J. Biosoc. Sci., (2012) **44**, 357–364, © Cambridge University Press, 2011
doi:10.1017/S0021932011000770 First published online 6 Jan 2012

FACTORS AFFECTING SEX RATIO AT BIRTH IN CROATIA 1998–2008

DARIO PAVIC

Department of Sociology, Hrvatski studiji – Centre for Croatian Studies, University of Zagreb, Croatia

Summary. This investigation aims to contribute to the existing literature on demographic and ecological factors affecting the sex ratio at birth, by analysing the births in Croatia from 1998 to 2008. Data from birth certificates for all Croatian births for the investigated period ($n = 420{,}256$) were used to establish the link between parental ages, birth order, region of birth, parental occupation and parental education level, and sex of the child. The χ^2 test and *t*-test were used to assess the significance of each of the factors, along with multiple logistic regression to control for possible confounding effects. The results suggest that a joint higher age of both parents significantly lowers the sex ratio at birth. There is also a regional variation in sex ratio at birth, the lowest value being in Central Croatia and the highest in the City of Zagreb. Changes in the reproductive physiology of older parents are most probably responsible for the lower sex ratio, although the limited sample size warns against widespread generalizations. The causes of the regional variation in sex ratio at birth are most likely the different regional levels of obesity and physical inactivity.

Introduction

The literature on sex ratio at birth is abundant but there is still a lively discussion about the population and ecological factors affecting the sex of a child, as well as how changes in these factors explain the temporal variation in sex ratio at birth values for some populations. It is now well established that extraneous factors affect parental reproductive physiology at or near the time of conception and/or during gestation, thus favouring the specific sex of the subsequent child. These factors most probably affect the levels of parental sex hormones, which in turn cause differential conception and/or differential survival *in utero*.

A substantial body of evidence exists that the sex of a child is affected by parental age (James, 1971; most probably father's age, see Jacobsen, 2001), birth order (Chahnazarian, 1988), parental socioeconomic status (Teitelbaum & Mantel, 1971; Catalano *et al.*, 2005b), parental occupation (Magnuson *et al.*, 2007), smoking and alcohol consumption (Dickinson & Parker, 1994) and nutrition (Mathews *et al.*, 2008). Also, parental exposure to environmental hazards, severe stress and other unfavourable conditions affect

the sex ratio at birth. This has been demonstrated in war situations (Graffelman & Hoekstra, 2000; Saadat & Ansari-Lari, 2004; Polasek *et al.*, 2005), and after earthquakes (Fukuda *et al.*, 1998; Saadat, 2008), terrorist attacks (Catalano *et al.*, 2005a, 2006) and ecological catastrophes (Mocarelli *et al.*, 2000). Additionally, the sex of a child is partially determined by geographical location (Masoudi & Saadat, 2007), temperature (Helle *et al.*, 2008) and season of birth (Lerchl, 1998; Melnikov, 2003).

Although it has been shown that the yearly values of sex ratio at birth for different countries fluctuate non-randomly (James, 2000), a visible secular trend emerged during the second half of the twentieth century. A decline in sex ratio at birth was observed in northern and eastern Europe, Greece, Portugal, Mexico (Parazzini *et al.*, 1998), Canada (Allan *et al.*, 1997), USA (Marcus *et al.*, 1998; Mathews & Hamilton, 2005; Davis *et al.*, 2007) and Japan (Davis *et al.*, 2007), while a rise was present in southern Europe, Australia (Parazzini *et al.*, 1998) and some Asian countries (Jha *et al.*, 2006; Guilmoto *et al.*, 2009). The most probable causes of lowered sex ratio at birth are increased environmental pollution (James, 1987) and the use of infertility treatments (James, 1985), while those of increased sex ratio are the cultural preference towards male children (Gu & Roy, 1995) and better health care, which results in lower mortality of male fetuses (Moller, 1996).

The sex ratio at birth in Croatia has not been thoroughly investigated. The sex ratio values in Croatia were not found to be affected by the 1991–1995 war conflict (Polasek *et al.*, 2005), although there is some evidence for the war effect in neighbouring countries (Polasek, 2006). A temporal trend in the yearly data was also found to be absent (Pavic, 2011). Because of the lack of research and relatively good and reliable sources of data, an investigation of the sex ratio in Croatia could prove fruitful. This research sought to explore more thoroughly the relationship between the population and ecological status of parents and the sex of their offspring, using data for each birth in Croatia from 1998 to 2008 provided by the Croatian Bureau of Statistics.

Methods

The Croatian Bureau of Statistics (CBS) gathers information on every childbirth in Croatia, provided by the local registrar (form DEM-1). There are twenty-seven variables on the DEM-1 form, ranging from the name of the child and place of birth to specific information about the socioeconomic status of both parents. This information is presented in an aggregate form in official publications, and the individual entries can only be acquired for research purposes, after signing a non-disclosure agreement with the CBS. This agreement has been signed by the CBS and the Center for Croatian Studies, University of Zagreb (class: 953-06/09-2/45, number: 380-1/1-09-2). The names of the children and other personal information are not available since the law forbids the disclosure of this information. The CBS provides a total of 468,783 birth records for the years 1998 to 2008, 466,656 of which were live births and 2127 were stillbirths. The variables chosen for this analysis were sex of the live-born child, birth order, county and region of birth, and age, education level and activity status of both parents. Multiple births were excluded from the analysis, as well as those entries with unknown values for any of the variables. This resulted in a total of 420,256 analysed units.

A somewhat short time period was chosen because of certain methodological constraints. Although Croatia's borders have remained approximately the same since 1946, today's internal administrative division into counties (*županija*) was established only in 1997. Also, up until 1998, every vital event was reported as occurring in the permanent residence of the mother instead of their usual residence, which is advised by the United Nations (United Nations, 2001). During the war period in Croatia (1991–1995) not every part of Croatia was available for registration and this situation lasted until 1998.

For the purposes of easier analysis, some of the variables were re-coded. The number of categories for the variable 'education' was changed from ten to just three, the first one consisting of persons with up to 3 years of vocational high school education, the second of persons with a 4-year high school diploma, and the third of those having some kind of higher education degree. Since there is no official regional division in Croatia, this investigation established four regions based on historical and geographical characteristics. The regions are Central Croatia, Eastern Croatia, Coastal Croatia and the City of Zagreb. Central Croatia consists of Bjelovarsko-bilogorska, Karlovačka, Koprivničko-križevačka, Krapinsko-zagorska, Međimurska, Sisačko-moslavačka, Varaždinska and Zagrebačka counties; Eastern Croatia consists of Brodsko-posavska, Osječko-baranjska, Požeško-slavonska, Virovitičko-podravska and Vukovarsko-srijemska counties; Coastal Croatia consists of Dubrovačko-neretvanska, Istarska, Ličko-senjska, Primorsko-goranska, Splitsko-dalmatinska, Šibensko-kninska and Zadarska counties; and the City of Zagreb is both a separate region as well as a separate county (Fig. 1). All other variables are used in the same form as received from the CBS. The parental activity variable had six values: employed, not employed (seeking first or new employment), with personal income, supported person, person working abroad and other. The ages of parents variables are continuous, while all other variables are categorical.

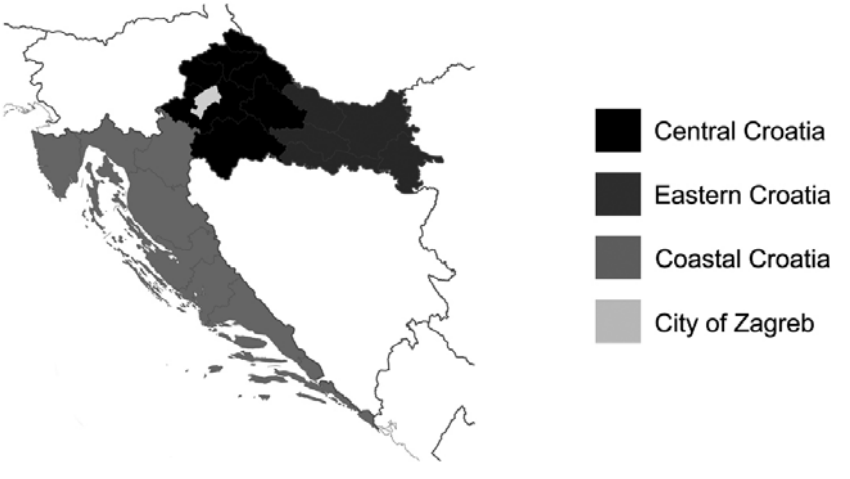

Fig. 1. Map of Croatia showing regions and counties.

https://doi.org/10.1017/S0021932011000770 Published online by Cambridge University Press

To investigate the relationship between each of the variables and the sex of a live-born child, both the χ^2 test and *t*-test were used. Also, the stepwise multiple logistic regression model was used to assess potential confounding effects between variables.

Results

During the period from 1998 to 2008 there were a total of 466,656 live births in Croatia, of which 239,928 were males and 226,728 were females (sex ratio 1.058). The majority of the children were born in the City of Zagreb (83,608) while the fewest were born in Ličko-senjska county (4808), which corresponds to the relative number of inhabitants in these counties. Both multiple births and births with incomplete data for any of the variables (total of 46,400 births) were excluded from the analysis. The mother's mean age at delivery was 27.78 years (SD = 5.25) and the corresponding father's mean age was 31.24 years (SD = 5.91).

The univariate analysis of the factors affecting the sex ratio at birth reveals that the only significant factors are the region and county of birth (Table 1). The region with the highest sex ratio is the City of Zagreb (1.073), followed by Eastern Croatia (1.068) and Coastal Croatia (1.056). The region with the lowest sex ratio at birth is Central Croatia (1.048). The sex ratio at birth at the county level ranges from 1.029 (Sisačko-moslavačka county, Central Croatia) to 1.093 (Brodsko-posavska county, Eastern Croatia).

The regional factor retains its significance in the logistic regression model, where the interaction effect of a mother's age and a father's age emerges as significant as well (Table 2). As in the univariate analysis, all other factors remain insignificant.

The odds ratio values suggest that Central Croatia has a significantly lower sex ratio at birth than Eastern Croatia and the City of Zagreb. The interaction of parental ages lowers the sex ratio at birth but this effect is clearly discernable only at high ages of both mother and father (Fig. 2). At the lower and middle ages of a father, the rise in a mother's age actually slightly increases the sex ratio at birth.

Table 1. Univariate analysis of factors affecting the sex ratio at birth

Factor	df	χ^2	*p*-value
Birth order	3	1.524	0.6766
Father's education level	2	0.706	0.7025
Mother's education level	2	2.265	0.3223
Region of birth	3	8.219	0.0417*
County of birth	20	36.720	0.0126*
Father's occupation	6	3.551	0.7371
Mother's occupation	5	9.106	0.1049
		t-value	
Father's age		0.13	0.8981
Mother's age		1.50	0.1300

* $p < 0.05$.

https://doi.org/10.1017/S0021932011000770 Published online by Cambridge University Press

Table 2. Results of the stepwise logistic regression of factors affecting the sex ratio at birth by sex of the live-born child

	Estimate	df	Wald χ^2	Prob > χ^2
Type III analysis of effects				
Father's age		1	2.9744	0.0846
Mother's age		1	7.1711	0.0074
Region of birth		3	8.0446	0.0451
Mother's age × father's age		1	5.9479	0.0147
Analysis of estimates				
Intercept	−0.1075	1	1.8427	0.1746
Father's age	0.00435	1	2.9744	0.0846
Mother's age	0.00762	1	7.1711	0.0074*
Region Zagreb	0.00985	1	2.5300	0.1117
Region Central	−0.0127	1	5.9615	0.0146*
Region Coastal	−0.00442	1	0.7879	0.3747
Mother's age × father's age	−0.00021	1	5.9479	0.0147*
Odds ratio estimates			95% Wald CI	
Region Zagreb vs. Eastern	1.003		0.983–1.023	
Region Central vs. Eastern	0.980		0.963–0.997	
Region Coastal vs. Eastern	0.988		0.972–1.005	
Region Central vs. Zagreb	0.978		0.960–0.996	

* $p < 0.05$.

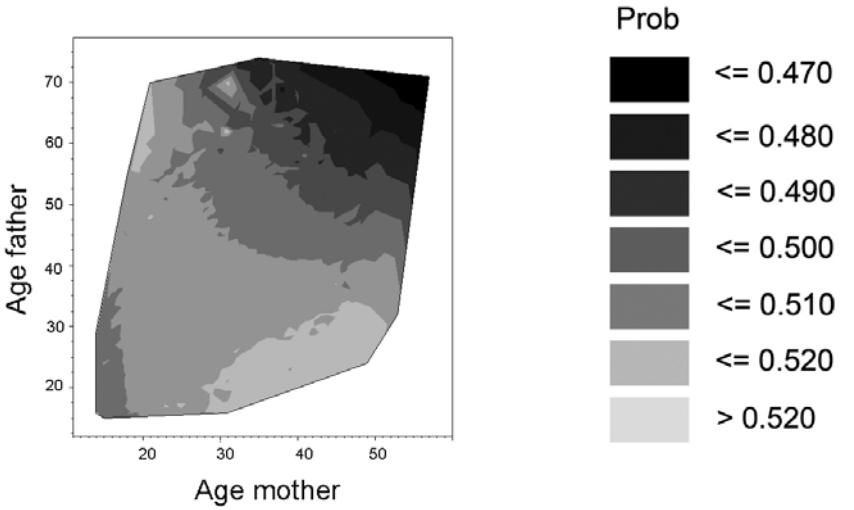

Fig. 2. Probability of male birth (Prob) by age of mother and father.

https://doi.org/10.1017/S0021932011000770 Published online by Cambridge University Press

Discussion

The results of this study are somewhat different from previous studies in the sense that the most replicated factors affecting the sex ratio at birth, namely birth order and age of the father, were found to be not significant. This could be due to the size of the investigated sample. It seems that the effect of father's age becomes visible when the sample size is more than half a million births, while birth order needs samples over 1 million births (James & Rostron, 1985; Jacobsen *et al.*, 1999). As already mentioned, the sample used in this study was restricted for methodological and material reasons.

However, an older age of both parents seems to lower the sex ratio at birth, i.e. a higher paternal age (40 and older) produces a lower sex ratio at birth in older mothers. It seems that a higher mother's age plays a major role and the present results can be partly explained by the 'over-ripeness ovopathy hypothesis', and more specifically by the 'dose–response fallacy'. It seems that although older women conceive more male offspring there is a threshold of danger for the weaker male fetuses that, when surpassed, results in more male losses *in utero*, which in turn leads to a lower sex ratio at birth (Jongbloet, 2004).

The significant regional variation in sex ratio at birth can be very perplexing given the size of the Croatian territory and its number of inhabitants, and the geographical, climatic and economic differences between Croatian regions. One of the most viable explanations for the negative impact on human reproductive physiology and consequently the sex ratio at birth is environmental pollution (James, 2008). While serving as a good explanation for the declining trend in sex ratio at birth at the population level, it is not clear whether environmental pollution can account for the regional differences in sex ratio at birth. It is true that the region with the lowest sex ratio at birth (Central region) has a high concentration of industrial plants and corresponding air pollution, yet there are other regions in Croatia with similar industrial activity and pollution levels that do not exhibit a lower sex ratio at birth.

Some elements of lifestyle, namely nutrition, have been shown to be associated with a biased sex ratio at birth (Mathews *et al.*, 2008). The nutritional and physical inactivity patterns fit the regional sex ratio at birth picture well. Central Croatia has the highest percentage of obese and overweight women and women with an increased waist circumference (Fišter *et al.*, 2009). Also the highest prevalence of unhealthy nutrition, defined by the intake of animal fats, the use of smoked meat products and salt, and the rare consumption of fruits, was found in Central and Eastern Croatia (Jelinic *et al.*, 2009). This might seem unusual since Eastern Croatia has a relatively high sex ratio at birth. Despite their unhealthy diet, women in Eastern Croatia have the lowest level of physical inactivity in Croatia (Milosevic *et al.*, 2009), which makes them less obese and overweight than their counterparts from Central Croatia. It seems that the regional variation in sex ratio at birth in Croatia is best explained by the complex interaction between nutrition and physical activity patterns. The inhabitants of the continental part of Croatia (Zagreb, Central and Eastern Croatia) have traditionally a diet rich in animal fats. This could, along with reduced physical activity, lead to an increased number of obese and overweight women, and consequently to a lower sex ratio at birth.

This study has several limitations, some of which have already been mentioned. The data on gestational ages and the children born by assisted reproduction were not

available, but because of the small number of such births in Croatia, this could not have affected the results of the study. Because of the constraints (especially the sample size), socioeconomic and environmental factors cannot be ruled out as potential explanations for the observed sex ratio at birth in Croatia. This calls for more detailed monitoring of these factors as well as the refinement in the methods of their reporting.

References

Allan, B. B., Brant, R., Seidel, J. E. & Jarrell, J. F. (1997) Declining sex ratios in Canada. *Canadian Medical Association Journal* **156**, 37–41.

Catalano, R., Bruckner, T., Anderson, E. & Gould, J. B. (2005a) Fetal death sex ratios: a test of the economic stress hypothesis. *International Journal of Epidemiology* **34**, 944–948.

Catalano, R., Bruckner, T., Gould, J. B., Eskenazi, B. & Anderson, E. (2005b) Sex ratios in California following the terrorist attacks of September 11, 2001. *Human Reproduction* **20**, 1221–1227.

Catalano, R., Bruckner, T., Marks, A. & Eskenazi, B. (2006) Exogenous shocks to the human sex ratio: the case of September 11, 2001 in New York City. *Human Reproduction* **21**, 3127–3131.

Chahnazarian, A. (1988) Determinants of the sex ratio at birth: review of recent literature. *Social Biology* **35**, 214–235.

Davis, D. L., Webster, P., Stainthorpe, H., Chilton, J., Jones, L. & Doi, R. (2007) Declines in sex ratio at birth and fetal deaths in Japan, and in U.S. whites but not African Americans. *Environmental Health Perspectives* **115**, 941–946.

Dickinson, H. & Parker, L. (1994) Do alcohol and lead change the sex ratio? *Journal of Theoretical Biology* **169**, 313–315.

Fišter, K., Kolčić, I., Milanović Musić, S. & Kern, J. (2009) The prevalence of overweight, obesity and central obesity in six regions of Croatia: results from the Croatian Adult Health Survey. *Collegium Antropologicum* **33** (Supplement 1), 25–29.

Fukuda, M., Fukuda, K., Shimizu, T. & Moller, H. (1998) Decline in sex ratio at birth after Kobe earthquake. *Human Reproduction* **13**, 2321–2322.

Graffelman, J. & Hoekstra, R. F. (2000) A statistical analysis of the effect of warfare on the human secondary sex ratio. *Human Biology* **72**, 433–445.

Gu, B. & Roy, K. (1995) Sex ratio at birth in China, with reference to other areas in East Asia: what we know. *Asia-Pacific Population Journal* **10**, 17–42.

Guilmoto, C. Z., Hoang, X. & Van, T. N. (2009) Recent increase in sex ratio at birth in Viet Nam. *PLoS One* **4**, e4624.

Helle, S., Helama, S. & Jokela, J. (2008) Temperature-related birth sex ratio bias in historical Sami: warm years bring more sons. *Biology Letters* **4**, 60–62.

Jacobsen, R. (2001) Parental ages and the secondary sex ratio. *Human Reproduction* **16**, 2244.

Jacobsen, R., Moller, H. & Mouritsen, A. (1999) Natural variation in the human sex ratio. *Human Reproduction* **14**, 3120–3125.

James, W. H. (1971) Coital rate, sex ratio, and parental age. *Lancet* **1**, 1294.

James, W. H. (1985) The sex ratio of infants born after hormonal induction of ovulation. *British Journal of Obstetrics and Gynaecology* **92**, 299–301.

James, W. H. (1987) The human sex-ratio. 2. A hypothesis and a program of research. *Human Biology* **59**, 873–900.

James, W. H. (2000) Secular movements in sex ratios of adults and of births in populations during the past half-century. *Human Reproduction* **15**, 1178–1183.

James, W. H. (2008) Further support for the hypothesis that parental hormone levels around the time of conception are associated with human sex ratios at birth. *Journal of Biosocial Science* **40**, 855–861.

James, W. H. & Rostron, J. (1985) Parental age, parity and sex ratio in births in England and Wales, 1968–77. *Journal of Biosocial Science* **17**, 47–56.

Jelinic, J. D., Pucarin-Cvetkovic, J., Nola, I. A., Senta, A., Milosevic, M. & Kern, J. (2009) Regional differences in dietary habits of adult Croatian population. *Collegium Antropologicum* **33** (Supplement 1), 31–34.

Jha, P., Kumar, R., Vasa, P., Dhingra, N., Thiruchelvam, D. & Moineddin, R. (2006) Low female-to-male sex ratio of children born in India: national survey of 1.1 million households. *Lancet* **367**, 211–218.

Jongbloet, P. H. (2004) Over-ripeness ovopathy: a challenging hypothesis for sex ratio modulation. *Human Reproduction* **19**, 769–774.

Lerchl, A. (1998) Seasonality of sex ratio in Germany. *Human Reproduction* **13**, 1401–1402.

Magnuson, A., Bodin, L. & Montgomery, S. M. (2007) Father's occupation and sex ratio of offspring. *Scandinavian Journal of Public Health* **35**, 454–459.

Marcus, M., Kiely, J., Xu, F., McGeehin, M., Jackson, R. & Sinks, T. (1998) Changing sex ratio in the United States, 1969–1995. *Fertility and Sterility* **70**, 270–273.

Masoudi, M. & Saadat, M. (2007) Altitude, latitude and sex ratio at birth in Iran. *Journal of Epidemiology and Community Health* **61**, 172.

Mathews, F., Johnson, P. J. & Neil, A. (2008) You are what your mother eats: evidence for maternal preconception diet influencing foetal sex in humans. *Proceedings of the Royal Society B, Biological Sciences* **275**, 1661–1668.

Mathews, T. J. & Hamilton, B. E. (2005) Trend analysis of the sex ratio at birth in the United States. *National Vital Statistics Report* **53**, 1–17.

Melnikov, V. (2003) Seasonality of live birth sex ratio in south western Siberia, Russia, 1959–2001. *Journal of Epidemiology and Community Health* **57**, 470–472.

Milosevic, M., Golubic, R., Mustajbegovic, J., Jelinic, J. D., Holcer, N. J. & Kern, J. (2009) Regional pattern of physical inactivity in Croatia. *Collegium Antropologicum* **33** (Supplement 1), 35–38.

Mocarelli, P., Gerthoux, P. M., Ferrari, E., Patterson, D. G. Jr, Kieszak, S. M. *et al.* (2000) Paternal concentrations of dioxin and sex ratio of offspring. *Lancet* **355**, 1858–1863.

Moller, H. (1996) Change in male:female ratio among newborn infants in Denmark. *Lancet* **348**, 828–829.

Parazzini, F., La Vecchia, C., Levi, F. & Franceschi, S. (1998) Trends in male:female ratio among newborn infants in 29 countries from five continents. *Human Reproduction* **13**, 1394–1396.

Pavic, D. (2011) An analysis of sex ratio at birth in Croatia 1946–2007. *Društvena istraživanja* **20**, 151–165.

Polasek, O. (2006) Did the 1991–1995 wars in the former Yugoslavia affect sex ratio at birth? *European Journal of Epidemiology* **21**, 61–64.

Polasek, O., Kolcic, I., Kolaric, B. & Rudan, I. (2005) Sex ratio at birth and war in Croatia (1991–1995). *Human Reproduction* **20**, 2489–2491.

Saadat, M. (2008) Decline in sex ratio at birth after Bam (Kerman Province, Southern Iran) earthquake. *Journal of Biosocial Science* **40**, 935–937.

Saadat, M. & Ansari-Lari, M. (2004) Sex ratio of birth during wartime and psychological tensions. *Human Reproduction* **19**, 465.

Teitelbaum, M. S. & Mantel, N. (1971) Socio-economic factors and the sex ratio at birth. *Journal of Biosocial Science* **3**, 23–41.

United Nations (2001) *Principles and Recommendations for a Vital Statistics System Revision 2*. United Nations, New York.