 1871; Trivers, 1972). In humans, physiological parental investment is considerably higher for females (i.e. gestation, lactation) than it is for males, implying an asymmetry in potential reproductive rates between men and women. Female mating strategies are thus hypothesized to be sexually selected towards long-term, committed relationships while men have an incentive for multiple mating (Clutton-Brock & Parker, 1992; Trivers, 1972). As the sex ratio in a population becomes more male skewed, this antagonistic mating competition among (single) men intensifies (Clutton-Brock & Parker, 1992; Emlen & Oring, 1977). Evolutionary Psychology suggests that male same-sex aggression represents one form of competition for females and resources that improves chances on the mating market (Campbell, 2007; Daly & Wilson, 1988). While this may not reflect the full complexity in the relationship between sex ratios and violence (see Schacht et al., 2014), one predicted consequence is that intensified intra-male competition for female partners may result in increased rates of male-male violence, particularly among those men who are looking for a partner.

This is compatible with findings that living in a committed relationship reduces both violent and non-violent criminal offending among men (Sampson, Laub, & Wimer, 2006; but see also Skardhamar, Sølvvågen, Aase, & Lyngstad, 2015). Hormonal responses might be one mechanism potentially driving the association between relationship status and the propensity for violence: entering marriage or cohabitation is associated with a decline in testosterone concentrations (Holmboe et al., 2017; Rosenbaum, Gettler, McDade, Bechayda, & Kuzawa, 2018). Similarly, fatherhood is associated with a decrease in testosterone concentrations (Gettler, McDade, Fernald, & Kuzawa, 2011).

Like male-male violence, male-female violence, too, might be associated with sex ratios. In Evolutionary Psychology, male-on-female intimate partner violence is seen as one of a number of different mate-guarding strategies that men may employ to ensure the sexual fidelity of their female mates (Buss, Larsen, Westen, & Semmelroth, 1992; D’Alessio & Stolzenberg, 2010; Daly & Wilson, 1998). Thus, when competition for female partners intensifies in a male-skewed population, men might experience increased sexual jealousy and increasingly turn to violence to deter their partners from infidelity (D’Alessio & Stolzenberg, 2010; Vandello, 2007). Moreover, rates of sexual coercion against women could be higher in populations with male-skewed sex ratios due to a larger share of men without sexual partners. Some men might then use force to gain sexual access (Malamuth, Huppin, & Paul, 2005).

1.2. More men, less violence

Predictions that sex ratios are negatively associated with violence highlight that, in the case of female scarcity, female partner preferences guide male mating competition (Schacht et al., 2014). This follows from a bargaining perspective on the partner market (Guttentag & Secord, 1983; Kokko & Jennions, 2008) and emphasizes that in order to find a partner, the more numerous sex has to display traits preferred by potential partners. Specifically, in populations with male-skewed sex ratio, men are expected to improve their mating chances by adjusting to female preferences for long-term mating (Noe, 2017; Schacht et al., 2016). Here, violence against male rivals is an unpromising strategy for attracting a spouse. Instead, men are predicted to compete for female partners by displaying the ability and willingness to commit and invest in common offspring (Schacht et al., 2014). In addition, a shortage of women disincentivizes short-term mating for men, because additional female partners are harder to find. Thus, Schacht et al. (2016) argue that when men are in abundance and surrounded by competitors, they should reduce, not increase, efforts to mate with multiple partners.

Conversely, when sex ratios are female-skewed, men are predicted to hold a bargaining advantage over women to realize any preferences for short-term mating (Schacht et al., 2014, 2016; Trivers, 1972). Therefore, men are expected to invest more in short-term mating effort and to behave more promiscuously (Noé, 2017; Schacht et al., 2016). This may lead to increased jealousy and rivalry between men, so that female-skewed sex ratios are predicted to be associated with increased levels of male-on-male violence (Barber, 2009a; Schacht et al., 2016). This dynamic should be particularly pronounced in societies in which uncommitted, non-marital sex is widespread and socially accepted (Diamond-Smith & Rudolph, 2018; Schacht & Borgerhoff Mulder, 2015).

Finally, the bargaining power perspective suggests that male-skewed sex ratios are also negatively associated with violence against women as they are expected to be treated more respectfully when they are scarce (Guttentag & Secord, 1983). Consequently, men are less likely to harass women because it would hurt their mating prospects in an already unfavorable partner market (South, Trent, & Bose, 2014).

1.3. Sex ratios and violence: Empirical evidence

The existing empirical evidence fails to consistently support either prediction of violent criminal offending being associated with male-skewed or female-skewed populations (Filser & Schnettler, 2018; Schacht et al., 2014; Schnettler & Filser, 2020). Rates of homicide, assault, and sexual offenses have been reported to be both positively (Avakame, 1999; Dreze & Khara, 2000; Edlund, Li, Yi, & Zhang, 2013; Messner & Sampson, 1991; Vandello, 2007) and negatively (Barber, 2000, 2009a; Esmail, Penny, & Eargle, 2013; O’Brien, 1991; Schacht et al., 2016) correlated with national, province-, and county-level sex ratios. A number of methodological problems may be responsible for this inconclusive state of evidence.

Data inconsistencies are a prime concern for cross-national comparisons (e.g. Barber, 2000, 2009a). Whether national sex ratios are positively or negatively associated with crime levels might depend on the data source (Nivette, 2011). Moreover, relying on country-level data is problematic because this ignores the considerable within-country variation in sex ratios (Wiest et al., 2013). Although people may migrate between regions, social contacts are more limited between than within regional populations and partner markets are commonly found to be local (Haandriksen, 2018). Spatial homogamy persists even in the
age of online dating, given that online dating contacts, too, are constrained by geographic distance (cf. Bruch & Newman, 2019). Therefore, entire countries are too large to function as a single marriage market and are consequently an inappropriate level at which to measure the sex ratio (cf. Fossett & Kiecolt, 1991; Pollet et al., 2017). Yet, studies analyzing sex ratio variation for smaller geographical units, too, yield contradictory conclusions. In the United States, for instance, homicide levels are reported to correlate positively with male-skewed sex ratios in state- and city-level data (Messner & Sampson, 1991; Vandello, 2007), while a county-level analysis yielded an inverse association (Schacht et al., 2016).

This contradictory state of evidence may be due to inherent methodological problems when analyzing aggregated data, such as sex ratios and crime rate indicators for nations, wards, provinces, districts or cities. Of particular concern are the ecological fallacy and Simpson’s paradox, the fact that associations in aggregate data may be actually reversed at the individual level (Pollet et al., 2017; Simpson, 1951). Furthermore, most studies analyze overall crime rates aggregated across the sex of both offenders and victims. This lack of detail is problematic, because theoretical predictions postulate distinct associations of the sex ratio with either male-on-male and male-on-female violence (Pedersen, 1991; Schacht et al., 2014; South et al., 2014). Aggregate indicators might obscure opposing associations: male-on-male violence may correlate positively with sex ratios, while there could be a negative correlation between sex ratios and male-on-female violence.

Moreover, previous findings may be limited by unobserved heterogeneity on the regional- and individual-level. Specifically, the sex-ratio-violence association may be driven by third variables that affect both crime rates and sex ratios. Given sex-specific patterns in migration rates between deprived and prosperous regions (Leibert, 2016; Uggla & Mace, 2017), socioeconomic conditions may potentially drive the sex-ratio-violence association. Also, previously unobserved variables on the aggregate and individual level may moderate the sex-ratio-crime association. It is possible that both theoretical approaches could be integrated. While imbalanced sex ratios may increase intra-sex competition among the more common sex, the form of competition might vary with unobserved contextual or individual characteristics.

A further problem is that aggregate data do not allow for explorations of how individual-level characteristics might drive or moderate the association between sex ratios and violence. Specifically, a male over-supply may affect low-status males more strongly than high-status males, as the former can find a partner from outside their status group more easily (Hudson & Den Boer, 2002). Consequently, the association between the sex ratio and the propensity for violence may vary across status groups. While existing research reveals diverging associations of sex ratios across status groups for separation and cohabitation with children (Uggla & Mace, 2017), no study so far has addressed this aspect with regard to the sex-ratio-violence link.

Similarly, relationship and parental status might moderate the sex-ratio-violence association. Theoretical approaches attribute the association between sex ratios and violence to behavioral adaptations of men in response to partner market prospects (Hudson & Den Boer, 2004; Pedersen, 1991; Schacht et al., 2014). Consequently, behavior of men who have found a partner and/or formed a family might not be as affected by partner scarcity or abundance as single men. This notion is supported by life history theory, which suggests that individuals shift their energy from mating competition to parental investment after finding a partner (life history, reproductive effort; Den Boer et al., 2005a; Uggla & Mace, 2015a). This dynamic might be reinforced by a change in daily routines. As husbands and fathers spend more time with their families, the amount of time spent in contexts with higher risks for offending related to jealousy and mating rivalry, such as nightlife venues, decreases (Zoutewelle-Terohan & Skardbamar, 2016).

Only two studies – using data from India and a number of South-East Asian countries - analyze individual-level data to explore the sex ratio-violence association (Diamond-Smith & Rudolph, 2018; South et al., 2014). Both studies report positive associations between regional sex ratios and violence against both female and male victims and therefore suggest support for the more-men-more-violence hypothesis. These studies constitute a major improvement over earlier ones that relied on aggregate data, yet some limitations remain. Most importantly, both study populations may be unsuitable test cases for the less-men-less-violence hypothesis, because this line of argument presupposes women’s freedom to choose their partners. However, arranged marriages constitute the dominant mode of union formation in large parts of both study populations. Furthermore, the more-men-less-violence hypothesis suggests that relationship instability and serial mating might are when women are abundant. This is less plausible in sexually restricted societies such as these study populations. A final set of limitations results from the cross-sectional design of both studies. Specifically, Diamond-Smith and Rudolph (2018) link survey respondents with local sex ratios based on their current place of residence, while survey questions capture whether an offense has ever been committed. Given that individuals might have migrated since offending, this could result in a mismatch between the local sex ratio at the time of the survey and the sex ratio at the time and place of residence when the offense occurred. South et al. (2014) calculate local sex ratios from census data which predate the reported twelve-month time span in the survey question by about two to three years, again leaving a potential mismatch between the analyzed sex ratio and the circumstances at the time of the offense. Longitudinal, individual-level data could circumvent such problems. However, to our best knowledge no study so far has used such data to analyze the potential link between sex ratios and violent crime.

1.4. Aims

In light of the inconclusive literature, we use individual-level, longitudinal Swedish register data to explore whether municipality-level sex ratios are associated with individual violent criminal offending. The detailed register data allow us to address several methodological limitations in the existing literature. They enable us to distinguish the sex of perpetrators and victims and avoid committing an ecological fallacy. By controlling for a set of indicators of relative and absolute socioeconomic deprivation on both the contextual and individual level we are able to account for what may constitute a (partially) unobserved confounder in previous research. Our data enable us to analyze whether individual sociodemographic characteristics moderate or confound the association between sex ratios and violent offending. Finally we provide a more suitable test case for the more-men-less-violence hypothesis than previous studies in societies with more restrictive sexual norms and less scope for individual choice of romantic partners.

Extending the existing focus on male offending in the sex ratio literature, we contrast male and female offending in our analysis. A recent reformulation of the “more-men-more-violence” hypothesis to a “more-rivals-more-violence” hypothesis suggests sex ratios might correlate with female violent offending (Stone, 2015). Female-skewed sex ratios increase intra-sexual mating competition among women, which potentially instigates violence against female competitors. Male and female violence might therefore be associated with the sex ratio in opposite directions: male offending increases, while female offending decreases as the sex ratio becomes more male-skewed. Yet, women are generally attributed a higher inclination towards indirect (mating) aggression, such as badmouthing a rival, compared to men (Campbell, 2007; Stone, 2015). Therefore, female violent offending data might be less sensitive to sex ratio variations, because these indirect forms of violence are not well captured in official crime statistics. Finally, the least plausible case is a parallel association of female and male offending in a way that both are similarly positively or negatively associated with the sex ratio. Such a finding would be most likely due to a set of unobserved confounders that are responsible for both systematic sex ratio skews and patterns of violent offending. Consequently, contrasting our results also helps us evaluate the potential problems of unobserved
heterogeneity in our estimates.

Moreover, we contrast our results for violent offending with associations between the sex ratio and other, more general crime indicators. While there is some indication for sex ratio effects on property offenses (Esmail et al., 2013), the literature primarily suggests a link between sex ratios and violent offending. Property and other non-violent offenses might be associated with the local sex ratio as competition for mates also implies resource acquisition (Schacht et al., 2014). Given that women’s minimal parental investment is higher than men’s (Trivers, 1972), women are expected to pay close attention to a partner’s ability to provide resources. In an unfavorable, male-skewed partner market, this might prompt men to resort to property offending to obtain resources and status to attract a mate. Nevertheless, given the scarce empirical evidence for an association between sex ratios and property crimes, we expect weaker — if any — associations between local sex ratios and non-violent offending. Contrasting results for non-violent offenses with those for violent offenses help us to identify potential problems of unobserved heterogeneity.

2. Data and methods

2.1. Data

Data for this paper come from Swedish population registers and police suspicion records. The register data comprise annual information on all residents aged 16 and older in the wider Stockholm metropolitan area (Stockholms län) between 1990 and 2003. We limit our analytical sample to individuals aged 16 to 30 for two reasons: first, most (violent) offending is committed by individuals in this age range (Hirschi & Gottfredson, 1983). This is also true in our data: the age-specific offending rate for men peaks at 1.94% at age 18 and declines to a level of 1% at 30 and below 1.1 for all higher age stages (Fig. S1.1). Second, the hypothesized link between sex ratios and violent crime relates to assumed side effects of relationship formation processes. For our study population, the median age at first birth for men was 30.5 years in 2002 and well below that throughout the 1990s (SCB, 2002, pp. 9, 23). Childbearing was commonly preceded by marriage or a phase of cohabitation (Holland, 2013). In sum, this suggests that the main ages of dating and mating proceeding family and relationship formation are below age 30, which is therefore a reasonable upper bound for our sample. However, re-partnering and childbearing extends well beyond the age of 30, particularly for men. Therefore, we provide a robustness check including all individuals up to age 40. We choose 16 as the lower bound because this is the common minimum age included in sex ratios in the literature (cf. Edlund et al., 2013; Schacht et al., 2016). Additionally, we estimate model variants for which we split the sex ratio and our sample into two narrower age groups (16–23 and 24–30) as an additional robustness check. Our final sample size contains 758,498 unique individuals (4,261,079 person-years) in the age range from 16 to 30 years, of which 383,658 (2,107,885) are men.

We link these demographic data to the official suspicion register by the Swedish police (Swedish Ministry of Justice, 1998). To appear in this register, an individual must be formally suspected by police in

2.2. Variables

2.2.1. Crime indicators

Our main dependent variable captures the registration of an individual by law enforcement as a suspect for a violent crime. For our analysis, we include the following types of offenses: attempted/completed homicide, aggravated/minor assault, threats, and sexual offenses. Sexual offenses include rape, coercion, and molestation of women older than 15 or of unspecified age and sex. The original suspicion data indicate the sex and the age category of the victim, or states both aspects as unspecified. Based on this information, we only include offenses committed against victims aged 15 or older, as well as offenses against unspecified victims. The suspicion data subsume all offenses against known victims who are 15 or older in the same adult category, precluding an upper bound for victim age for our analyses.

Overall, individual violent offenses are uncommon in our data (see Fig. S1.2). This precludes a separate analysis of particularly severe types of violent offenses, such as homicide. We therefore use this data to create three combined measures of violent offense. The first measure indicates any type of violent offending based on our definition. The second and third are measures of violent crimes against male and female victims, respectively. For our auxiliary models on non-violent offending, we include all registered non-violent offending such as property offenses, white collar crimes, or drug offenses. A full list of the offenses in this indicator can be found in the supplementary material (Supplement 4).

2.2.2. Independent variables

Our key independent variable is the sex ratio of the population aged 16 to 30 in each municipality in the Stockholm metropolitan area for the respective year. We operationalize the sex ratio as the population share of males to avoid the asymmetrical distribution of proper ratios (Ancona, Dénès, Krüger, Székely, & Beissinger, 2017). In auxiliary models, we operationalized the sex ratio using age ranges 16–40, 16–23, and 23–30.

Our data enable us to adjust our estimates for a set of potential confounders. In particular, we are able to adjust for an individual’s marital and parental status. Uncommitted individuals might have stronger reactions to mate abundance or scarcity than those living in committed relationships or those with children. Given that non-marital cohabitation was common in Sweden during our observation period (Hoem, 1996; Olah, 2001), parental status complements an individual’s marital status. However, this variable only identifies parents living in the same household as their children and therefore is only a weak proxy for an individual’s reproductive status. Previous research emphasizes the importance of socioeconomic status for violent offending (Agnew, 2016; Lochner & Moretti, 2004). Therefore, our models include time-varying variables (on an annual basis) capturing an individuals’ highest level of completed education, individual income (by quintile), and the disposable income of the individual’s family (by quintile). We introduce age as discrete independent variable to allow for non-linear associations. Moreover, we include citizenship status to adjust for the overrepresentation of non-citizens in criminal registers (Beckley, Karvellas, & Sarnacki, 2014). Unfortunately, our data does not contain information on foreign background. Beyond adjusting our models for these variables, we explore potential moderation of the sex-ratio-violence association via testing for interaction terms for parental and marital status, education, and personal income.

At the municipality level, our models include the logged median income as well as the Gini coefficient to account for the role of income disparities and deprivation for violent offending (Fajnzylber, Lederman, & Loayza, 2002). The latter captures the deviation of the distribution of income among households in a municipality from an equal distribution. A value of zero represents absolute equality, a value of one maximal income concentration. Furthermore, we adjust for population density, proportion of non-citizens, and the number of young adults (aged 16 to 25) as a proportion of the total population of the municipality. These variables adjust for aspects of the demographic profile of a municipality beyond the sex ratio, which have also been linked to violent offending (Christens & Speer, 2005; McCall, Land, Dollar, & Parker, 2013). Table S1.3 displays the bivariate correlations between municipality-level variables. Correlations of the sex ratio measures with the other
municipality-level variables are moderate to low, while there is a negative correlation (−0.6) of the sex ratio with population density. Given the importance population density, we keep this control variable in models and re-run them in models as a robustness check.

2.3. Methods

Given the longitudinal nature of our data, we estimate discrete-time proportional hazard models to study the link between individual level offending and municipal-level sex ratios, with person-years as units of analysis. Individuals are censored after committing their first violent crime to prevent repeat offenders to drive the results. Results from models including repeat offenders can be found in the supplementary material. The models are specified using logistic regression to estimate the predicted hazard for a person being suspected of the respective crime in year $t$:

$$\text{logit}(h_i(t)) = \log \left( \frac{e^{\beta'x_i}}{1 + e^{\beta'x_i}} \right)$$

Models include municipality dummies to capture unobserved heterogeneity between municipalities. This unconditional fixed effects approach is particularly adequate if a larger number of lower-level units are clustered within a limited number of higher levels units (Hilbe, 2009, p. 482), which to our models as we have a large number of individuals (>750,000) clustered into 26 municipalities.

To facilitate interpretation of the results, we transform the output from the logistic regression model to marginal effects. We then scale the differences in the estimated probability of the outcome by the baseline probability of experiencing the outcome. Therefore, our graphs show the percentage difference in the probability of the outcome at different levels of the sex ratio relative to the mean probability of the outcome in the analytical sample.

All analyses are performed using Stata 16; visualizations are created using R 3.6.3 and ggplot2 (R Core Team, 2020; StataCorp, 2019; Wickham, 2016). We provide code for our analysis in the supplementary material (Supplement 5). Due to the sensitive nature of the information, a formal application to Statistics Sweden and an ethics approval is necessary and our data cannot be made freely available.

3. Results

Fig. 1 shows a scatterplot of aggregated annual rates of violent offending and sex ratios for the 16 to 30-year-old population in the greater county of Stockholm from 1990 to 2003. The share of males among persons aged 16–30 ranges from 46.8 to 52.9%, which corresponds to sex ratios between 88 and 112 males per 100 females. During our observation period, annual numbers of registered suspects of violent offenses aged 16 to 30 vary between 0 and 20.5 per 1000 inhabitants in the same age group. Overall, 22,682 men and 3399 women have at least one suspicion record for the relevant violent offenses (Tables S1.5 & S1.6). The red line in Fig. 1 illustrates the results from a bivariate linear model with crime rate as dependent and sex ratio as independent variable. We include random intercepts to account for clustering of annual observations in municipalities. Overall, municipality-level violent crime rates and sex ratios correlate negatively, but the association is not statistically significant ($p = 0.07$, see also Table S1.7).

3.1. Local sex ratios and violent offending by sex of offenders

In a first model series, we analyze the association between municipality-level sex ratios and individual likelihood of a registered violent offense by the sex of the potential offenders separately. Contrary to the aggregate-level results, these estimates reveal a positive association between local sex ratios and registered violent offenses by both men and women. In bivariate models, the coefficient is statistically significant for female offending ($p < 0.001$), but not for male offending ($p = 0.052$, Table S1.8). After including individual- and municipality-level control variables the positive sign for both coefficients persists, while the models suggest a significant association for male ($p < 0.001$), but not for female ($p = 0.0193$) offending. Fig. 2 shows the differences in predicted probabilities for being suspected of a violent offense relative to the sex-specific mean probability. Relative to the mean probability, predicted probabilities of male violent offending are 20.7% lower than the mean at a male population share of 46% and increase to a level of 25.3% above the average at a proportion of men of 53%. Results for female offending suggest a positive trend as well. Predicted probabilities of female offending increase from 20.5% below the average probability to 25.3% above the mean probability of offending when moving from a male population share of 46% to 53%. Yet, the association between sex ratios and registered violent offending by women is not statistically significant. A full table of regression outputs can be found in the supplementary material (Table S1.9).

Models using different sex ratio operationalisations and age limits for the analytical sample (16–40 and split models for 16–23 and 24–30) can be found in the supplementary material (Supplement 2). Overall, results from these models are consistent with a positive association between local sex ratios and male violent offending. Notably, the slope in predicted probabilities for male offending is somewhat steeper in models based on all individuals aged 16 to 40, compared to the main model.
based on ages 16 to 30 (Fig. S2.1). For the split models, we find a significant and positive association between the sex ratio and violent offending in the age group 16 to 23, while the association is positive, but not significant for the age bracket 24 to 30 (Fig. S2.2). For female offending, we find a positive, but non-significant association with either of the alternative sex ratio measures (Fig. S2.1-S2.2). Finally, results for

Fig. 2. Percentage difference in the predicted probability of registered violent offenses by offenders’ sex. Men and women aged 16 to 30 living in the Stockholm metropolitan area, 1990–2003.

Percentage difference in the predicted probability of violent offending relative to the baseline probability of violent offending from logistic discrete-time event history models. Vertical bars show 95% confidence intervals. Violent offenses include attempted and completed homicide, assault, threat and sexual crimes. Models adjusted for individuals’ age, citizenship, civil status, individual and household income, education, parental status, and well as municipality-level Gini coefficients, population densities, shares of non-citizens, shares of young adults, and median incomes.
Source: Swedish register data.

Fig. 3. Percentage difference in the predicted probability of registered violent offenses by sex of offenders and victims. Men and women aged 16 to 30 living in the Stockholm metropolitan area 1990–2003.

Percentage difference in the predicted probability of violent offending relative to the baseline probability of violent offending from logistic discrete-time event history models. Vertical bars show 95% confidence intervals. Violent offenses include homicide, assault, and threat. Crimes against female victims also include sexual crimes. Models adjusted for age, citizenship, civil status, personal and family income, education, parental status, as well as municipal Gini coefficient, population density, share of non-citizens, share of young adults, and median income.
Source: Swedish register data.
models excluding population density as a control variable show a stronger association between sex ratios and violent offending.

### 3.2. Local sex ratios and violent offending by sex of offenders and victims

In a second model series, we differentiate registered offenders based on offenders’ as well as victims’ sex. Fig. 3 shows the adjusted predictions from the respective logistic regression models. For men, results reveal that predicted probabilities of a registered violent crime against a male victim are higher when municipality sex ratios are male-skewed as compared to when they are female-skewed (Fig. 3, upper left panel). The non-overlapping confidence intervals illustrate the statistical significance of this finding. Despite a similar pattern to male-on-male offenses, the sex-ratio-violence association is not statistically significant for male-on-female offenses (Fig. 3, lower left panel). This reflects a combination of smaller frequencies of offenses in the models (see Fig. S1.2) and a smaller sex-ratio coefficient in comparison to male-on-male offending (see Table S1.10). Relative to the mean probability, predicted probabilities of male-on-female offending increase from 17.5% below the mean to 21.3% above the mean when moving from a 46% to a 53% male population share. For male-on-male offenses, on the other hand, the predicted probabilities increase from 23.2% below the average at a male population share of 46% to 29.3% above the average at a male population share of 53%.

Similar to the overall indicator presented in Fig. 1, violent offenses by women are not statistically significantly associated with municipal sex ratios when split by victims’ sex (Fig. 3, right column). Female violent crime against men exhibits a small negative, but markedly insignificant association with the sex ratio (Fig. 3, upper right panel). While also not significant, female violent crime against women interestingly shows a positive association with the sex ratio (Fig. 3, lower right panel).

Models using different sex ratio operationalisations (16–23 and 24–30) can be found in the supplementary material (Supplement 2). Results for these models based on individuals aged 16 to 40 and 16 to 23 show a positive association between local sex ratios and violent offending by men against men (Fig. S2.3–S2.4). However, when limiting the sample and the sex ratio to ages 24 to 30, male-on-male offending is not significantly associated with the sex ratio. Male offending against females is significantly and positively associated with the sex ratio in models based on all individuals aged 16 to 40 (Fig. S2.3). This suggests that the non-significant association of male-on-female offending in the models for the ages 16 to 30 might primarily be due to the small number of offenses instead of a qualitative difference in the association with the sex ratio. For female offending, confidence intervals are similarly as wide as those seen in the main models when analyzing the sex ratio in the 16 to 40 and 24 to 30 age groups. However, we find a significant and positive association for female-on-female offending in the age group 16 to 23, while female-on-male reveals a non-significant, negative association for the same age operationalization (Fig. S2.4). Again, models excluding population density as a control variable yield stronger associations between sex ratios and all types of violent offending.

### 3.3. Interactions between local sex ratios and individual characteristics

Moreover, we analyze whether the association between sex ratios and violent offending varies with socioeconomic status as well as marital and parental status by including an interaction term for the local sex ratio with individuals’ parental status, marital status, educational attainment, and income, respectively. Following recent recommendations, we evaluate our interaction models based on adjusted predictions rather than significance of the coefficient of the product term (cf. Mize, 2019).

Our results suggest a stronger association between local sex ratios and violent offenses against male victims in men without offspring than among fathers (Fig. 4). Whereas the difference between fathers and non-fathers is marginal when sex ratios are skewed towards females, it is more pronounced when the sex ratio is skewed towards males. For childless men, the predicted probability of male-on-male offending increases from 23.1% below the mean to 32.2% above to the mean probability, when moving from a male population share of 46% to 53%. The corresponding predicted probabilities for fathers, however, remain below the mean probability across the entire range of the sex ratio: at a male population share of 46%, the predicted probability is 23.1% lower than the mean, but it is 4.7% higher than the mean at a male population share of 53%. Moreover, the probability of violent offending against another male is significantly associated with the local sex ratio among childless men, but not among fathers.

We also find some indication for different slopes for local sex ratios across marital status groups (Fig. S1.11). However, the difference in slopes of adjusted predictions between unmarried and married men is small. When compared across the range of the sex ratio, predicted probabilities of unmarried and married men differ by a factor of 1.37 - compared to a factor of 6.1 when contrasting childless men and fathers (Fig. 4). This contrast between marital and parental status is most likely due to high levels of non-marital cohabitation and child birth in Sweden.
during our observation period (Hoem, 1996; Olah, 2001), meaning that the registered civil status is a noisy indicator of men’s relationship status.

Finally, our results suggest that the association between municipal sex ratios and registered offenses by men against male victims does not differ substantially across educational and income status groups (Fig. S1.11). Overall, we do not find any systematic differences in the slopes for the sex ratios-crime association across the respective status groups.

3.4. Local sex ratios and non-violent offending

Finally, we fit models predicting non-violent offending to evaluate whether the associations reported above might be driven by unobserved heterogeneity. Fig. 5 shows that for both male and female non-violent offending, we find a positive association with the male-skewed municipality-level sex ratios. Notably, the association of the sex ratio with non-violent offending is more pronounced for women than for men. Moreover, Fig. 5 includes the predictions for violent offending from Fig. 2 as faint lines and points for reference. For men, the slope for violent offending is steeper, compared to non-violent offending. For female offending however, the association is more pronounced for non-violent than for violent offending.

4. Discussion

In this study, we use Swedish register data to investigate the link between local sex ratios and violent criminal offending. Existing theoretical approaches are contradictory and empirical evidence remains inconclusive, suggesting both negative and positive associations between male-skewed sex ratios and violence (Schacht et al., 2014, 2016; Schnettler & Filser, 2015, 2020). To our knowledge, this study is the first to use individual-level, longitudinal data to circumvent an ecological fallacy, a common problem of previous research on the issue (Filser & Schnettler, 2018; Pollet et al., 2017; Schacht et al., 2014). The detail of our data enable us to disentangle associations of intra- and inter-sexual violence with the sex ratio and to adjust for a number of socio-demographic confounders. Moreover, we investigate hypothesized, but largely untested differences in these associations by socio-economic, marital, and parental status.

On the surface, our results seem to provide additional support for the more-men-more-violence hypothesis. We find that male-on-male violence is positively associated with male-skewed sex ratios. Results for male-on-female violence suggest a similar positive association with male-skews, which is somewhat weaker and not statistically significant, due to a smaller sample size for these offenses. Both findings are compatible with the hypothesis that an abundance of men will particularly result in high levels male-male violence. Furthermore, our results suggest that intra-male violence correlates significantly with local sex ratios among childless men, but not among fathers. This may appear as further support for the hypothesis that local male-skews particularly instigate violent rivalry among men competing for partners.

However, the full set of results, including the results from models examining female-on-female violent offenses, and non-violent offenses, suggests caution before drawing any firm conclusions. First, when comparing our findings on male and female offending, we would expect either no association between sex ratios and female offending or one that is opposite to the association with male offending (cf. Stone, 2015). Yet, we find that the association between the sex ratio and female violent offending resembles that for male offending. The association for female offending is not significant, but this may be largely due to the low number of offenses by women in our data. The number of offenses is even lower for analyses of female offending split by victims’ sex, which precludes any meaningful interference from results on female-on-male and female-on-female violent offending.

Second, we find that municipality-level sex ratios are not only associated with violent offending, but also with a general indicator of any non-violent offending. Property and white-collar offenses might correlate with sex ratios, as individuals are more pressurized to obtain resources and resort to scramble competition (Benenson & Abadzi, 2020; Edlund et al., 2013). However, given the broadness of the indicator, we would expect these associations to be weaker, compared to violent offenses. While this is only true for non-violent offending by men, we find that the association of sex ratios with female non-violent offending is even stronger than the one for violent offending. Furthermore, we find that the associations of sex ratios with non-violent offending are in the same direction for both male and female offenders. This contradicts theoretical expectations related to scramble competition as women should become less and not more likely to engage in non-violent offending as the sex ratio increases, that is, as the environment becomes less female-skewed.

In sum, these findings prompt us to suspect that there are still

![Figure 5](https://via.placeholder.com/150)

**Fig. 5.** Percentage difference in the predicted probability of registered non-violent offenses by offenders’ sex. Men and women aged 16 to 30 living in the Stockholm metropolitan area, 1990–2003.
Percentage difference in the predicted probability of non-violent offending relative to the baseline probability of non-violent offending from logistic discrete-time event history models. Vertical bars show 95% confidence intervals. faint points and lines provide predictions for violent offending. Models adjusted for age, citizenship, civil status, personal and family income, education, parental status, as well as municipal Gini coefficient, population density, share of non-citizens, share of young adults, and median income.
potential confounders that might drive the association between sex ratios and violent crime that we are not able to account for. We are able to adjust our models for contextual and individual-level socio-economic deprivation in a more comprehensive way than previous studies. Socio-economic deprivation is a key confounder of the association between sex ratios and violent crime, given that young women are more likely to migrate to more economically thriving regions (Leibert, 2016) and levels of violent crime are correlated with prosperity (Hooghe et al., 2011). We address this issue by including municipality-level fixed effects to account for time-constant unobserved heterogeneity on the municipality level. Moreover, we include a range of time-varying socio-economic and demographic status variables on both the individual and context level. These adjustments should take care of socio-economic unobserved heterogeneity, yet some limitations remain.

Beyond socio-economic factors, sex-selective migration patterns might be a source of unobserved heterogeneity. Empirical evidence suggests that women out-migrate from male-biased areas to more strongly female-biased areas than men (Uggl a & Mace, 2017). With regard to violence and crime, one potential explanation could be that women are less concerned about falling victim to a crime (Jackson, 2009). Consequently, sex-selective migration might drive the association of sex ratios and violent crime independently of economic deprivation. Unfortunately, we are not able adjust our models for migration patterns in our analysis, particularly migration from outside our study area.

Another limitation of our study is the comparatively small geographical scope of our data. An underlying assumption of our analysis is that individuals are sensitive to cues of the municipality-level sex ratio and that municipalities meaningfully represents the local ecology which impacts individual behavior. However, individuals might have committed offenses in different contexts than their municipality of residence, resulting in a mismatch of the contextual sex ratio at the offense and our sex ratio measure. Moreover, municipalities might be too small entities to measure sex ratios in a way that also correlates closely with individuals’ perceptions of partner markets (Filser & Preetz, 2020; Possiet & Kiecolt, 1991; Gilbert, Uggl a, & Mace, 2016). Furthermore, our study area consists of a metropolitan area with an urban center, Stockholm city. Municipalities are a meaningful social entity in Sweden, because they organize schools and municipality centers serve as local hubs. However, individuals still commute and move between municipalities. With a size of 7150 km², the area is well connected by public transport and roads. Consequently, municipalities are not as separate as calculating specific municipality-level sex ratios suggests them to be.

Nevertheless, the level of detail in our data allow us to elucidate a number of aspects previous studies have not been able to explore. A key contribution of our paper is to support concerns about studying the association of sex ratios and aggregated rates of individual social outcomes, as it is commonly done in the existing sex ratio literature (cf. Pollet et al., 2017 for an in-depth critique). Specifically, our findings demonstrate how, based on the same data, sex ratios and aggregated violent offending rates can suggest a negative association, even when individual probabilities for violent offending are actually positively associated with sex ratios. This illustrates the importance of individual-level analyses to further establish a coherent empirical basis in the sex ratio literature.

Moreover, our paper illustrates that detailed offending data are necessary to generate clearer evidence with regard to which types of violent offenses are associated with sex ratio skews. We wish to remain cautious with too much emphasis on the differential levels of significance due to diverging sample sizes in offenses. Yet, the weaker association for male-on-female offending compared to male-on-male offending puts predictions of increased male-on-female intimate partner violence (D’Alessio & Stolzenberg, 2010; Daly & Wilson, 1998; Uggl a & Mace, 2015b; Vandello, 2007) or higher levels of sexual harassment in male-skewed environments into perspective (Malamuth et al., 2005; Trent & South, 2012; Trent, South, & Bose, 2015). However, our data do not differentiate between violence against (intimate) partners and other female victims and thus our results on male-on-female violence can only serve as a combined indicator of violence against women by both partners and other men. Additional research is necessary to disentangle these different types of male-on-female violence and their associations with the sex ratio.

Moreover, our results reveal that the association of skewed sex ratios with violence may differ across individual demographic characteristics, as has been shown for other outcomes (Uggl a & Mace, 2017). Specifically, sex ratios are positively associated with violent offending in childless men, but not among fathers. While we outlined above that this finding should be treated with caution, it still serves as an illustration for the yet untapped potential of individual-level data for the literature on sex ratios and violent offending. Future studies should further explore this aspect.

In sum, our findings demonstrate the need for studies relying on more detailed data and advanced causal identification strategies when exploring the association of sex ratios with violence and aggression. Observational studies, no matter how detailed, might be unable to overcome unobserved heterogeneity problems at both the individual and the aggregate level. Experimental studies have generated evidence for sex ratio effects on aggression by human participants (Arnocky, Ribout, Mirza, & Knack, 2014). We encourage future research to evaluate whether these effects vary across parental status groups as our results indicate.

Finally, our findings should be considered within their specific socio-sexual context (see Schacht et al., 2014). Our study population fits the WEIRD definition (Henrich, Heine, & Norenzayan, 2010), with high levels of acceptance for uncommitted sexual relationships (cf. Widmer, Treas, & Newcomb, 1998). Therefore, our paper complements the literature in that it comes from a sexually liberal society, while previous individual-level analyses use data from more sexually restrictive contexts (Diamond-Smith & Rudolph, 2018; South et al., 2014). Such societies might not be suitable test cases for the more-men-more-violence hypothesis, since this perspective emphasizes uncommitted sexual relationships as a main mediator for the link between sex ratios and male violence (Schacht et al., 2014, 2016). This limitation does not apply to our study. While we cannot provide evidence of a counterfactual causal effect of male-skewed sex ratios on violent crime, our findings at least cast doubt on the more-men-less-violence hypothesis versus the more-men-more-violence hypothesis in this context.

Acknowledgements

This project uses data from the Stockholm Metropolitan Area Database and is supported by a research grant of the NordForsk-funded research network: “Register-Based Life Course Studies: Sociological, Demographic, and Economic Perspectives.”

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.evolhumbehav.2020.10.001.

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