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Dirk Bethmann/Michael Kvasnicka

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*Verantwortlich für diese Ausgabe:*
Dirk Bethmann
Otto-von-Guericke-Universität Magdeburg
Fakultät für Wirtschaftswissenschaft
Postfach 4120
39016 Magdeburg
Germany

http://www.fww.ovgu.de/femm

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# WAR, MARRIAGE MARKETS AND THE SEX RATIO AT BIRTH

Dirk Bethmann*‡ Michael Kvasnicka†‡

Otto-von-Guericke-Universität Magdeburg RWI and IZA

November 23, 2011

**Abstract**

In belligerent countries, male-to-female sex ratios at birth increased during and shortly after the two world wars. These rises still defy explanation. Several causes have been suggested (but not tested) in the literature. Many of these causes are proximate in nature, reflecting behavioral responses to the dramatically changed marriage market conditions for women and men that were induced by war-related declines in adult sex ratios. Based on county-level census data for the German state of Bavaria in the vicinity and aftermath of World War II, we explore the reduced-form relationship between changes in adult and offspring sex ratios. Our results suggest that war-induced shortfalls of men significantly increased the percentage of boys among newborns.

Keywords: World War II, Adult Sex Ratio, Marriage Markets, Sex Ratio at Birth.

*Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany; email: dirk.bethmann@ovgu.de. Financial support by the Fritz Thyssen Stiftung is gratefully acknowledged.

†Contact author: Michael Kvasnicka, Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) (Berlin Office), Hessische Straße 10, 10115 Berlin, Germany; email: michael.kvasnicka@rwi-essen.de.

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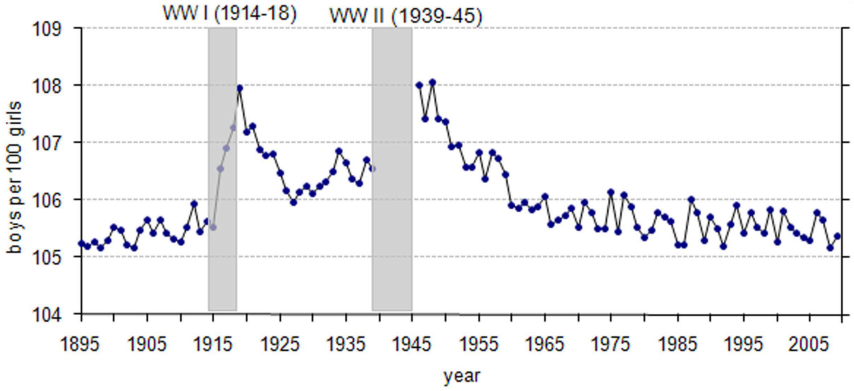
# 1 Introduction

Among the more than 200 countries recorded in the 2011 CIA World Factbook, the sex ratio at birth averages 105 boys per hundred girls. This slight excess of boys among newborns is remarkably stable across different populations, regions, and times. Statistically significant deviations from this "natural rate", however, have been recorded at several instances in history. In particular, during and in the immediate aftermath of the two world wars, the sex ratio at birth has temporarily increased in belligerent countries. For World War I (WWI), such a rise is documented for Austria, Belgium, Bulgaria, England, France, Germany, Hungary, Italy, Romania, and South Africa (Bernstein, 1958; Russell, 1936). For World War II (WWII), it has been observed, among others, in Austria, Belgium, Denmark, England and Wales, France, Germany, the Netherlands, and the United States (see Figure 1 for a time series plot of the sex ratio at birth in Germany).[1]

Figure 1: Sex ratio at birth in Germany, 1895-2009.




*Note:* No data are available for the war years 1940-1945. From 1946, data on West Germany only.
*Sources:* The time series of annual sex ratios at birth in Germany were calculated from statistics published by German Federal Statistical Office.

Although long noted, these wartime rises are still not understood (Ellis and Bonin, 2004; Hesketh and Xing, 2006). They are also bewildering for two reasons. First, at the time of the two world wars, sex of offspring at birth was yet beyond the direct control of parents, that is no choice variable.[2] Sex-selective abortions (and a preference for sons) hence cannot explain these historic incidences of male-biased sex ratios at birth.[3] Second, economic hardship, worsened nutrion, stress, and limited access to health care were often endemic in belligerent countries. As prenatal mortality rates of boys tend to be more sensitive to adverse environmental conditions (see Teitelbaum, 1970 or James, 1987), the sex ratio at birth should

[1]See, for example, the cross-country study by Graffelman and Hoekstra (2000) which covers most of the countries listed in the text, MacMahon and Pugh (1954) for the US during World War II, and Lowe and McKeown (1951) and van der Broek (1997) for respectively England and the Netherlands during both world wars.

[2]Technology for prenatal sex determination with ultrasound became available only in the early 1980s.

[3]Preference(-for-son)-based explanations have been advanced for the male-biased sex ratios at birth observed in parts of South-East Asia in recent decades. See, for example, Das Gupta (2005) for China and Jha et al. (2006) for India. Evidence for son preferences has also been found for developed countries, such as the US (see, for example, Lundberg and Rose (2003) and Dahl and Moretti (2008).

have fallen rather than increased in belligerent countries.

In search for explanations, the medical literature on the subject has pointed to a myriad of specific causes that could have affected the sex ratio among newborns. Candidates include declines in female and male age at conception (cf. Chahnazarian 1988 Tables 1 and 2), increases in parental age differences (e.g. Manning et al., 1997), reduced parity (i.e. birth order, see Biggar et al., 1999), and increases in out-of-wedlock childbearing (James, 2009). Empirical evidence for a causal influence of these factors, however, is still scant, as is knowledge on the precise mechanisms by which they may impact the ratio of boys to girls at birth.[4]

Ultimately, however, these factors at best constitute *proximate* reasons in the chain of causation. At times of major wars, they represent behavioral responses to the dramatic changes in marriage market conditions (declines in adult male-to-female sex ratios) that were induced by the great numbers of prime-aged men who went to war in belligerent countries. In the largely medical literature on the subject, however, war-induced declines in adult sex ratios have received little to no attention as a potential root cause of the war-time rises in the sex ratio at birth. This continuing disregard is surprising in light of the growing body of literature in economics that has found evidence for a sizable influence of adult sex ratio imbalances on spousal age at marriage, lifetime fertility, and the out-of-wedlock birth ratio (e.g. Grossbard-Shechtman, 1985; Edlund, 1999; Angrist, 2002; Chiappori et al., 2002; Bethmann and Kvasnicka, 2007; and Francis, 2011).

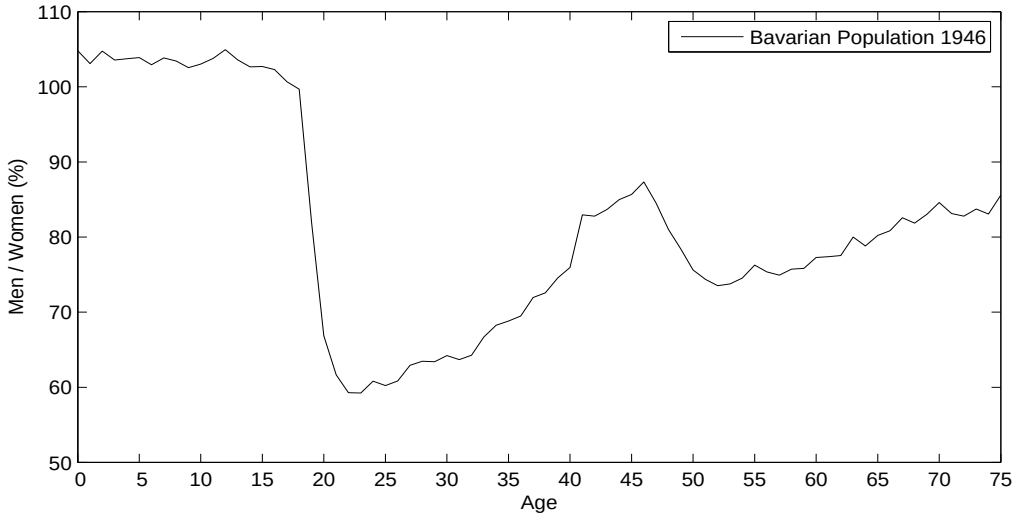
Based on a unique dataset of county-level census data for the south German state of Bavaria in the vicinity and aftermath of World War II, we study the reduced-form relationship between changes in the adult sex ratio and the sex ratio at birth. As common aggregate factors, such as economic hardship or limited access to health care after the war, may have had an influence on the sex ratio at birth and hence potentially confound the relationship between the two sex ratios, we exploit for identification war-induced regional variation in the magnitude of adult sex ratio changes. Our results suggest that war-induced declines in the adult sex ratio indeed had a sizable influence on the sex ratio at birth. The larger the female marriage market squeeze in a county, the more on average did the sex ratio at birth increase. Consistent with expectations, we also find evidence that aggregate factors on average tended to reduce the ratio of boys to girls at birth. Overall, our results suggest that economic analyses of the sex ratio at birth need to pay greater attention to adult sex ratio imbalances (i.e. general marriage market conditions) and their effects.

[4]Evidence is mostly based on simple correlations or univariate regression analyses of data that is not from (more recent than) the two world war periods.

## 2 Background: World War II and the Shortage of Men

At the time of the first post-war census in Germany (October 1946), 1.7 million refugees, 0.4 million evacuees, and more than 0.6 million soldiers dead, imprisoned, or missing in action (m.i.a.) were recorded in Bavaria. With a pre-war population of roughly 7 million, these war-induced population changes were tremendous. Above all, they led to a dramatic shortage of men in Bavaria among age cohorts in their prime fertility years, an unprecedented female marriage squeeze (see Figure 2).[5]

Figure 2: Post World War II sex ratios in Bavaria by age, October 1946 census




*Sources:* Age-specific sex ratios were calculated from population counts by age and sex in the October 1946 census, as reported in BSB (145); see the appendix for details.

Furthermore, declines in adult sex ratios varied in magnitude across Bavarian counties, a fact we exploit for identification. Initial inspection of the raw data suggests that more severe declines in prime-aged adult (20-40 year olds) male-to-female sex ratios at county level were indeed associated with greater increases of sex ratios at birth at the end of World War II (see Figure 3).[6]

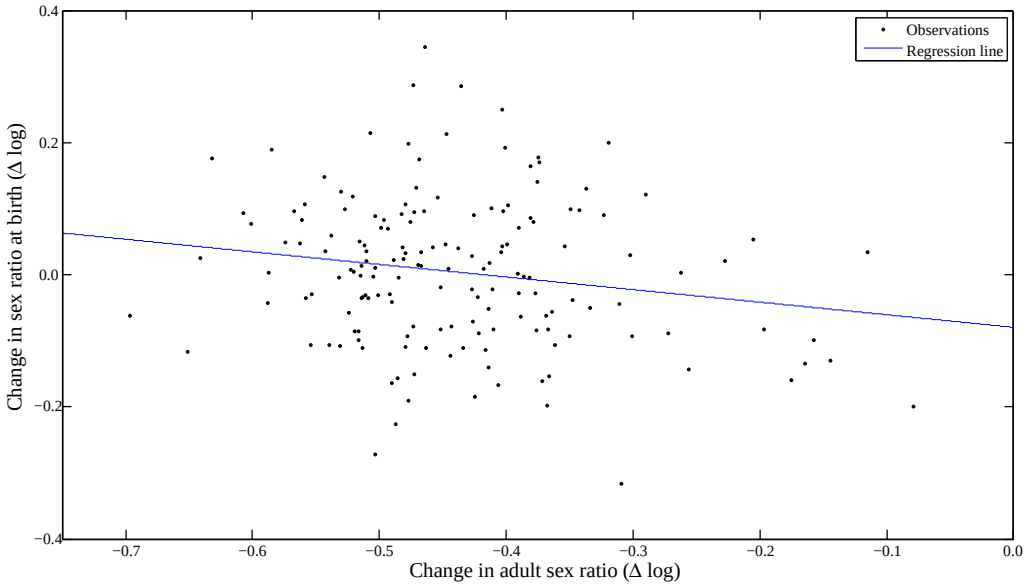
Last but not least, aggregate pre- and post-war statistics for Bavaria show that the aforementioned four proximate causes for the increase in the sex ratio among newborns did indeed materialize at mid century. The average age of mothers at birth fell from 29.7 in 1939 to 28.7 years in 1947, average child parity declined from 2.6 to 2.2, and the share of out-of-wedlock births in total births increased from 10.0% to 16.7%.[7] County-level data on these four causes, unfortunately, exist only for out-of-wedlock births. Consistent with conjectures, pre- to post-war rises in the share of out-of-wedlock births in total births

[5]The second but more moderate dip observable in the 1946 sex ratio at ages 47-68 reflects the military losses incurred during World War I (WWI). These age cohorts correspond to 19-40 years olds in 1918.

[6]Women in this age bracket account for more than 90% of total births both in 1939 and 1947. Statistics on the ages of fathers at birth do not exist.

[7]Data on parental age differences do not exist for mid century Bavaria. However, aggregate statistics on age differences between spouses at marriage are available. Age differences between spouses became much more dispersed after the war. For instance, the share of husbands ten or more years older than their wives at marriage increased almost twofold (from 4.5% to 12.4%) between 1939 and 1947. For more details, see Kellerer (1948).

Figure 3: Pre- to post-war percentage changes in Bavarian counties in the prime-aged adult sex ratio (1939,1946) and in the sex ratio at birth (1939,1947)




*Sources:* Changes in county-level prime-aged sex ratios (ages 20-40) were calculated from population counts by age and sex in the May 1939 and October 1946 censuses, as reported in ZdBSL (72b) and *BSB (145)*. Changes in county-level sex ratios at birth were calculated from ZdBSL (72a) and (81).

were larger in magnitude - by three per cent - in counties with an above-median decline in the adult sex ratio (ratio of men to women aged 20-40).[8]

At the same time, however, there is also evidence that aggregate environmental factors of importance for fertility and child health have considerably worsened in the aftermath of World War II.[9] Adverse conditions, as noted, tend to reduce the sex ratio at birth. In our analysis, we will control for such potential confounding factors by way of a period-specific indicator (for pre-, respectively post-war observations) that captures in a flexible way potentially common aggregate influences on the sex ratio at birth across counties.

# 3 Data

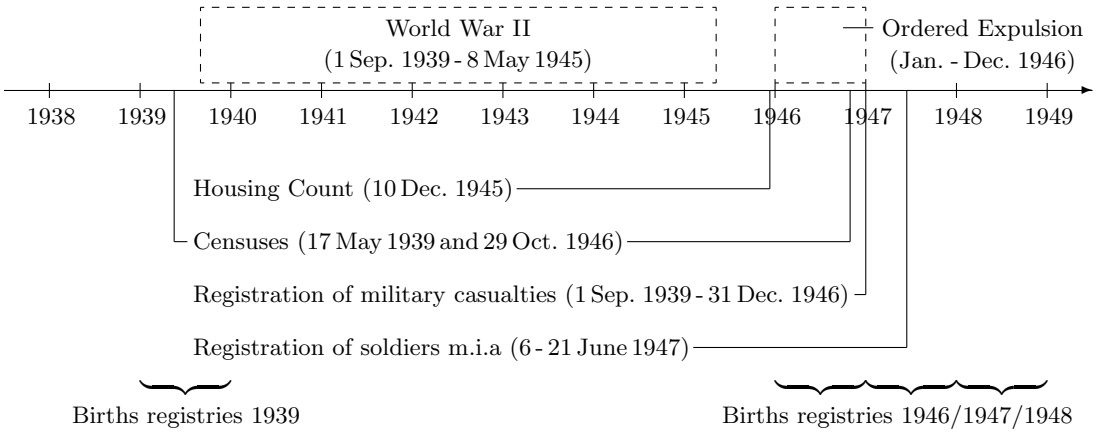
We use aggregate county-level data for the civilian population in Bavaria in the immediate forefront and aftermath of WWII. The data covers 168 counties and has been compiled from printed publications of the Bavarian Statistical Office and the Statistical Office of the Reich. A detailed tabulation of the various statistical publications used is provided in Table A.1 in the appendix. The data set reflects the county-level structure and territorial organization of Bavaria on the day of the first post-war census, i.e. the 29th of October 1946. Of the 168 counties that existed at this time, five had been subject to territorial

[8] Differences in means are significant at the 10% level.

[9] A central piece of evidence in this respect is provided by infant mortality (the share of children aged less than one who die in a given year relative to all live births in that same year). Infant mortality in Bavaria soared from 7.7% in 1939 to 9.3% in 1947.

changes after the May 1939 census, i.e. our pre-war sampling point. We exclude these five counties from our baseline estimation sample. A timeline summarizing our sampling strategy is provided in Figure 4.

Figure 4: Timeline of data sampling strategy.




Censuses carried out on 17 May 1939 and 29 October 1946 - the latter under the auspices of the allied occupation forces in Germany - are our primary sources of information on the levels and characteristics of county populations in Bavaria shortly before and after WWII. Stock measures sampled from the two censuses include the sizes of county populations and their structure (number of residents by age cohorts and by sex). From an analytical perspective, the timing of the two censuses is of great advantage. The May 1939 census took place in the vicinity of WWII, but well before its actual outbreak in September. The October 1946 census, in turn, is well timed for a first stock-taking of the main population changes induced by the war.[10] Annual birth statistics for counties (total births, sex of newborns, and number of infant deaths) are taken from place-of-residence birth registries for the years 1939 (pre-war period) and 1946, 1947, and 1948 (post-war period). In the analysis, we mainly use births in 1947 to construct our post-war measures of fertility. The reason for this choice is that prime-aged adult sex ratios obtained from the October 1946 census capture most correctly the marriage market conditions that prevailed at the time that births in 1947 (rather than 1946 or 1948) had been sired and carried to term.[11] Data on the number of military casualties recorded between September 1939 and December 1946 and on the proportion of the 1939 housing stock destroyed by December 1945 are sampled from special counts of the Bavarian Statistical Office. Numbers of military personnel missing in action are obtained from their

[10] Organized expulsions of Germans from the Sudetenland had climaxed already in June 1946, levelled of rapidly thereafter, and were terminated altogether in December of the same year (less than 20,000 arrived in the last two months of 1946). Furthermore, only 0.4% of soldiers m.i.a. and two out of five captives recorded in June 1947 returned by June 1948. Administrative restrictions imposed by the German authorities, including a general ban on cross-county migration in early 1946, made (endogenous) internal movements of civilians difficult if not impossible for 1946 and most of 1947. The last restrictions on cross-country mobility were lifted only in June 1950 (see Allied High Commission, 1950, p. 414).

[11] As noted, the majority of refugees arrived only in the spring and summer of 1946. Children born to refugees in Bavaria in 1946 were hence in the majority sired (and mostly carried to term) prior to displacement and therefore under different marriage market conditions (sex ratios) than those prevailing in Bavaria in late 1946. However, children born in early 1947, were sired in the spring of 1946 and hence during a priod in which refugees were still arriving in great numbers. It is for this reason that we also consider births in 1948 as a robustness check.

first official post-war registration in June 1947, which was initiated by the Allied Council of Ministers and carried out by the Bavarian Statistical Office. Being based on complete counts of the respective populations considered (residents, births, housing stock, etc.), the administrative and vital statistics in these data sources exhibit a very high degree of accuracy and reliability.

From this raw data, we construct the following variables for our regression analysis. The prime-aged adult sex ratio (*sex ratio*), our proxy for marriage market tightness and prime explanatory variable of interest, is operationalized as the ratio of men to women aged 20-40. As noted, this age range corresponds to the prime fertility years of women and men. In the current application, the use of such a broad age range is preferable to that of more narrow ones for two reasons. First, our vital statistics (birth registry data) do not contain information on the ages of mothers at birth. And second, narrow age ranges would, in all likelihood, fail to capture important intra-sexual competition across adjacent age cohorts at the time (see Fossett and Kiecolt, 1991).[12] The sex ratio at birth, our endogenous variable, is defined as the number of male live births per hundred female live births.

Additional variables we constructed control for potentially confounding influences and are used in our robustness analyses. They include a measure of the extent of war effects on the levels of county populations (*population density*), which implicitly captures also war effects on the composition and average standards of living of county populations;[13] a proxy variable to capture potential health and nutrition related factors that may lead to sex-biased rates of miscarriage (*ratio infant deaths/live births*, i.e. the ratio of newborns aged 1 year or younger that died to the total number of births in a county), and a measure of the damage to county infrastructures and hence proxy for county living conditions more generally (*share 1939 housing stock intact*).[14]

Summary statistics for these variables are provided in Table 1. As is evident, all variables exhibit great dispersion across counties in all years they are measured. Our adult sex ratio measure declined by more than one third from 1939 to 1946, a tremendous worsening of the marriage market conditions for women. In contrast, the average sex ratio at birth in counties rose. The increase, however, is far more moderate.[15] Infant mortality too increased, as did average county population density. Local destruction, as measured by the 1939 housing stock that had been destroyed during the war, is moderate on average, but exhibits great variation across counties (ranging from zero to almost three quarters of the pre-war

[12] As noted, in the early post-war period, age differences between between newly wed spouses were often quite large. In particular, the share of marriages that involved substantially older husbands increased relative to 1939.

[13] Apart from war-related male shortfalls (military deaths, soldiers missing in action, and prisoners of war) that reduced county populations, inflows of evacuees during the war and of refugees after the war led to significant increases in county populations. Most of these displaced individuals had lost their wealth and property (land, residential property, and businesses). Counties with larger increases in their population therefore also tended to experience a relative deterioration in the average economic situation of their inhabitants.

[14] As the measure of local destruction, by definiton, measures post-war quantities only, it will be re-defined in the regression analyses to measure the share of the September 1939 housing stock that is still intact.

[15] In part, this may be attributable to a dampening influence of adverse environmental factors in the immediate aftermath of World War II that tended to affect all counties (e.g. worse nutrition, health care, etc.). The next section provides evidence for the presence and importance of such countervailing aggregate influences.

stock). The last variable considered in Table 1, i.e. the number of solders dead or missing in action relative to 1939 numbers of women in their prime fertility years, will be used in the analysis as an instrument for county-level changes in the prime-aged adult sex ratio. Large in mean, this variable also shows great variation across counties.

Table 1: Summary statistics on Bavarian counties, pre- and post-WWII

| | Year | Mean | Sd | Min | Max |
|---|---|---|---|---|---|
| Sex ratio at birth (%) | 1939 | 107.1 | 8.1 | 87.5 | 129.6 |
| | 1946 | 108.0 | 8.3 | 81.8 | 130.6 |
| | 1947 | 107.5 | 8.1 | 85.0 | 136.3 |
| | 1948 | 107.0 | 8.0 | 81.5 | 128.4 |
| Adult sex ratio (men 20-40/women 20-40, %) | 1939 | 95.5 | 8.4 | 71.8 | 129.9 |
| | 1946 | 61.5 | 5.3 | 50.9 | 87.2 |
| Infant mortality (%) | 1939 | 7.8 | 2.3 | 2.6 | 14.1 |
| | 1947 | 9.5 | 2.4 | 2.2 | 16.7 |
| Population (per km$^2$) | 1939 | 303.7 | 613.1 | 34.0 | 3417.5 |
| | 1946 | 360.2 | 674.3 | 49.7 | 3511.6 |
| September 1939 housing stock destroyed (%) | 1945 | 4.2 | 9.2 | 0.0 | 74.7 |
| Soldiers dead or m.i.a./1939 women aged 20-40 (%) | 1947 | 44.1 | 8.7 | 15.4 | 63.1 |
| Number of counties: 163 (157) | | | | | |

Note: Six counties lack information on the number of dead soldiers recorded as of December 1946. The respective entry in the table is derived from 157 counties only (see the appendix for details). Two counties lack information on 1946 birth statistics, such that the 1946 statistics on the sex ratio at birth is based on 161 counties.

# 4 Statistical Model and Results

## 4.1 *Model*

We exploit regional variations across Bavarian counties in prime-aged adult sex ratio changes between 1939 and 1946 to identify the effects of imbalances in the relative numbers of men and women on the sex ratio at birth. In our baseline model, we run a panel regression with fixed county effects that controls for common shifts in the sex ratio at birth across time $t$ (pre war, respectively post war) and counties $i$:

$$y_{it} = \theta_t + \delta S_{it} + \alpha_i + u_{it},$$

where $y_{it}$ is the sex ratio at birth in a county, $\theta_t$ is a post-WWII indicator variable that controls for influences on the sex ratio at birth that are common to all counties in our observation period (e.g. worsened nutrition and health conditions), and $S_{it}$ is our county-level adult sex ratio measure. Fixed county effects ($\alpha_i$) control for time-invariant observable and unobservable characteristics of counties that may influence levels of fertility and sex of offspring. They control, among others, for regional differences

in temperature, altitude, urbanity, and more general features related to reproductive outcomes, such as persistent differences in mating and marriage patterns, in living conditions, and in the access to health care facilities.[16] Finally, $u_{it}$ is an error term with the usual ideal properties.

In our robustness analysis, we extend the above specification in two major directions. First, to check for the potential endogeneity of changes in prime-aged adult sex ratios at county level, we apply 2SLS and instrument changes in marriage market tightness (prime-aged adult sex ratios) by the ratio of male soldiers dead or m.i.a in late 1946 to the total number of females in 1939 that are aged 20 to 40. Second, we sequentially add controls for potentially confounding time-variant influences (changes in the infant death rate, degree of housing destruction, and changes in county population density). As we will see, however, neither of these model extensions produces results that differ qualitatively from those of our simple baseline specification regarding the within-county correlation over time in the prime-aged adult sex ratio and the sex ratio at birth.

The key identifying assumption of our difference-in-differences approach requires that relative trends in the sex ratio at birth would have had to be the same across counties, had the war not happened and the marriage market (adult sex ratio) not been shocked. Reassuringly, a means comparison test of 1933-1939 changes in the sex ratio at birth between counties which experienced an above-, respectively below-median decline in the adult sex ratio during WWII shows no differences in pre-war trends between more and less strongly affected counties, providing evidence in support of a common trend across counties in our outcome variable of interest.

## 4.2 *Baseline Results*

Our baseline regression results are reported in Table 2. Estimates in columns 1 and 2 stem from regressions that consider births in 1939 and 1947, estimates in columns 3 and 4 from regressions that use births in 1939 and 1946, and estimates in columns 5 and 6 from regressions that consider births in 1939 and 1948. The first two regressions (columns 1 and 2) use our preferred measure (year) of post-war fertility outcomes. The reason is, as already noted, that our post-war prime-aged adult sex ratio is constructed from data of the October 1946 census, which captures most correctly the marriage market conditions that prevailed at the time that births in 1947 (rather than 1946 or 1948) had been sired, respectively carried to term. Regression 1 (3 and 5) controls only for aggregate influences (including those of a generally and significantly lower prime-aged adult sex ratio) by way of a post-war indicator that captures common average changes across all counties. Regression 2 (4 and 6) control in addition for changes at county level in the prime-aged adult sex ratio (marriage market tightness).

As is evident, the average sex ratio at birth in counties did not change between 1939 and 1947. This

[16] A general discussion of several of these potential factors of influence is provided in Teitelbaum (1970) and James (1987).

overall stability, however, may mask systematic changes in the sex ratio at birth that were caused by time-variant factors at the level of counties. And indeed, when we add as a regressor our time-variant county-level measure of marriage market tightness (the prime-aged adult sex ratio), the post-war indicator becomes negative and significant. What is more, the adult sex ratio itself exerts a statistically significant negative effect on the sex ratio at birth. In other words, counties with a larger shortfall of men tended to experience a more pronounced increase in the sex ratio at birth. Consistent with expectations, therefore, aggregate factors (e.g. general economic hardship, lack of food, limited access to health care) indeed appear to have reduced in tendency the sex ratio at birth at mid century. However, the dramatic adult male shortfalls worked in the opposite direction, effectively neutralizing on average the negative impact that such aggregate factors had on the ratio of boys to girls at birth. This finding is robust to pre-, respectively post-dating by one year, the measurement of post-war fertility outcomes (see columns 3 to 6). In fact, the magnitude of the estimated effect of the adult sex ratio changes on marginally.

Table 2: Fixed-effects estimates for 1939/47(46,48) sex ratio at birth

| | 1947 | | 1946 | | 1948 | |
|---|---|---|---|---|---|---|
| Sex ratio (m/w, 20-40) | | $-0.19^{**}$ (0.08) | | $-0.23^{***}$ (0.07) | | $-0.16^{**}$ (0.08) |
| Post-war indicator | 0.004 (0.009) | $-0.08^{**}$ (0.04) | 0.008 (0.009) | $-0.09^{***}$ (0.03) | −0.001 (0.09) | $-0.07^{**}$ (0.04) |
| Observations | 326 | 326 | 324 | 324 | 326 | 326 |

Note: All variables, except post-war indicator, are in logs. $^{*,**,***}$ denote statistical significance at the 10%, 5%, and 1% level. Standard errors are clustered at the county level and reported in parentheses.

## 4.3 *Robustness Checks*

We checked the robustness of our finding along a number of dimensions taking as the benchmark the second regression of Table 2 (henceforth referred to as *baseline*). In the following, we discuss the results of these checks. Tabulated regressions results, if not provided in the text, can be obtained from the authors upon request.

First, we checked whether our finding can be explained by potentially endogenous changes of the adult sex ratio at county level (see column 2 of Table 3). To this end, we converted our county data into first differences and estimated by 2SLS the effect that changes in the adult sex ratio had on the sex ratio at birth. We instrumented the change in the adult sex ratio by the ratio of men recorded as either missing in action (as of June 1947) or dead in combat (as of December 1946) to the total number of females in 1939 that are aged 20 to 40, i.e. the pre-war county-level stock of prime-aged females. As is evident, however, within-county sex ratio changes remain negatively correlated with within-county changes in the sex ratio at birth.

Second, we checked the robustness of our result to two changes in the underlying estimation sample

Table 3: Robustness Checks:
estimation sample and potential endogeneity of sex ratio changes

| | Baseline | 2SLS | Restricted Sample | Full Sample |
|---|---|---|---|---|
| Sex ratio (men/women, 20-40) | $-0.19^{**}$ (0.08) | $-0.27^{**}$ (0.13) | $-0.19^{**}$ (0.09) | $-0.14^{*}$ (0.08) |
| Post-war indicator | $-0.08^{**}$ (0.04) | $-0.10^{**}$ (0.05) | $-0.08^{*}$ (0.04) | $-0.06$ (0.04) |
| Observations | 326 | 157 | 312 | 336 |
| Number of Counties | 163 | 157 | 156 | 168 |

Note: Births are measured in 1939 and 1947. 'Baseline' replicates our baseline result (column 2 of Table 2). '2SLS' reports second-stage results from a 2SLS regression of changes in the sex ratio at birth on changes in the adult sex ratio. The latter is instrumented in the first stage by the ratio of men recorded as either missing in action or dead in combat (in June 1947) to the total number of females aged 20 to 40 in 1939 (6 counties lack information on the number of dead soldiers). Partial R2 is 0.41, and the F-Statistic/(p-value) is 109.4/(0.000). 'Restricted Sample' and 'Full sample' report results from fixed-effects regressions. The first excludes counties in which more than 20% of the 1939 housing stock was destroyed during the war (7 counties or 14 observations). The second adds previously excluded counties to the estimation sample who had been subject to territorial changes between 1939 and 1946 (5 counties). All variables, except post-war indicator, are in logs. $^{*,**,***}$ denote statistical significance at the 10%, 5%, and 1% level. 2SLS uses robust standard errors. Otherwise, standard errors are clustered at the county level. Standard errors are reported in parentheses.

(see columns 3 and 4 of Table 3). First, we excluded those counties that had been most hard hit by the war in terms of local destruction as measured by our housing stock variable (>20% of 1939 housing stock destroyed). Excluding these six counties, which include the most populous counties in pre-war Bavaria (e.g. Munich, Nuremberg, or Augsburg), does not affect our estimate of the effect that changes in the adult sex ratio had on the sex ratio at birth. In fact, the estimated sex ratio coefficient and its standard error are virtually identical. Second, we included the five counties which had been subject to territorial changes in 1939-1946 and were therefore omitted from our baseline regression. Including these five counties again does not change our finding qualitatively (see last column of Table 3). Within-county sex ratio changes remain negatively correlated with within-county changes in the sex ratio at birth. The estimated coefficient of the adult sex ratio only declines somewhat in magnitude.

Third, we checked the robustness of our result to the use of alternative - yet still fairly broad given our aggregate fertility data - adult sex ratio measures (not reported).[17] Alternative measures we considered include the following ratios of men to women (male age bracket/female age bracket): 20-40/20-30, 20-40/14-30, 20-40/14-40, and 20-50/14-40. Running separate regressions for each of these produces an adult sex ratio effect that is throughout significant, negatively signed, and only marginally different in magnitude from our baseline estimate (estimated coefficients vary between -0.17 and -0.20). Our finding of a negative relationship between the magnitude of male shortfalls and the sex ratio at birth at county level therefore proves robust also to the use of alternative measures of marriage market tightness.[18]

Finally, we sequentially added controls for potentially confounding influences (Table 4). Ext. Spec. I

[17] Regression tables are available from the authors upon request.

[18] We also considered two sex ratios that should be largely irrelevant for fertility outcomes (age brackets 0-14/0-14 and 50-65/50-65). Neither exerts a statistically significant influence on the sex ratio at birth.

adds a measure to capture potential health and nutrition related factors that may have led to sex-biased rates of miscarriage (the ratio of newborns aged 1 year or younger that died in 1947 to the total number of births in 1947), and Ext. Spec. II a proxy for county infrastructure and county living conditions (per cent of 1939 housing stock destroyed during the war). Finally, Ext. Spec. III adds a covariate that accounts for any potentially confounding influences related to local differences in economic stress and hardship that were caused by the expansion of county populations through the inflows of refugees and evacuees. As shown in Table 4, however, in no specification does a potential confounder exert a statistically significant effect on the sex ratio at birth.[19] In fact, estimated coefficients are all close to zero and in no case of the expected sign. Most importantly, however, the estimated coefficient of the adult sex ratio throughout remains significant, negatively signed, and very close, if not identical, in absolute magnitude to our baseline estimate. These findings provide further evidence that changes in marriage market tightness among age cohorts in their prime fertility years, rather than some potential confounder, contributed causally to the increases in the sex ratio at birth in the aftermath of WWII.

Table 4: Robustness Checks: Adding potential confounders

| | Baseline | Ext. Spec. I | Ext. Spec. II | Ext. Spec. III |
|---|---|---|---|---|
| Sex ratio (men 20-40/women 20-40) | $-0.19^{**}$ | $-0.19^{**}$ | $-0.18^{*}$ | $-0.17^{*}$ |
| | (0.08) | (0.08) | (0.09) | (0.10) |
| Ratio infant deaths/live births | | 0.04 | 0.04 | 0.04 |
| | | (0.03) | (0.03) | (0.03) |
| Share 1939 housing stock intact | | | 0.01 | $-0.00$ |
| | | | (0.04) | (0.09) |
| Population density | | | | 0.02 |
| | | | | (0.11) |
| Post-war indicator | $-0.08^{**}$ | $-0.09^{**}$ | $-0.08^{*}$ | $-0.09^{*}$ |
| | (0.04) | (0.04) | (0.04) | (0.05) |
| Observations | 326 | 326 | 326 | 326 |

Note: Births are measured in 1939 and 1947. Ext. Spec. is a shortcut for extended specification. 'Baseline' replicates our baseline result (column 2 of Table 2). 'Ext. Spec. I-III' also report results from fixed-effects regressions. 'Ext. Spec. I' adds a measure of infant mortality to the set of covariates, 'Ext. Spec. II' furthermore a measure of the degree of local destruction, and 'Ext. Spec. III' also a measure of the net change in county population size that was induced by the war. All variables, except post-war indicator, are in logs. *,**,*** denote statistical significance at the 10%, 5%, and 1% level. Standard errors are clustered at the county level and reported in parentheses.

# 5 Conclusion

Belligerent countries during World War I and II experienced temporary, yet marked increases in the sex ratio at birth that have long defied explanation. Based on Bavarian data from mid century, we investigated the adult sex ratio as a potential deep determinant of this rise. Our findings suggest that the male shortfall, or female marriage market squeeze, that was induced by the war was indeed important

[19] The set of controls of potential confounders in Ext. Spec. III is jointly insignificant. The order of addition of these controls to our baseline specification is of no consequence for coefficient estimates, including that for our adult sex ratio measure.

for the observed increase in the relative number of boys among newborns.

Being reduced-form in kind, our analysis does not provide information on the particular causal pathways by which declines in the adult sex ratio impacted the sex ratio at birth. To explore these channels, and to gauge also their respective quantitative importance, requires more detailed data than the one used in our analysis, including the ages of parents at the time of conception, the sex ratio of marital and out-of-wedlock births, and the sex ratio of births at different birth order. Such data are not available for Bavarian counties (or other German regions) at mid century. Research on other belligerent countries can fruitfully extend our analysis in this direction and thereby help to shed light on the underyling mechanisms that link adult and offspring sex ratios.

Whatever the specific channel(s) are, our results suggest that marriage market tightness can be a potentially important determinant of the sex ratio at birth even when prenatal sex determination and sex-selective abortion (and hence structural preference-based explanations) are not, as in the historic context of our analysis, viable for technological reasons. This possiblity warrants greater recognition in the economics literature on the sex ratio at birth.

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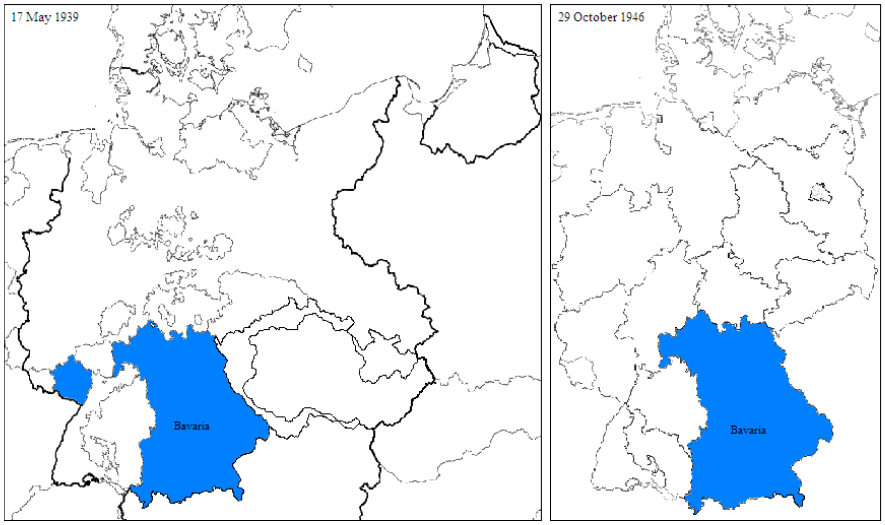
# A Appendix

## A.1 *Map of Pre- And Post-War Bavaria*

The following maps show Germany and Bavaria shortly before and after the Second World War.




Basis Geometries: Server IEG-Maps (www.ieg-maps.uni-mainz.de).

## A.2 *Data Sources*

The county-level data set has been constructed from statistical publications of the Bavarian Statistical Office (Bayerisches Statistisches Landesamt) and the Statistical Office of the German Reich (Statistisches Reichsamt). A detailed list of the various publications used - organized by variable and sampling year - is provided in Table A.1. For clarity of exposition, we use the following abbreviations: BSB - *Beiträge zur Statistik Bayerns*, SJB - *Statistisches Jahrbuch für Bayern*, SDR - *Statistik des Deutsches Reiches*, ZdBSL - *Zeitschrift des Bayerischen Statistischen Landesamts*.

Table A.1: Data sources for individual variables used in the empirical analysis

| | Pre-WWII | Post-WWII | | | |
|---|---|---|---|---|---|
| | 1939 | 1945 | 1946 | 1947 | 1948 |
| Births | ZdBSL (72a) | | ZdBSL (81) | ZdBSL (81) | ZdBSL (81) |
| Population | ZdBSL (72b) | | BSB (145) | | |
| Area (km$^2$) | SDR (552,1) | | BSB (145) | | |
| Infant mortality | ZdBSL (72a) | | ZdBSL (81) | ZdBSL (81) | ZdBSL (81) |
| Refugees | | | BSB (142) | | |
| Evacuees | | | SJB (23) | | |
| Military casualties | | | SJB (23) | | |
| Soldiers m.i.a. | | | | ZdBSL (80) | |
| Housing stock | | SJB (23) | | | |

BSB (142): Die Flüchtlinge in Bayern. Ergebnisse einer Sonderauszählung aus der Volks- und Berufszählung vom 29. Oktober 1946, *BSB*, Heft 142.

BSB (145): Die Volks- und Berufszählung am 29. Oktober 1946 in Bayern. Teil I Volkszählung, *BSB*, Heft 145.

SDR (552,1): Volkszählung. Die Bevölkerung des Deutschen Reichs nach den Ergebnissen der Volkszählung 1939. Heft 1: Stand, Entwicklung und Siedlungsweise der Bevölkerung des Deutschen Reichs, *SDR*, Band 552, Heft 1.

SJB (23): Kreisanhang, *SJB*, Band 23, 369-409.

ZdBSL (72a): Die Bevölkerungsbewegung in Bayern mit vorläufigen Ergebnissen für 1940, *ZdBSL*, Band 72, 259-311.

ZdBSL (72b): Altersgliederung der Ständigen Bevölkerung Bayerns in den Stadt- und Landkreisen nach der Volkszählung vom 17. Mai 1939, *ZdBSL*, Band 72, 312-320.

ZdBSL (80): Die Kriegsgefangenen und Vermißten Bayerns. Ergebnisse der Registrierung der Kriegsgefangenen und Vermißten in Bayern vom 6. bis 21. Juni 1947 sowie der Fortschreibung bis Juni 1948, *ZdBSL*, Band 80, 46-71.

ZdBSL (81): Die natürliche Bevölkerungsbewegung in Bayern 1948, *ZdBSL*, Band 81, 101-143.

**Otto von Guericke University Magdeburg**
Faculty of Economics and Management
P.O. Box 4120 | 39016 Magdeburg | Germany

Tel.: +49 (0) 3 91 / 67-1 85 84
Fax: +49 (0) 3 91 / 67-1 21 20

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