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Can economic stress affect secondary sex ratio in Poland?

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ABSTRACT The ratio of male to female births described as the male proportion is expected to be about 1.06. The secondary sex ratio can be influenced by various stresses experienced by parents (e.g., parents' exposure to chemical and physical pollution, natural phenomena, wars and economic crises). The seminal study in this field speculated that fewer goods and services than needed or desired might sufficiently stress human populations to lower the secondary sex ratio. The main purpose of this study is to examine the relationship between economic stress and the fluctuations of sex ratio at birth in Poland. The statistical analysis was based on annual demographic data obtained from year-books issued by the Central Statistical Office on the overall number of male and female live births in Poland in the years 1956-2005 as well as on the annual data of percentage change in total private consumption. In order to verify the hypothesis that the observed time-series of the secondary sex ratio in Poland declines with deterioration in economic conditions, we constructed mathematical models (ARIMA) of both analyzed phenomena following the statistical procedure proposed by Catalano and Bruckner [2005]. We found a statistically significant decline of SSR in Poland over the last 50 years. The decrease appeared to be stronger in villages than in towns. However, the consumption rate as related to the strength of economic stress had no effect on the fluctuation of the sex ratio at birth.

KEY WORDS: proportion of male live births, SSR, human sex ratio, total private consumption

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The secondary sex ratio (SSR) – expressed as the proportion of live male births to total births, or sometimes also as the proportion of male births to female births – in human populations ranges from 0.502 to 0.529 for the former, or 1.01 to 1.12 in the case of the latter. The slightly higher number of male live births (about 5%) constitutes part of an optimal developmental strategy for our species. However, in many studies it has been observed that the values of the male/female live births proportion are not constant, but fluctuate according to changing genetic and environmental factors.

According to the observations of MARTUZZI *et al.* [2001], the consistent decline of the secondary sex ratio and an nonmonotonous trend can be noticed almost in the entire post-war Europe (the exception is Ireland where a consistently increasing trend was observed). Poland, Bulgaria, Sweden and United Kingdom are the four countries in which a monotonously decreasing trend in a number of male births/newborns is most distinctly visible (Fig. 1). In Poland, between 1950–1996 there were 9.13 less live male births per 1000 births than expected. Fig. 2 presents the values of SSR registered in Poland from 1948–2005.

Factors responsible for the SSR decrease include the parents' exposure to chemical pollutants such as dioxins, TCDD [MOCARELLI *et al.* 2000, JONGBLOET *et al.* 2002, RYAN *et al,* 2002], pesticides [VARTIAINEN *et al.* 1999,

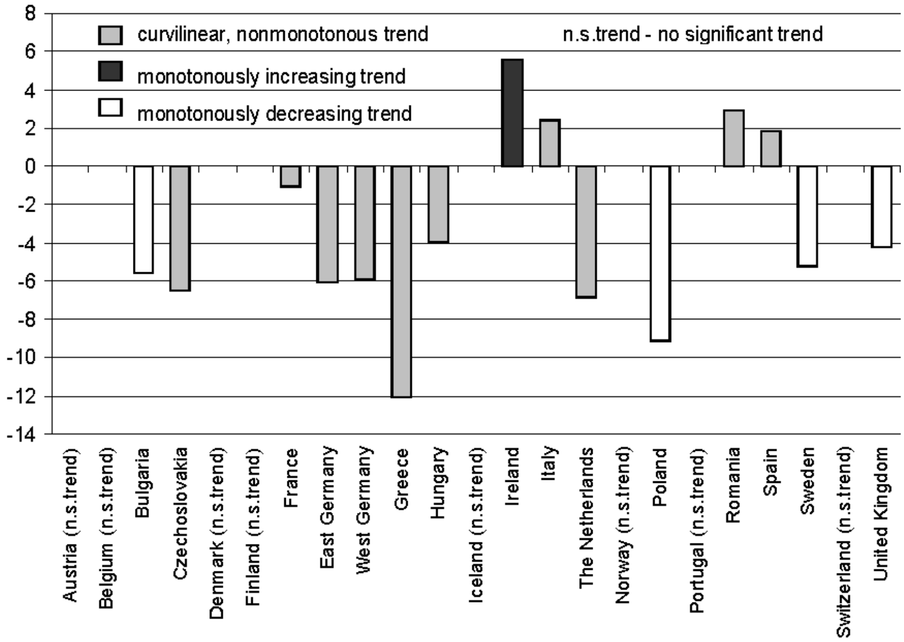

Fig. 1. Change in male proportion between 1950-1996 (per 1000) in Europe. After MARTUZZI *et al.* [2001].

FIGA-TALAMANCA *et al.* 2003], fumes [PERGAMENT *et al.* 2002] and radioactive substances [PETERKA *et al.* 2004]; the mothers' heavy tobacco smoking [DOUGHERTY and JONES 1982, KORNAFEL 1995, ŻĄDZIŃSKA 2003], stresses brought about by natural phenomena such as floods [CATALANO 2003] or earthquakes [FUKUDA *et al.* 1998], wars [VARTIAINEN *et al.* 1999, GRAFFELMAN and HOEKSTRA 2000, JONGBLOET *et al.* 2001, ZORN *et al.* 2002], terrorist attacks [CATALANO *et al.* 2005] and economic crises [JARRELL 2002, CATALANO 2003]. On the other hand, according to KARMAUS *et al.* [2002] Michigan fish eaters exposed to a high concentration of polychlorinated biphenyls (PCB) have a relatively higher proportion of male offspring and therefore higher SSR.

It has also been suggested that in recent years, the decrease in SSR is influenced by the mother's illnesses (in particular metabolic alterations, such as diabetes) [JAMES 1998, RJASANOWSKI *et al.* 1998], medications used in infertility treatment (mostly clomifene citric, which stimulates and intensifies ovulation) [JARRELL 2002], an older average age of the parents' [TEITELBAUM *et al.* 1971, IMAIZUMI and MURATA 1979, RUDER 1986, KORNAFEL 1995, GUTIERREZ-ADAN *et al.* 2000]; and the mothers' low body weight recorded just prior to pregnancy [CAGNACCI *et al.* 2004].

The regulation of male to female ratio (within a population) can probably be effected in two ways. According to one hypothesis, hormones induced under stress in the mother cause idiopathic miscarriage of male embryos [HASSOLD *et al.* 1983, BYRNE and WARBURTON 1987, HOBEL *et al.* 1999]. These also may disturb the releasing mechanism of the SRY protein (the important event in male ontogenesis) (e.g., PHILIPS *et al.* 2006). According to FUKUDA *et al.* [1996], male hormones produced under stress significantly reduce the quantity and quality of spermatozoa in the semen. It is also possible that both of these phenomena are coincident and both account for a population's reaction to perturbations to the environmental conditions within which it lives.

The hypothesis presented by TRIVERS and WILLARD [1973], according to which natural selection should favor mothers that produce sons in favorable conditions but daughters in unfavorable conditions, triggered research on the analysis of the economic stress impact on the coefficient of male births (relative to all live births). It is assumed that less than required consumption of goods and services can finally result in economic stress, which in consequence results in reduction of the rate of the secondary sex ratio. Such an assumption implies that the monitored secondary rate of sex ratio among alive newborns will decrease (as the result of a decrease of male births and/or an increase in a number of girls being born), when the population consumes less goods and services than it should according to its needs.

In the literature, however, there is a lack of any direct test that would verify such an hypothesis. What are usually analyzed are individual stressogenic factors impacting on a human population in the short time (e.g., a terrorist attack, war outbreak, or an earthquake). In such a case the relationship between socio-economic status (SES) and SSR is studied only "cross-sectionally". Meanwhile, it is commonly known that poverty can be a chronic stressor acting on an individual. The problem is, however, how to assess the level of "poverty" and its impact on stress level, and how to differentiate the impact on consumption, depending on the level of poverty. Additionally, SSR is often autocorrelated because it contains a distinctive trend or cycle that tends to register overstated (or understated) values after high (low) values occurring in time. Such autocorrelation complicates all such tests because the expected value of the correlated time series is not its average value.

The method of analysis of the impact of economic stress on the SSR within the defined time range has been put forward by CATALANO and BRUCKNER [2005], who based their research on data of the Swedish population which encompassed 129 observations (years) of the rate of sex ratio of live newborns and percentage changes of household consumption capacity.

This method has been employed in the present work in order to attempt to answer the question of whether in the post-war Poland, deterioration of conditions of living resulted in a decrease of secondary sex ratio in newborns.

Materials and methods

Material

We used the data on the total number of live male (M) and female (F) newborns born in Poland in the consecutive years from 1956 to 2005 (source: Demographic Yearbooks of the Central Statistical Office (GUS). On the basis of the data for the whole country, as well as the separate data for cities/towns and villages, the time series of SSR (the ratio of male to female newborns (M/F) was calculated for each of 50 examined years) has been constructed (Fig. 2).

A variable that defines economic conditions within the examined period was the time series of the percentage change of household, private consumption at constant prices from 1995 within the period of 1956–2005 (50 observations)

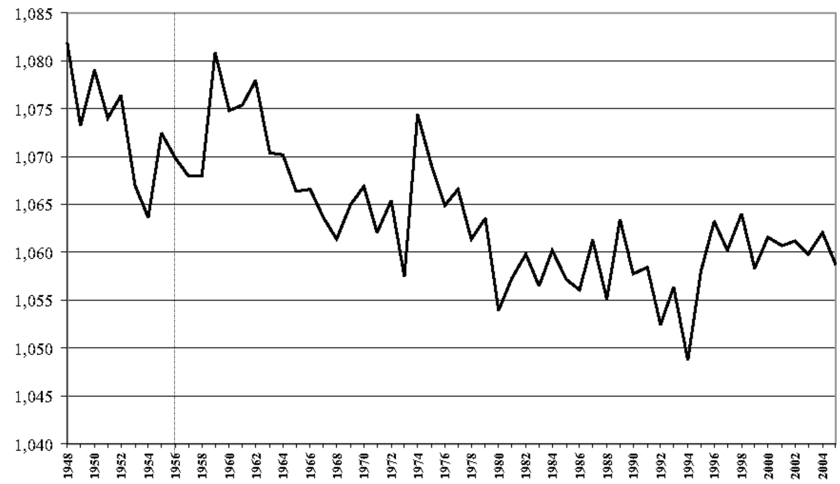

Fig. 2. Proportion of male to female live births in Poland between 1948 and 2005. After Demographic Yearbooks of the Central Statistical Office (GUS).

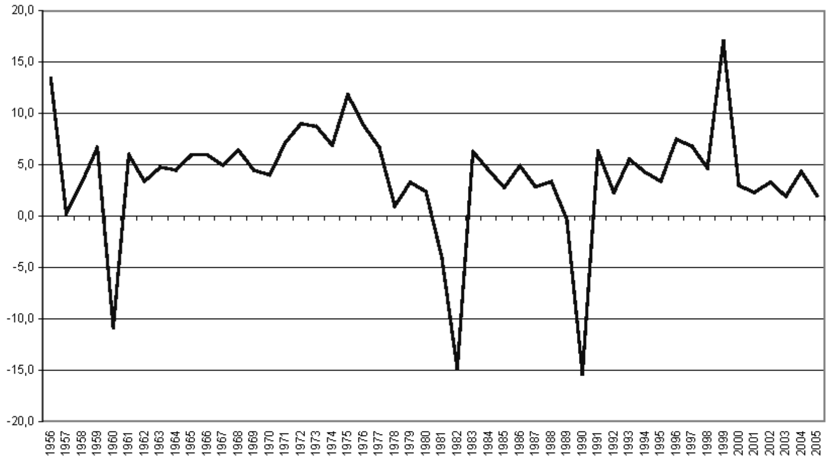

Fig. 3. Percentage change in total private consumption, Poland 1956-2005.

(calculations based on the Statistical Yearbooks of Poland from the years 1956–2006). The sequence has been constructed on the basis of private consumption value (in millions PLN, execution in current prices) converted to constant prices from 1995 with the aid of a "consumption deflator" (Fig. 3). A "consumption deflator" is a statistical tool used to convert the value of consumption (time series in current prices) into an inflation-adjusted value of consumption (time series in set prices) in order to compare the changes of consumption over time after factoring out the overall effects of inflation.

Description of statistical method

In the statistical procedure employed, the null hypothesis (H_0) that has been formulated implies that economic conditions (consumption rate) do not have an influence on SSR. The alternative hypothesis (H_1), was that SSR is influenced by the economic factors measured by the consumption rate. In the next steps of analysis we aim to reject the H_0 hypothesis in favor of H_1. A detailed approach to the analysis of consumption impact on SSR is as follows:

In the first step, values of the equation parameters of percentage consumption change are estimated by use of AR (autoregression), MA (moving average), or ARIMA (autoregressive-integrated moving average) method, proposed by BOX and JENKINS [1983] as the procedure used in estimation of the stochastic model for analysis of the time-series. Thus, the series has been deconstructed into two parts, an autoregressive part consisting of lagged values of percentage change of consumption from the previous periods, and a moving average part, consisting of lagged error terms.

In the second stage, to identify the appropriate ARIMA model the stationarity of the time series is investigated, i.e., occurrence of trend is assessed. If a trend occurs, time series are often transformed to become stationary by differencing in order to eliminate it if a non-equation is left unchanged. A time series which needs to be 'differenced' to be rendered stationary is said to be "integrated".

For the Polish data, modeling of the SSR time series required differentiation of the series (due to the significant decreasing trend) as well as to eliminate the impact of outliers occurring in the SSR and consumption change series, including dummy variables in the equation. Taking into consideration the variables as descriptive variables we eliminated the problem of untypical observations that stood out from other years, such that those variables remaining in the model do not have to describe these observations, resulting in better model fitness. In this way we dealt with outliers that could have strongly influenced the results – these outliers were detected on the basis of graph analysis.

The Dickey-Fuller and Box-Jenkins [BOX and JENKINS 1983] method is used for identification and expression of series autocorrelation. Partial (PACF) and total (ACF) autocorrelation of a series is examined in order to define a number of lags for autoregressive parameters AR(p) and a number of lags of moving average terms MA(q). On the basis of the obtained information, the ARIMA (p, d, q) model is constructed, which describes the variance of consumption time series.

In a consecutive step of the same method, the M/F time series – SSR is used in order to find "p" lags of the explained variable (SSR) and "q" lags of random elements (error terms) in the SSR model. The equation of SSR has been completed with the "unexplained part of consumption" obtained from the previous model – residuals from the model that are realizations of random elements from the consumption equation (after first making sure that the residuals are not correlated). Next, the model parameters are estimated in such a way that estimated values should be statistically significant and extend the model with the lags of additional variables.

In the final step, the assessment of parameter values obtained for the SSR model was carried out. The objective was to reject the "erroneous" null/H0 hypothesis on the basis of evaluation of values and signs of the estimated parameters. If the value of the estimated parameter of residuals from "the consumption model" is at least 2 times higher than the standard deviation, we assume that the obtained estimate of parameter is stationary and we reject the H_0 hypothesis in favor of the alternative hypothesis, whereas we draw the whole interpretation from the coefficient sign and the variable lag of consumption rate residuals.

There are 3 possible variants:

(1) Estimate of the parameter is two times higher than standard deviation, and estimate of the parameter is positive, which means a stationary and correct solution, (consumption increases → SSR increases);

(2) Estimate of the parameter is two times higher than standard deviation, and estimated parameter is negative, which means that the economic stress hypothesis is not confirmed because when consumption increases → SSR decreases;

(3) Estimate of the parameter is not (less than) two times higher than standard deviation, (parameter of no importance), which means that the solution is unstable.

Estimations of the parameters of the models have been carried out using statistical program GRETL 1.6.0 [KUFEL 2004].

Results

The analysis of time series of annual rates of household consumption (in constant prices from 1995) showed its stationarity, as there were no grounds for rejection of the H_0 hypothesis that the value of coefficient of regression line equals 0. The value of the trend line's slope (-0.026) within the whole analyzed period (*t-Stat* = -0.46; *p* = 0.64) appeared to be insignificant.

For the evaluation of variances' non-stationarity, the augmented Dickey-Fuller test (ADF) was used with null hypothesis where the process is cumulative (integrated) in the first degree I(1), against the alternative hypothesis where the process is not cumulative I(0). Significantly negative values of the parameters have been obtained at the delayed consumption variables in ADF tests, which indicates the lack of integration process. It allowed us to reject the H_0 hypothesis that the process is integrated in 1 (d=1) degree in favor of the alternative hypothesis that the integration row amounts to 0 (d=0) – and the time-series is stationary.

Further analysis of the properties of the consumption change time series (PACF and ACF), which respectively examine the „pure" relation between studied observations and more distant dependencies among observations, allowed us to construct an autoregressive equation of percentage consumption change with a one year lag - AR(1). The dependent variable was denoted as "Δ C/C". In the equation, dummy variables for the years 1960, 1982, 1990, 1999 were used.

From the model of consumption rate (Table 1), residuals (differences between theoretical values, calculated from the equation, and empirical values – variable named e Δ C/C), have been calculated.

A following step was analysis and identification of the time series of SSR. Within the entire analyzed period (*t Stat* =

Table 1. Estimation of AR(1) with use of 50 observations (1956–2005).

Dependent variable: Δ C/C

Variable	Coefficient	Standard error	*t* statistics	*p* value	
Δ C/C(1)	0.8513	0.0803	10.6062	<0.00001	***
Z1990	-18.3213	2.4068	-7.6124	<0.00001	***
Z1982	-16.0353	2.4064	-6.6636	<0.00001	***
Z1999	13.2593	2.4070	5.5086	<0.00001	***
Z1960	-17.1536	2.4082	-7.1230	<0.00001	***

Mean of dependent variable = 3.8916
Standard deviation of dependent variable = 5.6455
Average of random disturbances = 0.7268
Variance of random disturbances = 9.9873
Log-likelihood = -129.13
Akaike Information Criterion (AIC) = 270.25
Schwarz Bayesian criterion (BIC) = 281.72
Hannan-Quinn Information Criterion (HQC) = 274.62

Dependent variable Δ C/C – relative consumption value rate (percentage rate of consumption value with one year lag in constant prices of 1995); **Δ C/C(1)** – autoregressive parameter of consumption equation – relative consumption value rate with one year lag; **Z1990, Z1982, Z1999, Z1960** – dummy variables to explain untypical values in the time series and to increase model fit (coefficient of determination);

= -6.38; $p < 0.0001$) SSR had a significantly decreasing trend (-0.00031). The SSR series was not stationary. In order to make any further analyses on SSR, this time series general trend should be removed. To do that, a new M/F_t-$M/F_{(t-1)}$ series has been obtained, which is a stationary series (variable named dM_F – SSR values after single-time differentiation I(1)).

Function analysis of partial and total autocorrelation has allowed us to point out the significance of first lags for the autoregressive process AR(p) (PACF) and for moving the average process MA(q) (ACF). The method put forward by Catalano and Bruckner suggests that while constructing the M/F equation one should additionally make sure that any further delays of the described variable do not have to be taken into consideration. Finally, the equation has been constructed is based on M/F_t-$M/F_{(t-1)}$ difference, where two lags of the differenced M/F variable and 1 lag for the moving average occurred. However, for effective sequence modeling, it is necessary to eliminate certain untypical values in years 1959, 1963, 1974, 1980, 1995, by introduction of dummy variables.

According to the CATALANO and BRUCKNER [2005] method, residuals from the consumption model with a one-year lag (e Δ C/C(1)) have been used as independent variable for the constructed equation M/F.

Table 2. ARIMA (2,1,1) estimation using 49 observations (1957-2005)

Dependent variable: dM_F

Variable	Coefficient	Standard error	*t* statistics	*p* value	
dM_F(1)	-1.6211	0.0981	-16.5219	<0.00001	***
dM_F(2)	-0.6983	0.0976	-7.1526	<0.00001	***
MA(1)	1.0000	0.0653	15.3123	<0.00001	***
Z1959	0.0097	0.0023	4.2146	0.00003	***
Z1963	-0.0065	0.0023	-2.8770	0.00402	***
Z1974	0.0111	0.0023	4.8701	<0.00001	***
Z1980	-0.0071	0.0023	-3.1669	0.00154	***
Z1995	0.0089	0.0023	3.9022	0.00010	***
e Δ C/C(1)	-0.00036431	0.00012379	-2.9431	0.00325	***

Mean of dependent variable = -0.0002
Standard deviation of dependent variable = 0.0054
Average of random disturbances = -0.0004
Variance of random disturbances = 7.2e-006
Log-likelihood = 219.18
Akaike Information Criterion (AIC) = -418.36
Schwarz Bayesian criterion (BIC) = -399.44
Hannan-Quinn Information Criterion (HQC) = -411.18

Dependent variable dM_F – SSR values after single-time differentiation I(1) – stationary time series; **dM_F(1), dM_F(2)** – two autoregressive parameters of SSR equation, respectively with one-year and two-year lags; **MA(1)** – parameter of moving average (estimated random term of SSR equation with one-year lag(1)); **Z1959, Z1963, Z1974, Z1980, Z1995** – dummy variables to explain untypical values in the time series and to increase model fit (coefficient of determination); **e Δ C/C(1)** – residuals from consumption model with one-year lag(1).

As a result, we obtained a statistically significant model of SSR difference changes with a one year lag in relation to changes of the consumption rate (Table 2). Estimation of the model indicated that all the parameters were statistically significant, and the model residuals are uncorrelated. While selecting the final model we used the lowest value of the Akaike Information Criterion (AIC), Schwarz Bayesian criterion (BIC) and Log-likelihood.

The evaluation of rate of „consumption residuals" showed stability of the constructed model (parameter value to its standard deviation was at least 2.9 times higher – s.d. equals only 34% of the parameter). However, its negative value (Tab. 2) does not allow us to confirm the hypothesis that decrease in consumption causes decrease in SSR.

Discussion

Within the analyzed period of 50 years (1956–2005), we found no significant relationship between consumption of private households and SSR. It is possible that this resulted from the minimal number of observations necessary to apply the ARIMA method (50 observations). The suggested statistical procedure [CATALANO and BRUCKNER 2005] used in the present work has been based on Swedish data that included 129 years of observations. It is also possible that the indicator of economic stress used in our studies (percentage changes of households' consumption), does not fully reflect economic conditions in communist and post-communist countries. CATALANO and BRUCKNER [2005] claim that their method is only one of the possible approaches to as difficult a problem as the relationship between economic stress and SSR.

The time series has been constructed for the whole population, while the trend can also differ due to the environment. In cities (data from the period of 1948-2005), the trend coefficient is -0.00031 (t $Stat$ = -6.63; p < 0.0001) and for the rural population its value is lower and equals -0.00040 (t $Stat$ = -8.40; p < 0.0001) (Fig. 4). The pace of SSR decline is significantly slower in cities than in villages (t $Stat$ = -1.92 which exceeds the critical value of t = 1.67). The decline of SSR in the Polish rural community was already observed by HENNEBERG [1977] for 19th century inhabitants of Szczepanowo (Great Poland region). One of the possible explanations of the difference can be based on the maternal dominance hypothesis, according to which women who are relatively more dominant and achieve are more likely to conceive sons [GRANT 1996, GRANT and YANG 2003]. It is likely that women who make decisions about leaving the countryside and move into cities are significantly more likely to have scored higher on the tests of dominance. This result also confirms earlier reports which suggest that the decline in the SSR is an effect of parents' exposure to chemical fertilizers as well as to pesticides used in agriculture [VARTIAINEN *et al.* 1999, FIGA-TALAMANCA *et al.* 2003]. It is also possible that the intensive decline in SSR in the last 50 years observed in Polish villages could be influenced by increasing migration from rural to urban centers, but due to lack of precise data e.g., on migration, we are not able to test this hypothesis.

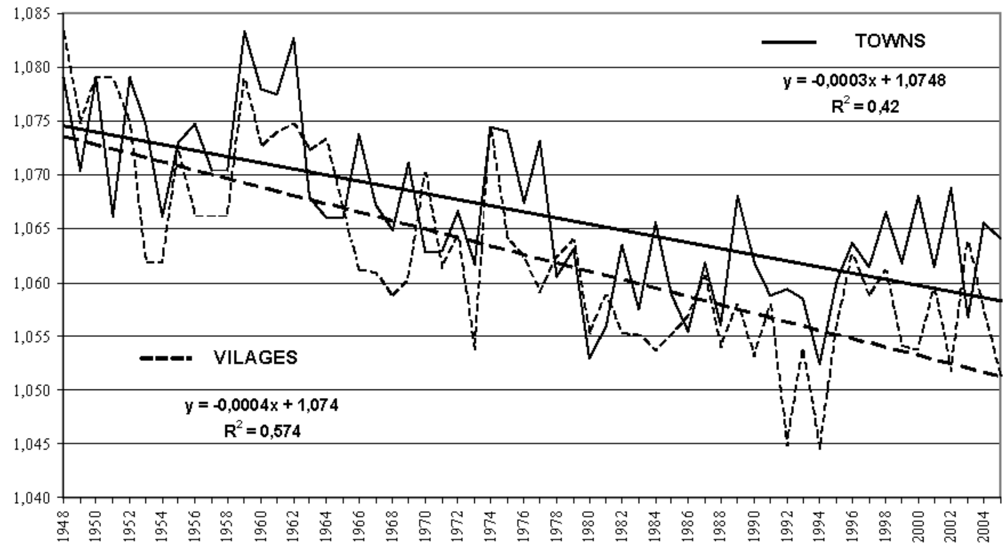

Fig. 4. Time series and regression line for secondary sex ratio observed separately for towns and villages, Poland 1948-2005.

Such distinct environmental differences in the rate of SSR decline were not as marked in the Swedish population [CATALANO *et al.* 1999, CATALANO and BRUCKNER 2005]. Possibly, in the case of the Polish population, modeling for time series of consumption and SSR should be done separately for villages and cities. This procedure would however require regionally and environmentally different consumption coefficients that would describe changes in household consumption separately for cities and villages. Finally, the procedure of initial stationarization of time series characterized by a distinct decreased tendency can affect the process of statistical modeling.

It seems that the explanation of the SSR decreasing with time, which is a matter of concern in many European countries, is an issue that requires further research on multi-factorial causes that modify the dynamics of the process.

Conclusions

1. The decreasing trend of time series of secondary sex ratio in Poland is statistically significant for the entire analyzed period.
2. The decreasing trend of time series is more distinctive in villages than in cities/ towns.
3. The analysis carried out in this paper does not allow us to reject the hypothesis that the decrease in SSR is not related to the economic conditions measured by the total private consumption rate.

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References

BOX G.E.P., G.M. JENKINS, 1983, *Analiza szeregów czasowych: prognozowanie i sterowanie*, PWN, Warszawa

BYRNE J., D. WARBURTON, 1987, *Male excess among anatomically normal fetuses in spontaneous abortions*, Am. J. Med. Genet., **26**, 605-611

CAGNACCI A., A. RENZI, S. ARANGINO, C. ALESSANDRINI, A. VOLPE, 2004, *Influences of maternal weight on the secondary sex ratio of human offspring*, Hum. Reprod., **19**, 442-444

CATALANO R., 2003, *Sex ratios in the two Germanies: a test of the economic stress hypothesis*, Hum. Reprod., **18**, 1972-1975.

CATALANO R., T. BRUCKNER, 2005, *Economic antecedens of the Swedish sex ratio,* Soc. Science and Medicine, **60**, 537-543

CATALANO R., E. BRUCKNER, J. GOULD, B. ESKENAZI, E. ANDERSON, 2005, *Sex ratios in California following the terrorist attacks of September 11, 2001*, Hum. Reprod., **20**, 1221-1227

CATALANO R., H.T. HANSEN, T. HARTIG, 1999, *The ecological effect of unemployment on the incidence of very low birthweight in Norway and Sweden,* J. Health Soc. Behav., **40**, 422-428

DOUGHERTY C.R., A.D. JONES, 1982, *The determinants of birth weight*, Am. J. Obstet. Gynecol., **144**, 190-200

FIGA-TALAMANCA I., CARBONE P., LAURIA L., SPINELLI A., ULIZZI L., 2003, *Environmental factors and the proportion of males at birth in Italy*, Arch. Environ. Health, **58**, 119-124

FUKUDA M., K. FUKUDA, T. SHIMIZU, W. YOMURA, S. SHIMIZU, 1996, *Kobe earthquake and reduced sperm motility*, Hum. Reprod., **11**, 1244-1246

FUKUDA M., K. FUKUDA, T. SHIMIZU, H. MOLLER, 1998, *Decline in sex ratio at birth after Kobe earthquake*, Hum. Reprod., **13**, 2321-2322.

GRAFFELMAN J., R.F. HOEKSTRA, 2000, *A statistical analysis of the effect of warfare on the human secondary sex ratio*, Hum. Biol., **72**, 433-445

GRANT V.J., 1996, *Sex determination and the maternal dominance hypothesis*, Hum. Reprod., **11**, 2371-2375

GRANT V.J., S. YANG, 2003, *Achieving women and declining sex ratios*, Hum. Biol., **75**, 917-927

GUTIERREZ-ADAN A., B. PINTADO, J. DE LA FUENTA, 2000, *Demographic and behavioral determinants of the reduction of male-to-female birth ratio in Spain from 1981 to 1997*, Hum. Biol., **72**, 891-898

HASSOLD T., S.D. QUILLEN, J.A. YMANE, 1983, *Sex ratio in spontaneous abortions*, Ann. Hum. Genet., **47**, 39-47

HENNEBERG M., 1977, *Ocena dynamiki biologicznej wielkopolskiej dziewiętnastowiecznej populacji wiejskiej I. Ogólna charakterystyka demograficzna*, Przeglad Antropologiczny, **43**, 67-89

HOBEL C.J., C. DUNKEL-SCHETTER, S.C. ROESCH, L.C. CASTRO, C.P. AROSA, 1999, *Maternal plasma corticotropin-releasing hormone associated with stress of 20 weeks' gestation in pregnancies ending in preterm delivery*, Am. J. Obstet. Gynecol., **180**, 257-263

IMAIZUMI Y., M. MURATA, 1979, *The secondary sex ratio, parental age, maternal age, and birth order in Japan*, Ann. Hum. Gen., **42**, 457-465

JAMES W.H., 1998, *Sex ratio of offspring of diabetics*, Lancet, **351**, 1514

JARRELL J., 2002, *Rationale for study of the human sex ratio in population studies of polluted environments*, Cad. Saud. Publica, **18**, 429-434

JONGBLOET P.H., N. ROELEVELD, H.M. GROENEWOUD, 2002, *Where the boys aren't: Dioxin and the sex ratio*, Environ. Health Perspect., **110**, 1-3

JONGBLOET P.H., G.A. ZIELHUIS, H.M. GROENEWOUD, P.C. PASKER-DE JONG, 2001, *The secular trends in male: female ratio at birth in post-war industrialized countries*, Environ. Health Perspect., **109**, 749-752

KARMAUS W., S. HUANG, L. CAMERON, 2002, *Parental concentration of dichlorodiphenyl dichloroethane and polychlorinated biphenyls in Michigan fisheaters and sex ratio in offspring*, J. Occup. Environ. Med., **44**, 8-13

KORNAFEL D., 1995, *Czynniki determinujące urodzeniową masę ciała człowieka*, Wyd. Uni. Wroc., Acta Univ. Wrat., 172

KUFEL T., 2004, *Ekonometria. Rozwiązywanie problemów z wykorzystaniem programu GRETL*, PWN, Warszawa

MARTUZZI M., N. DI TANNO, R. BERTOLLINI, 2001, *Declining trends of male proportion at birth in Europe*, Arch. Environ. Health, **56**, 358-364

MOCARELLI P., P.M. GERTHOUX, E. FERRARI, D.G.JR PATTERSON, S.M. KIESZAK, P. BRAMBILLA, N. VINCOLI, S. SIGNORINI, P. TRAMACERE, V. CARRERI, E.J. SAMPSON, W.E. TURNER, L.L. NIDHAM, 2000, *Paternal concentrations of dioxin and sex ratio of offspring*, Lancet, **355**, 1858-1863

PERGAMENT E.,P.B. TODYDEMIR, M. FIDDLER, 2002, *Sex ratio: A biological perspective of "sex and the city"*, Reprod. Biomed. Online, **5**, 43-46

PETERKA M., R. PETERKOVA, Z. LIKOVSKY, 2004, *Chernobyl: Prenatal loss of four hundred male fetuses in the Czech Republic*, Reprod. Toxicol., **18**, 75-79.

PHILIPS N.B., A. JANCSO-RADEK, V. ITTAH, R. SINGH, G. CHAN, E. HAAS, M. A. WEISS, 2006, *SRY and human sex determination: The basic tail of the HMG box functions as a kinetic clamp to augment DNA bending,* J. Mol. Biol., **358**, 172-192

RJASANOWSKI I., I. KLOTING, P. KOVACS, 1998, *Altered sex ratio in offspring of mothers with insulin-dependent diabetes mellitus*, Lancet, **351**, 497-498

RUDER A., 1986, *Paternal factors affect the sex ratio*, Hum. Biol., **58**, 357-366

RYAN J.J., Z. AMIROVA, G. CARRIER, 2002, *Sex ratios of children of Russian pesticide producers exposed to dioxin*, Environ. Health Perspect., **110**, 699-701

TEITELBAUM M.S., N. MANTEL, C.R. STARK, 1971, Limited dependence of the human sex ratio on birth order and parental ages, Am. J. Hum. Genet., **23**, 271-280

TRIVERS R.L., D.E. WILLARD, 1973, *Natural selection of parental ability to vary the sex ratio of offspring*, Science, **179**, 90-91.

VARTIAINEN T., L. KARTOVAARA, J. TUOMISTO, 1999, *Environmental chemicals and changes in sex ratio: analysis over 250 years in Finland*, Environm. Health Perspect., **107**, 813-815

ZORN B., ŠUČUR V., STARE J., MEDEN-VRTOVEC H., 2002, *Decline in sex ratio at birth after 10-day war in Slovenia*, Hum. Reprod., **17**, 3173-3177

ŻĄDZIŃSKA E., 2003, *Fluctuating asymmetry of some head structures and its possible causes,* Prz. Antropol. – Anthropol. Rev., **66**, 39-54

Streszczenie

Celem pracy było uzyskanie odpowiedzi na pytanie, czy w powojennej Polsce pogarszanie się warunków życiowych (stres ekonomiczny) powodowało obniżenie wskaźnika wtórnej proporcji płci (*secondary sex ratio* – SSR) przychodzącego na świat potomstwa. Trend spadkowy SSR jest notowany niemal w całej współczesnej Europie (rys. 1).

Materiał badawczy stanowiły dane dotyczące ogólnej liczby żywo urodzonych dzieci płci męskiej (M) i żeńskiej (F) urodzonych w Polsce w kolejnych latach od 1956 do 2005 roku (źródło: Roczniki Demograficzne GUS). Na ich podstawie skonstruowano ogólne (dla całego kraju) i szczegółowe (dla miast i wsi) szeregi czasowe wartości SSR, obliczone jako stosunek liczebności noworodków płci męskiej do żeńskiej (M/F) (rys. 2).

Zmienną opisującą warunki ekonomiczne ludności w badanym okresie był szereg czasowy procentowego przyrostu wartości konsumpcji gospodarstw domowych (źródło: obliczenia własne na podstawie Roczników Statystycznych RP za lata 1956–2006). Szereg ten – inaczej określony jako względny przyrost wartości konsumpcji (Δ C/C) – skonstruowano na podstawie wartości konsumpcji prywatnej (w mln. zł, realizacja w cenach bieżących), przeliczonej na ceny stałe z roku 1995 za pomocą „deflatora konsumpcji" (rys. 3).

W zastosowanej procedurze statystycznej sformułowana została „błędna" hipoteza zerowa (H_0), która implikuje że poprawa warunków ekonomicznych (wzrost konsumpcji), powoduje spadek wskaźnika proporcji płci (tj. przy założeniu, że konsumpcja nie ma wpływu); wobec alternatywnej (H_1), że występuje wpływ czynnika ekonomicznego na badany wskaźnik proporcji płci. W kolejnych krokach analizy dąży się do odrzucenia H_0.

Zaproponowana metodologia identyfikacji i dekompozycji równań badanych szeregów dąży do budowy jednego modelu AR (w procesie autoregresji), MA (w procesie średniej ruchomej) lub ARIMA (w procesach mieszanych autoregresji i średniej ruchomej) [BOX & JENKINS 1983],

który w najlepszy sposób objaśni zmienność SSR z rocznym opóźnieniem w stosunku do zmian przyrostu konsumpcji (Δ C/C). W ostatnim kroku analizy dokonuje się oceny własności parametrów otrzymanego ostatecznie równania, która jest podstawą odrzucenia „błędnej” H_0.

W warunkach polskich, z powodu istotnego statystycznie trendu spadkowego (*t-Stat* = -6,38; $p<0.0001$) modelowanie szeregu czasowego SSR wymagało jednokrotnego zróżnicowania szeregu I(1). W efekcie zróżnicowania otrzymano stacjonarny szereg oparty na różnicach M/F_t-$M/F_{(t-1)}$, nazwany zmienną dM_F. Dla efektywnego modelowania badanych szeregów konieczne okazało się eliminowanie nietypowych, odstających od pozostałych lat, obserwacji poprzez wprowadzenie zmiennych zero-jedynkowych. Obliczenia wykonano przy użyciu programu statystycznego GRETL 1.6.0 [KUFEL 2004].

Wyniki badań przedstawiają tabele 1 i 2. W tabeli 1 zaprezentowano autoregresyjny model (AR(1)) procentowej zmiany konsumpcji z rocznym opóźnieniem. W tabeli 2 przedstawiono istotny statystycznie model ARIMA (2,1,1) zmian różnic proporcji płci z rocznym opóźnieniu w stosunku do zmian przyrostu konsumpcji. Ocena wartości parametru „reszty z modelu konsumpcji” (e Δ C/C(1)) wskazała na stabilność skonstruowanego modelu, jednak jego ujemna wartość nie pozwoliła potwierdzić jednokierunkowej zależności, że „spadek konsumpcji powoduje spadek współczynnika M/F” – tym samym odrzucić H_0.

Szereg czasowy proporcji płci poddany ocenie (charakteryzujący się istotnym statystycznie trendem spadkowym) został skonstruowany dla całej populacji polskiej, podczas gdy w zależności od środowiska (miasto – wieś) trend jest wyraźnie zróżnicowany (wartości trendu malejącego w obu przypadkach są statystycznie istotne). W miastach (dane za okres 1948-2005) współczynnik trendu wynosi -0,0003111 *(t Stat* = -6,6334; p < 0,0001) dla populacji wiejskiej zaś jego wartość jest niższa i wynosi -0,000403 (*t Stat* = -8,3973; p < 0,0001) (rys. 4). Tempo obniżania się wartości wskaźnika wtórnej proporcji płci jest znacząco wolniejsze w środowisku miejskim niż na wsiach (*t Stat* = -1,9167 przekracza wartość krytyczną testu *t* dla jednostronnego obszaru odrzucenia -1,6740), zatem w przypadku materiału polskiego należy powtórzyć zaproponowane modelowanie dla szeregów czasowych konsumpcji i proporcji płci osobno dla wsi i miast co wymagać będzie skonstruowania zróżnicowanych regionalnie i środowiskowo wskaźników opisujących zmiany konsumpcji gospodarstw domowych ludności.