HelmholtzZentrum münchen
German Research Center for Environmental Health

Radiation-induced genetic effects in Europe and the Chernobyl Nuclear Power Plant catastrophe

Conference "Criticisms and Developments in the Assessment of Radiation Risk"
ECRR and University of the Aegean, Molyvos Island of Lesvos, Greece, 5th and 6th May 2009

Hagen Scherb and Kristina Voigt

Institute of Biomathematics and Biometry

HELMHOLTZ ASSOCIATION

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- Dosimetry
- Fallout and genetic effects: own publications
- Sex odds and atmospheric atomic bomb testing
- Sex odds in USA, Europe, and parts of Asia: 1970 – 2007
- Ecological dose-response
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- Conclusion

Genetic effects – *Definition*

Discovery of X–ray mutagenesis by HJ Muller 1926

- Muller carried out experiments with varied doses of X-rays to *Drosophila*. A connection between radiation and lethal mutations emerged.

- By 1928, others had replicated his results, expanding them to other model organisms such as wasps and maize.

- **Definition** A genetic effect may be the result of radioactivity or substances that cause damage to (the genes of) a reproductive cell (sperm or egg), or a somatic cell, which can then be passed from one generation to another, or may induce disease (e.g. cancer) in an individual.
  http://www.doh.wa.gov/Hanford/publications/overview/genetic.html

- **Examples** Sex odds, birth defects, stillbirths, leukemia, thyroid cancer

Muller HJ *(1927). Artificial transmutation of the gene. Science 66: 84-87*

Genetic effects – *sex odds (or less systematically: sex ratio)*

Genetic theory for the human sex odds at birth

Irradiated parents and offspring gender

Fathers only	=>	sex odds ↑
Mothers only	=>	sex odds ↓
Both parents	=>	**???**

Schull WJ, Neel JV *(1958). Radiation and the sex ratio in man. Science 128: 343-348*

Dickinson HO et al. *(1996). The sex ratio of children in relation to paternal preconceptional radiation dose. J Epidemiol Community Health 50(6): 645–652*

Padmanabhan et al. *(2004) Heritable anomalies among the inhabitants of regions of normal and high background radiation in Kerala. Int J Health Serv 34 (3), 483-515*

Dosimetry – *Fallout and dose formation*

Working hypothesis

In the first few years after the ChNPP accident, deposition of

46.6 kBq/m2 Cs-137

+ 23.3 kBq/m2 Cs-134

generated an effective dose of **1 mSv/a**

Jacob P et al. *(1990) Calculation of organ doses from environmental gamma rays using human phantoms and Monte Carlo Methods. GSF-Bericht 12/90*

Drozdovitch V et al. *(2007) Radiation exposure to the population of Europe following the Chernobyl accident. Radiat Prot Dosimetry 123 (4), 515-528*

Bundesamt für Strahlenschutz *(2006). Jahresbericht 2005, p. 36. Editor: Bundesamt für Strahlenschutz, Germany, Salzgitter*

BStMLU and BStMELF *(1987). Radioaktive Kontamination der Böden in Bayern. Munich: Bayerische Staatsministerien für Landesentwicklung und Umweltfragen (BStMLU) und für Ernährung, Landwirtschaft und Forsten (BStMELF)*

Fallout and genetic effects: own publications

Perinatal mortality and stillbirths

Scherb H, Weigelt E, Bruske-Hohlfeld I *European stillbirth proportions before and after the Chernobyl accident. Int J Epidemiol. 1999 Oct;28(5)*

Scherb H, Weigelt E, Bruske-Hohlfeld I *Regression analysis of time trends in perinatal mortality in Germany 1980-1993. Environ Health Perspect. 2000 Feb;108(2)*

Birth defects

Scherb H, Weigelt E *Congenital Malformation and Stillbirth in Germany and Europe Before and After the Chernobyl Nuclear Power Plant Accident. ESPR - Environ Sci & Pollut Res, 10 Special (1) 2003 Dec, 117-125*

Scherb H, Weigelt E *Cleft lip and cleft palate birth rate in Bavaria before and after the Chernobyl nuclear power plant accident [Article in German, Abstract in English]. Mund Kiefer Gesichtschir. 2004 Mar;8(2):106-10*

Sperling K, Neitzel H, Scherb H (2008) *Low dose irradiation and nondisjunction: Lessons from Chernobyl, 19th Annual Meeting of the German Society of Human Genetics, April 8-10, 2008, Hanover, Germany, Abstractbook, p. 174-175*

Sex odds in Europe

Scherb H, Voigt K *Trends in the human sex odds at birth in Europe and the Chernobyl Nuclear Power Plant accident. Reproductive Toxicology, Volume 23, Issue 4, June 2007, Pages 593-599*

Scherb H, Voigt K *Analytical ecological epidemiology: Exposure-reponse relations in spatially stratified time series. Environmetrics, published Online: 12 Sep 2008*

Fallout and genetic effects: own publications – *examples*

1. Example: Stillbirth in Bavaria, Germany, and stillbirth in Europe, 1981 – 1992

Fig. 1 Stillbirth proportion for the combined tw o most highly contaminated districts in Bavaria: Augsburg-City (53.7 kBq/m^2) and Berchtes-gaden (50.3 kBq/m^2) including change-point (CP) and reduced change-point (CPr) models

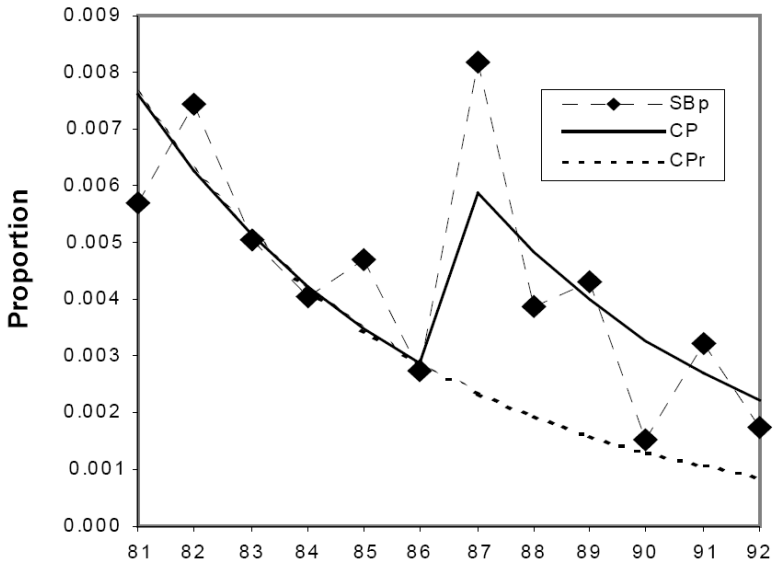
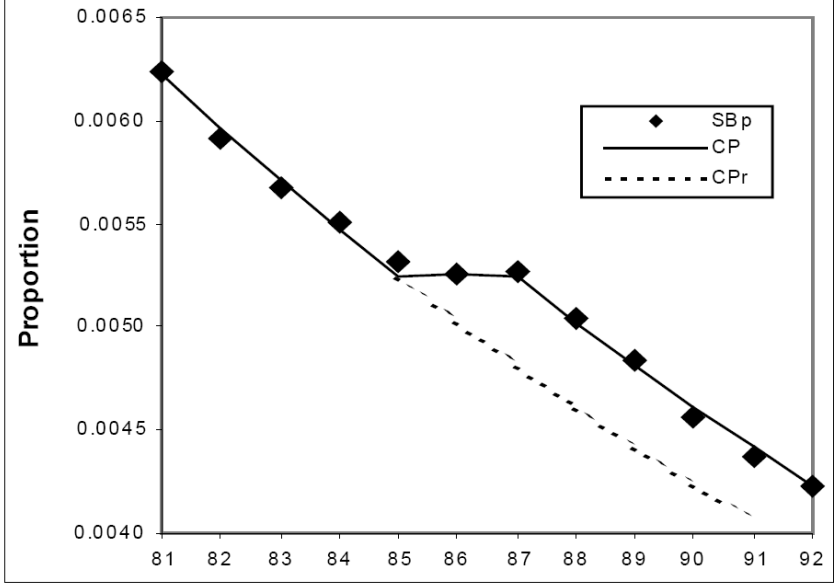
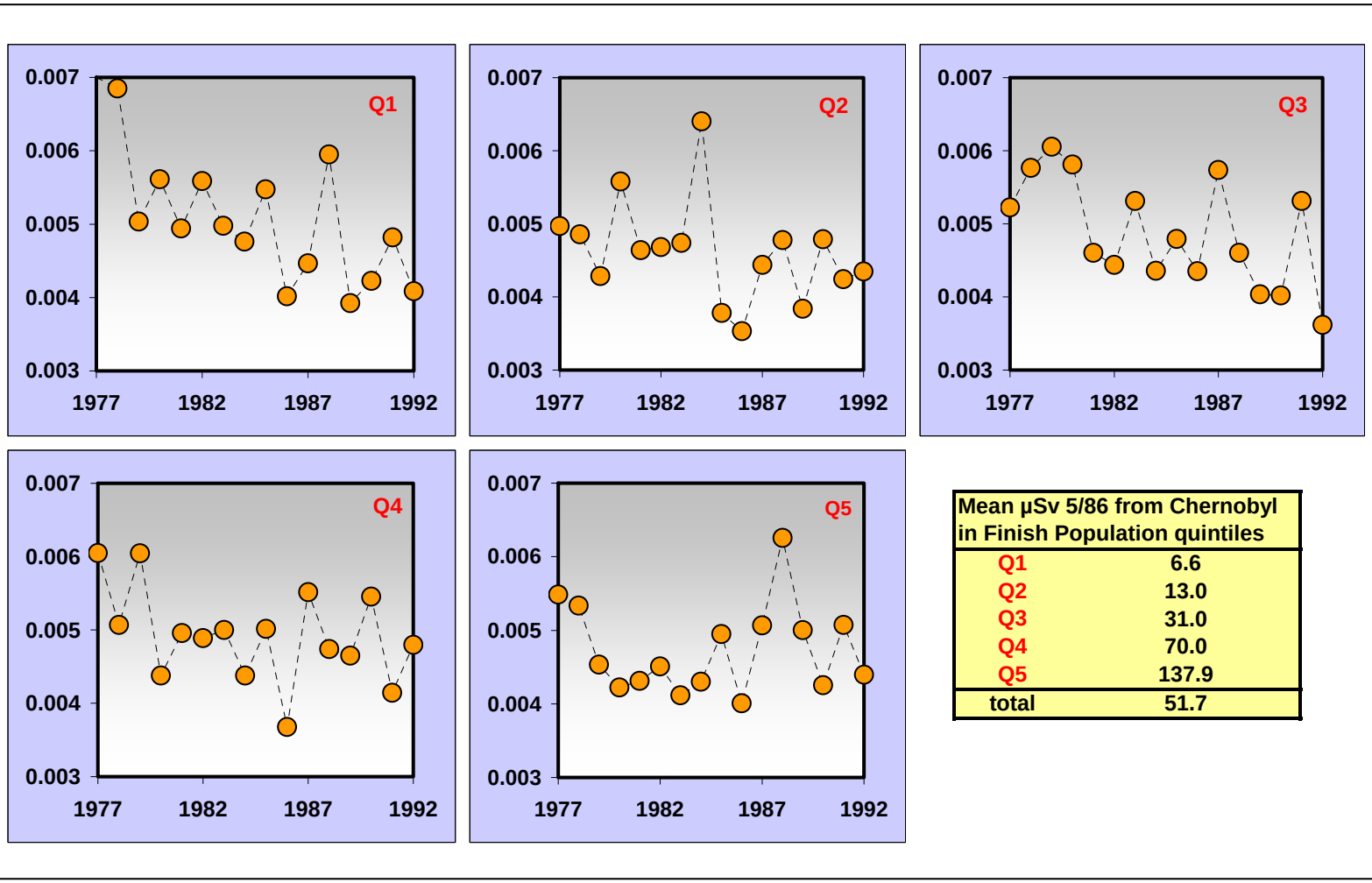


Fig. 2 Stillbirth proportions for Bavaria+GDR, WestBerlin, Denmark, Hungary, Iceland, Latvia, Norw ay, Poland, and Sw eden combined, change-point (CP) and reduced change-point (CPr) models



Fallout and genetic effects: own publications – *examples*

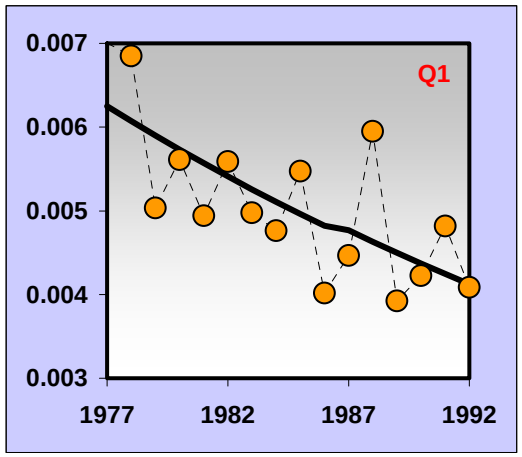
2. Example: Stillbirth in Finland, 1977 – 1992 prevalence data by exposure quintiles

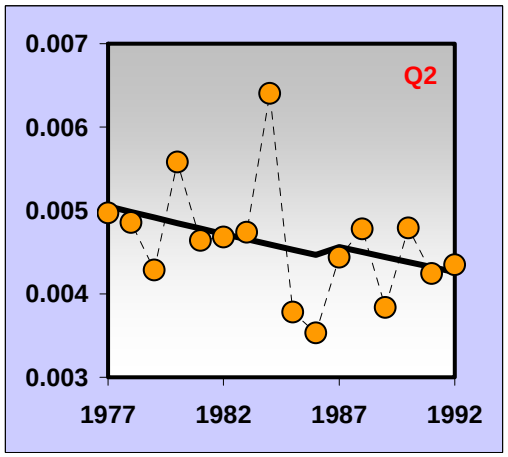


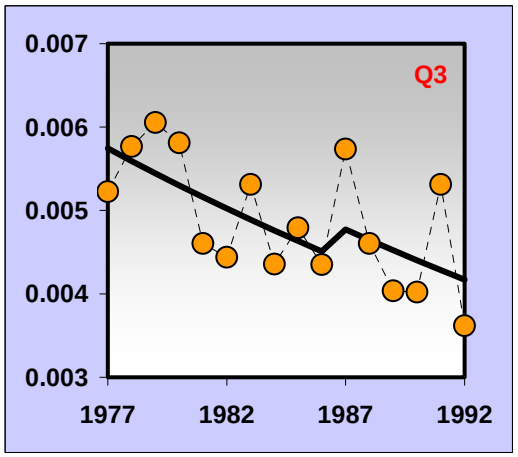
Mean µSv 5/86 from Chernobyl in Finish Population quintiles	
Q1	6.6
Q2	13.0
Q3	31.0
Q4	70.0
Q5	137.9
total	51.7

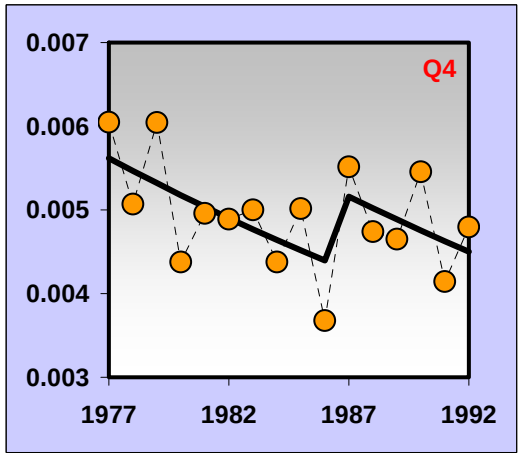
Fallout and genetic effects: own publications – *examples*

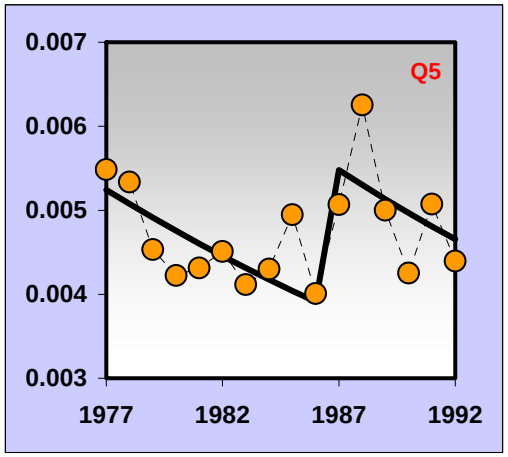
2. Example: Stillbirth in Finland, 1977 – 1992 spatial temporal model











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total	51.7

Fallout and genetic effects: own publications – *examples*

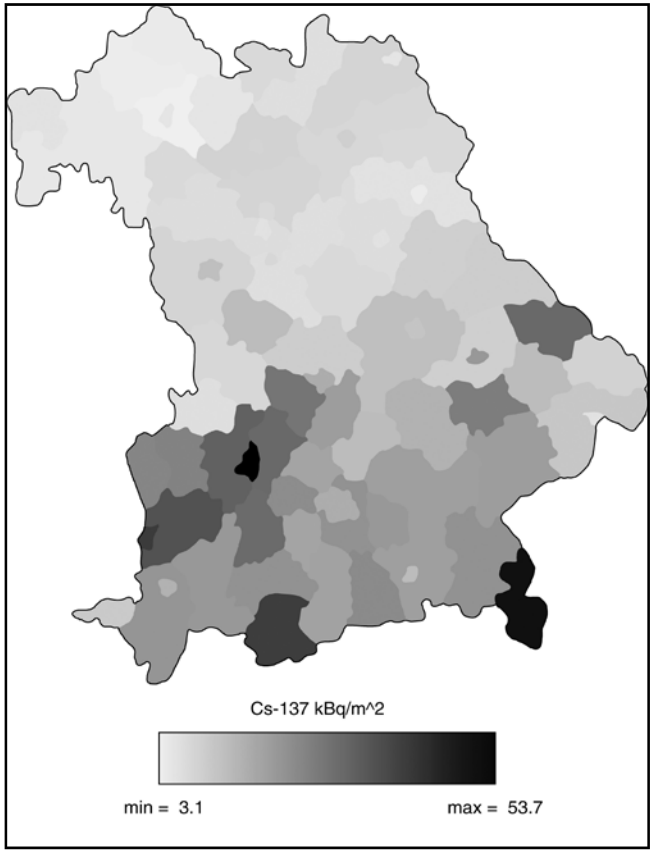
2. Example: Stillbirth in Finland, 1977 – 1992 **dose specific risk**

OR per mSv/a	**1.25**
95% CL	[1.10, 1.42]
p-value	0.0006

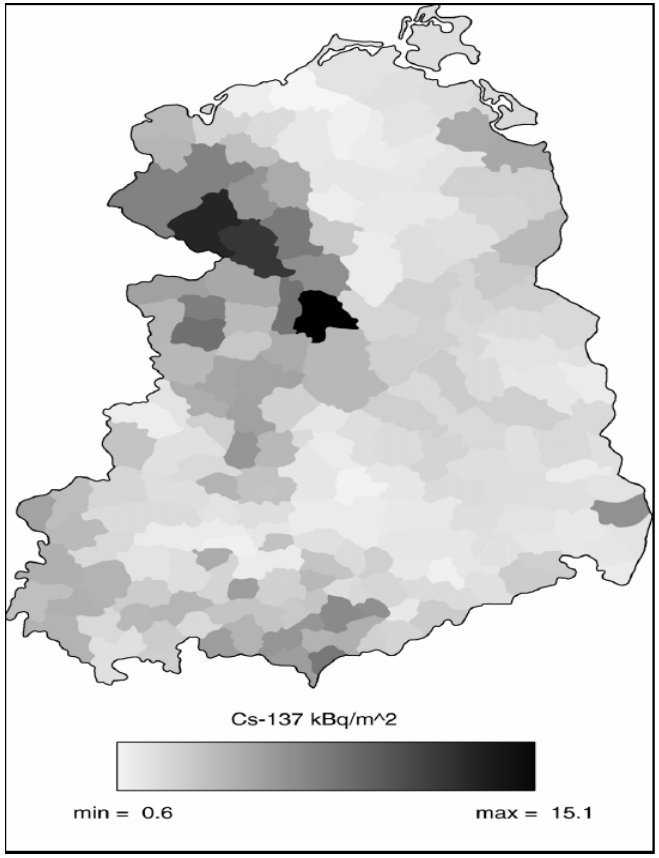
Fallout and genetic effects: own publications – *examples*

3. Example: Sex odds and fallout (dose) in Germany **spatial distribution of fallout**

Bavaria

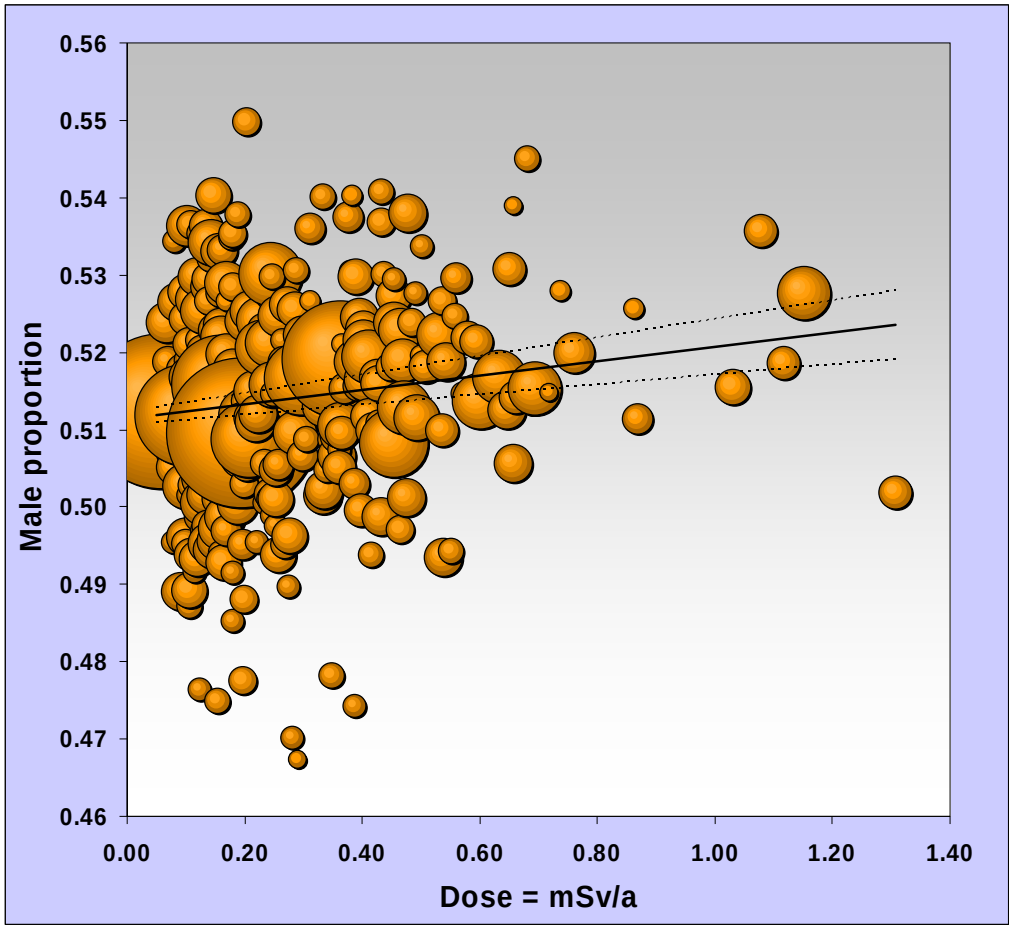


former GDR



Fallout and genetic effects: own publications – *examples*

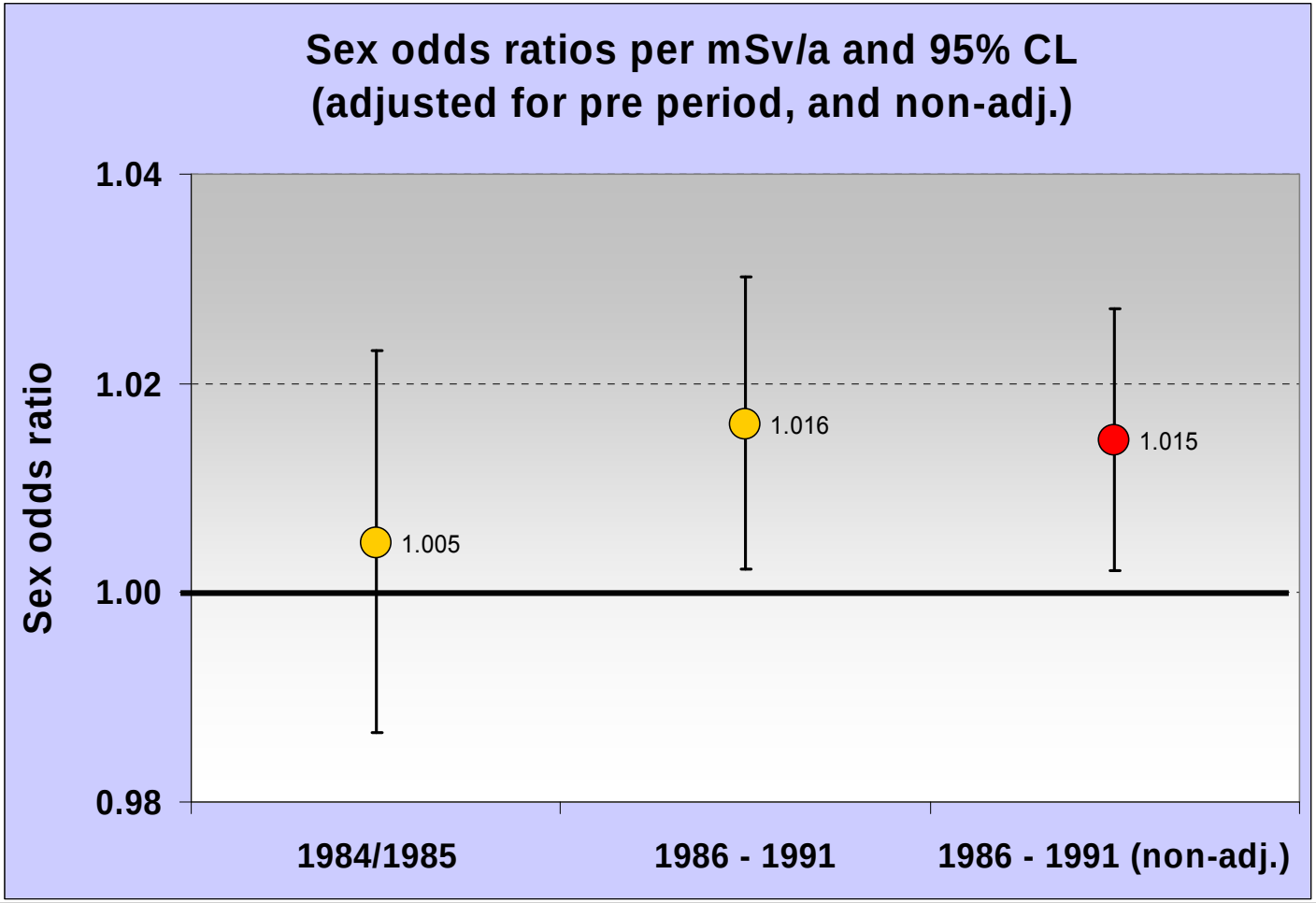
3. Example: Sex odds and fallout (dose) in Germany 1986+1987 depending on the excess dose by Chernobyl fallout: 0.0143 (mSv/a)/(kBq/m2)



OR/(mSv/a)	**1.0380**
95%-CI	[1.0126, 1.0640]
p-value	0.0031

Fallout and genetic effects: own publications – *examples*

3. Example: Sex odds and fallout (dose) in Germany 1984-1991, long-term dose dependent jump heights 1986-1991



Fallout and genetic effects: own publications – *examples*

4. Example: Congenital malformation of the heart 1984-1991, long-term dose dependent jump heights 1987-1991

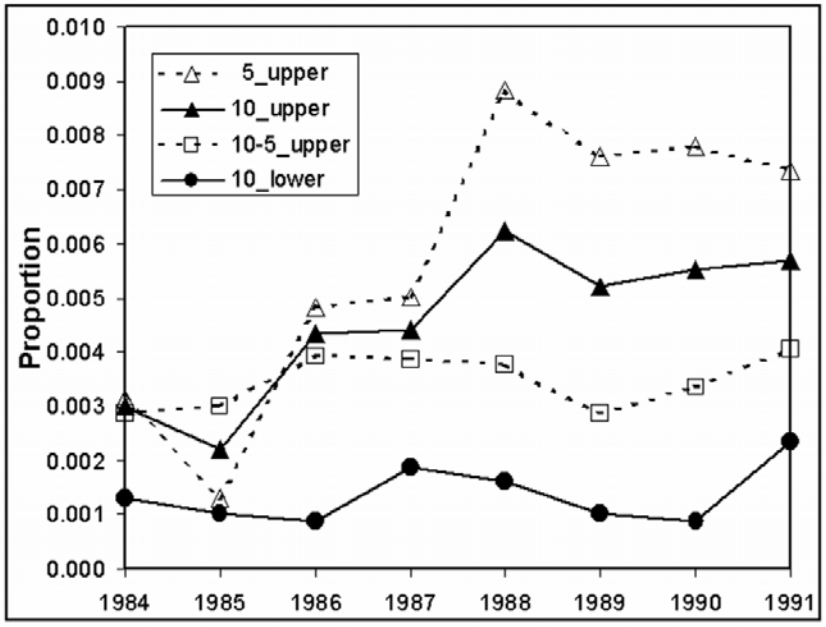


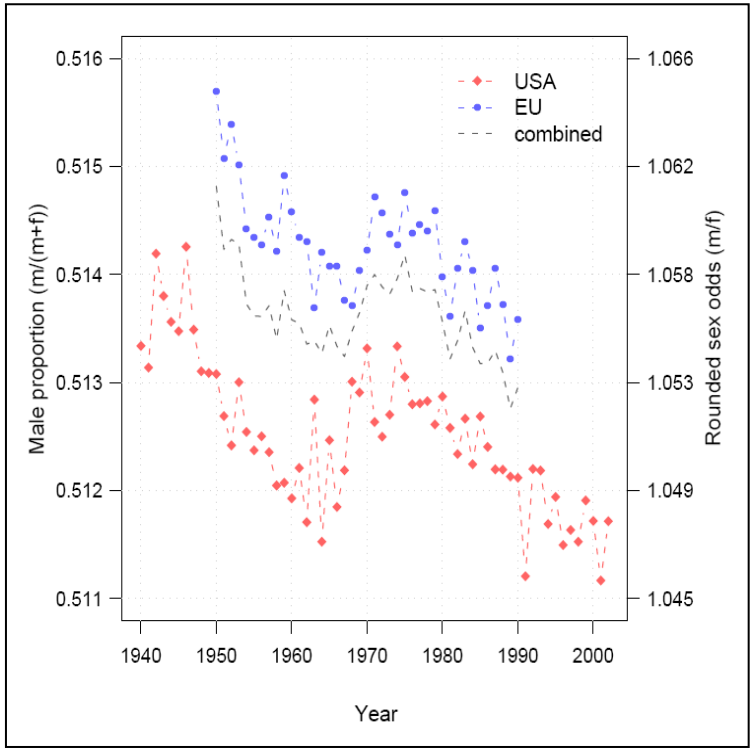
Table 1: The ten least and most contaminated districts in Bavaria, mean ^{137}Cs measurements

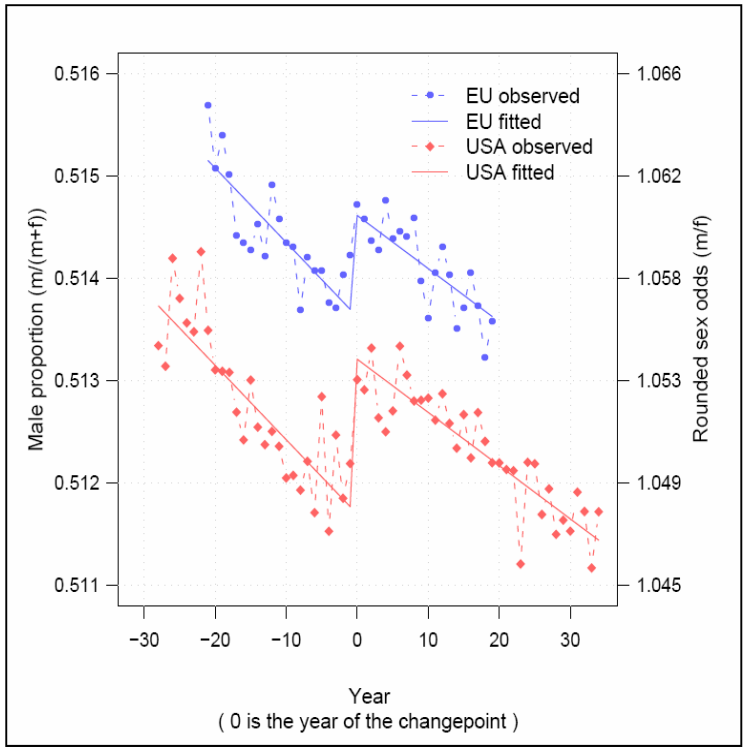
10 Most-Contaminated Districts	^{137}Cs kBq/m^2	10 Least-Contaminated Districts	^{137}Cs kBq/m^2
Augsburg, City	53.7	Schweinfurt, City	5.3
Berchtesgaden	50.3	Hof, City	5.3
Garmisch-Partenkirchen	40.5	Miltenberg	4.9
Memmingen, City	40.2	Main-Spessart	4.7
Unterallgäu	35.5	Würzburg, City	4.6
Augsburg	32.3	Würzburg	4.6
Regen	30.8	Rhön-Grabfeld	4.4
Aichach-Friedberg	30.6	Bad Kissingen	3.9
Landsberg/Lech	30.3	Weiden, City	3.7
Neuburg-Schrobenhausen	27.7	Schweinfurt	3.1

Fig. 5: Birth prevalences of two congenital heart malformations (ICD7454+ICD7455, n = 2797) in Bavaria; stratification according to contamination of districts (see Table 1)

Sex odds and atmospheric atomic bomb testing

Similar effects on the sex odds as recently published have already been observed in the USA and in Europe on a global scale in the 1960s and 1970s, but have not yet been acknowledged as possible effects of atmospheric atomic bomb test fallout. **Note, the "missing boys" in the "sex ratio literature" may be "less missing girls" from the 1970s onward, after the atmospheric atomic bomb test ban**.

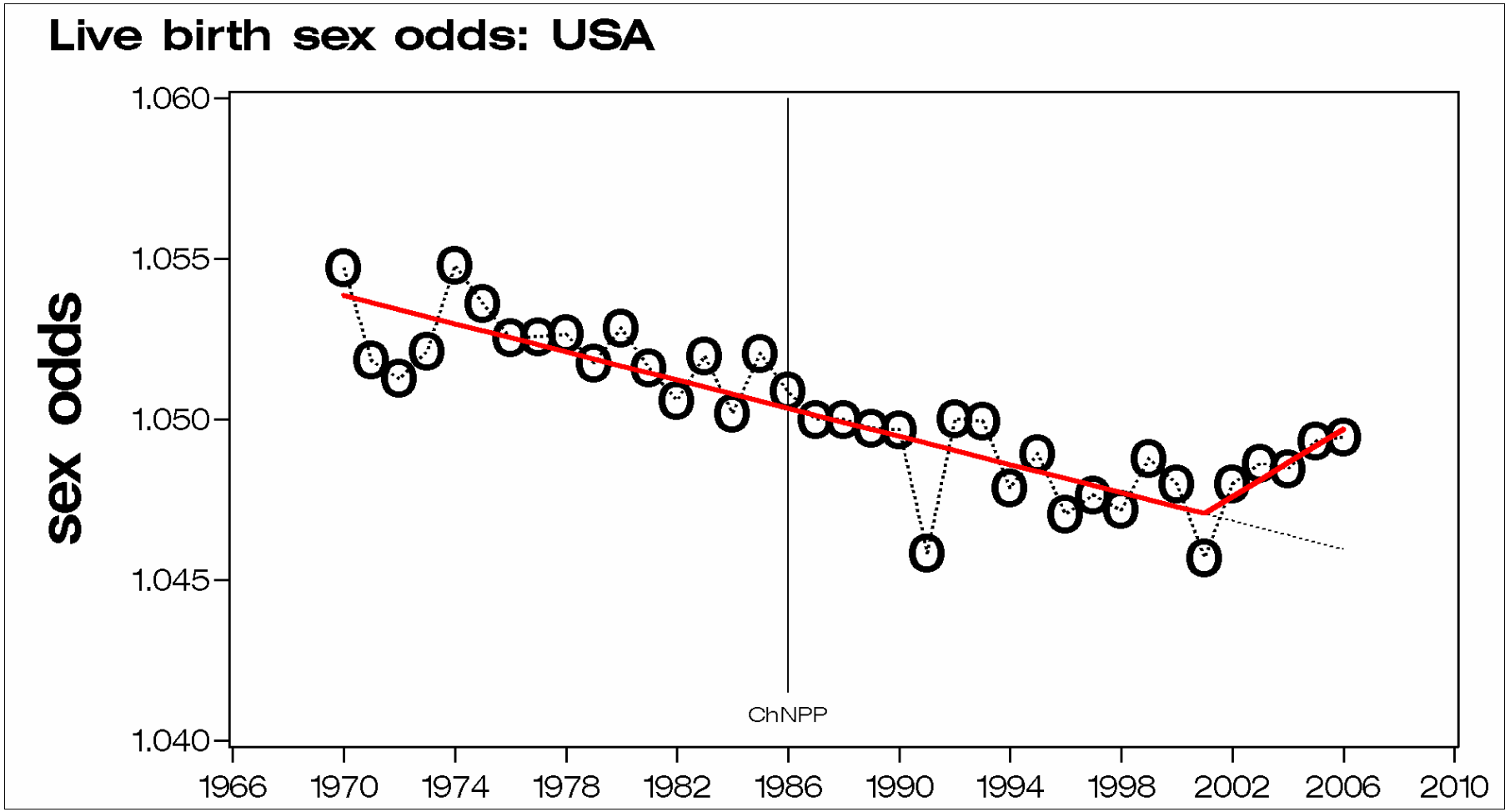




M Martuzzi, N Di Tanno, R Bertollini. *Declining trends of male proportion at birth in Europe*. Archives of Environmental Health, 56(4):358 364, Jul- Aug 2001.
TJ Mathews and BE. Hamilton. *Trend analysis of the sex ratio at birth in the united states*. Nat Vit Stat Rep, 53(20):1 17, Jun 2005. Nat Cent for Health Stat.
S Meyer, H Scherb. Untersuchung des jährlichen Geschlechterverhältnisses der Neugeburten in Europa und den USA auf Changepoints, July 31 2007 (synoptic reanalyses).

Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

USA



Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Europe and parts of Asia

Europe IIIa, 1970-2007, complete data			Births and sex odds	
Belgium	Luxembourg	Portugal	**total**	**80,373,314**
France	Malta	Switzerland	**male**	**41,249,601**
Ireland	Netherlands	UK	**sex odds**	**1.0543**

Europe IIIb, 1970-2007, complete data			Births and sex odds	
Albania	Germany	Poland		
Austria	Greece	Romania		
Belarus	Hungary	Russ. Fed.		
Bulgaria	Iceland	San Marino		
Czechoslovakia (f.)	Italy	Sweden		
Denmark	Latvia	Yugoslavia (f.)	**total**	**216,491,268**
Estonia	Lithuania		**male**	**111,258,587**
Finland	Norway		**sex odds**	**1.0573**

Former SU Republics, 1980-2005, incomplete data			Births and sex odds	
Kazakhstan (E)	Tajikistan	Uzbekistan	**total**	**47,655,378**
Kyrgyzstan	Turkmenistan		**male**	**24,463,930**
Moldova (E)	Ukraine (E)		**sex odds**	**1.0549**

40 countries with territory in Europe + 4 Asian countries; Spain omitted because of unusual trend; also ommitted: Andorra, Liechtenstein, Monaco, Turkey, and Vatican due to no data at all, or essentially incomplete data.

Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Pertinent demographic INTERNET data bases

http://data.euro.who.int/hfadb/

http://data.un.org/Data.aspx?d=POP&f=tableCode%3a4

http://data.un.org/Data.aspx?d=POP&f=tableCode%3A54

http://unstats.un.org/unsd/demographic/products/dyb/dyb2.htm

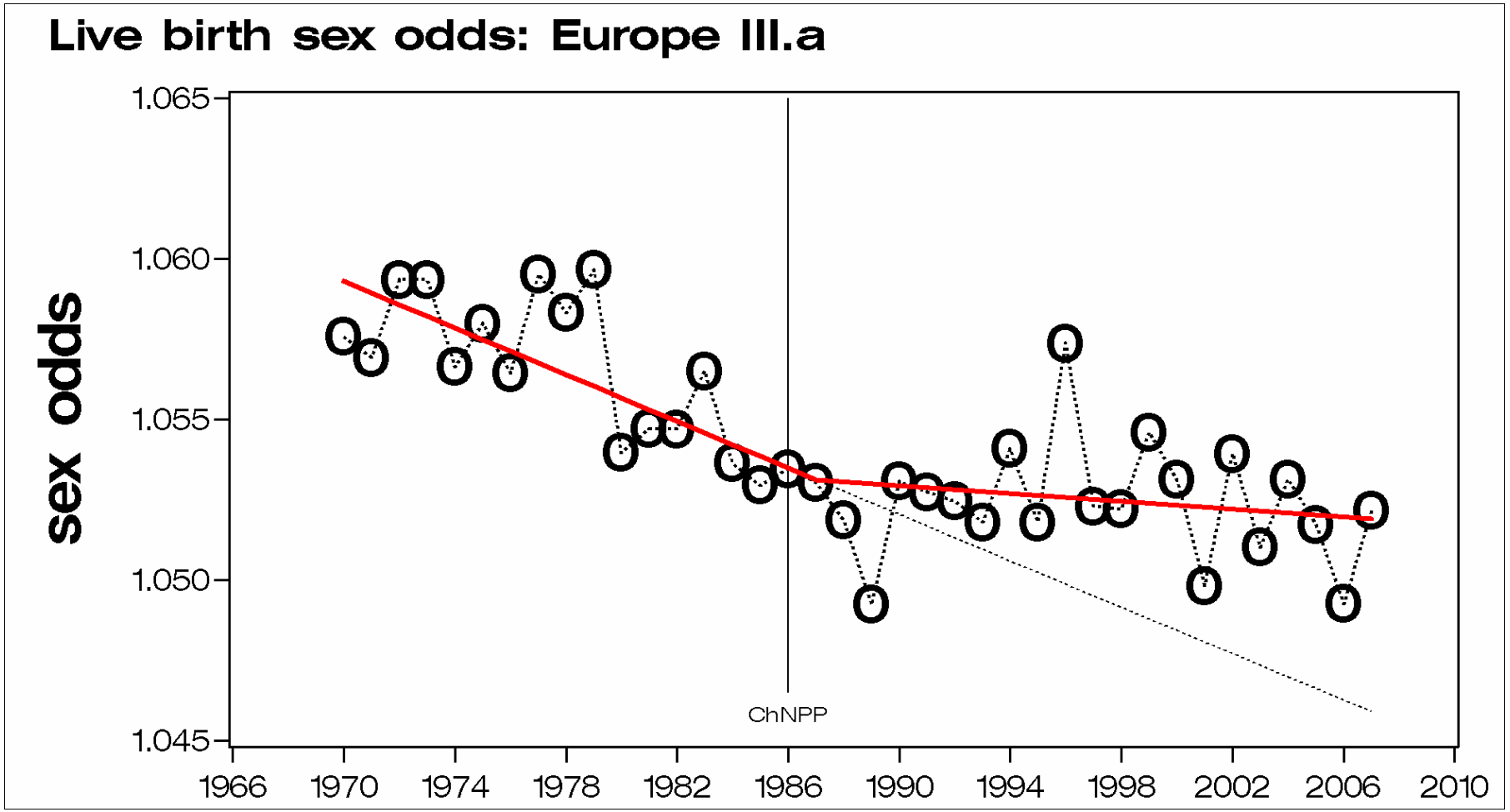
http://www.coe.int/t/e/social_cohesion/population/BELTAB2.xls

http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136184,0_45572595&_dad=portal&_schema=PORTAL

http://www.johnstonsarchive.net/policy/abortion/ab-poland.html

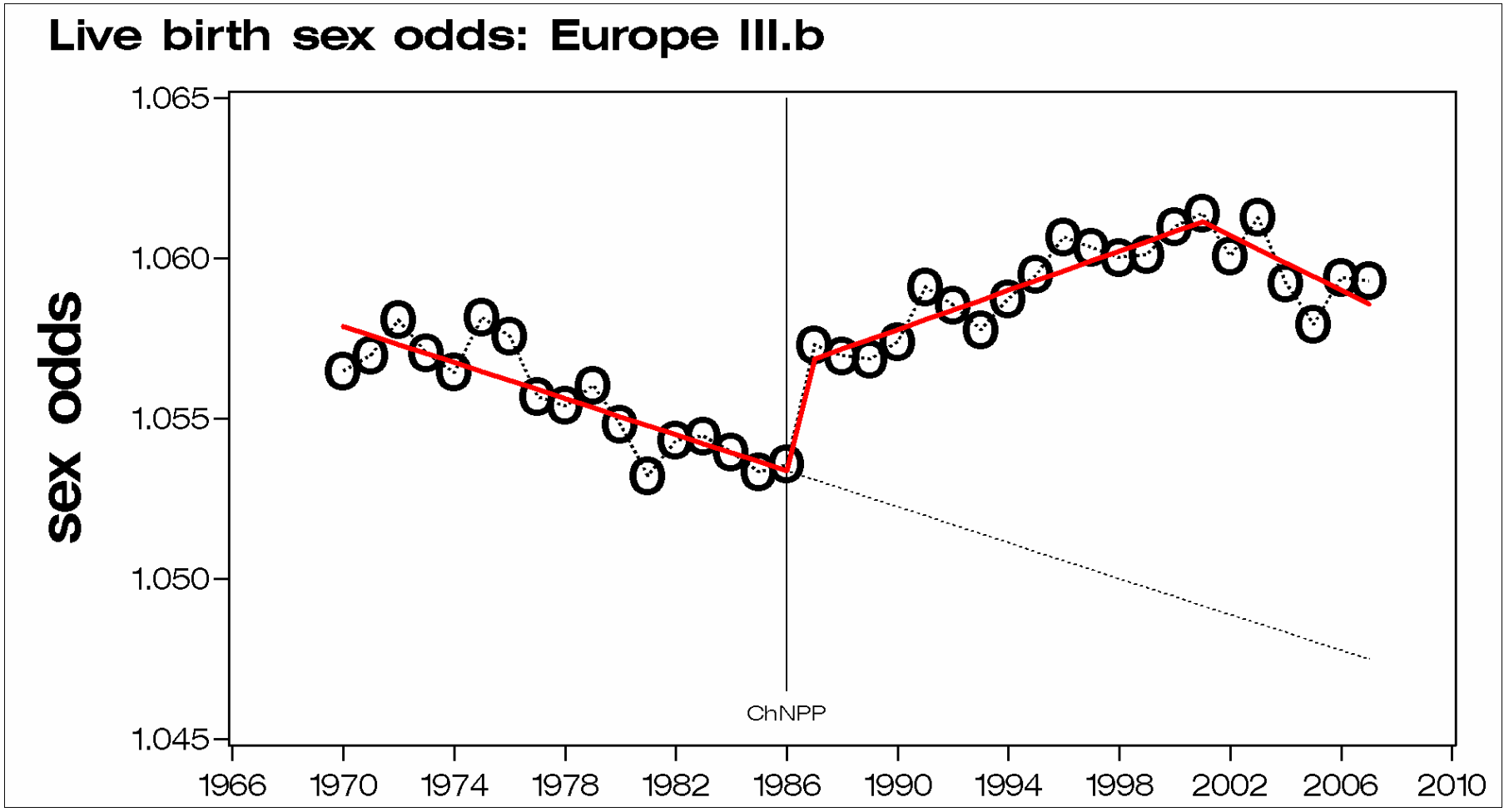
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Western Europe – less exposed



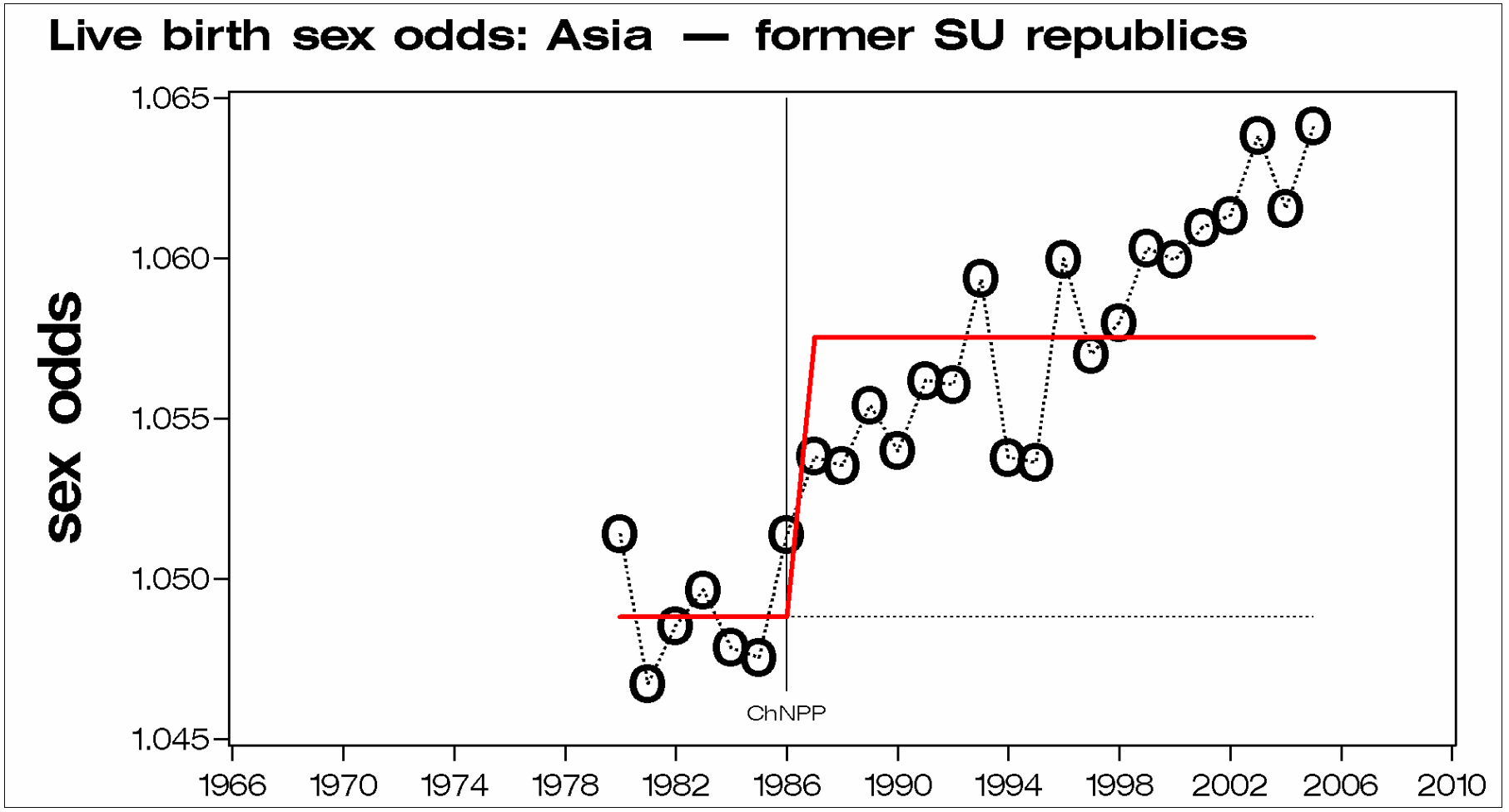
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Central and eastern Europe – moderately or highly exposed



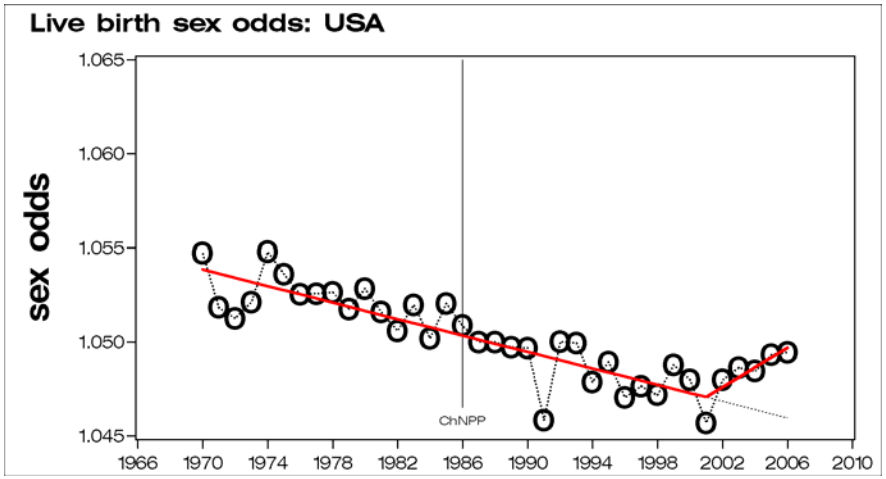
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

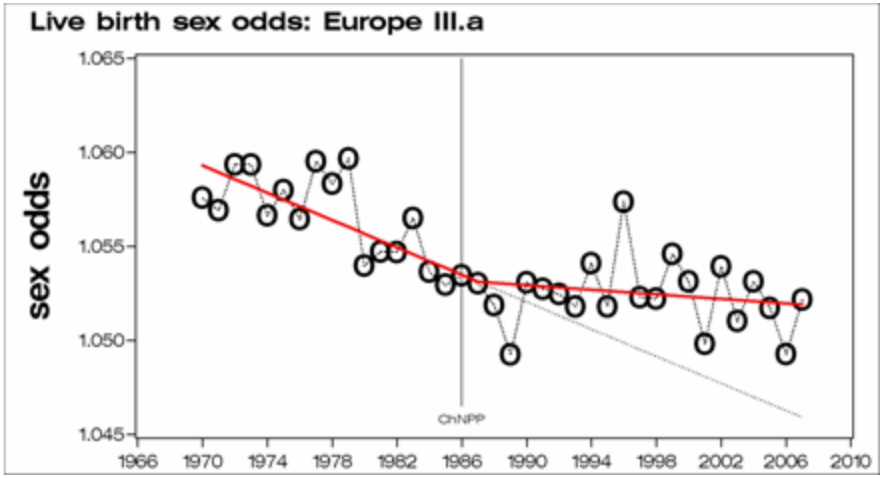
Former SU republics, parts of Asia – presumable high exposure

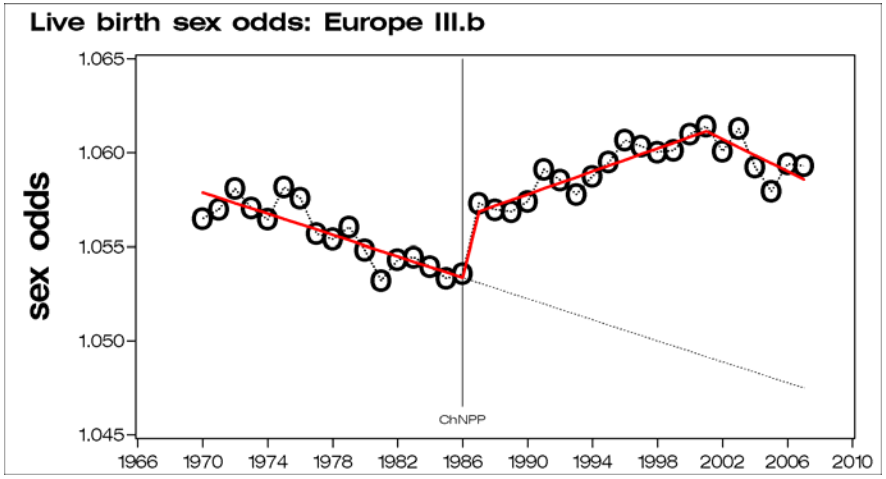


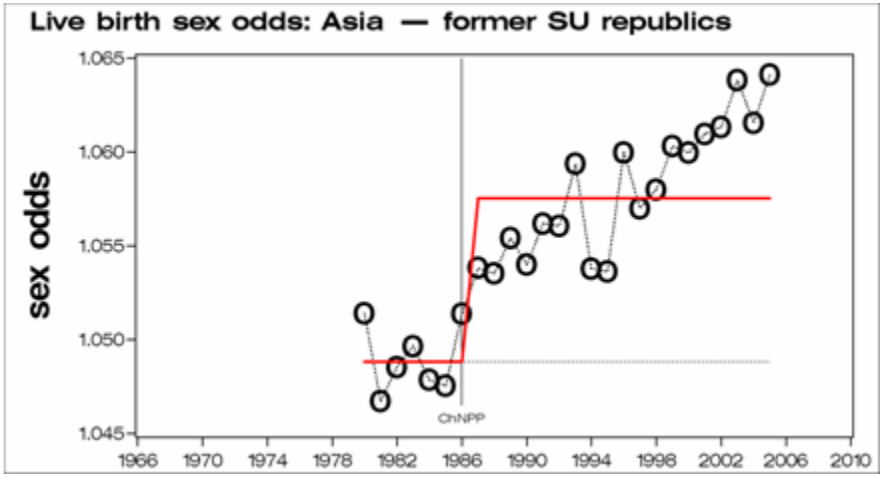
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Summary: USA, Europe, and parts of Asia









Ecological dose-response

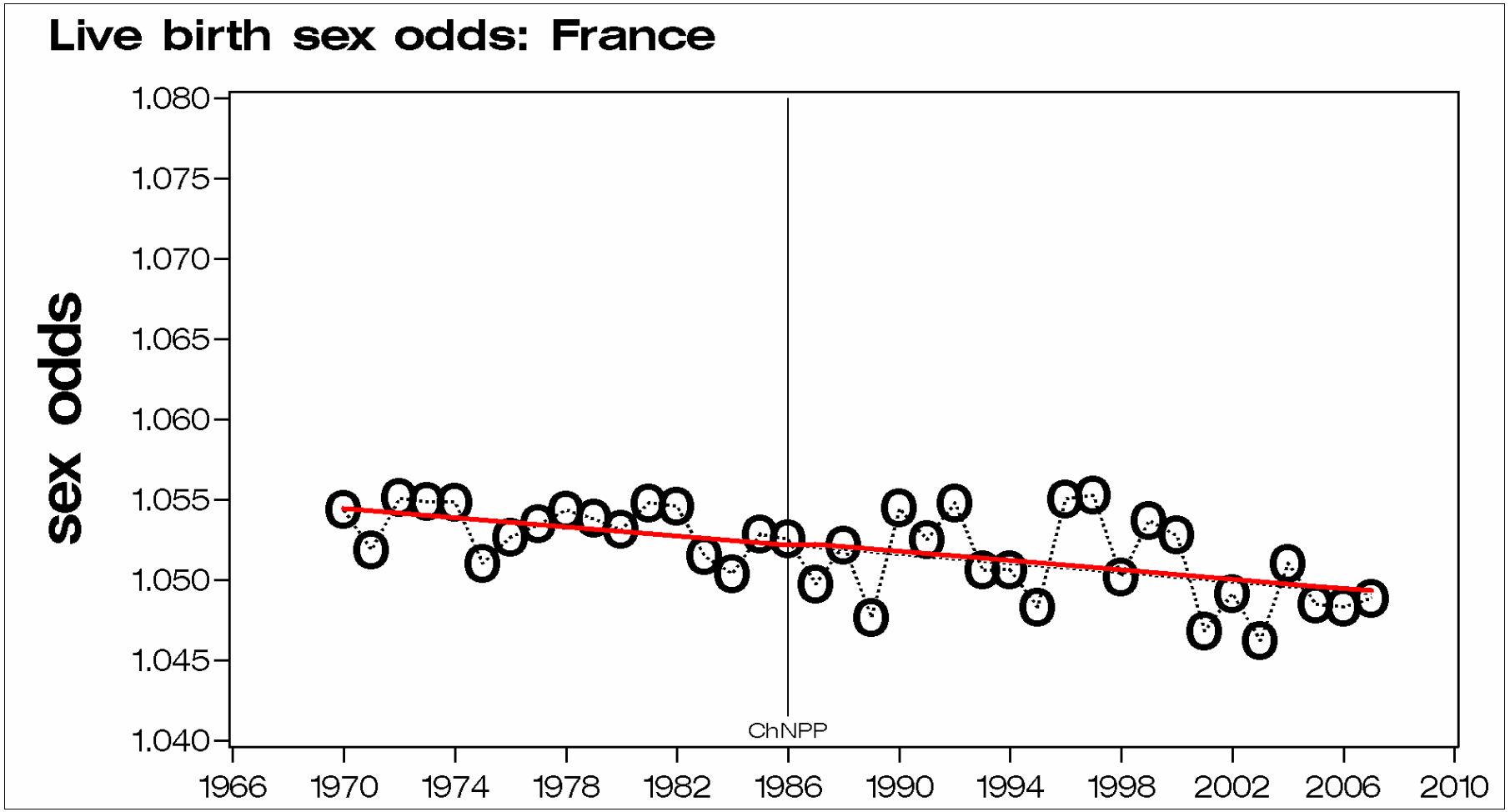
- **Hypothesis** — Jump heights in sex odds after Chernobyl are depending on the amount of fallout (=> national excess average effective doses)

- **Test** — Consider sex odds ratios in countries with differing levels of fallout after Chernobyl

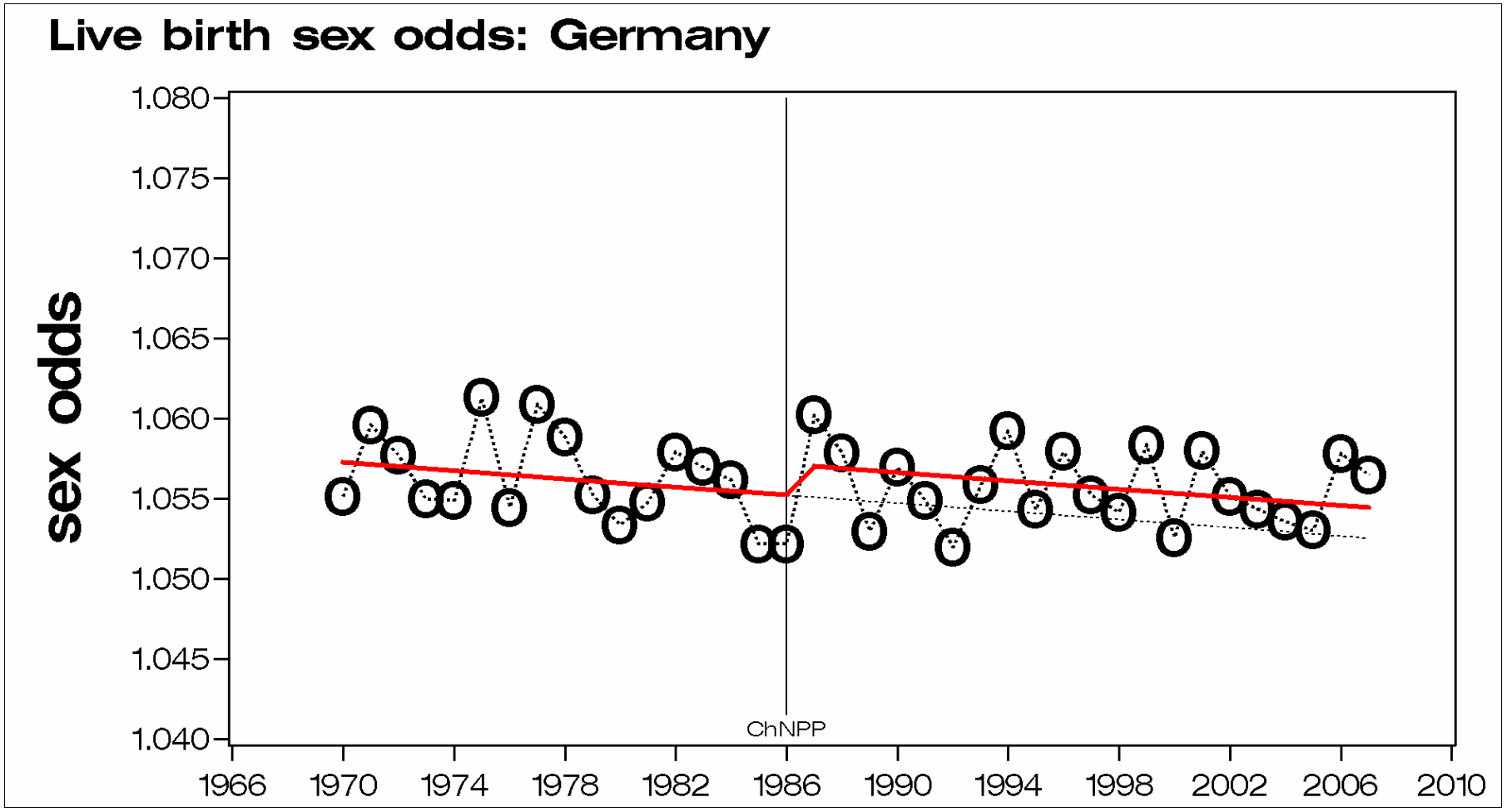
- **Fallout level**

low	**France**
intermediate	**Denmark, Germany, Italy, Yugoslavia (f.)**
high	**Belarus, Russian Federation**

Ecological dose-response



Ecological dose-response



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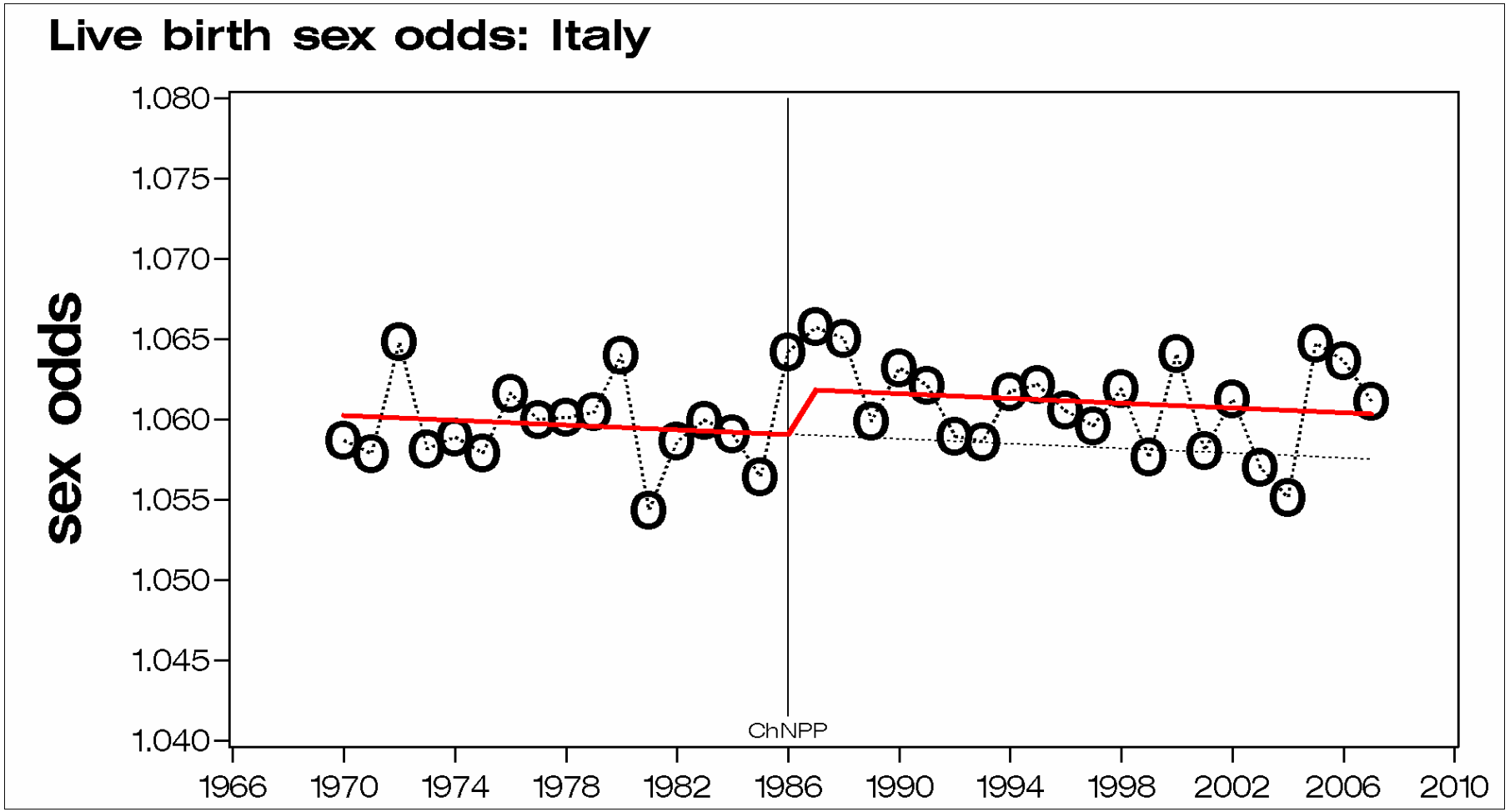

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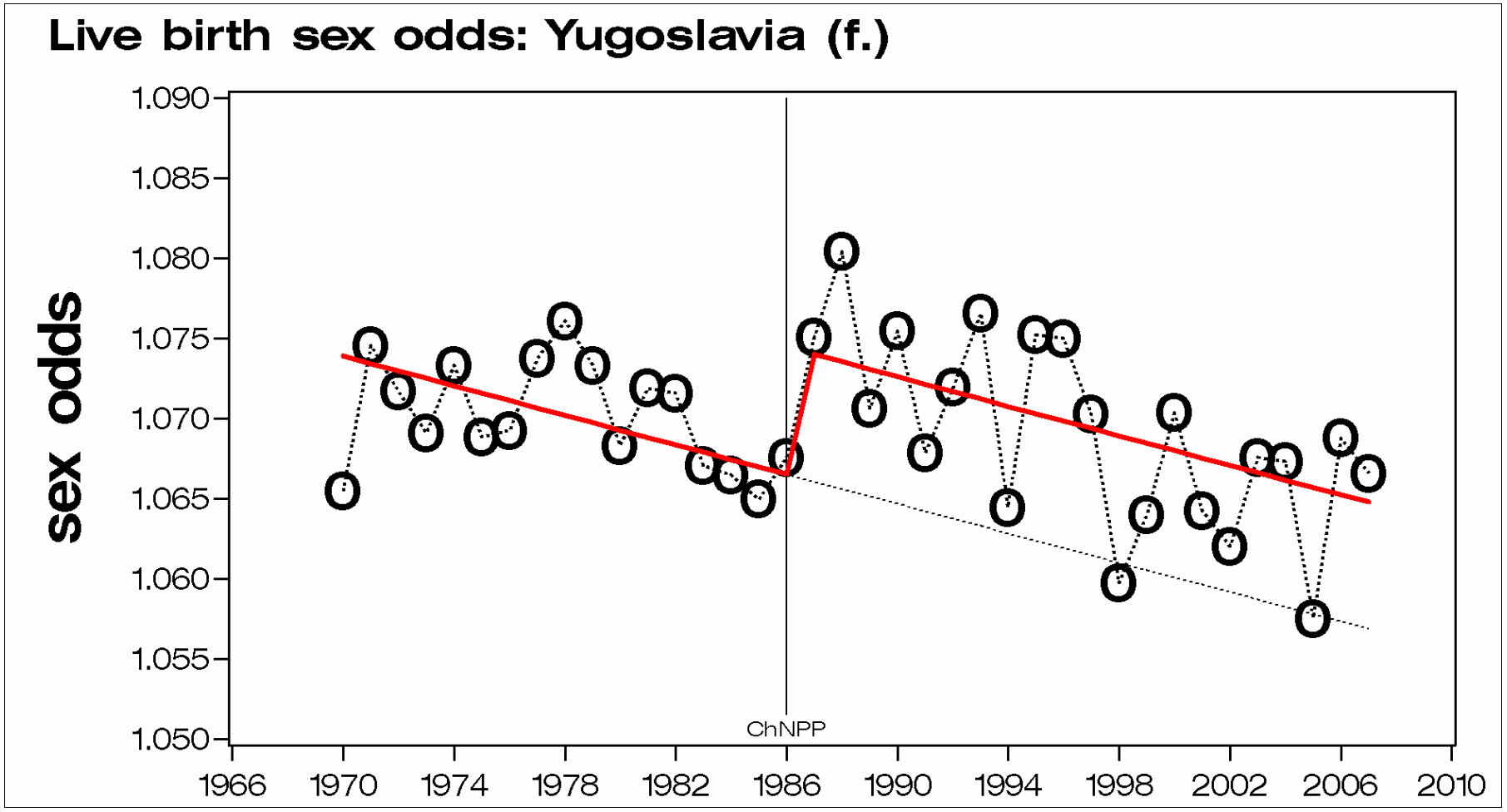
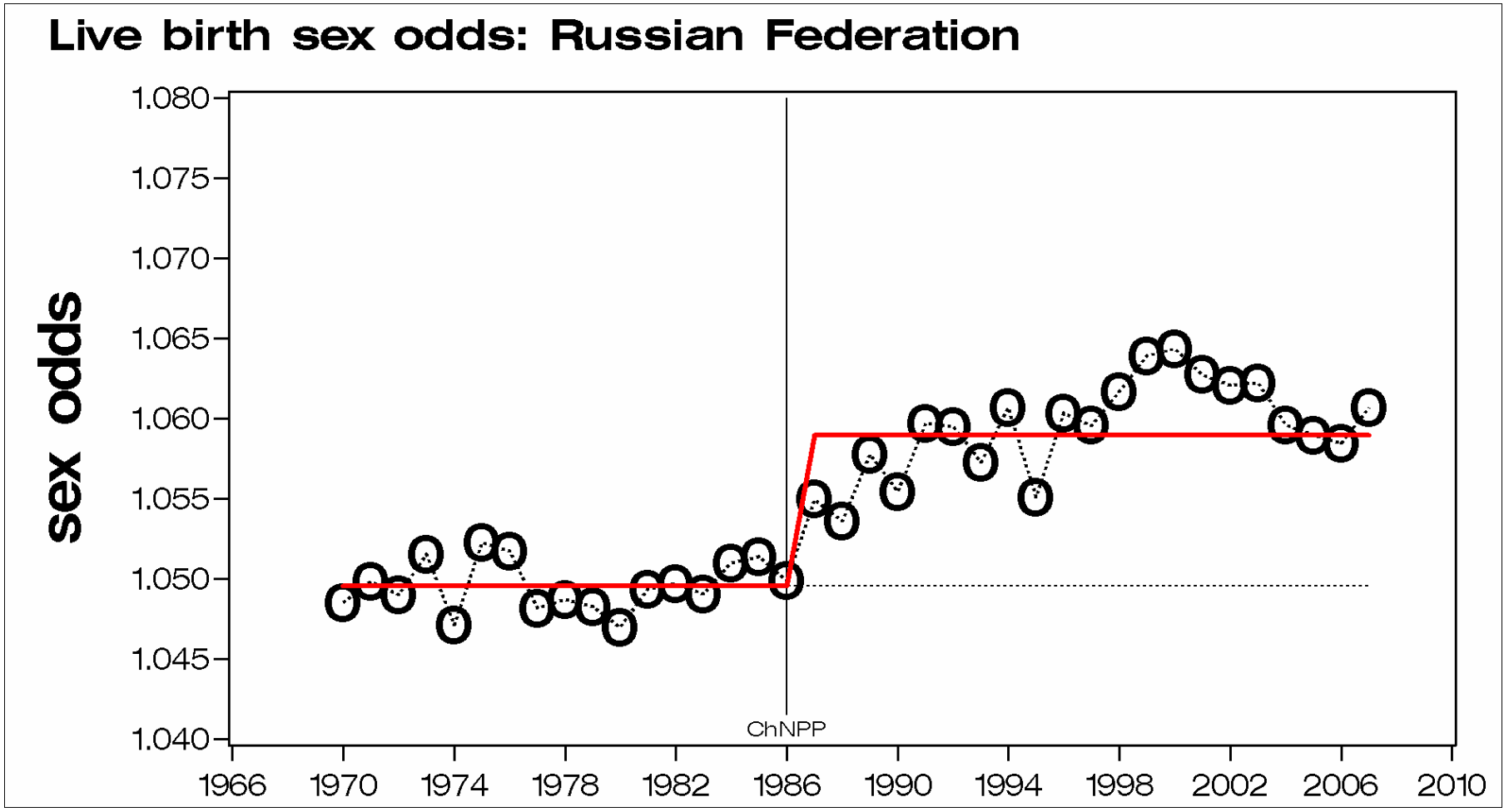
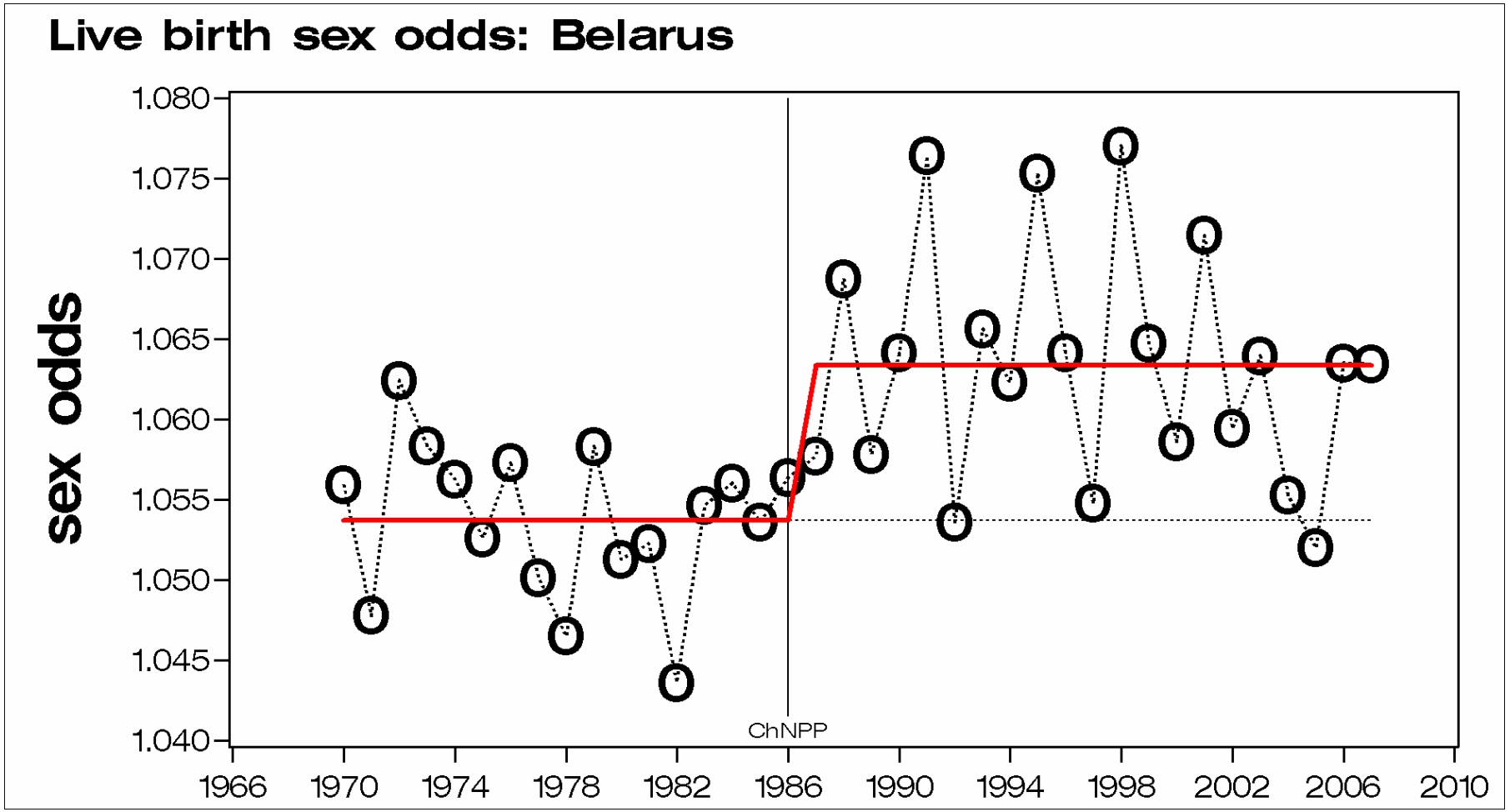


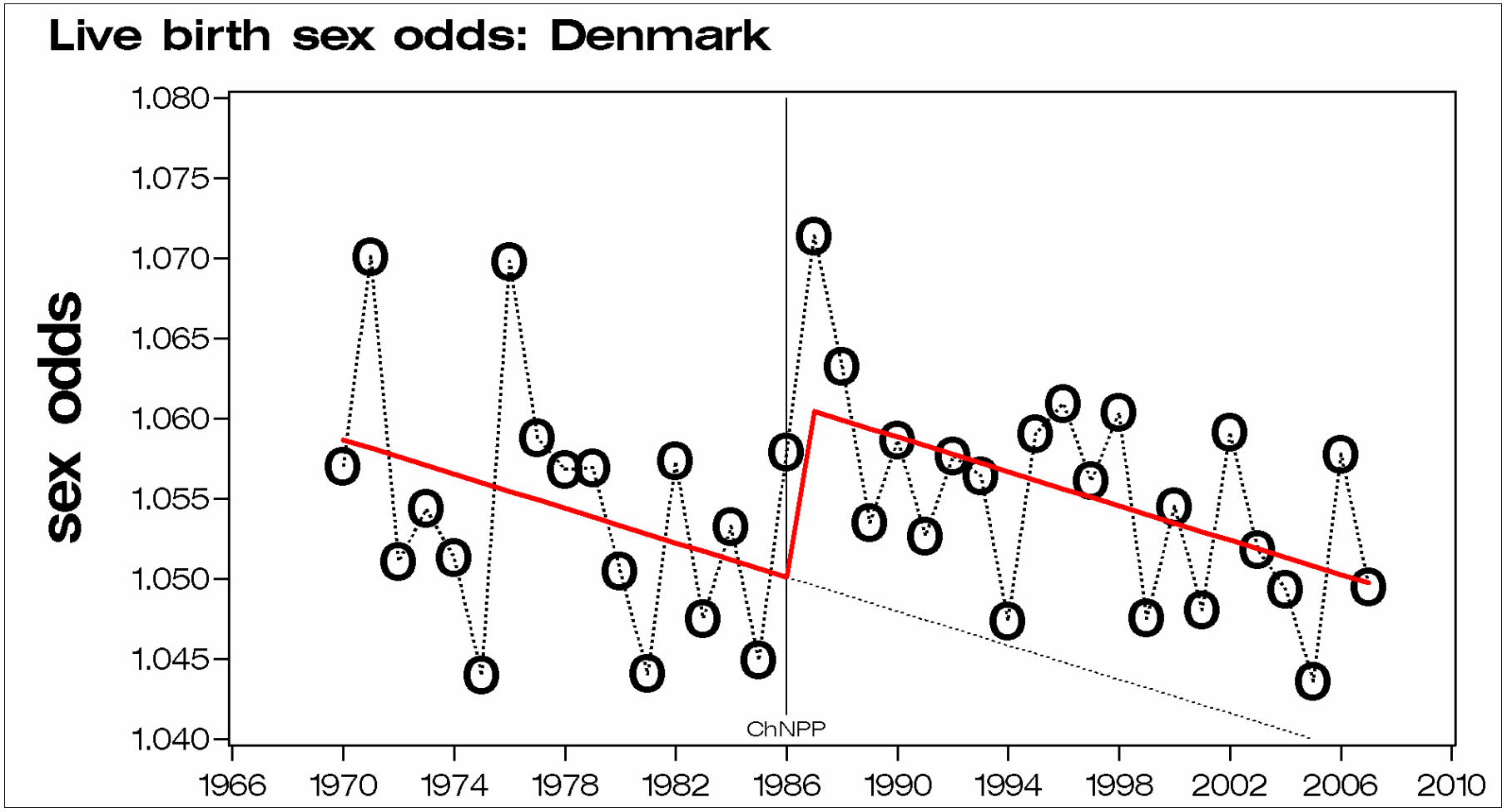
Ecological dose-response



Ecological dose-response



Ecological dose-response

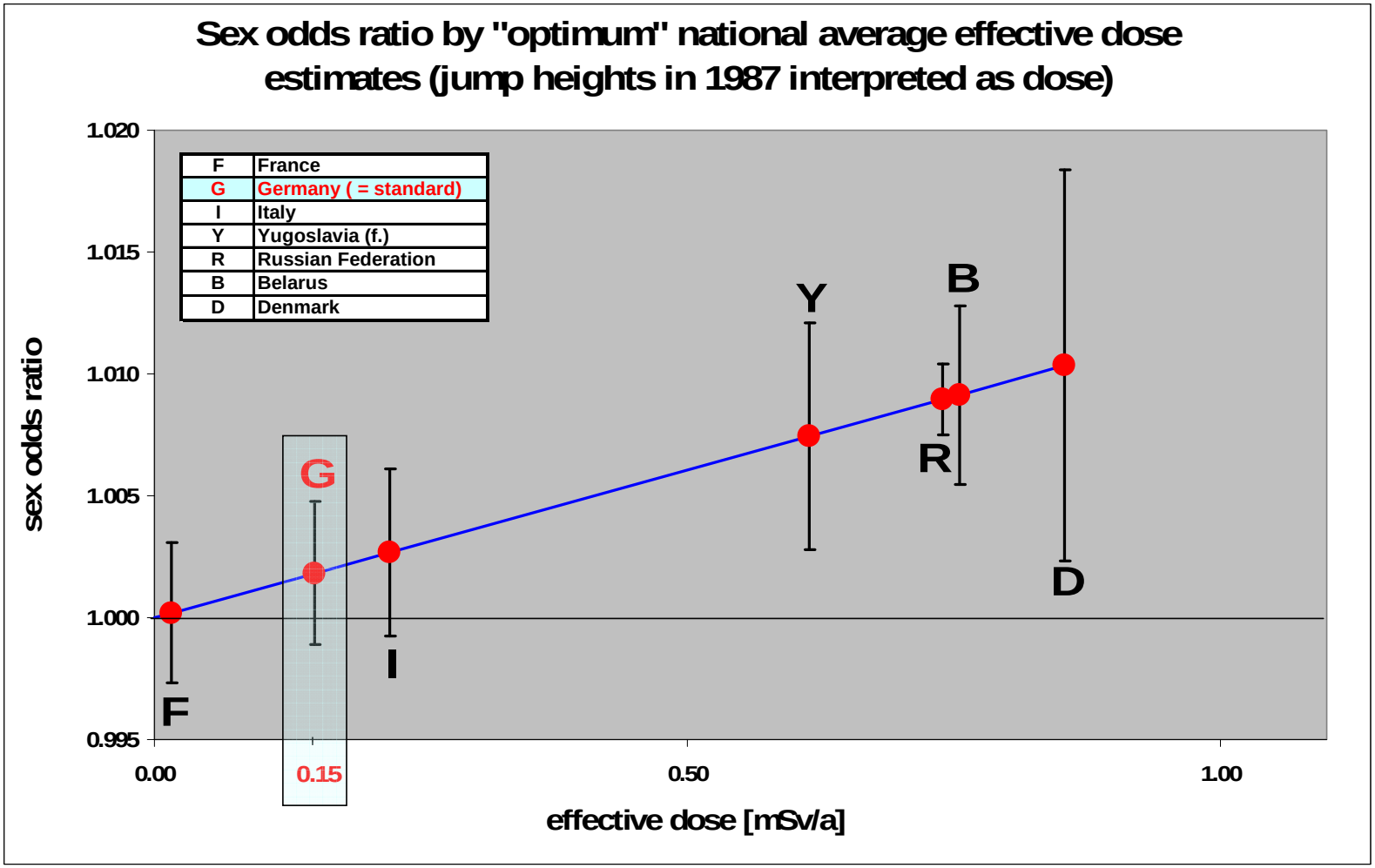


Ecological dose-response *(German collective dose data)*

Vergleich der in den Jahren 1986, 1987, 1996 und 2006 berechneten effektiven Dosen für Erwachsene durch die SSK

Gebiet	Effektive Dosis im 1. Jahr (mSv)				Gesamte effektive Dosis für die nach dem Unfall folgenden 50 Jahre (mSv)			
	1986	1987	1996	2006	1986	1987	1996	2006
Voralpengebiet		1,2	0,65	0,5		3,8	2,2	2,1
Südlich Donau	0,5–1,1	0,6	0,35	0,3	1,5–4,0	1,9	1,3	1,1
Nördlich Donau		0,2	0,17	0,1		0,6	0,55	0,4

Ecological dose-response *(“national dosimetry”)*



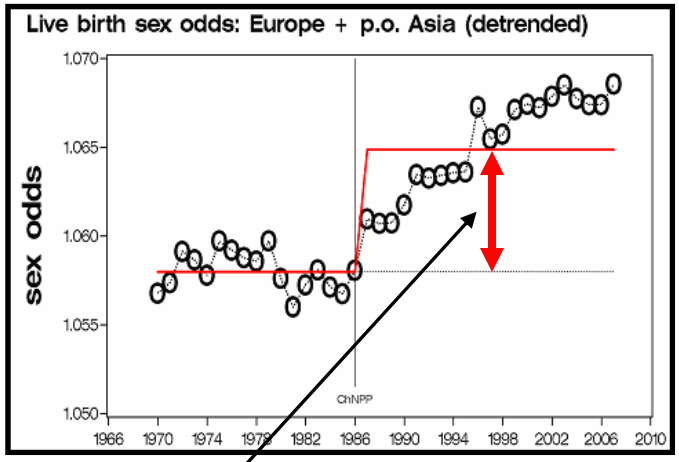
Ecological dose-response *("national dosimetry")*

Optimum **excess collective doses per year** in France, Italy, former Yugoslavia, Russian Federation, Belarus, and Denmark based on the linearity assumption, the jump heights in 1987 and the overall excess collective dose in Germany of 0.15 mSv/year from 1987 to 2007 (Germany serves as a standard)

Country	jump OR	mSv/a
France	1.0002	0.02
Germany	**1.0018**	**0.15**
Italy	1.0027	0.22
Yugoslavia (f.)	1.0074	0.61
Russian Federation	1.0090	0.74
Belarus	1.0092	0.75
Denmark	1.0104	0.85
jump OR per mSv	**1.0121**	

Possible scale of reproductive detriment due to the Chernobyl accident

Possible scale of lost or impaired children after Chernobyl in all of Europe and the part of Asia covered		
Observed	1987 ≤ Births ≤ 2007	183 802 030
	male	94 446 893
	female	89 355 137
	sex odds	1.0570
	missing boys	**249554**
	missing girls	**831846**
Expected	Births	184 883 430
	male	94 696 447
	female	90 186 983
	sex odds	1.0500
	sex OR	**1.0066 (1.0052–1.0079)**
sex OR/mSv 1.0145 (1.0021–1.0271)		**0.460**
	1987 ≤ Births ≤ 2007	183 802 030
	BD 3%(LB)+0.5%(TB)	6 437 689
	OR/mSv*	1.54
	BD doubling dose	**1.61**
	OR BD+SB	1.22
	Excess BD+SB	**1 415 769**
Lost or impaired children		**2.5 millions**



Chernobyl gender gap

0.6 million missing girls, if only girls were susceptible

1.1 million missing children, if the sex odds of missing children were 3:10

* Scherb H, Weigelt E. (2003)

Conclusion

UNSCEAR[1] states "*The estimate of risk*" (at 1 Gray) "*for **congenital abnormalities** is about 2,000 cases per million live births (compared to 60,000 cases per million live births)*"

RR/1Gy=62,000/60,000=1.033

This means **Doubling Dose=21.3 Gy**

As we have shown for congenital malformations[2,3] (e.g. malformations of the heart, deformities, Down syndrome, using data from the Bavarian congenital malformation data set), the doubling dose is in the order of magnitude of below a few mSv. Thus,

UNSCEAR is in error at least at 3 orders of magnitude

[1] *UNSCEAR 2001 Report, Hereditary Effects of Radiation, Scientific Annex, p. 82*

[2] *Scherb H, Weigelt E. Congenital Malformation and Stillbirth in Germany and Europe Before and After the Chernobyl Nuclear Power Plant Accident. ESPR - Environ Sci & Pollut Res, 10 Special (1) 2003 Dec, 117-125*

[3] *Sperling K et al. Low dose irradiation and nondisjunction: Lessons from Chernobyl, 19th Annual Meeting of the German Society of Human Genetics, April 8-10, 2008, Hanover, Germany, Abstractbook, p. 174-175*

Conclusion

The consistency of our results implies

- there is harm of ionizing radiation below 1 mSv, or
- the dose concept is invalid altogether, or
- the exposure after Chernobyl was higher than assumed, or
- some combination of the above points

Genetic effects of ionizing radiation in humans, animals (and plants) should be investigated more objectively and more thoroughly

- birth defects
- stillbirths
- secondary sex ratio
- cancer induction, e.g. leukemia
- combinatory effects (radiation & chemicals)
- synergistic effects

Concluding remark

A Wake-Up Call for Everyone
Who Dislikes Cancer and Inherited Afflictions

Spring 1997
By John W. Gofman, M.D., Ph.D.
Egan O'Connor, Executive Director of CNR

In our own view, it is quite possible that a permanent doubling of the "background" dose of ionizing radiation, worldwide, would very gradually double mankind's burden of inherited afflictions --- from mental handicaps to predispositions to emotional disorders, cardio-vascular diseases, cancers, immune-system disorders, and so forth. Such a doubling would be the greatest imaginable crime against humanity *(**nature** ...)*

Thank you

Dr. Hagen Scherb and Dr. Kristina Voigt
Institute of Biomathematics and Biometry, Helmholtz Zentrum München – German Research Center for Environmental Health
Ingolstaedter Landstr. 1, D-85764 Neuherberg, Germany
scherb@helmholtz-muenchen.de