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Geographic Variation in Fertility Measures in Sweden in (1749-1870)

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Authors' contributions

This work was carried out in collaboration between both authors. Author JF collected the demographic data and performed the statistical analyses. Author AWE had the responsibility for the genetic contributions. Both authors approved the manuscript.

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ABSTRACT

We analysed geographic variation in the number of males per 100 females at birth also called the secondary sex ratio (SR), the crude birth rate (CBR), the total fertility rate (TFR) and the twinning rate (TWR). Earlier studies have noted geographic variations in the TWR and racial differences in the SR. Statistical analyses have shown that comparisons between SRs demand large data sets because random fluctuations in moderate data are marked. Consequently, reliable results presuppose national birth data. In this study, we analysed historical demographic data and investigated the geographic variations between the counties in Sweden for the SR among the live born (1749-1869), the CBR in 1751-1870, the TFR in 1860 and the TWR in 1751-1860. We built spatial models and as regressors we used geographic co-ordinates for the residences of the counties in Sweden. The influence of the CBR and TFR on the SR and TWR was examined. For all variables, we obtained spatial variations, albeit of different patterns and power. Hence, no common spatial pattern for the demographic variables SR, TFR, CBR and TWR was detected, but a better fit was noted for TFR, CBR and TWR than for SR.

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Keywords: Counties; crude birth rates; geographic co-ordinates; live births; multicollinearity; secondary sex ratios; spatial models; stepwise regression; total fertility rates; twinning rates.

1. INTRODUCTION

In a long series of papers, attempts have been made to identify factors influencing the male/female ratio at birth, also called the secondary sex ratio (SR). Hawley [1] stated that where prenatal losses are low, as in Western countries with a high standard of living, the SRs are usually high, around 105 to 106. On the other hand, in regions with a lower standard of living where the frequencies of prenatal losses are relatively high, the SRs among live born are around 102. Visaria [2] stated that racial differences appear to exist in the SR. Variations in the SR that have been reliably identified in family data have in general been slight and without notable influence on the SR in national birth registers (for references, see [3,4,5]).

The crude birth rate (CBR) is the number of childbirths per 1000 people per year. Hofsten and Lundström [6] stressed that the CBR is a poor measure of fertility and can only be used for rough comparisons or for comparisons when no other factors—notably, the age composition of the population, the marriage pattern or the time-schedule for the birth of children—will interfere with the comparison. However, they stated that differences between the Swedish counties were minor before the transition started from high to low fertility, and they assumed that this change did not occur before the 1880s. We therefore assume that the CBR can be used in this study of geographic comparisons between fertility measures in Sweden up to 1870.

The total fertility rate (TFR) of a population is the average number of children born to a woman over her lifetime if (1) she experienced the exact current age-specific birth rates through her lifetime and (2) she survived from birth to the end of her reproductive life. TFR is obtained by summing the single-year age-specific birth rates at a given time.

The TWRs in Sweden are among the highest noted in Caucasian populations (cf. [7,8,9]). In a series of papers, we have studied the geographic and temporal variations in the twinning rate per 1000 maternities (TWR) for Sweden. In this study we intend to study if the spatial variation in SR and TWR can be explained when the fertility variables, TFR and CBR are included in the regression analyses.

2. MATERIALS AND METHODS

2.1 Materials

Hofsten and Lundström [6] stated that the boundaries of the counties in Sweden have only been subject to minor revisions, and consequently, the counties are ideal for use in analyses of geographic differences. The counties and their codes introduced by Statistics Sweden are presented in Fig. 1 and used in Table 1. Berg [10] published SRdata for live births in the counties of Sweden in 1749-1869 (Table 1). The available periods varied between the counties. Berg defined the SRs as males per 1000 females, but we have transformed his data to the traditional definition, number of males per 100 females.

Hofsten and Lundström [6] presented in their Table 6.1 the CBRs for the counties in Sweden for the decades between 1751 and 1970.In this study, we define our variable CBR as the mean value of the decennial CBR data given by them for the period 1751-1870. Furthermore, Hofsten and Lundström have in Tables 6.2–6.16 also presented TFR values per 1000 women for all decades starting from around 1860 to 1970. The variable TFR used by us is their data for 1860.

The geographic twinning rates (TWRs) for the period 1751-1860 are also included in this study. In the period 1774-1794, only Stockholm city and the county of Gotland have registered data. For some counties, the registers start in 1811. A detailed presentation of the geographic TWRs is presented in [9]. In Table 1, we included the geographic data for SR, CBR, TFR and TWR. We have also included the number of live births (*n*) associated with the SRs and the number of maternities (*N*) connected to the TWRs. Furthermore, Table 1 displays the observation periods for the SR for the different counties. Recently, Fellman and Eriksson [11] presented short, preliminary studies of the spatial variation of fertility variables.

2.2 Methods

In accordance with the concepts outlined in [9], we introduced spatial regression models for the geographic fertility data. The location of the counties was defined as the geographic co-ordinates of the corresponding residences (provincial capitals). The residences can be seen in Fig. 1. They are not centrally located in the counties, but we assumed that they are sufficiently central with respect to the population density, and their co-ordinates are given in Table 1. The presumptive regressors for the spatial regression models were the longitude (meridian) *M* and the latitude *L* and the transformed variables L^2, M^2 and *LM*. The regressors *M* and *L* were defined as deviations from the co-ordinates of the unweighted centre (59.18° N and 15.87° E) of the cluster of residences, and consequently, the intercepts obtained in the spatial models are the estimates of the regressands in this centre. Table 1 shows that the geographic co-ordinates of Örebro are closest to the centre of the cluster of residences. The geographic co-ordinates for Sweden are eastern longitude and northern latitude. The elongated shape of Sweden indicates that attention must be paid to the multicollinearity between the regressors. Fellman and Eriksson [9] studied spatial models for the twinning rate in Sweden and provided a thorough analysis of the multicollinearity in the regression models with the geographic co-ordinates as regressors. In that study, we considered different measures of multicollinearity proposed in the literature. They were all functions of the eigen values (λ_i) of the correlation matrices. In this study, we restrict ourselves to one measure, $m_4 = \sum_i \frac{1}{\lambda_i}$. This measure includes all eigen values and for uncorrelated regressors it equals the dimension of the correlation matrix and with increasing multicollinearity it increases towards infinity. For the total model all the regressors *L*, *M*, L^2, M^2 and $L{\cdot}M$ we obtained the multicollinearity measure $m_4 = 38.09$. The measure for the total model for the TWR presented in [9] differs from the value obtained here since in the earlier paper the number of births was obtained for different periods, and consequently, the weights were slightly different. In addition, the county of Örebro was missing in the earlier study. When all spatial regressors were included, the multicollinearity was rather strong, but for the optimal regression models with reduced number of regressors the multicollinearity measure was reduced.

We analysed the spatial variation in the SR by weighted regression models. The regressand was the observed geographic SR. The variance of the SR is approximately proportional to n^{-1}, and therefore, we used the number of live births (*n* in Table 1) in the counties as weights. The spatial variations in CBR and TFR were also studied with the geographic co-ordinates as regressors, but now no weights could be included in the regression analyses because no information about the heterogeneity in the variances was available. For TWR, we had information about the number of maternities (*N* in Table 1) and could use weighted regression. In this study, we tried to improve the spatial models for SR and TWR by including TFR and CBR as additional regressors.

3. RESULTS

For TFR, the optimal regression model contains the regressors *M*, *L*, M^2 and *ML* ([11]). The estimated regression model is

$$\begin{aligned} TFR &= 4584 - 123.40\,M + 81.96\,L \\ &- 55.29\,M^2 + 82.37\,M\,L. \end{aligned} \tag{1}$$

All of the parameter estimates are significant and the adjusted $\overline{R}^2 = 0.573$, indicating a better fit than for SR, analysed below. This can also be seen in Fig. 2. Counties with low TFRs are the city of Stockholm (A) and the counties of Gotland (I), Uppsala (C), Stockholm (B) and Gävleborg (X). Regions with high TFRs are the counties of Norrbotten (BD), Västerbotten (AC), Örebro (T), Skaraborg (R) and Kronoberg (G). If we compare the intercept 4584 with the observed TFR value for the county of Örebro (5067), a marked discrepancy is noted.

For CBR, the optimal regression model contains the regressors L and the product LM and the estimated regression model is

$$CBR = 31.65 - 0.395\,L - 0.242\,L\,M. \tag{2}$$

All of the parameter estimates are significant and the adjusted $\overline{R}^2 = 0.525$. The fit is comparable with the fit for the TFR model. This can also be seen in Fig. 3. Counties with low CBRs are Jämtland (Z), Gotland (I), Gävleborg (X), Kopparberg (W) and Uppsala (C) and those with high CBRs are Västerbotten (AC), Norrbotten (BD), Blekinge (K), Malmöhus (M) and Göteborg and Bohus (O). If we compare the intercept 31.65 with the observed TFR value for county of Örebro (32.3), a discrepancy emerges.

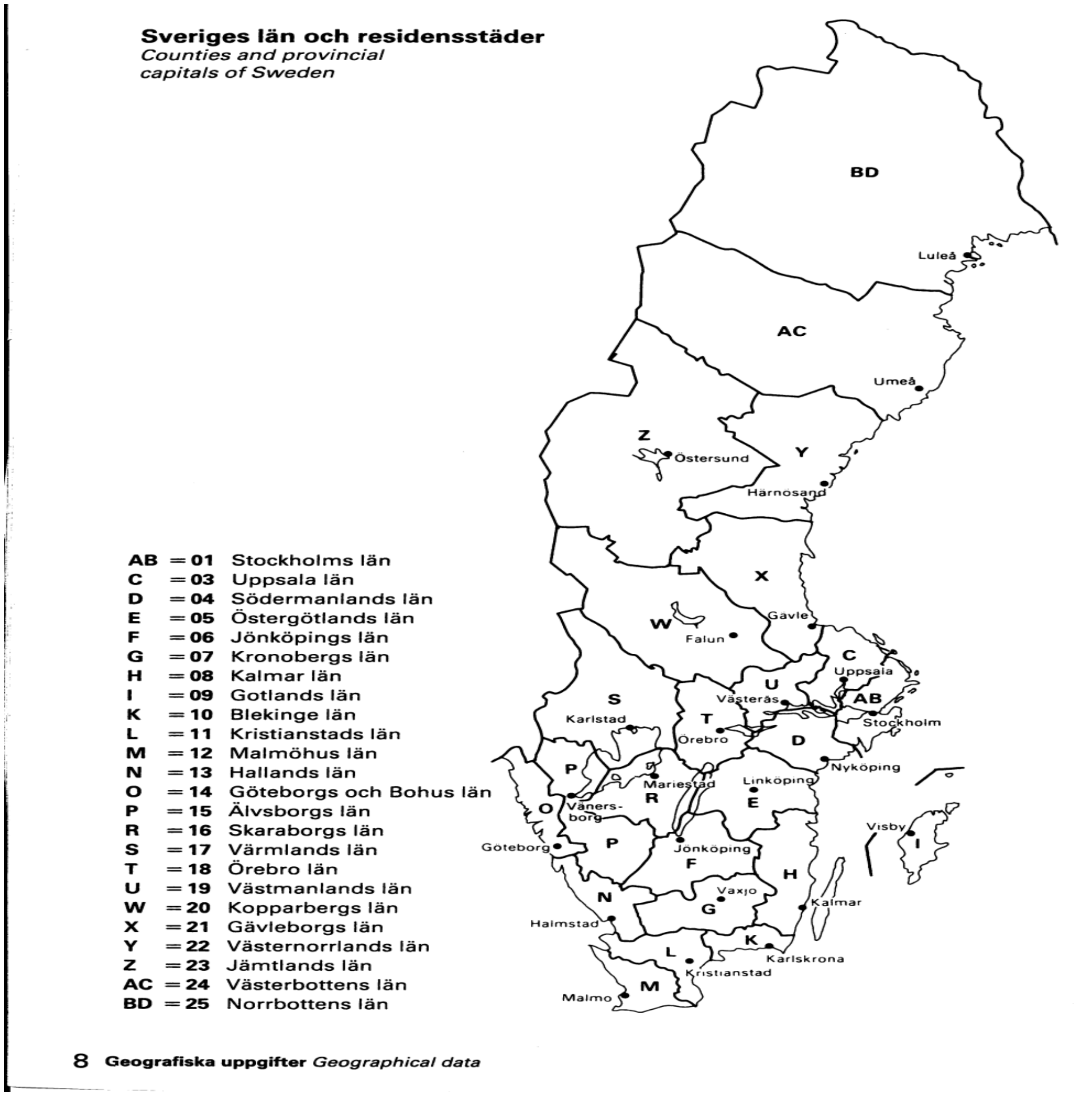

Fig. 1. Map of Sweden including the counties (län) and their provincial capitals and the letter codes according to statistics Sweden the code AB includes both the city (A) and the county (B) of Stockholm

Our first analysis of the SR was to check the geographic heterogeneity in the SR for live births. This was performed with χ^2 tests so that the number of males and females in the counties were estimated by the total number of live births and by published geographic SRs, both given by Berg [10]. Significant geographic differences in the sex proportions were found, and our next step was to build spatial models for the SR. In general, for moderate data sets, the SR is influenced by large random fluctuations ([2,4,5]). This can be seen in Fig. 4, where we present the geographic SRs with 95% confidence intervals. Note the broad confidence intervals for the counties of Gotland (I), Gävleborg (X), Västernorrland (Y), Jämtland (Z), Västerbotten (AC) and Norrbotten (BD). For these, the number of live births is less than 200000.

The estimated optimal spatial model for SR is [11]

$$SR = 104.56 + 0.0681 L^2 - 0.0666 L\,M. \quad (3)$$

The adjusted coefficient of determination $\overline{R}^2 = 0.103$ indicated a poor fit. The estimated parameter $\hat{\beta}_{L^2}$ is statistically significant, and $\hat{\beta}_{ML}$ is almost significant. The intercept $SR = 104.56$ is an estimate of the SR in a hypothetical county whose latitude equals $59.18°$ and longitude equals $15.87°$. For the county of Örebro the observed SR was 104.5 which isclose to the intercept. Together with the observed SRs, the estimated SRs for the optimal model are given in Fig. 5. The most marked discrepancies between the observed and estimated SRs are seen in the city of Stockholm (A) and the counties of Blekinge (K), Kalmar (H) and Jämtland (Z).

For the SR, we constructed a weighted regression model based on the spatial variables and the fertility variables CBR and TFR. In the optimal model, the spatial variables had insignificant parameter estimates and were eliminated. The fertility model was

$$SR = 104.68 + 0.000855\,TFR - 0.144483\,CBR. \tag{4}$$

The optimal model obtained has a rather good fit. The adjusted coefficient of determination was $\overline{R}^2 = 0.373$, and the regression parameter estimates were significant. Together with the observed SRs, the estimated SRs for the optimal model are given in Fig. 6. The most marked discrepancies between the observed and estimated SRs are in the counties of Gotland (I), Kalmar (H) and Jämtland (Z).

Table 1. Geographic co-ordinates, the number of live births associated with the SR, the secondary sex ratio (SR), the crude birth rate (CBR), the total fertility rate (TFR) and the twinning rate (TWR) for the counties of Sweden the residences are given in Fig. 1

Codes[a)]	Periods[b)]	Lat.	Long.	n[c)]	SR	CBR[d)]	TFR[e)]	N[f)]	TWR[g)]
A	1749-1869	59.32	18.07	336854	103.4	34.5	3583	293070	15.92
B	1749-1869	59.32	18.07	324901	104.6	31.4	4070	266053	17.99
C	1749-1869	59.90	17.80	246344	104.2	30.7	4011	215290	16.81
D	1749-1869	58.76	17.01	319940	104.6	31.0	4448	268508	16.89
E	1749-1869	58.42	15.64	581692	104.5	32.4	4494	490915	15.56
F	1749-1869	57.78	14.18	424184	104.9	31.6	4771	365952	13.82
G	1749-1869	56.86	14.82	356405	104.7	34.2	4942	309611	13.58
H	1749-1869	56.80	16.00	516021	105.8	33.7	4776	452081	15.70
I	1749-1869	57.63	18.30	119541	105.3	28.2	3612	99902	21.67
K	1749-1869	56.16	15.58	283511	103.7	35.6	4738	246401	14.89
L	1749-1869	56.02	14.13	455200	104.8	32.8	4613	406505	14.71
M	1749-1869	55.61	13.06	637249	104.6	34.9	4629	551927	15.20
N	1749-1869	56.67	12.86	271859	104.5	32.0	4646	237796	14.01
O	1749-1869	58.35	11.93	482251	103.9	34.8	4226	407899	13.65
P	1749-1869	58.37	12.32	597113	104.8	32.5	4574	518883	12.95
R	1749-1869	58.71	13.82	522657	104.8	33.5	5004	451746	14.34
S	1749-1869	59.38	13.50	552016	105.1	33.0	4825	535186	13.75
T	1749-1869	59.27	15.22	367499	104.5	32.3	5067		
U	1749-1869	59.67	16.55	272943	104.3	31.4	4277	238776	16.69
W	1749-1869	60.61	15.64	395484	104.7	30.5	4681	322518	15.13
X	1810-1869	60.68	17.16	188398	104.8	29.0	4085	208415	16.48
Y	1810-1869	62.63	17.94	175813	105.1	32.6	4880	174079	14.95
Z	1810-1869	63.18	14.65	77473	106.4	27.3	4539	75916	15.00
AC	1749-1869	63.83	20.27	169733	104.4	37.6	5366	112573	12.45
BD	1749-1869	65.59	22.17	153877	105.1	37.6	5509	104610	12.58
Total	1749-1869	59.18	15.87	8828958	104.66			7354612	14.96

[a)]The codes are explained in Fig. 1. [b)]forstockholm city and the county of Gotland, data are known for the whole period, but the rest of the counties have missing data for the period 1774-1794.[c)]the number of live births for the defined period. the twinning rate for the period 1751-1860, but for some decades and some counties, data are missing.[d)]CBR is the mean value of the decennial CBR data given by hofsten and lundström (1976).[e)]TFR for 1860 given by hofsten and lundström (1976).[f)]the geographic number of maternities for the period 1751-1860 associated with the TWR.[g)] TWR for the period 1751-1860

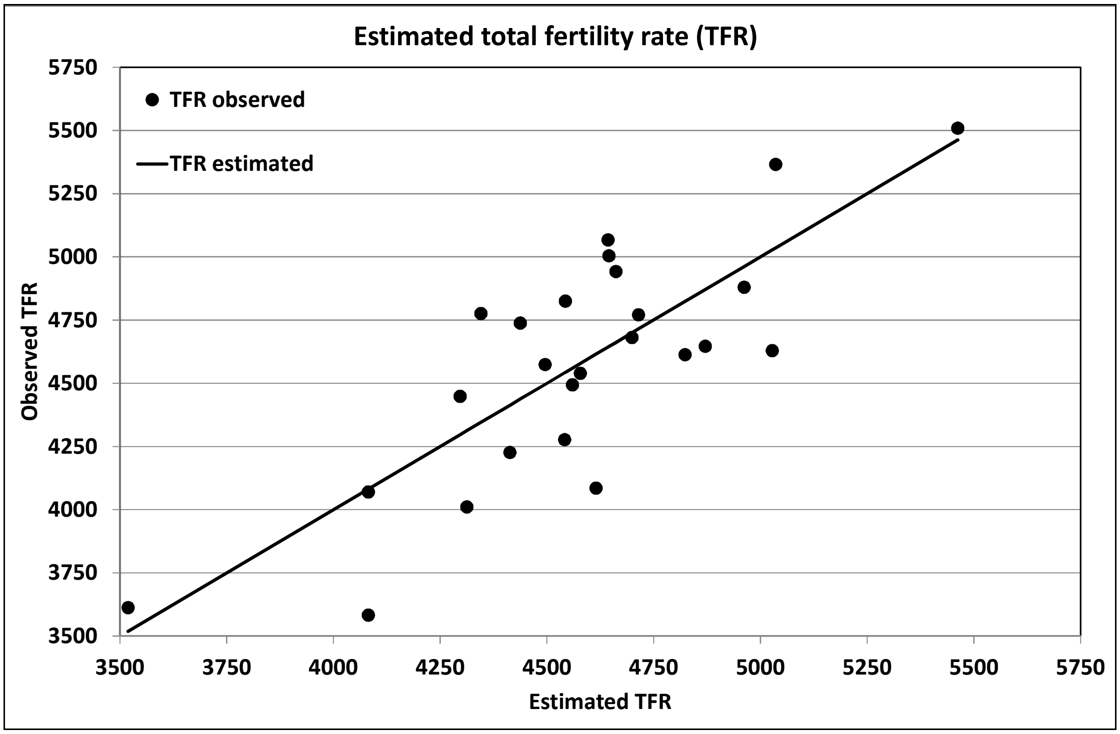

Fig. 2. Comparison between observed and estimated total fertility rates (TFRs)

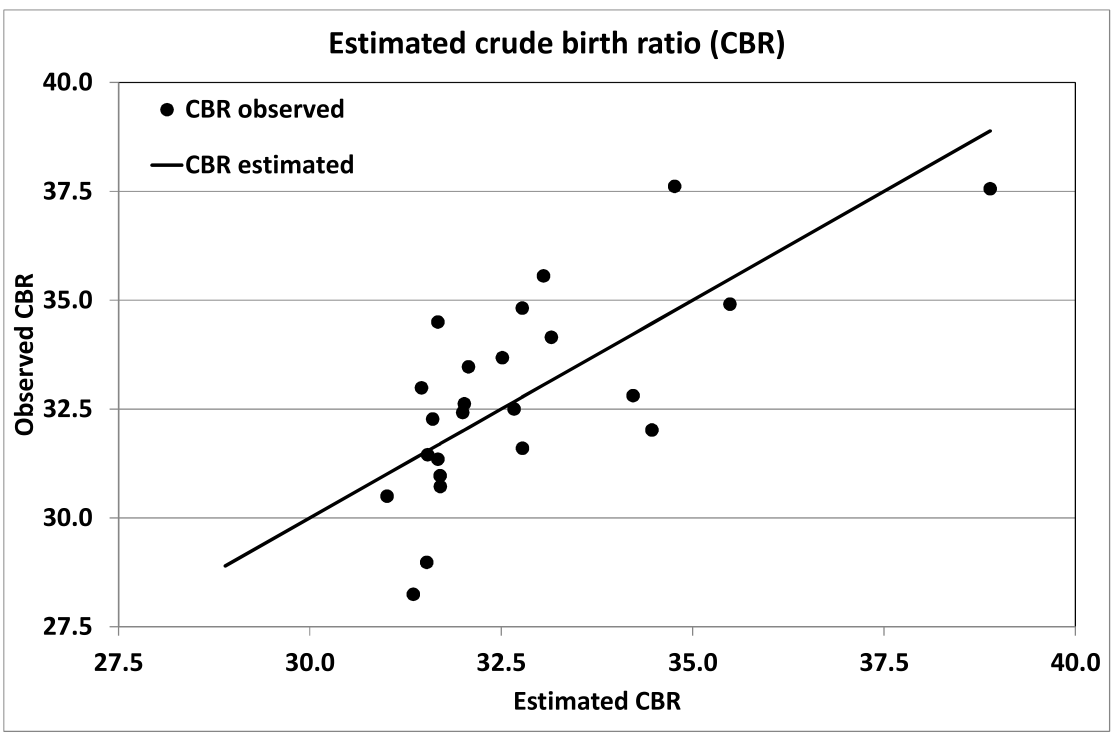

Fig. 3. Comparison between observed and estimated crude birth rates (CBRs)

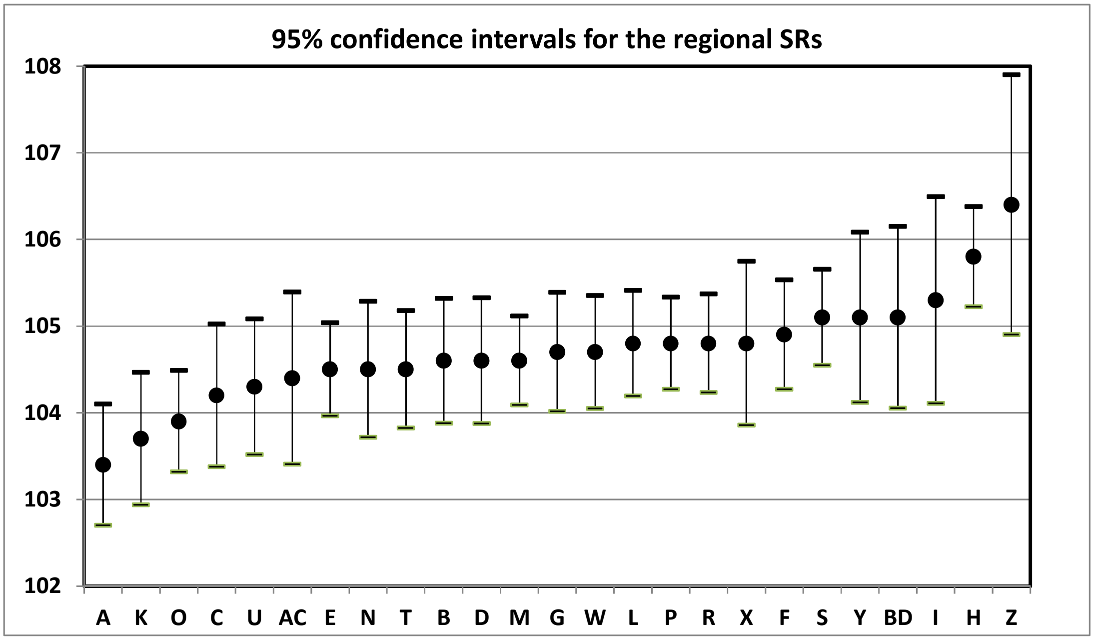

Fig. 4. Observed secondary sex ratios (SRs) and their confidence intervals (CIs) for different counties; Note the broad CIs for the counties of Gotland (I), Gävleborg (X), Västernorrland (Y), Jämtland (Z), Västerbotten (AC) and Norrbotten (BD); For these, the number of live births is less than 200 000; the counties are ordered according to increasing SR and the county codes are given in Fig. 1

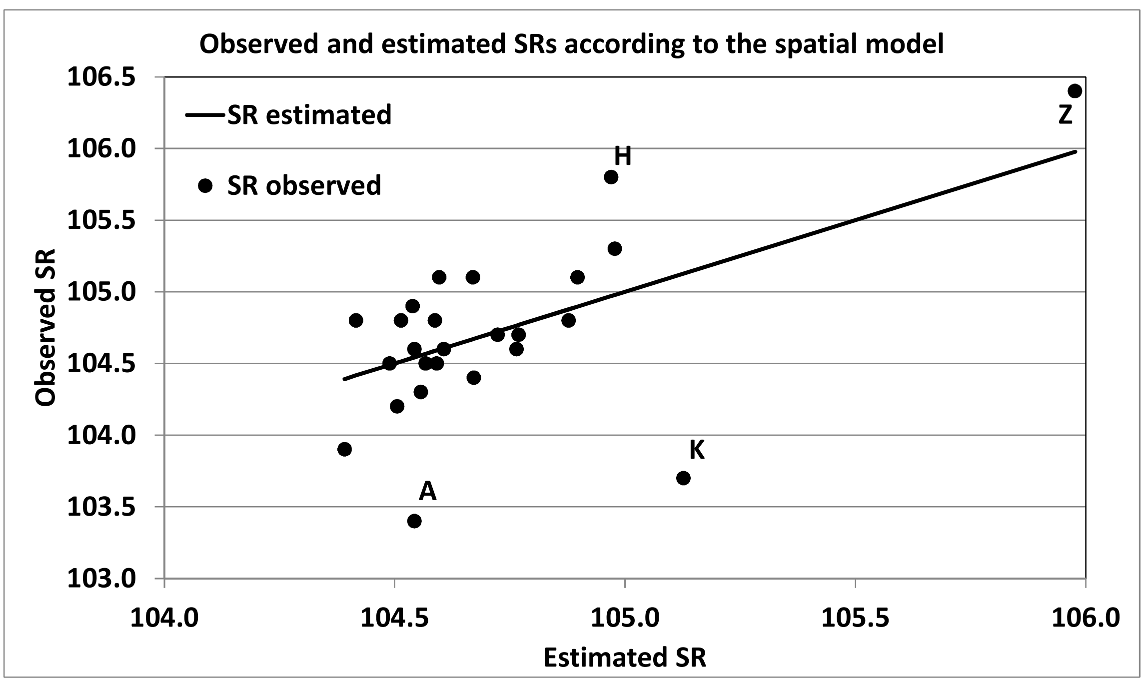

Fig. 5. Comparison between observed and estimated sex ratios (SRs) according to the spatial model; the discrepancies between observed and estimated SRs are marked for the city of Stockholm (A) and the counties of Blekinge (K), Kalmar (H) and Jämtland (Z); The codes of the counties are defined in Fig. 1

If we build a weighted regression model for the TWR based on the regressors TFR and CBR and the spatial variables, the optimal regression model will contain the fertility variables TFR and CBR and the geographic co-ordinates *M* and *L*. The optimal model is

$$TWR = 15.387 - 0.001355TFR - 0.323763CBR + 0.4953M - 0.3813L. \quad (5)$$

All of the parameter estimates are significant and the adjusted $\overline{R}^2 = 0.758$, indicating a good fit. We note negative effects of the fertility variables, and the TWR increases when one moves towards the east and south.The observed and expected TWRs are presented in Fig. 7. In this figure, one observes that the TWR in Gotland with its high TWR is an outlier. This finding confirms our earlier results ([7, 8, 9]). Among all the other counties, no outliers were found. This holds also for the Nordic counties of Norrbotten (AC) and Västerbotten (BD) and the Western county of Älvsborg (P) with extremely low TWRs.

4. DISCUSSION

No common spatial pattern for the demographic variables SR, TFR, CBR and TWR was detected, but a better fit was noted for TFR, CBR and TWR than for SR. The spatial model (3) for SR indicates a poor fit. The optimal model (4) based on both spatial and fertility regressors yields a better fit, but this model contains no spatial variables. Hence, the optimal model supports the finding that SR does not show marked geographic variation.

For TWR the optimal model (5) contains spatial variables. The coefficient for *M* is negative and for *L* is positive. Hence, this model supports the finding that the gradient for the TWR levels, directed towards increasing TWRs, have south-eastern directions. It indicates that the TWR obtains its maximum for Sweden in an eastern region in the county of the island of Gotland (I) and the counties of Stockholm (B), Uppsala (C) and Södermanland (D) around the city of Stockholm on the eastern coast of central Sweden [9].

Comparing these results one observes that for the Eastern counties of Gotland, Uppsala and Gävleborg both fertility measures are low and for the Northern counties of Västerbotten and Norrbotten both measures are high. Hofsten and Lundström [6] reported that the CBR for the city of Stockholm was above the CBR for the whole country, simultaneously with the TFR being low. They stressed that as early as about 1860 the city of Stockholm (low TFR in our study) and the county of Gotland (low TFR and CBR in our study) displayed a fertility considerably lower than that for the country overall. The difference being most marked in the higher age groups seems to indicate an early influence of birth control.

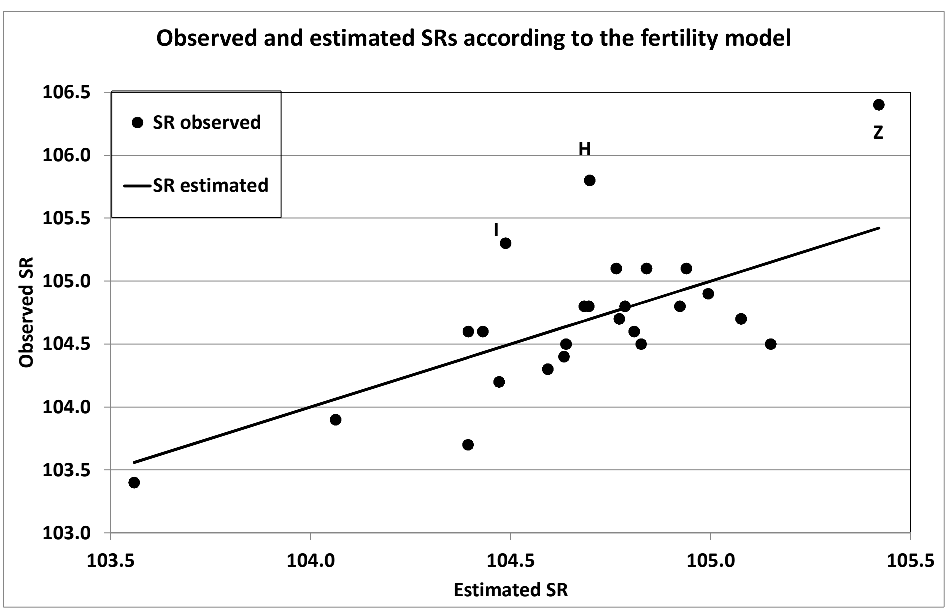

Fig. 6. Comparison between observed and estimated SRs according to the fertility model

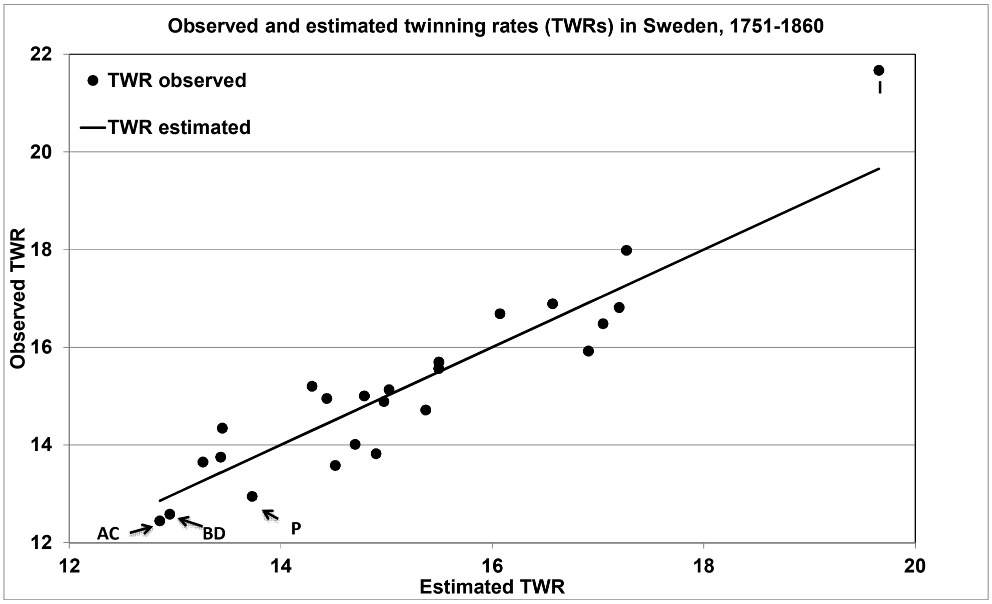

Fig. 7. Comparison between observed and estimated twinning rates (TWRs) according to the optimal model. One observes that the TWR in Gotland (I) with its high TWR is an outlier

5. CONCLUSION

Significant geographic differences in the sex proportions were found, but the spatial regression model generated a poor fit. Counties with high and low TWRs were identified and the weighted spatial regression model for the TWR yielded a good fit.

CONSENT

This section is not applicable

ETHICAL APPROVAL

This section is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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