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Effect of Fertility on Secondary Sex Ratio and Twinning Rate in Sweden, 1749–1870

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We analyzed the effect of total fertility rate (TFR) and crude birth rate (CBR) on the number of males per 100 females at birth, also called the secondary sex ratio (SR), and on the twinning rate (TWR). Earlier studies have noted regional variations in 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. Here, we analyzed historical demographic data and their regional variations between counties in Sweden. We built spatial models for the TFR in 1860 and the CBR in 1751–1870, and as regressors we used geographical coordinates for the provincial capitals of the counties. For both variables, we obtained significant spatial variations, albeit of different patterns and power. The SR among the live-born in 1749–1869 and the TWR in 1751–1860 showed slight spatial variations. The influence of CBR and TFR on the SR and TWR was examined and statistical significant effects were found.

■ **Keywords:** crude birth rates, total fertility rates, secondary sex ratios, twinning rates, live births, counties, geographical coordinates

In a long series of papers, attempts have been made to identify factors influencing the number of males per 100 females at birth, also called the secondary sex ratio (SR). The literature concerning sex ratio is mainly based on birth register data. Such studies can only identify effects of population differences and socio-economic differences. Especially, war effects are identified and stressed. Hawley (1959) 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 areas with a lower standard of living, where the frequencies of prenatal losses are relatively high, the SRs are around 102. Visaria (1967) stated that racial differences appear to exist in the SR (see also Fellman & Eriksson, 2010, 2011, including references). Recently, Grech has studied temporal and regional variations in the SR (e.g., Grech, 2012, 2013a, 2013b). 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 (Fellman et al., 2002). Torche and Kleinhaus (2012) studied the effects on SR of individual stress caused by exposure to a natural disaster. They also presented an exhaustive list of studies concerning the effects of varying causes of individual stress. Their findings may support the war effects discussed in earlier papers.

In a series of papers, we have studied the regional and temporal variations in the twinning rate per 1,000 maternities (TWR) in Sweden. The TWRs in Sweden are among the highest noted in Caucasian populations (cf. Fellman & Eriksson, 2003, 2005, 2009). In this study we continue the regional studies of the TWR in Fellman and Eriksson (2009) in order to identify demographic factors influencing the regional heterogeneity in the twinning rate. We considered the demographic factors, the crude birth rate (CBR; i.e., the number of childbirths per 1,000 people per year) and the total fertility rate (TFR). The total fertility rate compares figures for the average number of children that would be born per woman if all women lived to the end of their childbearing years and bore children according to a given fertility rate at each age. TFR is a more direct measure of the level of fertility than the crude birth rate, since it refers to births per woman.

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FIGURE 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.

Materials and Methods

Hofsten and Lundström (1976) stressed that the crude birth rate (CBR) is a poor measure of fertility and should 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. Hofsten and Lundström 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 geographical differences. We therefore assumed that the CBR can be used in this study of regional comparisons between fertility measures in Sweden up to 1870. The counties and their codes introduced by Statistics Sweden are presented in Figure 1 and used in Table 1.

Hofsten and Lundström (1976) 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 their Tables 6.2–6.16 also presented

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TABLE 1

Geographical Coordinates, Number of Live Births Associated With Secondary Sex Ratio, Crude Birth Rate, Total Fertility Rate and Twinning Rate for the Counties of Sweden

Code[(a)]	Period[(b)]	Latitude	Longitude	n[(c)]	SR	CBR[(d)]	TFR[(e)]	N[(f)]	TWR[(g)]
A	1749–1869	59.32	18.07	336,854	103.4	34.5	3,583	293,070	15.92
B	1749–1869	59.32	18.07	324,901	104.6	31.4	4,070	266,053	17.99
C	1749–1869	59.90	17.80	246,344	104.2	30.7	4,011	215,290	16.81
D	1749–1869	58.76	17.01	319,940	104.6	31.0	4,448	268,508	16.89
E	1749–1869	58.42	15.64	581,692	104.5	32.4	4,494	490,915	15.56
F	1749–1869	57.78	14.18	424,184	104.9	31.6	4,771	365,952	13.82
G	1749–1869	56.86	14.82	356,405	104.7	34.2	4,942	309,611	13.58
H	1749–1869	56.80	16.00	516,021	105.8	33.7	4,776	452,081	15.70
I	1749–1869	57.63	18.30	119,541	105.3	28.2	3,612	99,902	21.67
K	1749–1869	56.16	15.58	283,511	103.7	35.6	4,738	246,401	14.89
L	1749–1869	56.02	14.13	455,200	104.8	32.8	4,613	406,505	14.71
M	1749–1869	55.61	13.06	637,249	104.6	34.9	4,629	551,927	15.20
N	1749–1869	56.67	12.86	271,859	104.5	32.0	4,646	237,796	14.01
O	1749–1869	58.35	11.93	482,251	103.9	34.8	4,226	407,899	13.65
P	1749–1869	58.37	12.32	597,113	104.8	32.5	4,574	518,883	12.95
R	1749–1869	58.71	13.82	522,657	104.8	33.5	5,004	451,746	14.34
S	1749–1869	59.38	13.50	552,016	105.1	33.0	4,825	535,186	13.75
T	1749–1869	59.27	15.22	367,499	104.5	32.3	5,067		
U	1749–1869	59.67	16.55	272,943	104.3	31.4	4,277	238,776	16.69
W	1749–1869	60.61	15.64	395,484	104.7	30.5	4,681	322,518	15.13
X	1810–1869	60.68	17.16	188,398	104.8	29.0	4,085	208,415	16.48
Y	1810–1869	62.63	17.94	175,813	105.1	32.6	4,880	174,079	14.95
Z	1810–1869	63.18	14.65	77,473	106.4	27.3	4,539	75,916	15.00
AC	1749–1869	63.83	20.27	169,733	104.4	37.6	5,366	112,573	12.45
BD	1749–1869	65.59	22.17	153,877	105.1	37.6	5,509	104,610	12.58
Total	1749–1869	59.18	15.87	8,828,958	104.66			7,354,612	14.96

Note: SR = secondary sex ratio, CBR = crude birth rate, TFR = total fertility rate, TWR = twinning rate. The counties and provincial capitals are given in Figure 1. (a) The codes are explained in Figure 1. (b) For Stockholm city and the county of Gotland, data are known for the whole period, but for the rest of the counties data are missing for the period 1774–1794. (c) Number of live births for the defined period. The twinning rate is for the period 1751–1860, but for some decades and 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) Regional number of maternities for the period 1751–1860 associated with the TWR. (g) TWR for the period 1751–1860.

TFR values per 1,000 women for all decades starting from around 1860 to 1970. The variable TFR used by us is their data for 1860.

Berg (1871) published SR data for live births in the counties of Sweden for the period 1749–1869, but the periods for which information was available varied between the counties (Table 1). Berg defined the SRs as males per 1,000 females, but we have transformed his data to the traditional definition, number of males per 100 females.

The regional twinning rates (TWRs) for the period 1751–1860 are 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 began in 1811. A detailed presentation and analysis of the regional TWRs is given in Fellman and Eriksson (2009). In Table 1, we included the regional 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.

In accordance with the concepts outlined in Fellman and Eriksson (2009), we introduced spatial regression models for the regional fertility data. The location of the counties was defined as the geographical coordinates of the corresponding residences (provincial capitals). The residences can be seen in Figure 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 coordinates are given in Table 1. The geographical coordinates for Sweden are eastern longitude and northern latitude. 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 coordinates of the unweighted center (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 center. Table 1 shows that the geographical coordinates of Örebro are closest to the center of the cluster of residences.

The spatial variations in TFR and CBR were studied with the geographical coordinates as regressors, but now no weights could be included in the regression analyses because no information about the heterogeneity in the variances was available. We analyzed the effect of TFR and CBR on the SR and on the TWR by weighted regression models. The regressand was the observed regional SR. The variance of the observed regional 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. For TWR, we had information about the number of maternities (N in Table 1), and thus could use weighted regression.

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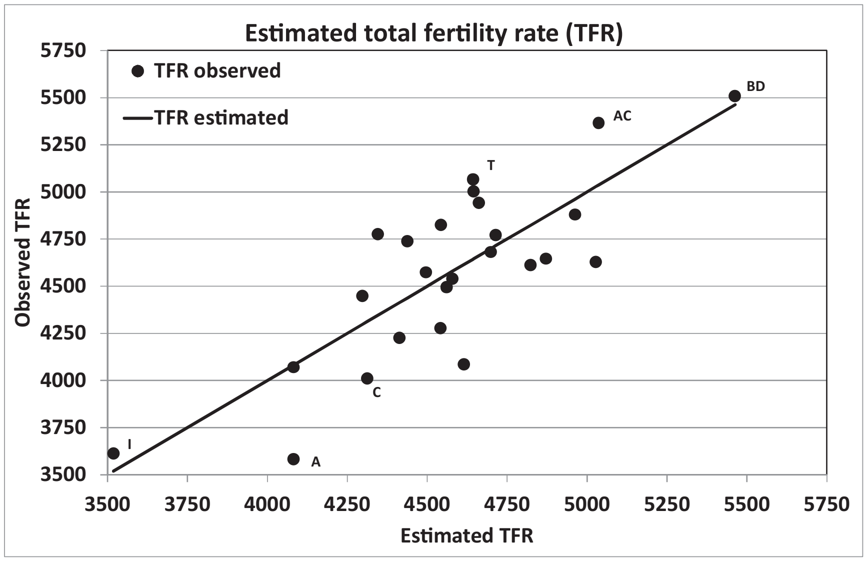

FIGURE 2

Comparison between observed and estimated total fertility rates (TFRs). The estimated TFR values are obtained by a spatial regression model (for details, see the text).

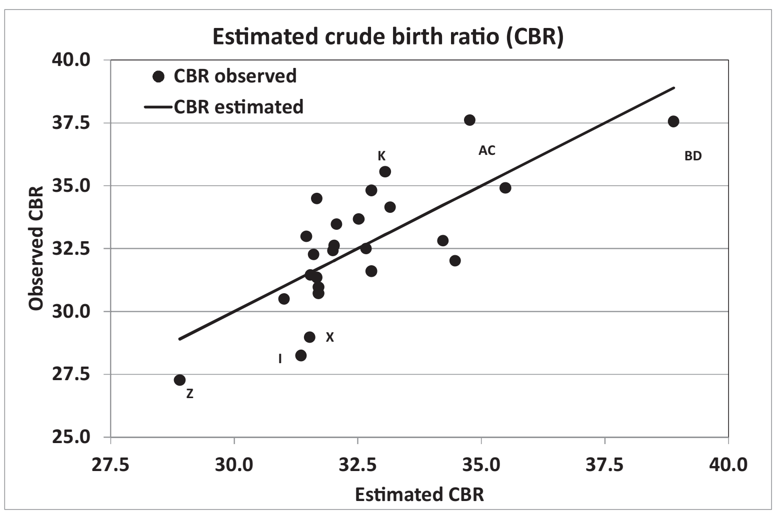

FIGURE 3

Comparison between observed and estimated crude birth rates (CBRs). The estimated CBR values are obtained by a spatial regression model (for details, see the text).

Results

For TFR, the optimal spatial regression model contains the regressors M, L, M^2 and ML. The estimated regression model is

$$\text{TFR} = 4584 - 123.4\ M + 81.96\ L - 55.29\ M^2 + 82.37\ M\ L.$$

All of the parameter estimates are significant and the adjusted $\bar{R}^2 = 0.573$, indicating rather good fit. This can also be seen in Figure 2. Counties with low TFRs are the city of Stockholm (A) and the counties of Gotland (I) and Uppsala (C). Regions with high TFRs are the counties of Norrbotten (BD), Västerbotten (AC) and Örebro (T). If we compare the intercept 4,584 with the observed TFR value for the county of Örebro (5,067), a marked discrepancy is noted.

For CBR, the optimal regression model contains the regressors L and the product $L\ M$, and the estimated regression model is

$$\text{CBR} = 31.65 - 0.395\ L - 0.242\ L\ M.$$

All of the parameter estimates are significant and the adjusted $\bar{R}^2 = 0.525$. The fit is comparable with the fit for the TFR model. This can also be seen in Figure 3. Counties

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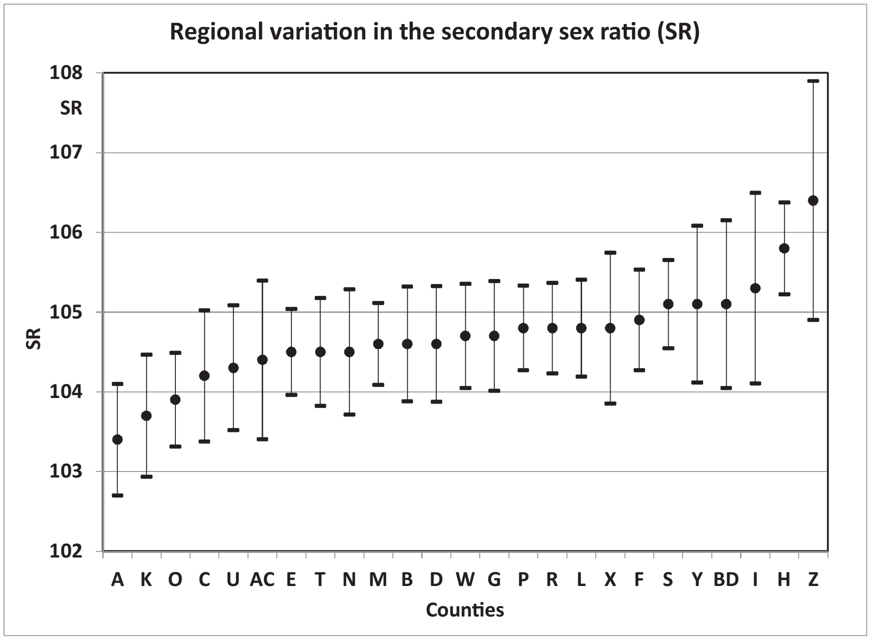

FIGURE 4

Observed secondary sex ratios (SRs) and their confidence intervals (CIs) for different counties. The counties are arranged according to increasing SR, and the county codes are given in Figure 1. Note the broad CIs for the counties of Jämtland (Z), Gotland (I), Norrbotten (BD) and Västerbotten (AC). For these, the number of live births is less than 175,000.

with low CBRs are Jämtland (Z), Gotland (I) and Gävleborg (X), and those with high CBRs are Västerbotten (AC), Norrbotten (BD) and Blekinge (K). If we compare the intercept 31.65 with the observed TFR value for the county of Örebro (32.3), a discrepancy emerges.

Our first analyses of the SR and the TWR were to check the regional heterogeneity. For SR, 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 regional SRs, both given by Berg (1871). Significant regional differences in the sex proportions were found ($\chi^2 = 54.6$, 24 degrees of freedom, $p < .001$). In general, for moderate data sets, the SR is influenced by large random fluctuations (Fellman and Eriksson, 2010, 2011; Visaria, 1967). This can be seen in Figure 4, where we present the regional SRs with 95% confidence intervals. Note the broad confidence intervals for the counties of Jämtland (Z), Gotland (I), Norrbotten (BD) and Västerbotten (AC). For these, the number of live births is less than 175,000.

For TWR, stronger regional variations were obtained ($\chi^2 = 1152.4$, 23 degrees of freedom, $p < .001$). This strong variation can also be seen in Figure 5, showing short confidence intervals. Low TWRs can be observed in the northern counties of Västerbotten (AC) and Norrbotten (BD) and the western county of Älvsborg (P). The TWR of the county of Gotland is so extreme that it can be considered an outlier. These regional variations support the findings in Fellman and Eriksson (2003, 2005, 2009). Spatial models for TWR and especially for SR yield rather poor fit.

For the SR, we constructed a weighted regression model based on the fertility variables TFR and CBR. The fertility model was

$$SR = 104.68 + 0.000855\,TFR - 0.1445\,CBR.$$

The optimal model obtained has a rather good fit. The adjusted coefficient of determination was $\bar{R}^2 = 0.373$, and the regression parameter estimates were significant. We note a positive effect of TFR and a negative effect of CBR. Together with the observed SRs, the estimated SRs for the optimal model are given in Figure 6. The most marked discrepancies between the observed and estimated SRs are in the counties of Gotland (I), Kalmar (H) and Jämtland (Z), characterized by high SR values, and the city of Stockholm (A), with a low SR.

When we build a weighted regression model for the TWR based on the regressors TFR and CBR, the optimal model is

$$TWR = 15.27 - 0.002110\ TFR - 0.2499\ CBR.$$

All of the parameter estimates are significant and the adjusted $\bar{R}^2 = 0.436$, indicating a good fit. We note negative effects of both fertility variables. The observed and expected TWRs are presented in Figure 7. This figure confirms that the high TWR in Gotland (21.67 per 1,000) is an outlier.

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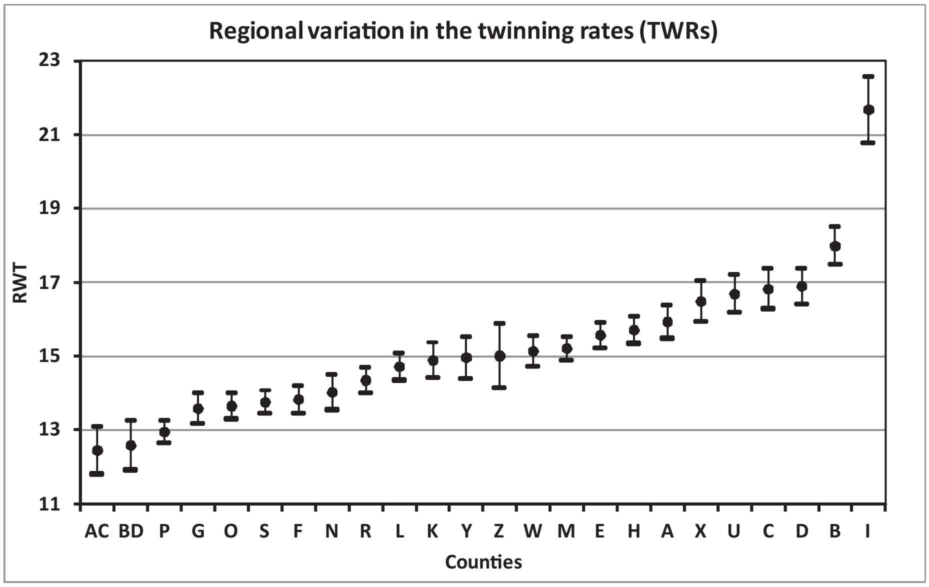

FIGURE 5

Observed twinning rates (TWRs) and their confidence intervals (CIs) for different counties. The counties are arranged according to increasing TWR values, and the county codes are given in Figure 1. Note the outlier Gotland (I) and the broad CIs for the counties of Gotland (I), Jämtland (Z), Norrbotten (BD) and Västerbotten (AC). For these, the number of maternities is less than 125,000.

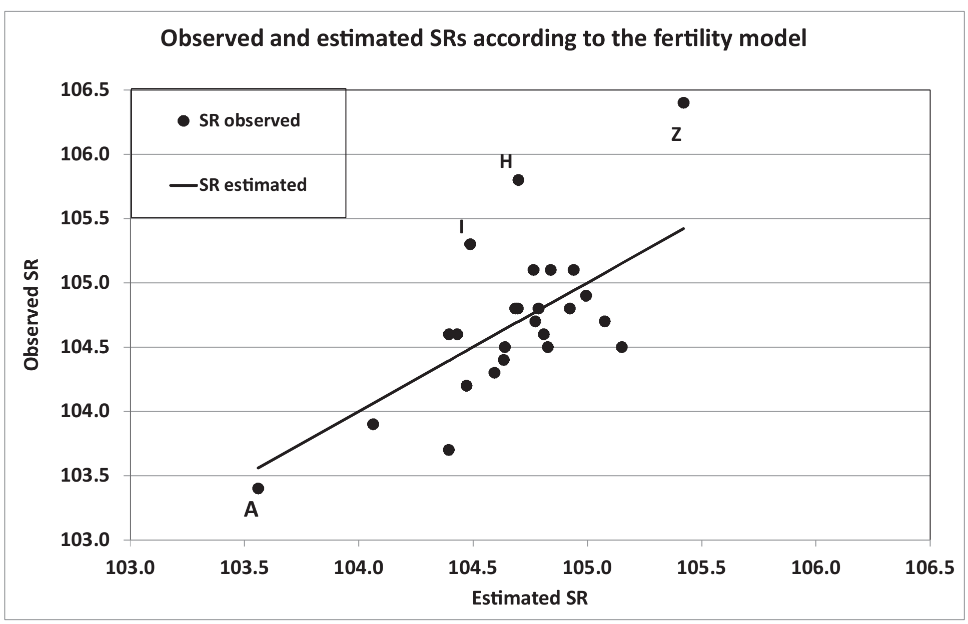

FIGURE 6

Comparison between observed and estimated sex ratios (SRs) according to the spatial model. The discrepancies between observed and estimated SRs are marked for the counties of Kalmar (H), Gotland (I) and Jämtland (Z). The codes of the counties are provided in Figure 1.

This finding supports our earlier results that the TWR values for Gotland are continuously quite high (Fellman & Eriksson, 2003, 2005, 2009). Among 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. In these counties, the TWRs are the lowest (below 13 per 1,000) for Sweden.

Discussion

No common geographical pattern for the demographic variables TFR, CBR, SR and TWR was detected, but a

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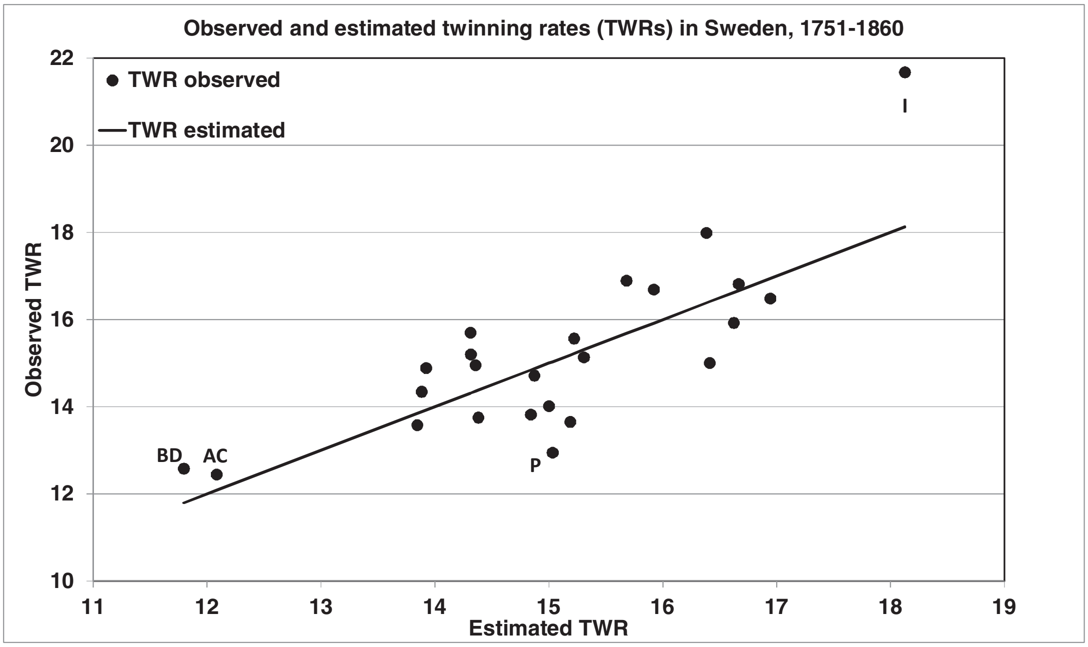

FIGURE 7

Comparison between observed and estimated twinning rates (TWRs) according to the fertility model. The high TWR in Gotland (I) is an outlier. Note also that the low TWR value for the county of Älvsborg (P) differs markedly from the regression line.

significant spatial fit was noted for TFR and CBR. Our results show that for the eastern counties of Gotland (I), Uppsala (C) and Gävleborg (X) both fertility measures are low, and for the northern counties of Västerbotten (AC) and Norrbotten (BD) both measures are high. Hofsten and Lundström (1976) reported that the CBR for the city of Stockholm (A) was above the CBR for the whole country, simultaneously with a low TFR. They stressed that as early as about 1860 the city of Stockholm (rather high CBR and low TFR in our study) and the county of Gotland (low CBR and TFR 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. The high TWRs in the county of Gotland with low CBR and TFR and in the region around Stockholm connected with low TFRs seem mainly to contribute to the negative regression parameters in the regression models.

According to Fellman and Eriksson (2009), low TWRs were observed in the western counties of Älvsborg (P) and in the northern counties of Västerbotten (AC) and Norrbotten (BD). The low TWRs in Västerbotten and Norrbotten have been considered as the influence of the Samis (Lapps) settled in northern Sweden. The gradient for the TWR levels, directed towards increasing TWRs, has a south-eastern course and 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 (Fellman & Eriksson, 2009). According to Eriksson (1973) the neighboring regions in the southwestern part of Finland (the Åland Islands and the county of Turku and Pori) show similar high TWRs and consequently, a marked peak for the TWR can be found in this region bordered to the Baltic Sea.

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