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# The Sex Ratio at Birth: The Role of Ionizing Radiation Vs. Social Factors

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## Abstract

The concept has been propagated by certain writers that elevation of the radiation background due to nuclear testing and Chernobyl fallout skewed the sex ratio at birth towards more males. This hypothesis remains unproven and seems to camouflage the following tendencies exemplified here on the basis of the former Soviet Union. Almost all regions displayed an increase in the male/total ratio at birth from 1986 onwards. The highest ratios have been reported from the South Caucasus, being explained by the son preference and sex-selective abortions. The same is probably true for the North Caucasus, where birthrate has been the highest in Russian Federation. Elevation of male/fenale ratios at birth coincided with the increasing availability of the prenatal ultrasonic gender testing.

**Migrations further contribute to the gender imbalance:** Shortage of men due to the emigration creates additional stimuli for sex-selective abortions in their native areas.

**Male/female ratios at birth in developed countries are influenced by the immigration from regions with the son preference and gender imbalance:** Immigrants bring their reproductive stereotypes with them. The predominance of males may contribute to antisocial behaviour and militarism. Nuclear facilities are potential targets in armed conflicts. One of the motives to exaggerate consequences of low-dose radiation exposures and threats to use nuclear weapons seems to be boosting fossil fuel prices. In more developed countries, antinuclear resentments have been supported by green activists, well in agreement with the interests of fossil fuel vendors, certain companies and governments.

**There are no long-term alternatives to the nuclear energy:** Non-renewable fossil fuels will become more expensive, contributing to excessive population growth in the regions rich in fossil fuels and decreasing quality of life in the rest of the world..

## Introduction

In humans, the natural sex ratio at birth (SRB) is slightly skewed towards males. The objective of this review was questioning the hypothesis that an increase in SRB has been caused or influenced by low-dose ionizing radiation from nuclear testing and Chernobyl fallout [1-19]. Conclusions by Dr. Grech were that "elevated levels of man-made ambient radiation may have reduced total births, affecting pregnancies carrying female pregnancies more than those carrying male pregnancies, thereby skewing M/T (male live births divided by total live births) toward a higher male proportion" [3] and that "birth rates are greatly reduced and the M/T ratio is skewed upward significantly with population exposure to ionizing radiation, even at great distances from major nuclear events" [1]. Significance of supposedly radiation-related shifts of sex ratios [2,15] has been questioned [20,21]. A review concluded that "there is little consistent evidence that ionizing radiation affects the sex ratio" [22].

Social and other factors that could have influenced SRB have not been analysed exhaustively. Additional doses due to contaminations were often negligible compared to the natural radiation background (NRB). Worldwide annual doses from NRB are generally expected to be in the range of 1-10 mSv, with 2.4 mSv being the estimated global average [23]. Some national averages are over 10 mSv [24]. In Europe, mean annual doses from NRB are around 5-7 mSv in several countries [25,26]. There are populated areas in the world where the dose rate from NRB is 10-100 times higher than the average; yet there have been no reliable data on SRB shifts in such areas [27,28]. A study based on over 150,000 consecutive live singleton newborns in the areas of Kerala with elevated NRB did not indicate any impact of radiation on the sex ratio [29]. The maximum annual dose from the global fallout due to nuclear tests was estimated to be 0.14 mSv in 1963, having decreased by almost an order of magnitude by 1979 [23]. Annual individual doses in the vicinity of reactors have been in the range 0.001-0.5 mSv [23], so that the above dose comparisons pertain also to the reported shift of SRB among people residing near nuclear plants [14,16]. In this connection, a role of confounding factors cannot be excluded [30].

In a study from 1958, radiation was found to influence the sex ratio among infants born to survivors of the atomic bombing [31]. However, this association has not been confirmed in later studies; the data on the total number of births in Hiroshima and Nagasaki in the period 1956-1962 indicated no significant difference in the sex ratio of infants [32]. In regard to the Chernobyl accident, "as far as whole-body doses are concerned, the six million residents of the areas of the former Soviet Union (SU) deemed contaminated received average effective doses for the period 1986-2005 of about 9 mSv, whereas for the 98 million people considered in the three republics, the average effective dose was 1.3 mSv, a third of which was received in 1986. This represents an insignificant increase over the dose due to background radiation over the same period (around 50 mSv)" [33]. Outside the former SU, individual doses were lower: the first-year doses after the Chernobyl accident reached 1 mSv only in several places in Central Europe, all country averages being below 1 mSv/a [25,34]. For comparison, a single computed tomographic (CT) examination produces a dose 2-20 mSv, while the doses from interventional

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diagnostic procedures usually range from 5 to 70 mSv [35]. Neither health risks nor SRB shifts have been reliably proven for the above-mentioned dose levels [36,37].

Male radiologists tended to father even a lower proportion of boys compared to the control group [38]. Results of human studies of paternal preconceptional exposures are summarized in [39], whereas both increased and decreased male/female (M/F) ratios in the offspring were reported, most of the differences being statistically insignificant. The most significant result ($P < 0.001$) was a *decrease* of SRB in the offspring of fathers exposed to a pelvic irradiation (1394 exposed individuals vs. 1926 controls) with estimated testicular doses 20-200 mSv [39,40]. Reduced sex ratio (deficit of boys) was found also in the offspring of irradiated women with a mean ovarian dose about 200 mGy [41]. The diversity of results and potential bias in the epidemiological research (discussed below) indicate that the question can be reliably solved only by means of wide-scale animal experiments. Admittedly, studies with primates (which might be similar enough to humans to extrapolate the results directly) are expensive while extrapolations from laboratory animals are associated with uncertainties [42]. However, experiments with low radiation doses seem to be feasible in animal breeding facilities. The use of various specimens must enable more precise extrapolations to humans.

The following studies should be cited in this connection. Experiments using 18 generations of exposed mice with the daily dose about 0.29 mGy suggested that low-dose low-rate exposures do not affect the sex ratio in mouse litters [43]. No radiation-induced sex ratio changes in the offspring of mice were found by other researchers [44-48]. Note that doses applied in animal experiments are much higher than average doses to the residents of contaminated territories after the Chernobyl accident. These latter doses are generally within the window for the maximum adaptive response protection. Admittedly, the concept of hormesis based on adaptive responses is a controversial topic. Adaptive responses in mammals and mammalian cells operate within a certain window, typically between about 1 and 100 mGy for a single low dose rate exposure but the upper dose threshold for protective responses against neoplastic transformation is probably above 100 mGy, for both human and mouse cells [49].

**Bias in epidemiological studies of low-dose radiation**

Bias is not excluded in many epidemiological studies of low-dose radiation effects: dose-dependent selection and self-selection, surveillance bias, higher participation of cases (e.g., cancer patients) compared to controls etc. [37]. Better recollection by cases of the facts related to radiation exposures (recall bias) may contribute to the overestimation of doses in the cases. The recall bias was noticed in some studies of CT and other radiological procedures, whereby patients are more likely to recall medical exposures than healthy controls [50]. The selection and self-selection bias is a problem for epidemiological research; it is known also from studies of radiofrequency magnetic fields, where, analogously to low-dose ionizing radiation, there is some epidemiological association with cancer but no supporting experimental evidence [51]. In populations exposed to ionizing radiation, the self-selection bias must be stronger than for radiofrequency electromagnetic fields because carcinogenicity of the former is known by the broad public. It can be reasonably assumed that people informed on their higher doses would visit medical facilities more often being averagely given more attention. It is known that correlations are not necessarily causative. Other kinds of bias are not excluded in the epidemiological research; for example, men employed at Sellafield nuclear plant fathered a greater than expected proportion of boys, a possible explanation being their on average younger age. It is known that fathers aged 20-29 years produce more boys than other fathers, while there was an excess of Sellafield fathers in this age range [39]. Addressing the issue of occupational exposure, a study of 621 radiation workers could not find a link between the radiation exposure and gender ratio of their children [27]. In the author's opinion, the reported relationships of low-dose exposures with SRB and other non-cancer endpoints, being devoid of physiological plausibility, witness against cause-effect relationships of the same doses with cancer, discussed on the basis of epidemiological research.

In this connection, ideological bias aimed at the strangulation of nuclear energy should be pointed out [52], well in agreement with the interests of fossil fuel producers, certain companies and governments [37]. Accordingly, conflicts of interest may be surmised in some scientific writers. Nuclear power has returned to the agenda because of the concerns about increasing global energy demand, declining fossil fuel reserves and climate changes. Health burdens were reported to be the greatest for power stations based on lignite, coal, and oil. The health burdens are smaller for natural gas and still lower for the nuclear power. This ranking also applies for greenhouse gas emissions [53]. In the author's opinion, the global development of nuclear energy must be managed by a powerful international executive based in the most developed parts of the world. It would enable construction of nuclear power plants (NPP) in optimally suitable places, disregarding national borders, considering all socio-political, geological and other preconditions, quality of working by local professionals, etc. [37,54]. In this way, nuclear accidents like in Fukushima, caused by the earthquake and tsunami, or in Chernobyl, favoured by disregard for written instructions [55,56], would be prevented. Obviously, durable peace is needed because NPPs are potential targets. By analogy with the Chernobyl accident, the war damage and shutdown of the Zaporozhie NPP (the largest NPP in Europe) due to the current Ukraine conflict will enhance demands for fossil fuels.

**Other Factors That Can Influence the Male to Female Ratio at Birth**

The following important statements by Dr. Grech [4,5] have been commented previously [57]: "However, all of the above are overshadowed by femicide, the selective destruction of female foetuses in societies (primarily Asian) which prize males more than females" and "Gendercide and femineglect (the deliberate neglect of females vis-à-vis health, education, etc.) is rampant, especially in Asia". Indeed, except for the Baltic States, all regions of the former SU showed a significant SRB increase from 1986 onwards [1]. The highest SRB ratios were reported from the South Caucasus (Azerbaijan, Armenia and Georgia) [1], being explained by the son preference and sex-selective abortions [58]. The same is probably true for the North Caucasus, where birthrate has been the highest in the Russian Federation. The elevation of SRB in the former SU coincided with the increasing availability of the prenatal ultrasonic gender testing in

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the late 1980s [1,58]. A relatively high M/T ratio at the time of the generally unavailable prenatal gender testing (1981-1985) in Caucasus [1] is an indication to the female neonaticide - an ancient family planning tool [59-61]. Not only in the Caucasus, the main driver of the gender imbalance among neonates was female infanticide and negligence towards female children until the 1980s. Since about 1985, ultrasound-enabled prenatal sex determination followed by selective abortion of female fetuses has become the predominant method for families to enact cultural preferences for sons [62].

**Migrations Further Contribute to The Gender Imbalance**

The shortage of men in consequence of emigration creates additional stimuli for sex-selective abortions. Considerable gender imbalance is observed in Russia among immigrants from the Caucasus and Middle Asia. According to a census, the male/female ratio in Crimea among ethnic Russians was 0.85, Tatars – 0.98, Karaites – 1.3, Krymchaks – 1.4 [63]. Evaluating statistics, it should be taken into account that gender imbalance is masked by a relatively low life duration of males. Obviously, the social significance of the gender imbalance decreases with age. Official statistics based on censes tends to underestimate the gender imbalance as predominantly males are involved in migrations, some of them remaining uncounted by censes. Presumably, prohibitive measures against sex-selective abortions will not be sufficiently effective. Such prohibitions would stimulate "traditional" methods of demographic regulation such as the female neonaticide and neglect of newborn girls, driven by socioeconomic, cultural, and historical factors [64-66]. Apart from traditions, a mechanism maintaining the higher birth rate and son preference is an insufficient social security. Ageing people depend on their children for support, while sons and their families are more likely than daughters to be caregivers e.g., in China [67]. Many families try to ensure that at least one boy is born, especially following a firstborn girl [68]. Therefore, an improvement of the social security in developing countries must positively influence the demographic processes. These considerations are more constructive than discussions of the role of radiation from nuclear tests or Chernobyl fallout as a cause of gender shifts as far as in Cuba [12].

Gender imbalance due to the son preference and sex-selective abortions is a known fact in China, India and Korea, in the Caucasus and among immigrants from Asia to Europe and the United States [58,60,66,68-72]. On the one hand, there are many immigrants from the Caucasus in the former SU (except for the Baltic States mentioned above); on the other hand, similar tendencies of the son preference probably exist also in some other groups of the ex-Soviet population. Insufficient security coupled with the tolerant attitude towards violations of laws and regulations might have motivated some families to have sons: for more safety and economical success. The dynamics of SRB in Central Europe [1] must be influenced by the ongoing immigration from countries with the son preference and gender imbalance.

## Discussion

There has been some discussion recently [6,8,17,73,74]. The following arguments should be further commented: "A social factor that may skew the birth sex ratio is gender selective abortion, a practice reported from parts of Asia and parts of North Africa [75]. However, this method requires advanced techniques for prenatal gender ascertainment that were not available at the time of the Windscale fire in 1957 and during the era of the major atmospheric nuclear weapons testing prior to 1963" [8]. Apart from sex-selective abortions, requiring prenatal gender testing, there has always been some percentage of female neonaticide and neglect of newborn girls - the ancient tools of the demographic regulation in certain cultures [59-62]. Moreover, since olden times, there have been methods of attempted prenatal gender prediction and selection, possibly successful in some cases [76]. Finally, reduced SRB has been linked to the older age at childbearing [71,77]. The mean age of mothers at childbirth is higher in more developed countries, generally tending to increase [78]. The higher SRB values and their dynamics in Europe compared to the United States [8], have an explanation unrelated to radiation: the ongoing immigration to Europe from Asia and Africa including regions with the son preference. The immigration to the United States occurs largely from Latin America, where prenatal sex-selection is not part of the culture, females are valued high, the son preference being "fairly mild" [79]. Immigrants bring their reproductive stereotypes with them [62,72]; the dynamics of the sex ratio at birth may be partially determined by the immigration.

Furthermore, "…we found a significant dose-response association of Chernobyl fallout with subsequent sex ratio increases at the district level in Germany" [8]. It should be commented that the increase in SRB with an odds ratio of 1.009 in 1987 in the data subset from Bavaria, former GDR and West Berlin [9] was deemed "extremely small" [22] and may be a spontaneous fluctuation. Of note, the average first year dose from Chernobyl accident in the former GDR was around 0.21 mSv, and in the Western part of the country (former FRG) - 0.16 mSv, which is a small addition to national averages from NRB: around 3.6 mSv/a in Germany, 3-7 mSv/a in the most of European countries [25,26]. The slight increase of the perinatal mortality in the Eastern part of Germany after 1986 was discussed in support of the radiation role after the Chernobyl accident [10,11,80]. The ratios perinatal deaths/total births in GDR and West Berlin were as follows: 1986 - 2,183/242,068 = 9.02 per 1,000 total births; 1987 - 2,281/246,704 = 9.24 per 1,000 [10]. This slight increase might have been caused by social factors (decline of the communist regime) and emigration of some medical personnel from the former GDR to the West. In general, oscillations of the perinatal mortality in Central and Eastern Europe after the Chernobyl accident [10,81] could have been caused by sociopolitical perturbations of the late 1980s.

It has been argued that "without specific empirical evidence and reference, Sergei V. Jargin insinuates a possible cause of the observed long-term increases in perinatal mortality in contaminated prefectures after Fukushima: 'It is not surprising that cataclysms with evacuation of people, associated with stress, temporary derangements of perinatal care services, of diets, etc., are accompanied by an increase in the perinatal mortality.' The data (by Dr. Scherb et al.) clearly show that in highly tsunami-impacted regions there is indeed a more than 50% increase in perinatal mortality, but this is confined to March and April 2011 only. From May through December 2011, nowhere in Japan perinatal mortality remained elevated. Moreover, the perinatal mortality increase in Chiba, Saitama, and Tokyo 10 months after the natural and technical catastrophes cannot be explained by 'derangements of perinatal care' as the general infrastructure had

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not been compromised at all in these 3 prefectures" [17]. Appeals to dismantle nuclear power plants can be heard e.g., from Germany [82], being in agreement with the interests of fossil fuel producers and making the country dependent on the energy carriers coming from Russia. Cui bono? Some connections could have remained from the time of the former GDR. The radiophobia causes misappropriation of resources to accommodate pseudo-dangers [83]. Overtreatment e.g., of thyroid and bladder lesions favoured by radiation phobia has been discussed previously [84-86]. It is known by the example of Chernobyl accident that evacuations of people, psychological stress and anxiety favoured by exaggerated radiation-related risks are noxious factors that would be less potent after a catastrophe without radioactive contamination. In particular, anxiety after a nuclear accident may have detrimental effects on pregnant women [87,88]. Expectant mothers with anxiety and post-traumatic stress were reported to be at a higher risk of preterm birth [89]. Note that the proportion of male births declines with increasing gestation, the male excess tending to be maximal in spontaneous preterm births [90]. Exaggeration of risks from low-dose exposures by some writers, resonated by mass media, contributed to anxiety in pregnant women. A presumed risk of fetal abnormalities, illustrated e.g., by newspaper images in a report by [91], available on the Internet, can move some families toward the decision to make abortion. There was an increase in the induced abortion rate in several European countries after the Chernobyl accident [92-95]. It was reasonably assumed that "the public debate and anxiety among the pregnant women and their husbands 'caused' more foetal deaths… than the accident" [96]. Biased information "repeatedly created a situation of panic, like a posttraumatic stress disorder" [97]. After the Chernobyl accident, "conflicting information and false rumours spread considerable alarm among the public in general and among pregnant women in particular" [98]. Certain publications in professional journals may prevent physicians from giving adequate advice to pregnant women inquiring about a possible abortion. Radiation phobia with psychosomatic manifestations developed in many exposed people [99], being probably more prevalent in contaminated areas thus contributing to dose-effect correlations. Reiterations of the perinatal mortality "jump" [18,19] after the Fukushima Daiichi accident can contribute to anxiety in pregnant women in similar situations in the future and to an increase in the abortion rate. According to this mechanism, wanted pregnancies were interrupted after the Chernobyl accident [97]. Moreover, it cannot be excluded that radiation phobia contributed to illegal abortions during the last trimester of pregnancy possibly influencing perinatal mortality figures. Considering that a certain percentage of abortions after a prenatal ultrasonic gender testing would be sex-selective, the enhanced abortion rate can contribute to an elevation of SRB. Analogously, non-married women of all racial/ethnic groups had higher SRB levels than married women [71]. The probable explanation is that non-married women tend to have more abortions; therefore, the total number of sex-selective abortions must be higher than among married women.

"The doubling of the background radiation level, say, from 1 mSv/a to 2 mSv/a, represents a doubling of an important physical environmental parameter relevant for the development of life on the earth, and cannot as such be considered a 'low dose' and of no effect" [8]. A local increase from 1 to 2 mSv/a is of minor significance as the doses would remain under the global average radiation dose from NRB. Considering the possibility of radiation hormesis [36], the doubling of "background radiation level… from 1 mSv/a to 2 mSv/a" [8] can be even beneficial, by analogy with a doubling of exposure to the sunlight e.g., of prison inmates. An elevation of the mean value from 2.4 to 4.8 mSv/a is a real doubling although the twofold value would remain below many national NRB averages. Among arguments is also the claim that "the dose (Gray or Sievert) in the radiation sciences is a surprisingly old and crude concept" [8,17]. Some refinement of the biological weighting factors for different types of radiation can be indeed awaited from further research [100] but hardly any gross revision of the scale of values.

Potentially misleading is the concluding phrase: "Social factors and negligibility of doses is not convincing as gradually changing social factors cannot entail abrupt sex ratio changes and a doubling of the background radiation is certainly not trivial" [8]. As discussed above, neither abrupt sex ratio changes nor doubling of the background radiation have ever been satisfactorily demonstrated on sufficiently large territories to allow discussions on the radiation background elevation as a cause of the sex ratio changes.

"Furthermore, the letter to the editor [73] implies that low doses of radiation are innocuous. This flies in the face of the linear no-threshold (LNT) hypothesis that states that at even at low doses, there is a linear relationship between dose and risk, particularly vis-a-vis the probability of cancer induction, all the way down to zero exposure" [6]. The concept of LNT may be "pragmatic or prudent for radiation protection purposes" [101] but it is not the same as scientific validity. The LNT postulates that linear dose-effect correlations, proven to some extent for higher doses, can be extrapolated down to minimal doses. However, the DNA damage and repair are permanent processes in a dynamic equilibrium. Living organisms have been adapting to the

**NRB In a Similar Way as To Other Environmental Factors**

chemical substances and elememts, products of water radiolysis, ultraviolet light, etc. Natural selection is slow; adaptation to a changing environmental factor would correspond to some average from the past. The NRB has been decreasing during the time of life existence on the Earth [102]. The mutation repair mechanisms evolved in the distant past so that organisms may have retained some capability of efficient reparation in conditions of a higher NRB than that existing today. Considering the above, with the dose rates tending to the wide range NRB level, radiation-related risks would tend to zero, and can even descend below zero within some dose range in accordance with hormesis. Undoubtedly, ionizing radiation can cause damage of the developing embryo or fetus, which can enhance the prenatal mortality. Mainly on the basis of animal studies and observations of exposures in pregnant women, both the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) considered that there is a threshold at about 100 mGy [103,104], which is much higher than average doses discussed above for nuclear testsing and accidents.

There is no reliable evidence that exposures to low-dose ionizing radiation or elevated radiation background can modify SRB in humans.

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The conclusions that "elevated levels of man-made ambient radiation may have reduced total births, affecting pregnancies carrying female pregnancies more than those carrying male pregnancies, thereby skewing M/T toward a higher male proportion" [3] and that "the M/T ratio is skewed upward significantly with population exposure to ionizing radiation, even at great distances from major nuclear events" [1] have not been sufficiently corroborated. The conclusion that "the global correlation of health and socioeconomic indicators with M/T suggests that M/T may be a useful sentinel health indicator" [7] can hardly be agreed with as SRB depends on many known and unknown factors. A significant role of radiation from the nuclear testing and Chernobyl fallout as a factor modifying SRB is improbable. Dose-response relationships at low radiation doses should be studied in large-scale animal experiments involving different mammal species, using doses and dose rates comparable to human exposures in question, shielded from bias and conflict of interest.

Evidence suggests that the experts overestimating medical and ecological consequences of a moderate increase in a radiation background, have acted in agreement with the interests of fossil fuel vendors, certain companies and governments. In more developed countries, antinuclear resentments have been supported by green activists, well in agreement with the interests of fossil fuel vendors, several companies and certain governments. After the Chernobyl accident, literature over estimated its medical consequences. The accident has been exploited to strangle nuclear energy, thus boosting fossil fuel prices. Furthermore, nuclear facilities are potential targets in armed conflicts. One of the motives to unleash the war in Ukraine and threats to use nuclear weapons seems to be boosting fossil fuel prices [37,105]. Ramzan Kadyrov, head of the Chechen Republic, called up to use nuclear weapons in Ukraine. The former Russian president Dmitry Medvedev made explicit threats of a nuclear strike [106]. Today, there are no alternatives to nuclear energy. In the long run, non-renewable fossil fuels will become more expensive, contributing to excessive population growth in fossil fuel-producing regions and poverty elsewhere.

## Conclusion

The concept that a slight increase in the radiation background elevates SRB has been propagated by certain writers. This and similar suppositions seem to camouflage the following relationships exemplified in this review on the basis of the former SU. Except for the Baltic States, all regions showed a significant SRB elevation since 1986. The highest SRB ratios were reported from the South Caucasus, being explained by the son preference and sex-selective abortions. The same is probably true for the North Caucasus, where the birthrate has been the highest in the Russian Federation. The SRB elevation in the former SU coincided with the increasing availability of the prenatal ultrasonic gender testing in the late 1980s. Migrations further contribute to the gender imbalance: shortage of men due to emigration creates additional stimuli for sex-selective abortions in their native areas. The SRB in countries receiving migrants is influenced by the ongoing immigration from regions with the son preference and gender imbalance: the immigrants bring their reproductive stereotypes with them. The predominance of males is more conspicuous in lower socio-economic classes; their marginalization may lead to antisocial behavior. The weightiest argument against nucler energy is that NPPs are potential targets in armed conflicts. One of the motives to exaggerate consequences of low-dose radiation exposures and threats to use nuclear weapons seems to be boosting fossil fuel prices.

The birth control has been obfuscated by presumed national interests: the demographic growth was supposed to strengthen the sovereignty and defenses. Smoldering international conflicts contribute to the population growth in corresponding regions. The gender imbalance with an excess of males is conductive to militarism and international conflicts. The problems delineated above can be solved by a worldwide demographic planning and economical governance in conditions of globalization. Grandiose projects could be accomplished to improve the quality of life all over the world: irrigation systems, nuclear and other energy sources as an alternative to fossil fuels; hydroelectric power plants can be built on large rivers to produce hydrogen as eco-friendly energy carrier. New substances used in the industry, nutrition and medicine must be tested in large animal populations to achieve statistical significance and record stochastic outcomes. Such projects would create many jobs, being a reasonable alternative to excessive military expenditures. Not only durable peace but also mutual trust is required for that.

**Conflicts of interest:** The author has no conflicts of interest to declare.

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