Research on Sex Structure and Sex Ratio at Birth

WANG Guangzhou

Institute of Population and Labor Economics, Chinese Academy of Social Sciences (IPLE-CASS)

Sex Ratio at Birth(SRB)

$$\text{Sex Ratio at Birth} = \frac{\text{Male Births}}{\text{Female Births}}$$

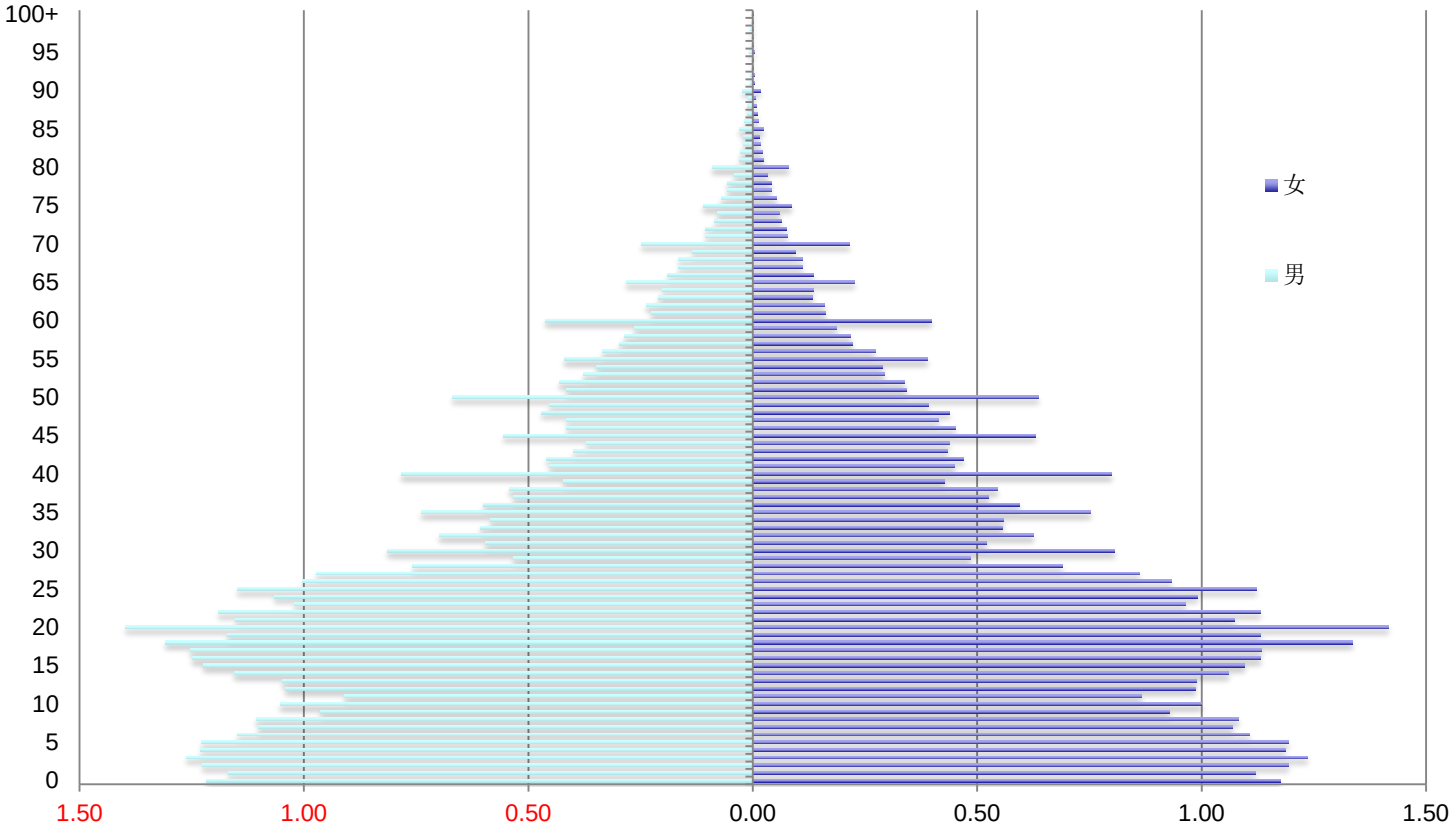
Normal Range: 102-107

Sex Ratio

$$\textbf{Sex Ratio of Population Aged X} = \frac{\textbf{Male Population Aged X}}{\textbf{Female Population Aged X}}$$

$$\textbf{Total Sex Ratio} = \frac{\textbf{Male Population}}{\textbf{Female Population}}$$

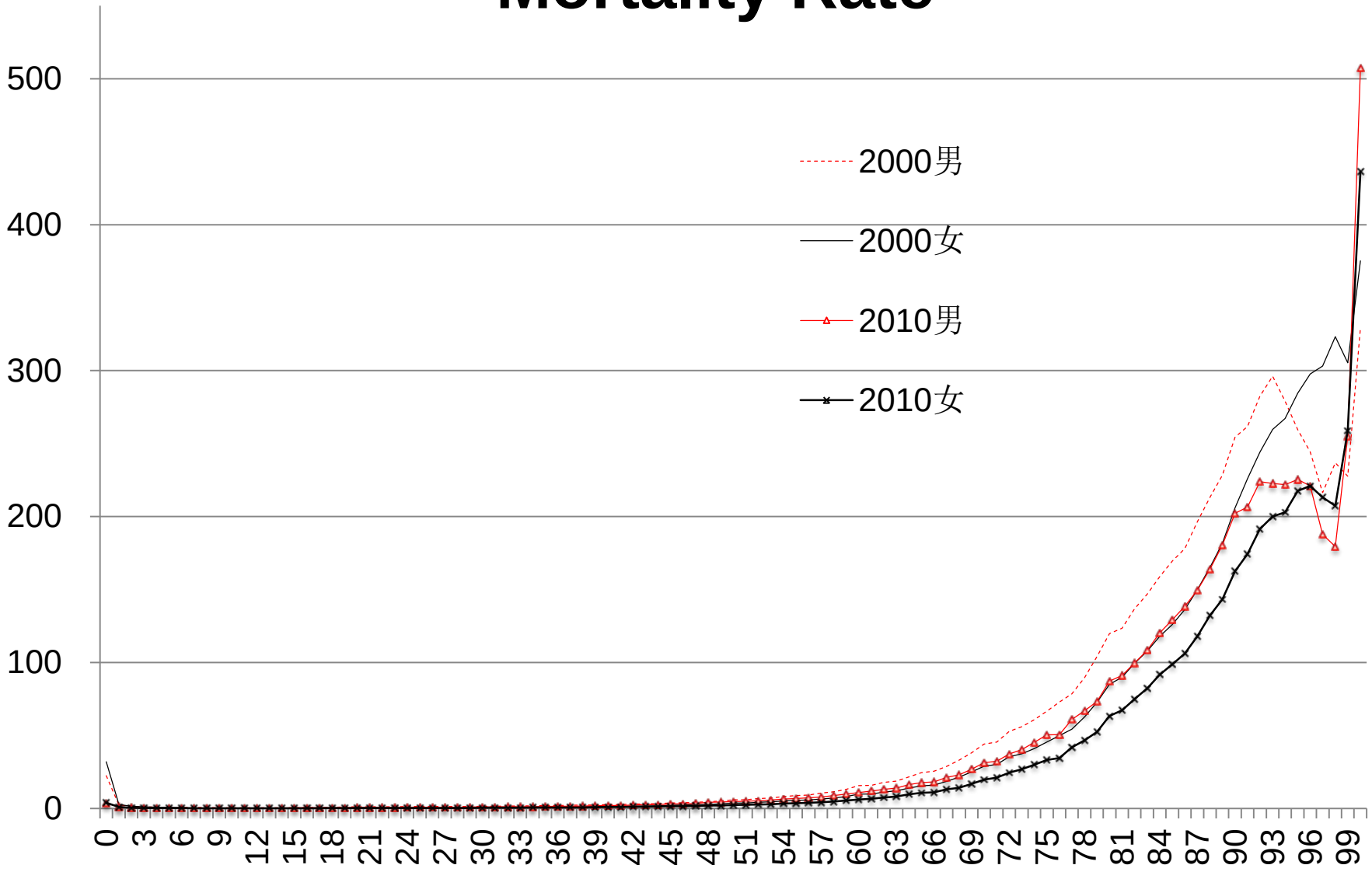
1990 Age Structure (Xinjiang)



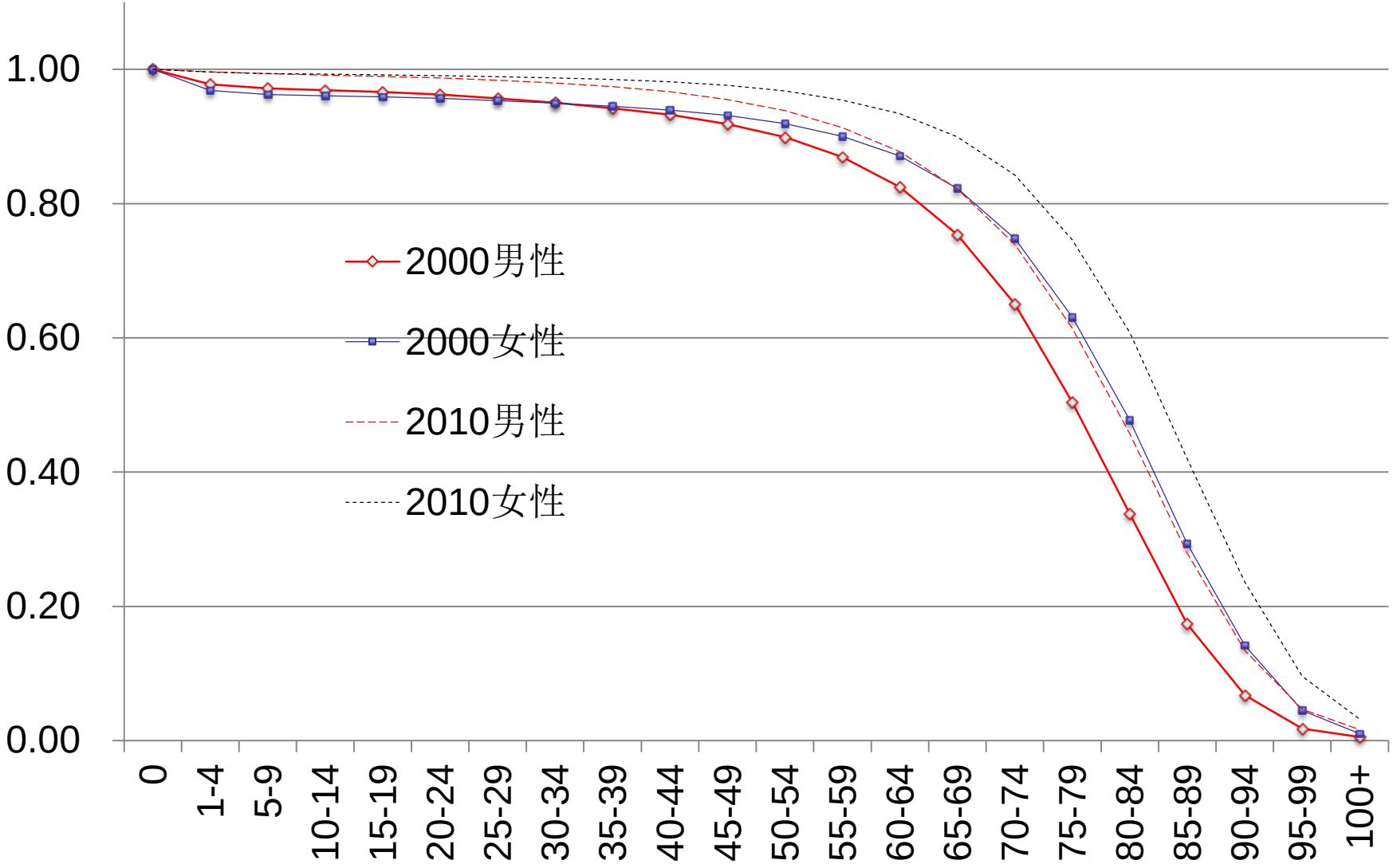
Age-Specific Mortality Rate of 2000, 2010 Census

Age	2000		2010	
	Male	Female	Male	Female
0	22.56	32.10	3.73	3.92
1-4	1.48	1.49	0.69	0.59
5-9	0.65	0.44	0.36	0.23
10-14	0.50	0.33	0.37	0.22
15-19	0.77	0.47	0.52	0.25
20-24	1.21	0.72	0.70	0.30
25-29	1.36	0.84	0.84	0.37
30-34	1.66	0.98	1.11	0.50
35-39	2.15	1.18	1.59	0.71
40-44	3.05	1.70	2.37	1.11
45-49	4.33	2.57	3.50	1.68
50-54	6.71	4.19	5.48	2.81
55-59	10.57	6.63	8.04	4.29
60-64	17.92	11.43	13.02	7.49
65-69	29.59	19.06	21.26	13.06
70-74	51.03	34.11	37.01	24.36
75-79	79.89	55.70	59.13	40.89
80-84	133.28	97.48	98.56	73.98
85-89	188.75	145.36	146.53	115.29
90-94	268.63	231.23	211.66	180.24
95-99	241.40	298.02	212.07	219.46
100 +	329.42	375.24	507.28	436.34

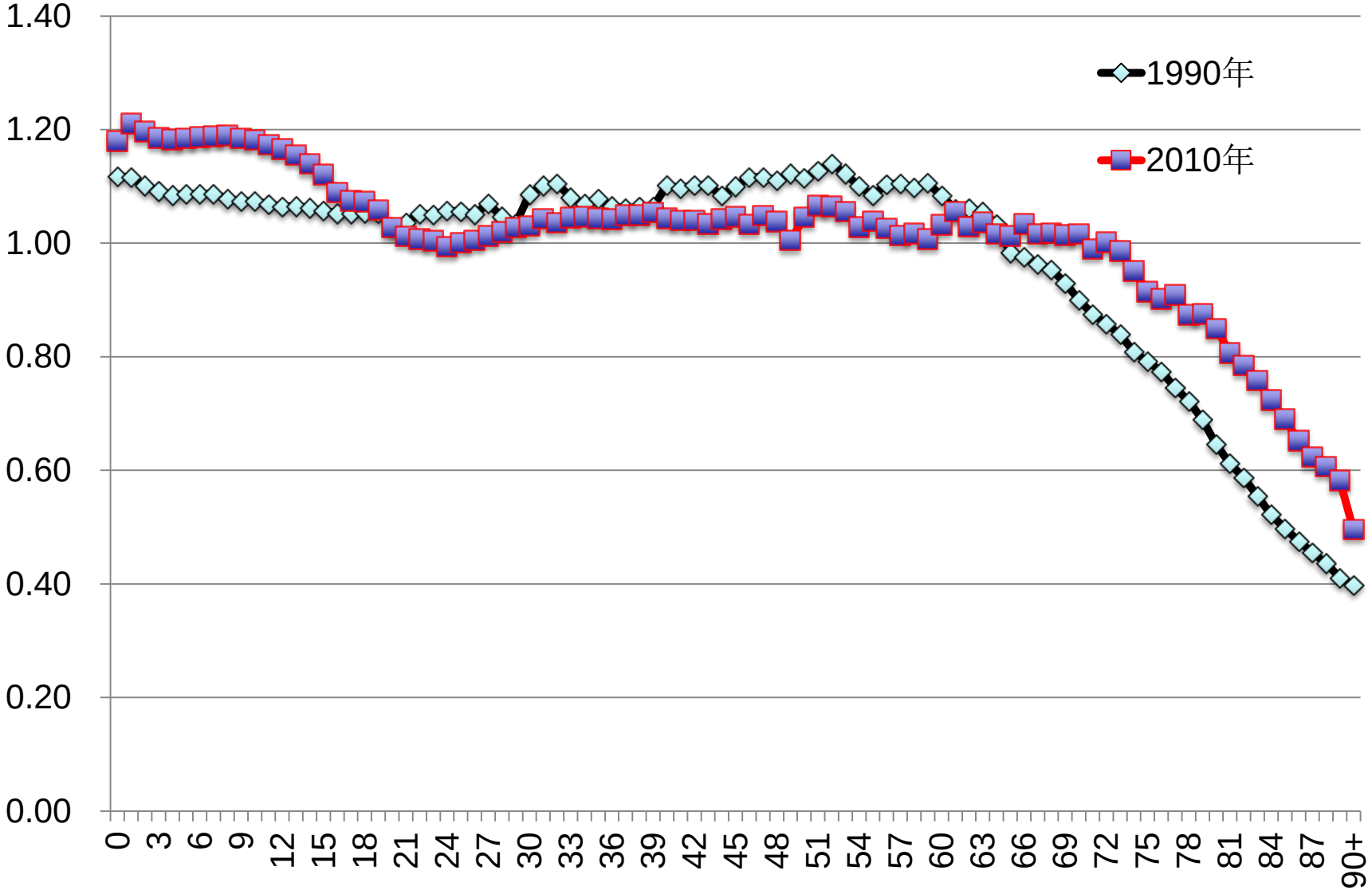
2000, 2010, China Age-Sex-Specific Mortality Rate



2000, 2010, China Sex-Specific Life Table & Survival Curve

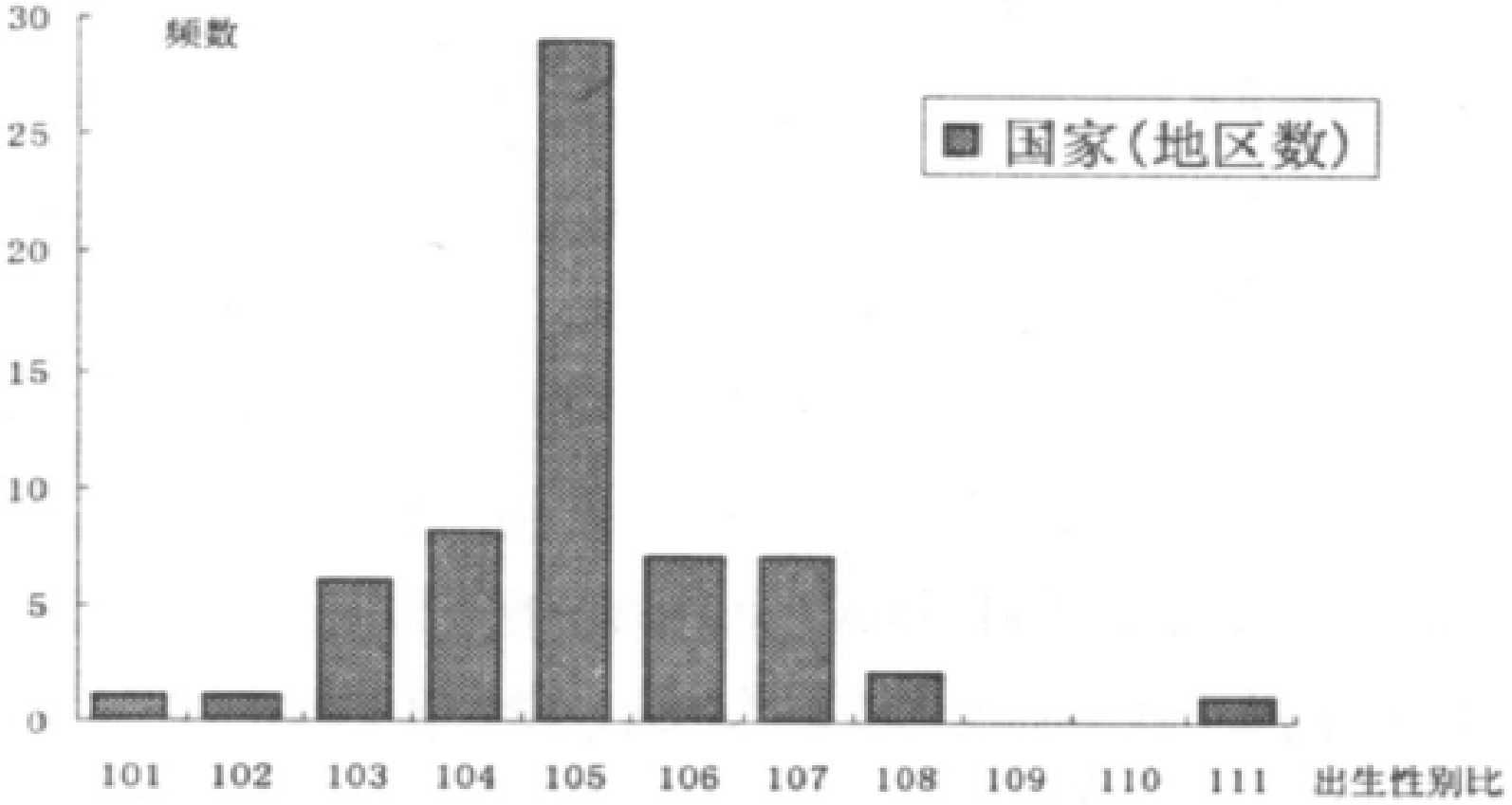


Age-Specific Sex Ratio



SRB Analysis

世界各国（地区）20世纪 80、90年代人口平均出生性别比的分布



资料来源：The Statistics Division, Department of Economic and Social Affairs of the United Nations Secretariat Natality Statistics of Demographic Yearbook 2002.

世界主要发达国家20世纪80、90年代人口出生性别比的统计特征

国家（地区）	出生性别比正常值范围	出生性别比的最低值	出生性别比的最高值	出生性别比的平均值	标准差	有效数据年数	出生性别比在标准范围内的年数
加拿大	102.3－107.8	104.9	106	105.5	0.2	16	全部
美国	102.6－107.4	104.6	105.3	105.2	0.7	15	全部
日本	102.6－107.4	105.2	106	105.6	0.2	19	全部
丹麦	101.4－108.7	104.4	107.1	105.6	0.4	20	全部
芬兰	101.2－108.9	103.3	105.9	104.6	0.3	16	全部
挪威	101.2－108.9	103.7	107.6	105.8	0.5	17	全部
瑞典	101.7－108.4	104.3	106.6	105.6	0.5	17	全部
荷兰	102.1－107.9	103.5	106.1	104.8	0.3	19	全部
比利时	101.7－108.3	104	106.8	105.4	0.4	19	全部
奥地利	101.6－108.5	103.3	106.5	105.2	0.5	19	全部
法国	102.5－107.5	104.8	105.5	105.2	0.1	18	全部
德国	102.6－107.5	105.2	107.5	105.6	0.3	17	全部
英国	102.5－107.5	104.9	105.8	105.2	0.1	16	全部
瑞士	101.6－108.5	103.4	106.7	105.2	0.5	17	全部
澳大利亚	102.1－107.9	104.9	106.1	105.4	0.2	17	全部
新西兰	101.2－108.9	103.8	108	105.7	0.6	19	全部

世界较发达国家（地区）20世纪80、90年代人口出生性别比的统计特征

国家（地区）	出生性别比正常值范围	出生性别比的最低值	出生性别比的最高值	出生性别比的平均值	标准差	有效数据年数	出生性别比在标准范围内的年数
巴　西	102.6－107.4	104	104.8	104.3	0.1	16	全　部
智　利	102.1－107.9	103.6	105.5	104.7	0.3	19	全　部
中国香港	101.2－108.9	105.9	109.7	106.9	0.7	19	除1年外
以色列	101.7－108.3	102.5	107	105.5	0.5	19	全　部
韩　国	102.5－107.5	106	116.6	111.4	2.7	19	3
新加坡	101.0－109.1	106.4	109.4	107.6	0.6	20	除1年外
葡萄牙	101.7－108.3	104.9	108.3	106.5	0.7	18	全　部
希　腊	101.7－108.3	104.7	108.1	106.9	0.6	15	全　部
匈牙利	101.7－108.3	104.2	107.2	105.3	0.5	19	全　部
西班牙	102.3－107.8	106.1	109.2	107.3	0.7	16	除2年外
意大利	102.4－107.6	105.7	107	106.2	0.2	18	全　部
爱尔兰	101.2－108.9	104.8	108.7	106.4	0.5	19	全　部
保加利亚	101.4－108.7	104.2	108.1	105.7	0.5	17	全　部
乌克兰	102.4－107.7	105.3	106.8	105.9	0.3	15	全　部
斯洛文尼亚	100.2－110.0	103.5	107.1	105.6	0.5	17	全　部
罗马尼亚	102.1－107.9	104.7	107	105.5	0.5	13	全　部
波　兰	102.4－107.7	104.9	106.3	105.8	0.2	18	全　部
爱沙尼亚	101.0－109.1	103.8	108.2	105.6	0.4	14	全　部
拉托维亚	100.2－110.0	103.4	108.2	105.8	1.1	13	全　部

世界部分发展中国家20世纪80、90年代人口出生性别比的统计特征

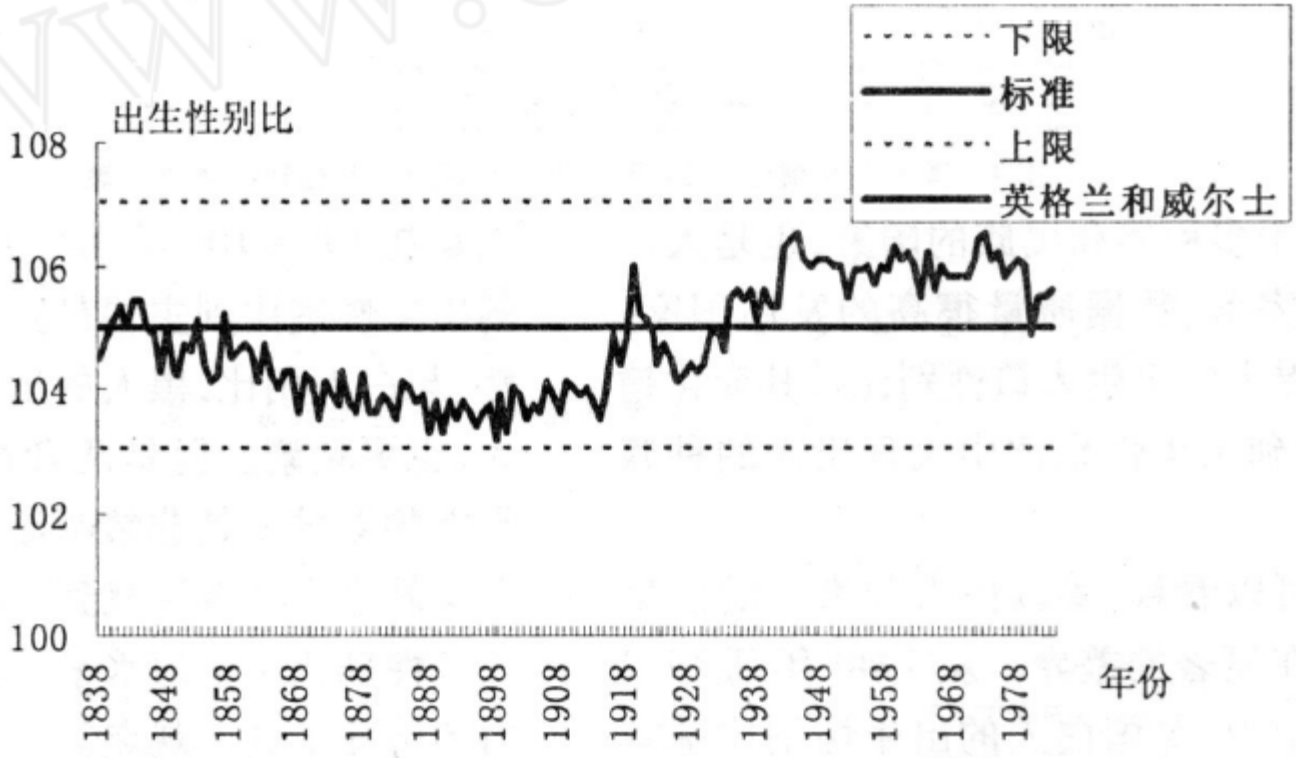
国家（地区）	出生性别比正常值范围	出生性别比的最低值	出生性别比的最高值	出生性别比的平均值	标准差	有效数据年数	出生性别比在标准范围内的年数
埃　及	102.6－107.4	103.2	112	106.8	1.7	18	13
突尼斯	101.7－108.3	105.6	109.1	107.1	0.9	17	15
古　巴	101.7－108.3	105.6	118	108.8	2.7	19	9
萨尔瓦多	101.7－108.3	100.2	107.1	103.9	0.9	19	18
危地马拉	102.3－107.8	102.4	105	103.9	0.4	18	全　部
墨西哥	102.6－107.4	95	102.9	101.5	1.0	17	3
巴拿马	101.4－108.7	103.7	107.3	105.2	0.5	19	全　部
特立尼达和多巴哥	100.2－110.0	102.1	106.8	103.7	0.8	18	全　部
委内瑞拉	102.4－107.6	103.7	109.5	105.5	1.4	19	17
苏　丹	101.7－108.3	102.8	111.7	105.4	0.9	20	19
马来西亚	102.4－107.7	105.1	107.1	106.4	0.3	19	全　部
巴基斯坦	102.6－107.4	104	110.9	107.3	1.3	11	5
菲律宾	102.6－107.4	107.2	109.8	108.6	0.6	14	1
斯里兰卡	102.3－107.8	103.6	106.2	104.3	0.4	18	全　部
叙利亚	102.4－107.6	98.1	109.1	104.4	1.5	17	14
泰　国	102.6－107.4	102.8	106.2	104.9	0.7	16	全　部

世界各人口规模较小国家（地区）20世纪80、90年代人口出生性别比的统计特征

国家（地区）	出生性别比正常值范围*	出生性别比的最低值	出生性别比的最高值	出生性别比的平均值	标准差	有效数据年数	SRB在标准范围内的年数
冰　岛	96.8－113.2	97.5	111.9	105.7	1.8	18	全　部
卢森堡	97.5－113.1	99.8	111.2	105.6	1.4	15	全　部
汤　加	94.4－116.8	94.3	119.7	107.8	3.9	17	除3年外
卡塔尔	99.0－111.3	103.1	109.4	105.1	0.9	14	全　部
塞浦路斯	98.6－111.3	103.6	110.6	107.4	0.9	19	全　部
巴　林	99.0－111.3	101.4	108	104.4	1.3	18	全　部
圣路易斯	94.4－116.8	96.8	109.4	102.7	2.6	19	全　部
中国澳门	96.8－113.9	100.7	113.8	107.2	2.3	19	全　部
伯利兹	97.9－112.6	98.1	112.5	103.4	1.4	19	全　部
巴哈马	97.9－112.6	97.5	107.8	103.1	1.8	16	全　部
巴巴多斯	96.8－113.9	92.6	109	103.2	2.2	12	除1年外
布鲁内达鲁萨兰国	98.3－112.1	102.2	111.1	106.8	1.7	13	全　部

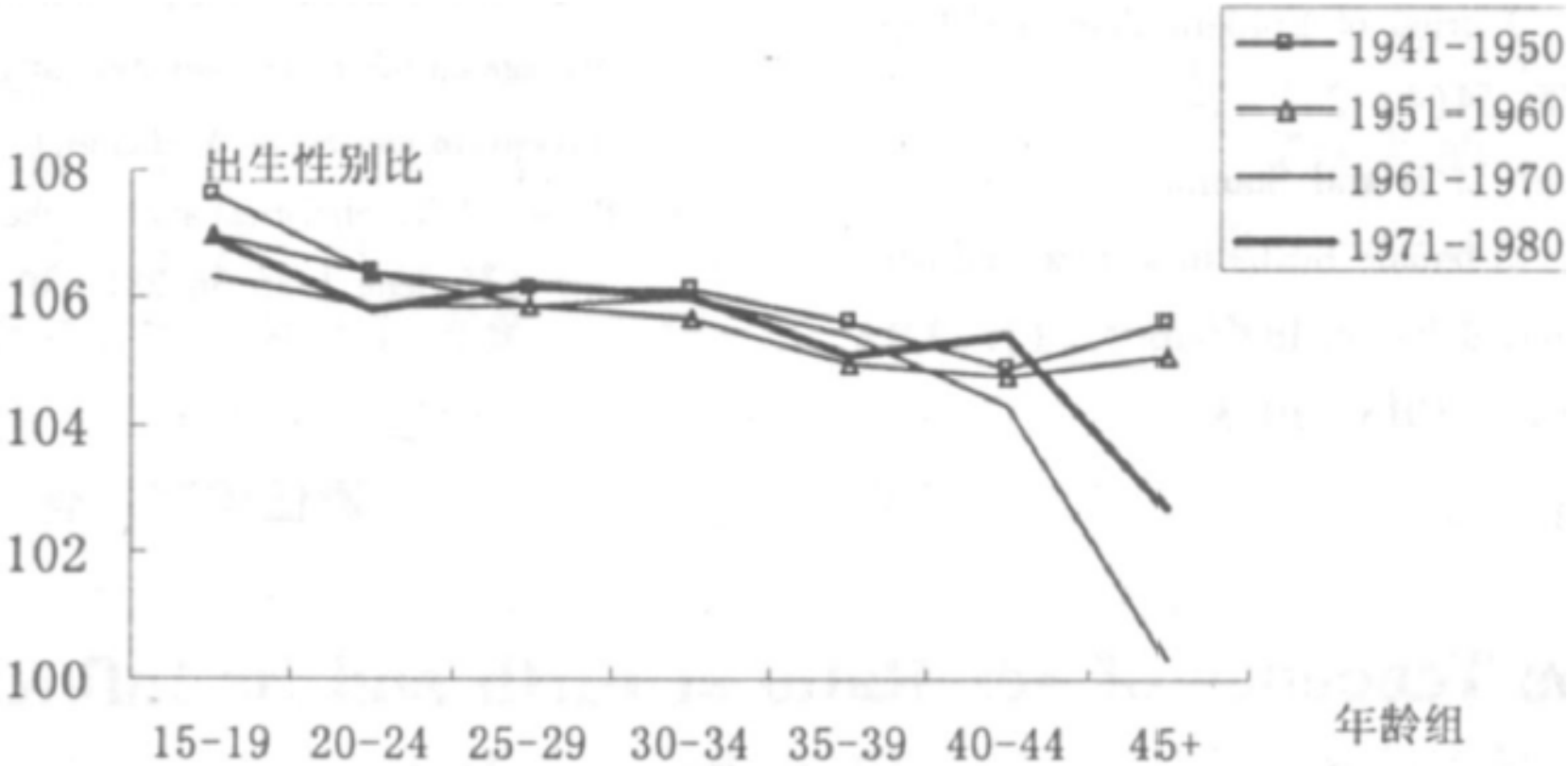
资料来源：The Statistics Division, Department of Economic and Social Affairs of the United Nations Secretariat. Natality Statistics of Demographic Yearbook. 2002

英格兰和威尔士 1838 - 1983年的出生人口性别比



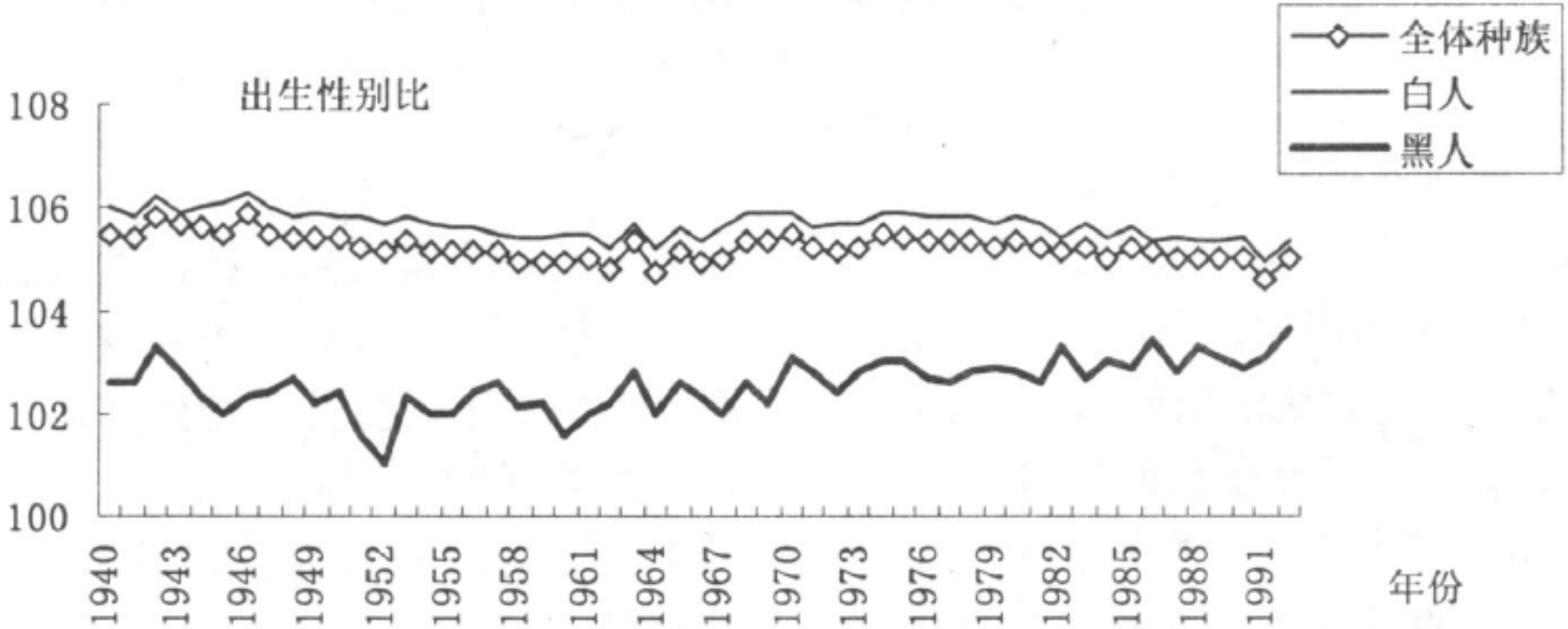
资料来源：Office of Population Censuses and Surveys "1837 - 1983 England and Wales, Birth Statistics, Historical Series". Series FM1 No. 13. (A Publication of the Government Statistical Service). London

英格兰和威尔士 1941 - 1980 年间按母亲年龄的出生性别比



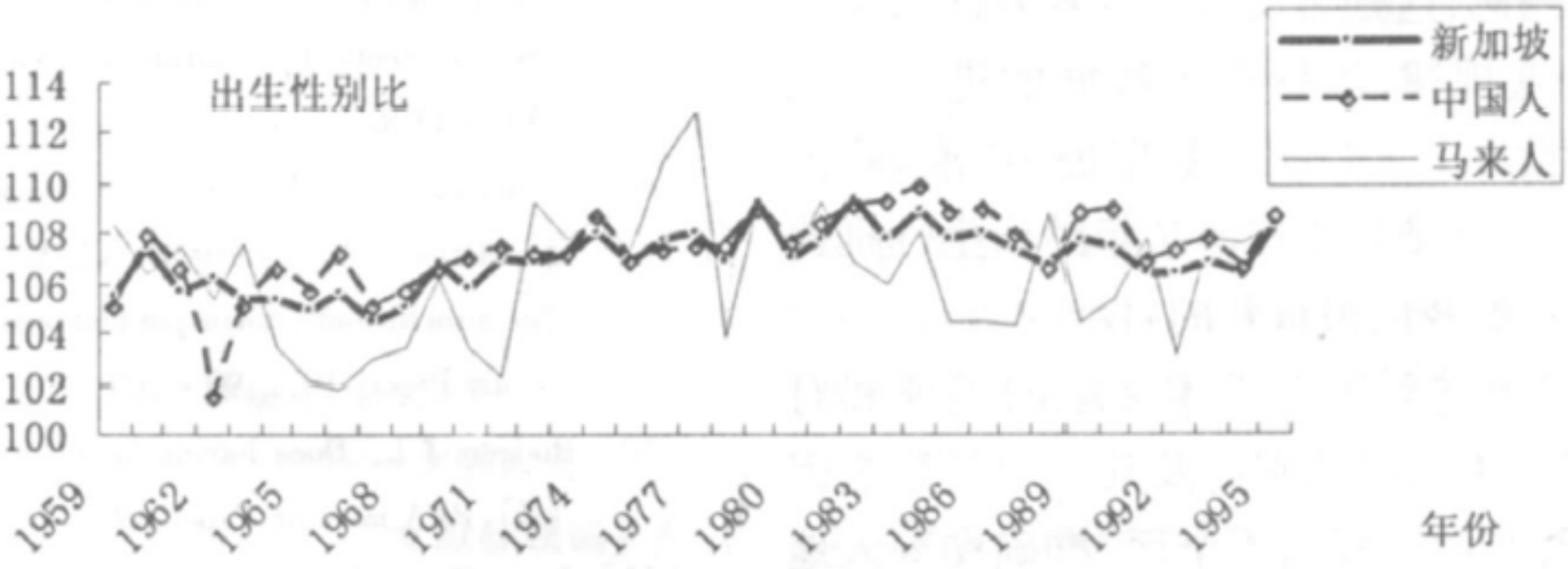
资料来源:Office of population censuses and surveys. 1837 - 1983, England and Wales: Birth Statistics, Historical Series. Series FM no. 13 (A publication of the Government Statistical Service).

美国 1940 - 1992年间按种族的出生人口性别比



资料来源: U. S Department of Health, Education, and Welfare Health Resources Administration National Center for Health Statistics "Vital Statistics of The United States" (Volume Ⅰ - natality). 1972, 1977, 1982, 1987, 1992. Rockville, Maryland

新加坡 1959 – 1995 年全国及分种族的人口出生性别比



资料来源:(1) Department of Statistics, Singapore. Monthly Digest of Statistics Singapore. 1964, 1966, 1971, 1976, 1981, 1986, 1991, 1996.

(2) Registry of births and deaths National Registration Department. Singapore. "Report on registration of births and deaths, 1994".

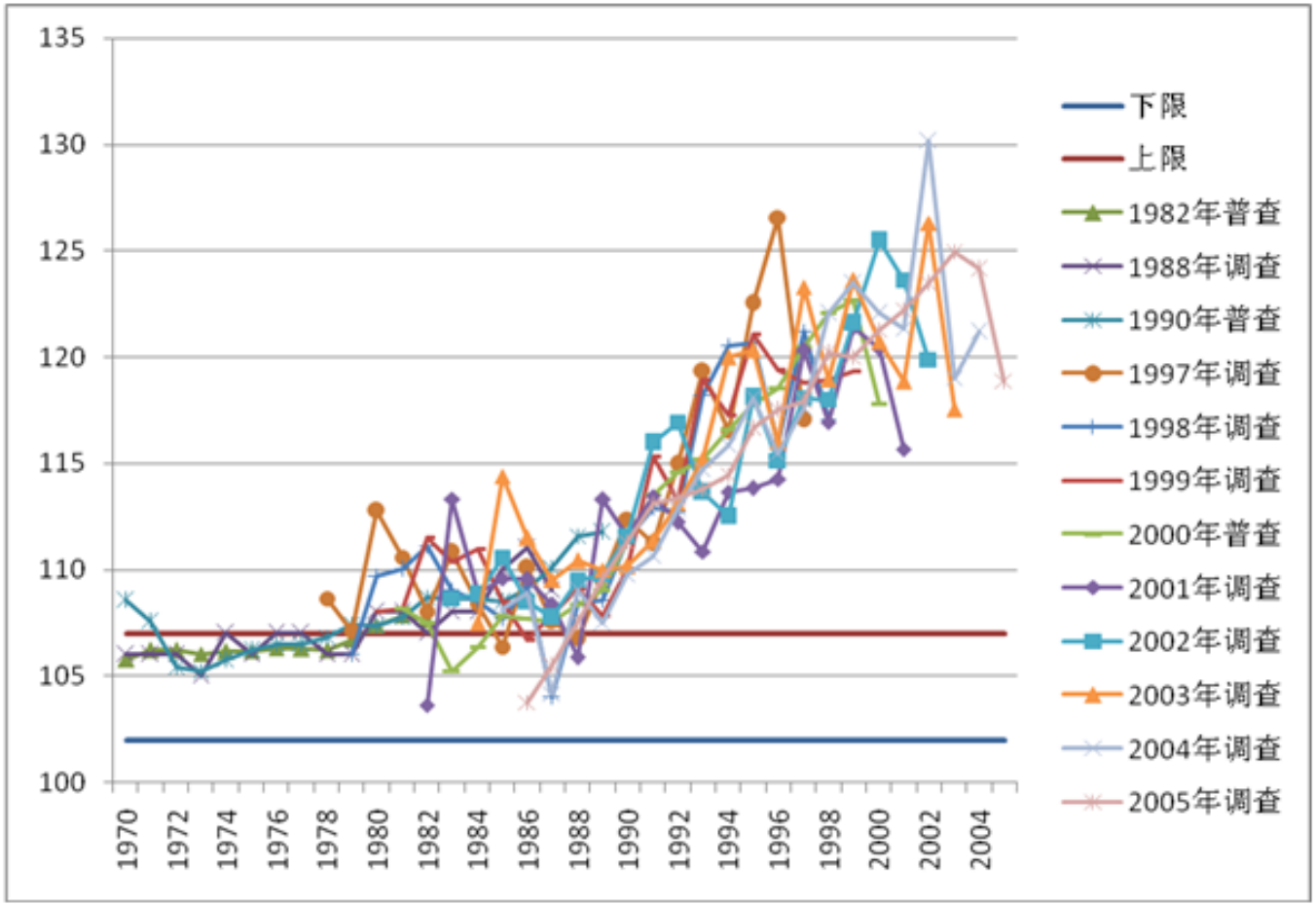
Sex Ratio at Birth

Year	SRB
1982	107.19
1990	110.92
2000	116.86
2005	120.49

Historical Review of SRB Researches: From Phenomenon to Conclusion?

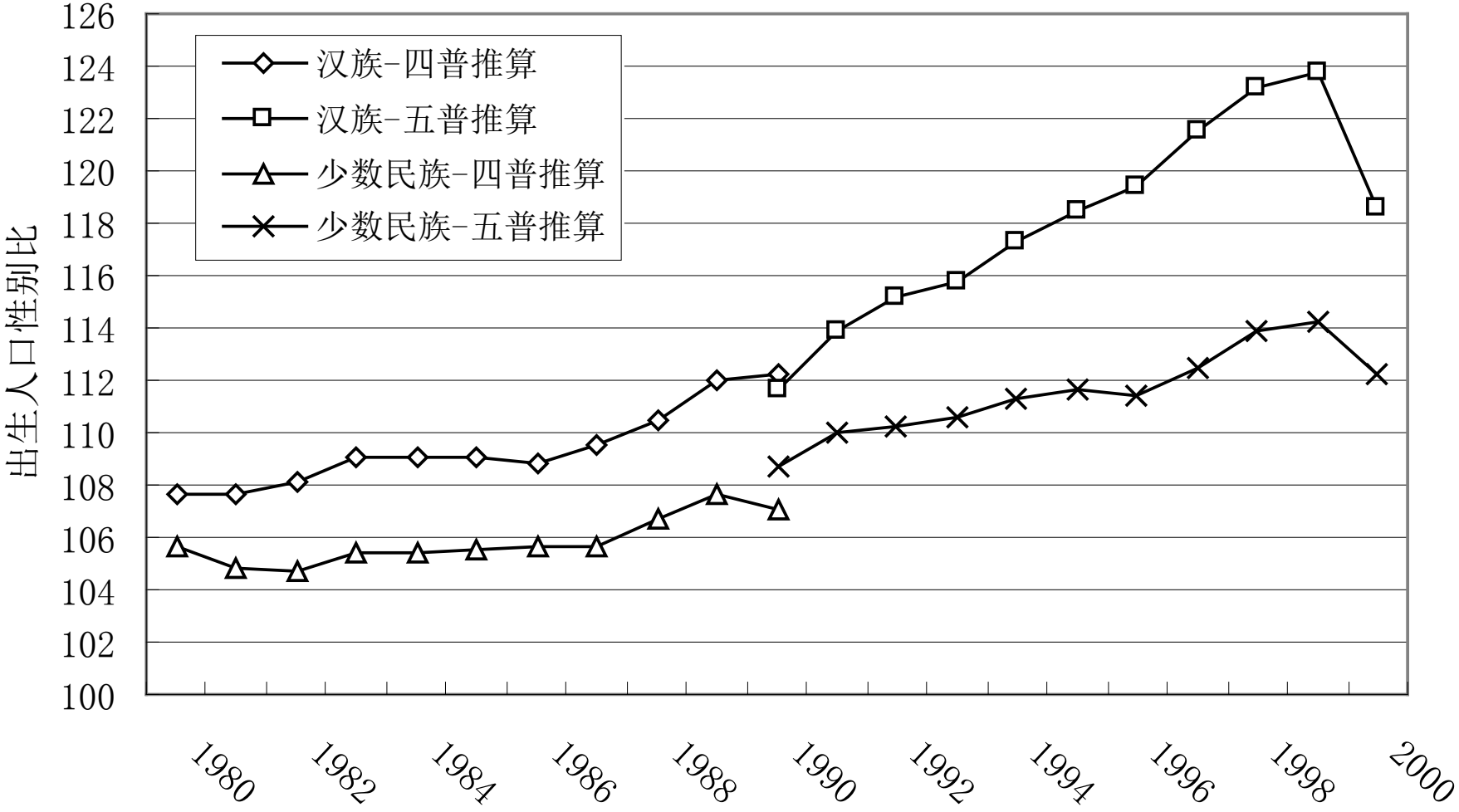
Historical Trend: Rise of SRB

Figure 2 Estimation of SRB from 1970 to 2006



数据来源：中国人口统计年鉴，根据 1988 年千分之二生育节与抽样调查数据计算、1982 年、1990 年和 2000 年人口普查、2005 年 1%人口抽样调查。

图2 1980-2000年少数民族、汉族
出生人口性别比变化情况



中国各普查年份获得的各省、自治区、直辖市出生人口性别比的分布状况

出生性别比范围	1982年	1990年	2000年
103 -	西藏	贵州	西藏
103 - 107	北京、天津、内蒙古、辽宁、吉林、黑龙江、上海、江苏、江西、湖北、湖南、四川、贵州、云南、甘肃、青海、宁夏、新疆	北京、黑龙江、上海、云南、西藏、青海、宁夏、新疆	贵州、新疆
108 - 109	河北、山西、浙江、福建、山东、陕西	山西、内蒙古、吉林、福建、湖北、甘肃	内蒙古、黑龙江、云南、宁夏
110 - 120	安徽、河南、广东、广西	天津、河北、辽宁、江苏、浙江、安徽、江西、山东、河南、湖南、广东、广西、海南、四川、陕西	北京、天津、河北、山西、辽宁、吉林、上海、江苏、浙江、福建、江西、山东、河南、重庆、四川、甘肃、青海
121 +			安徽、湖北、湖南、广东、广西、海南、陕西

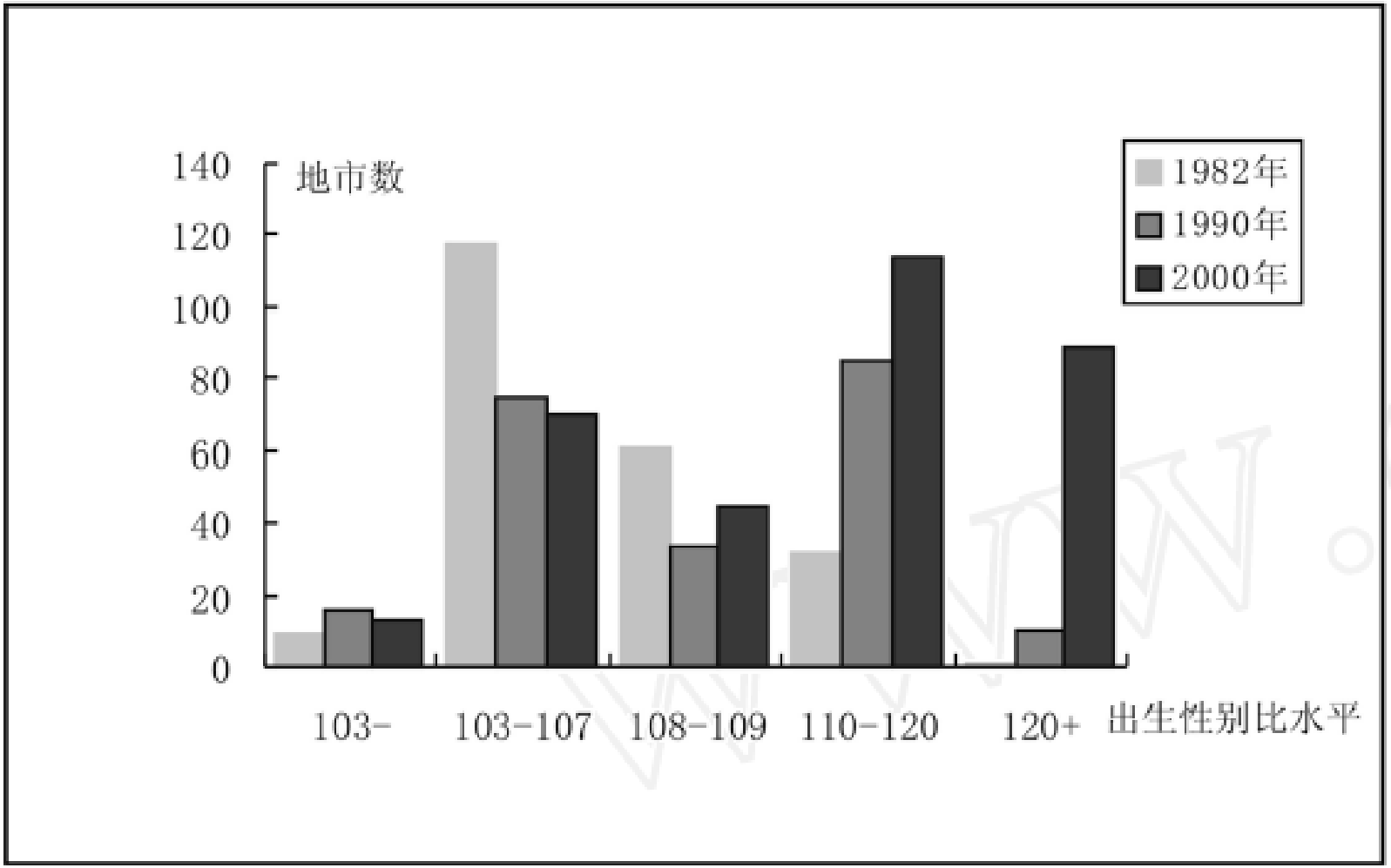
资料来源:刘爽(2007):中国人口出生性别比失常及其思考,甘肃社会科学,2007.6.

2005年中国各省、自治区、直辖市的出生人口性别比分布状况

出生性别比范围	2005年
103 -	
103 - 107	西藏、新疆、宁夏
108 - 109	黑龙江
110 - 120	云南、辽宁、重庆、吉林、浙江、北京、山东、内蒙古、河南、天津、甘肃、四川、山西、青海、上海、广东、河北、广西
121 +	湖北、安徽、陕西、江西、贵州、江苏、海南、福建、湖南

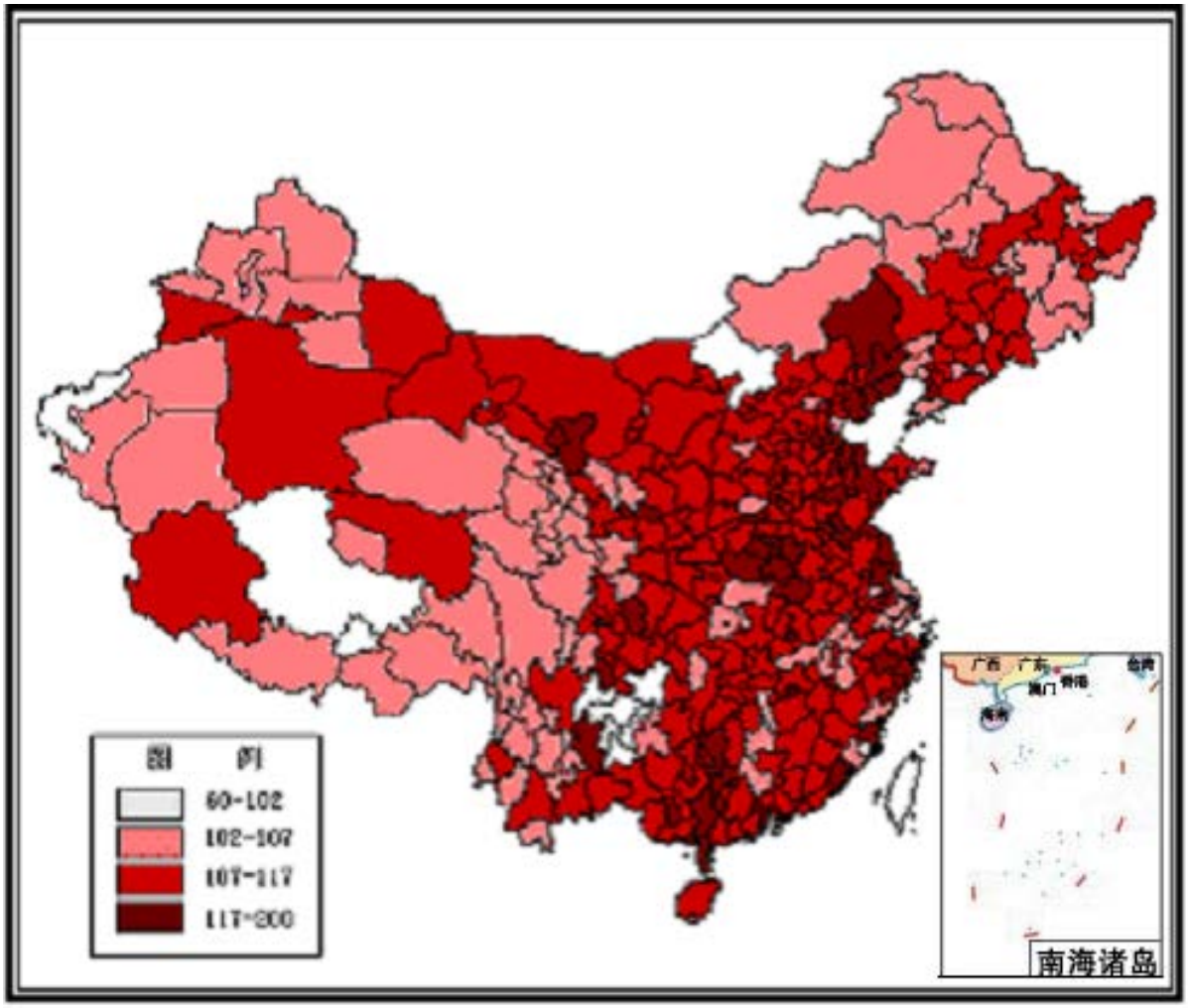
资料来源:刘爽(2007):中国人口出生性别比失常及其思考,甘肃社会科学,2007.6.

中国三次全国人口普查地市人口出生性别比分布

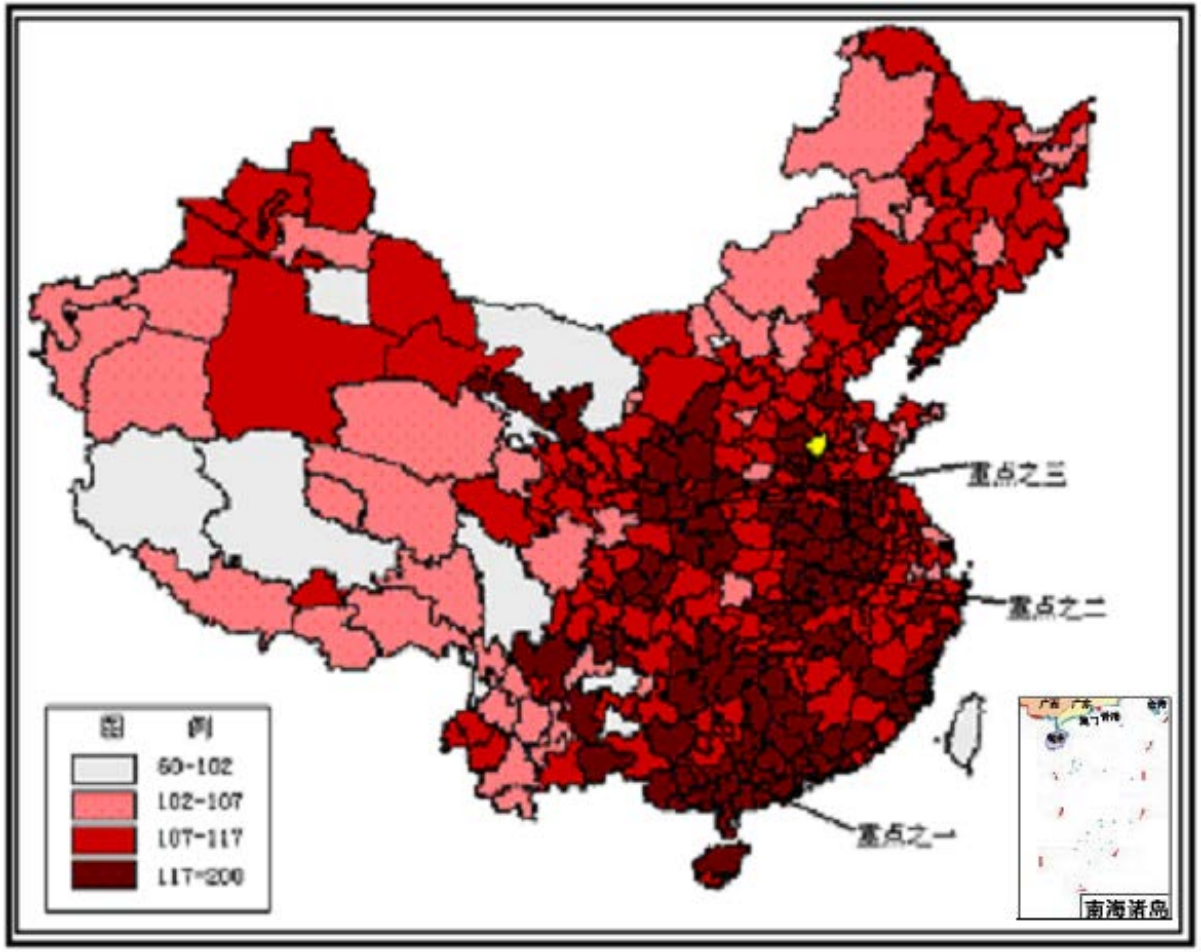


资料来源:刘爽(2007):中国人口出生性别比失常及其思考,甘肃社会科学,2007.6.

1990 Regional Distribution of Higher SRB (China)



2000 Regional Distribution of Higher SRB



SRB Observation Method(1)

TABLE 3.– SEX RATIOS OF LIVE BIRTHS BY PARITY IN HOSPITAL DATA FROM HANOI AND HO CHI MINH CITY

Parity	Hanoi	Ho Chi Minh City		
	2001	1996	1999	2001
All	103.9	109.5	109.0	107.5
First	99.4	110.6	109.4	108.9
Second	108.6	106.8	109.0	106.1
Third and over	156.4	110.7	105.9	104.0

Source: Unpublished data from the Hanoi Obstetric and Gynecology Hospital and from the Tu Du Obstetric and Gynecology Hospital.

Shenzhen Sex Ratio at Second Birth

	Household Registered Population			Migrant Population		
	Boy	Girl	Sex Ratio at Second Birth	Boy	Girl	Sex Ratio at Second Birth
2000	1140	688	165.70	8947	5391	165.96
2001	986	570	172.98	9422	5409	174.19
2002	885	558	158.60	10020	5922	169.20
2003	988	581	170.05	11187	7048	158.73
2004	1083	880	123.07	13933	9164	152.04
2005	1313	951	138.07	16036	10882	147.36
2006	539	454	118.72	6133	4458	137.57

SRB Observation Method(2)

表 6-1 曾生子女性别序列别妇女生育下一孩的性别比

	1 男 1 女		2 男 1 女			1 男 2 女		
时期	MF	FM	MMF	MFM	FMM	MFF	FMF	FFM
50-59	107.2	108.75	97.95	113.22	105.68	92.35	110	92.82
60-69	104.45	108.31	101.73	99.84	101.59	111.25	109.29	117.52
70-79	104.3	104.34	106.43	105.1	101.18	99.2	113.19	113.93
80-88	108.62	104.02	98.36	106.87	100.91	125.09	103.76	118.57
平均	106.14	106.36	101.12	106.26	102.34	106.97	109.06	110.71

数据来源：引自马漱逸、冯立天、陈友华、冷眸，《出生性别比新理论与应用》，首都经济贸易大学出版社，1998，p45-59.根据1988年中国千分之二人口生育节育抽样调查原始数据与修正后的权数汇总得出。

SRB Observation Method(3)

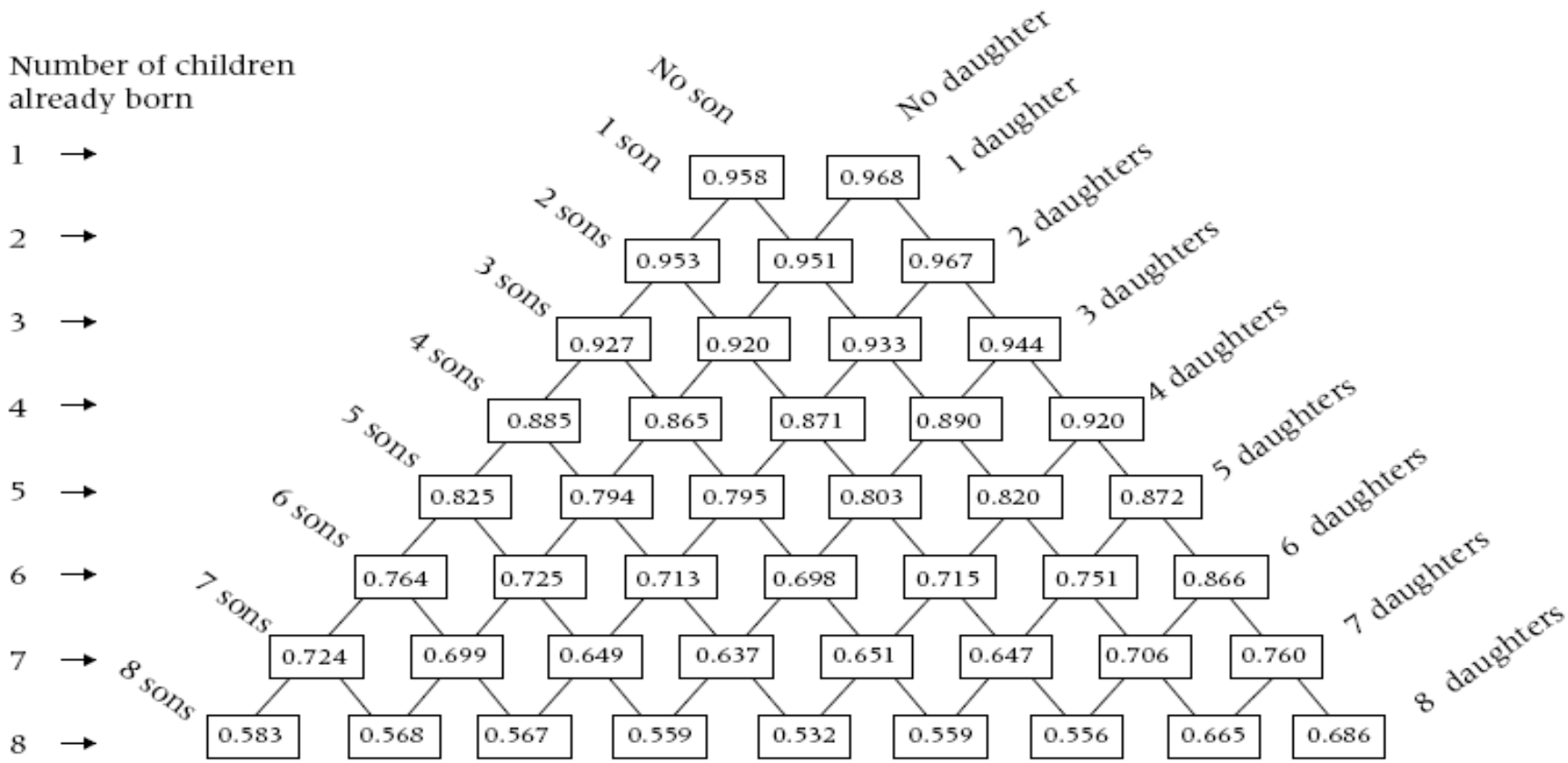
TABLE 6.– SEX RATIOS AT THIRD BIRTH BY PREVIOUS SEX DISTRIBUTION OF CHILDREN BORN TO WOMEN

Sex of first 2 children	Boy	Girl	Total	Sex ratio
2 girls	144	85	229	169.4
1 girl 1 boy	244	248	492	98.4
2 boys	108	136	244	79.4
Total	496	469	965	105.8

Source: Vietnam Living Standards Survey 1997-98.

SRB Observation Method(4)

FIGURE 3 Parity progression ratios by sex composition of preceding children

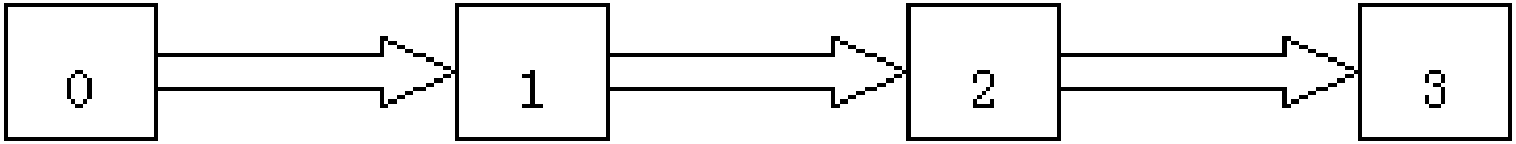


SOURCE: China's 1982 One-per-Thousand-Population Fertility Survey data.

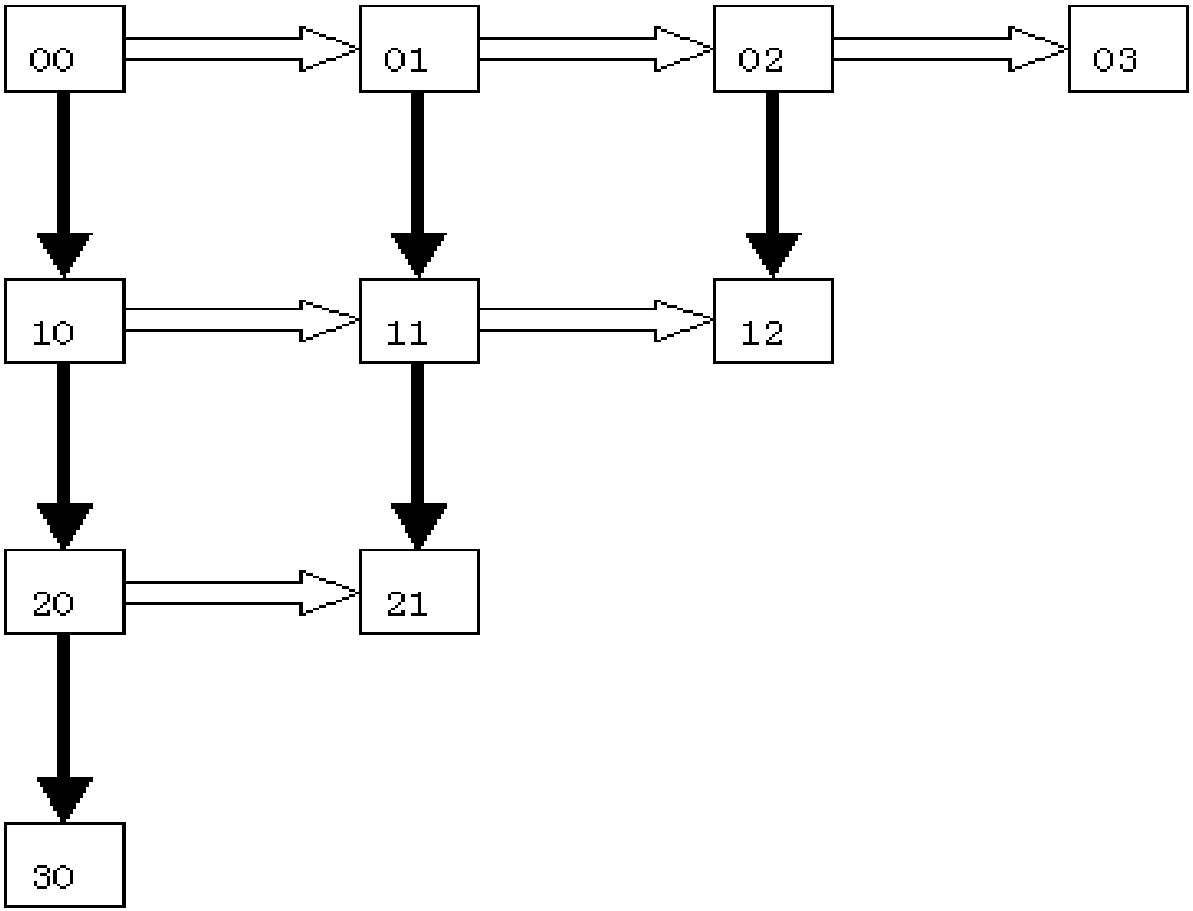
The Innovation of SRB Research Methods

- Theory
- Indicator
- Method
- Model

Fertility History



Parity-Sex Progression State Spaces



New Approaches to SRB Researches

- SRB researches (constant->variable)
- SRB researches (child->woman)
- SRB researches (point estimation->status space)

Parity and Birth Sex Progression Ratio

$$\mathrm{P}SR_{\mathrm{m,f}}(t) = \frac{B^{(1)}_{m,f}(t)}{B^{(2)}_{m,f}(t)} * 100$$

Research Background

- Decline in fertility
- Continuous rise in SRB
- Gender Choice?
- Who choose?

Global Comparison of SRB

- Is China's SRB really higher?
- Historically have China and other countries ever had such a high SRB?
- Any racial/ethnic disparity in SRB?

How Do We Research SRB?

- The history of SRB research methods
- The innovation of SRB research methods

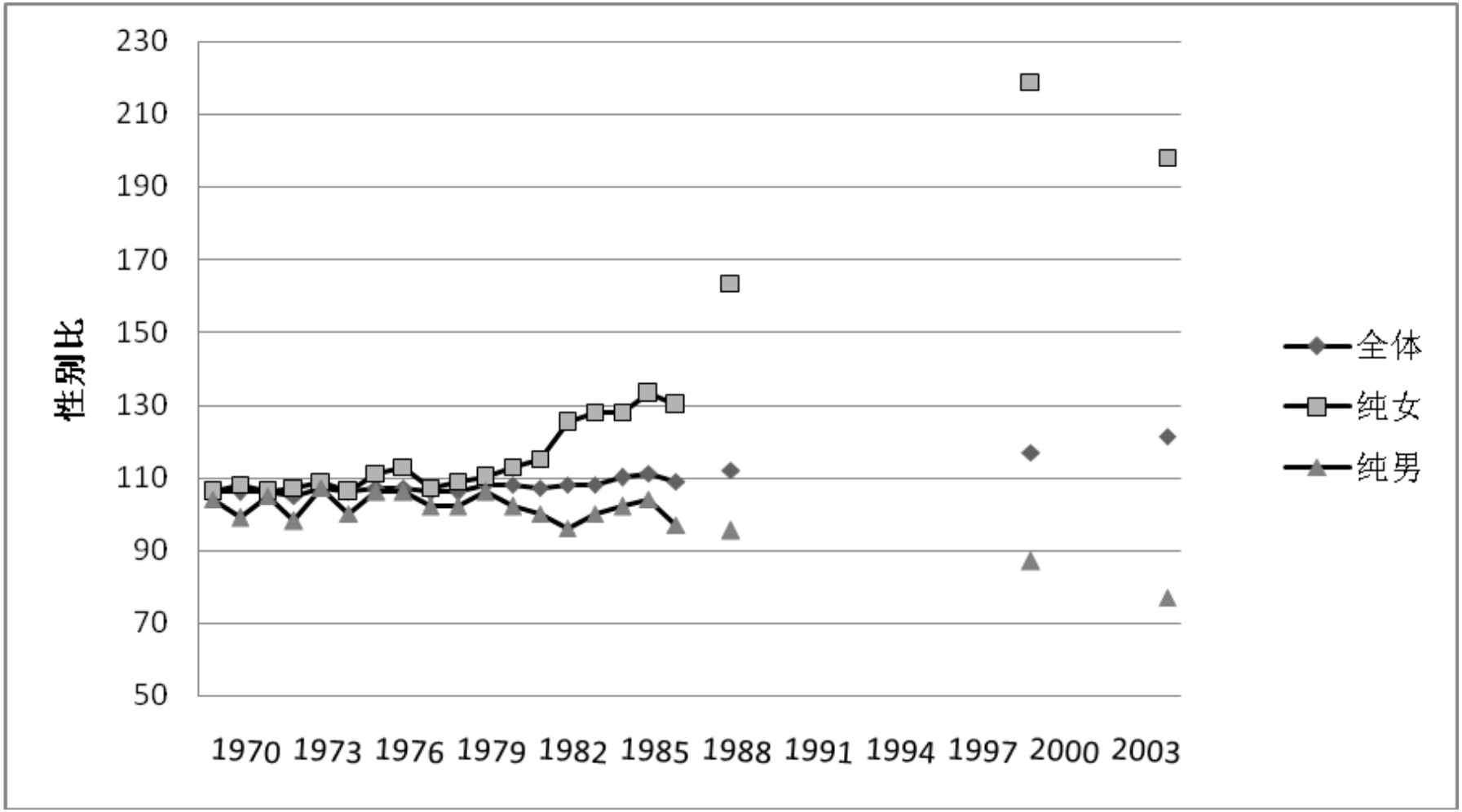
How Should We Research SRB Issues?

- Levels
- Mechanisms
- Research Groups
- Monitoring
- Child and His / Her Mother

Data Source

- The sampling raw data from 1990, 2000 Census and 1% of sampling raw data from 2005 Census.

China Classified Birth Sex Ratio（1970-2005）



Source: calculations based on 1% of sampling data of 2005 Census, data of 1990 and 2000 Census, and China's 1982 Two-per-Thousand-Population Fertility Control survey data. 1970-1987 data source: YANG Shuzhang, WANG Guangzhou (2006), *Fertility Decline and Imbalance of Sex Ratio under Birth Control*[J], Market & Demographic Analysis, No 4, 2006: 18-28.

Parity-Sex Progression State and Process

1990 China Parity and Birth Sex Progression Ratio

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}	PSR_{05}		104.70	147.78	219.43	214.69	218.89	260.66
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}	PSR_{14}			99.43	115.11	138.17	130.94	160.42	
PSR_{20}	PSR_{21}	PSR_{22}	PSR_{23}				76.59	88.54	115.29	119.42		
PSR_{30}	PSR_{31}	PSR_{32}					56.72	96.73	72.16			
PSR_{40}	PSR_{41}						56.45	94.44				
PSR_{50}												

2000 China Parity and Birth Sex Progression Ratio

PSR_{00}	**PSR_{01}**	**PSR_{02}**	**PSR_{03}**	**PSR_{04}**	**PSR_{05}**		**105.59**	**209.45**	**353.74**	**365.08**	**366.67**	**266.67**
PSR_{10}	**PSR_{11}**	**PSR_{12}**	**PSR_{13}**	**PSR_{14}**			**88.45**	**130.82**	**169.72**	**166.67**	**75.00**	
PSR_{20}	**PSR_{21}**	**PSR_{22}**	**PSR_{23}**				**68.16**	**97.06**	**90.48**	**125.00**		
PSR_{30}	**PSR_{31}**	**PSR_{32}**					**84.21**	**31.82**	**50.00**			
PSR_{40}	**PSR_{41}**						**100.00**	**75.00**				
PSR_{50}												

Source: calculations based on 2000 China’s One-per-Thousand-Population survey data

2005 China Parity and Birth Sex Progression Ratio

PSR_{00}	**PSR_{01}**	**PSR_{02}**	**PSR_{03}**	**PSR_{04}**	**PSR_{05}**		**110.93**	**189.73**	**341.38**	**261.54**	**233.33**	
PSR_{10}	**PSR_{11}**	**PSR_{12}**	**PSR_{13}**	**PSR_{14}**			**78.82**	**115.29**	**177.78**	**160.00**		
PSR_{20}	**PSR_{21}**	**PSR_{22}**	**PSR_{23}**				**45.98**	**35.29**	**62.50**			
PSR_{30}	**PSR_{31}**	**PSR_{32}**					**100.00**	**75.00**				
PSR_{40}	**PSR_{41}**											
PSR_{50}												

Source: calculations based on 2005 China’s One-per-Thousand-Population survey data

1990 Guangdong Parity and Birth Sex Progression Ratio

PSR_{00}	**PSR_{01}**	**PSR_{02}**	**PSR_{03}**	**PSR_{04}**	**PSR_{05}**		106.67	131.60	192.63	190.91	161.29	257.14
PSR_{10}	**PSR_{11}**	**PSR_{12}**	**PSR_{13}**	**PSR_{14}**			106.15	132.70	174.50	154.72	156.25	
PSR_{20}	**PSR_{21}**	**PSR_{22}**	**PSR_{23}**				93.64	80.81	74.47	266.67		
PSR_{30}	**PSR_{31}**	**PSR_{32}**					97.06	81.82	66.67			
PSR_{40}	**PSR_{41}**						30.00	100.00				
PSR_{50}							100.00					

Source: calculations based on 1990 China's 1% population survey data.

2000 Guangdong Parity and Birth Sex Progression Ratio

PSR_{00}	**PSR_{01}**	**PSR_{02}**	**PSR_{03}**	**PSR_{04}**	**PSR_{05}**		120.67	292.93	400.00	361.54	466.67	800.00
PSR_{10}	**PSR_{11}**	**PSR_{12}**	**PSR_{13}**	**PSR_{14}**			122.08	185.15	267.74	230.00	62.50	
PSR_{20}	**PSR_{21}**	**PSR_{22}**	**PSR_{23}**				65.38	80.77	109.09	166.67		
PSR_{30}	**PSR_{31}**	**PSR_{32}**					50.00					
PSR_{40}	**PSR_{41}**						66.67					
PSR_{50}												

Source: calculations based on 2000 China’s One-per-Thousand-Population survey data

2005 Guangdong Parity and Birth Sex Progression Ratio

PSR_{00}	**PSR_{01}**	**PSR_{02}**	**PSR_{03}**	**PSR_{04}**	**PSR_{05}**		108.07	241.61	272.73	200.00		
PSR_{10}	**PSR_{11}**	**PSR_{12}**	**PSR_{13}**	**PSR_{14}**			81.98	130.43	133.33			
PSR_{20}	**PSR_{21}**	**PSR_{22}**	**PSR_{23}**				44.44					
PSR_{30}	**PSR_{31}**	**PSR_{32}**										
PSR_{40}	**PSR_{41}**											
PSR_{50}												

Source: calculations based on 2005 China’s One-per-Thousand-Population survey data

Distribution of Women $PSR_{m,f}$ ($PSR_{m,f}$ = 105)

P_{00}	P_{01}	P_{02}	P_{03}	P_{04}		1	0.487805	0.237954	0.116075	0.056622
P_{10}	P_{11}	P_{12}	P_{13}			0.512195	0.499703	0.365636	0.237812	
P_{20}	P_{21}	P_{22}				0.262344	0.383918	0.374554		
P_{30}	P_{31}					0.134371	0.262188			
P_{40}						0.068824				

China $PSR_{m,f}$ Distribution of Women of Childbearing Age

SRB	1 boy **(10)**	1 boy and 1 girl**(11)**	2 boys and two girls**(22)**
102.00	0.504950	0.4999510	0.3749265
105.00	0.512195	0.4997030	0.3745540
107.00	0.516908	0.4994282	0.3741428
110.92（1990)	0.511480	0.5478320	0.4295610
116.86（2000）	0.513595	0.6017580	0.4869710
120.49 (2005)	0.525909	0.6045590	0.6173911

Ideal Number of Children

Children		2003 in 13 provinces of rural China	
		(No. of Cases)	(%)
0		9	0.1
1		1947	17.3
2		8239	73.2
	1 boy 1 girl	7719	68.69
3+		1055	9.3

YFR(95%) & SRB Goal
(M: Male; F: Female)

	SRB=102				SRB=105				SRB=107			
m \ F	0	1	2	3	0	1	2	3	0	1	2	3
0	0.00	1.95	3.96	5.98	0.00	1.98	4.02	6.08	0.00	1.99	4.05	6.13
1	1.92	2.94	4.46	6.22	1.90	2.94	4.49	6.31	1.88	2.94	4.53	6.36
2	3.90	4.41	5.43	6.83	3.85	4.38	5.43	6.88	3.82	4.36	5.45	6.91
3	5.84	7.84	6.77	7.80	5.77	7.74	6.71	7.79	5.72	7.65	5.71	7.80

1990, 2000 and 2005 China YFR(95%) under Parity and Birth Sex Progression Ratio

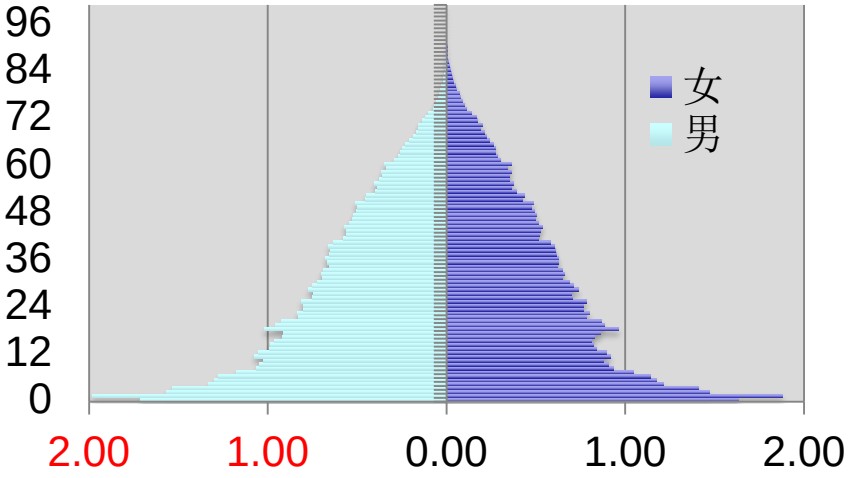
1990				2000				2005			
0.00	1.92	4.08	6.17	0.00	1.90	4.17	6.28	0.00	1.87	4.00	6.27
1.79	2.77	4.23	5.52	1.69	2.65	4.23	5.51	1.69	2.62	4.07	5.35
3.78	4.25	5.09		3.69	4.14	5.03		3.73	4.14	5.02	
5.80	7.72			5.80	7.71			5.96	7.84		

Conclusion

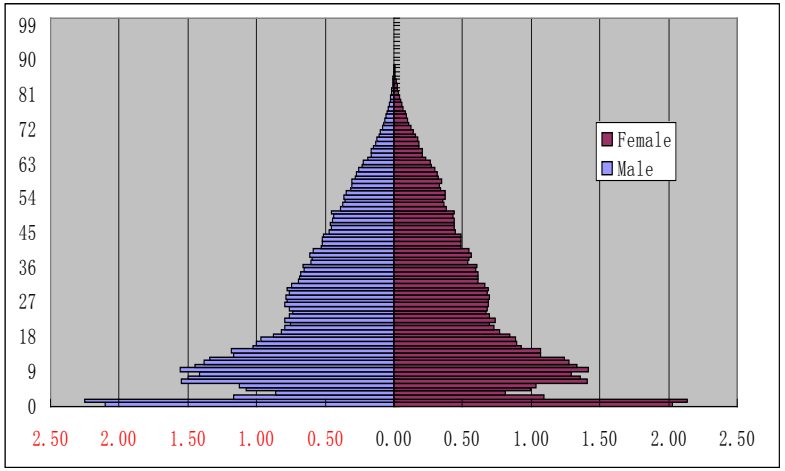
- China's sex ratio will continue its momentum of continuous rise.
- **The birth sex progression ratio** in families with daughters only rises while **that in families with sons only** is relatively low.
- As China **parity and birth sex progression ratio rises**, families no longer want two children and more, and have started to **have only one child.**
- **Multi-channel data validation**

Rise of SRB and Marriage Squeeze

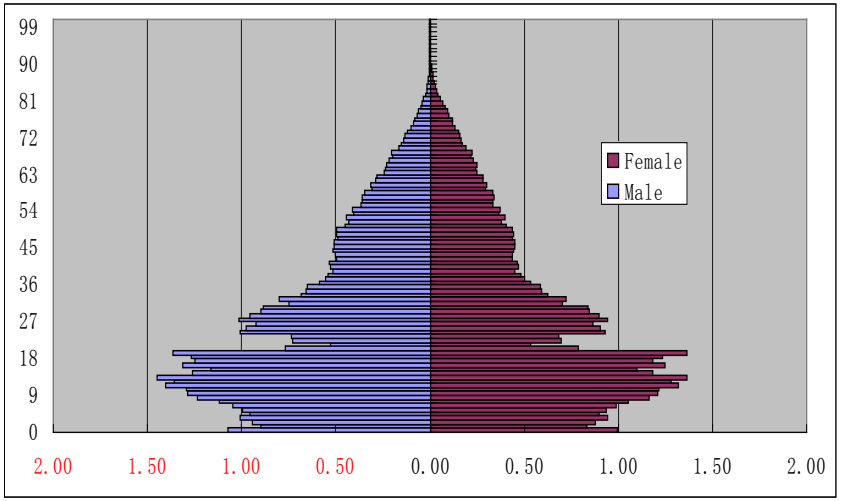
1953 Age Structure



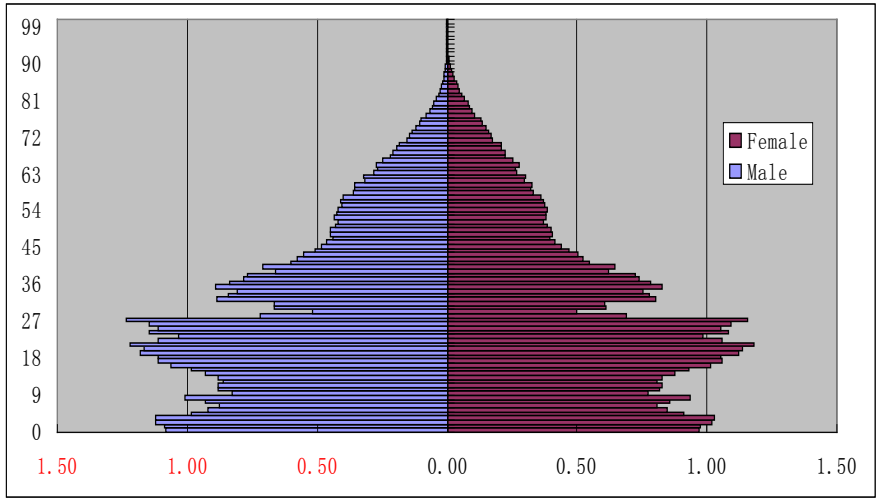
1964 Age Structure



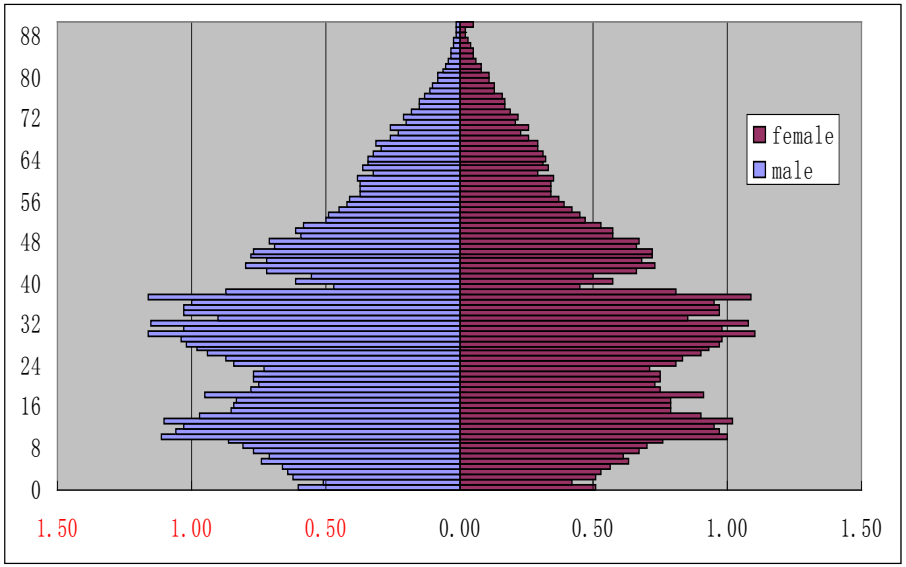
1982 Age Structure



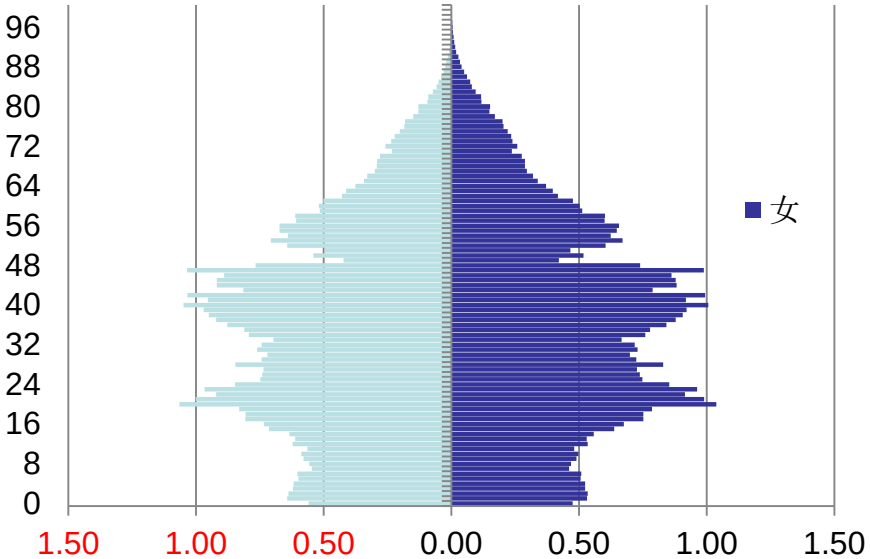
1990 Age Structure



2000 Age Structure



2010 Age Structure



Changes of China Age Structure

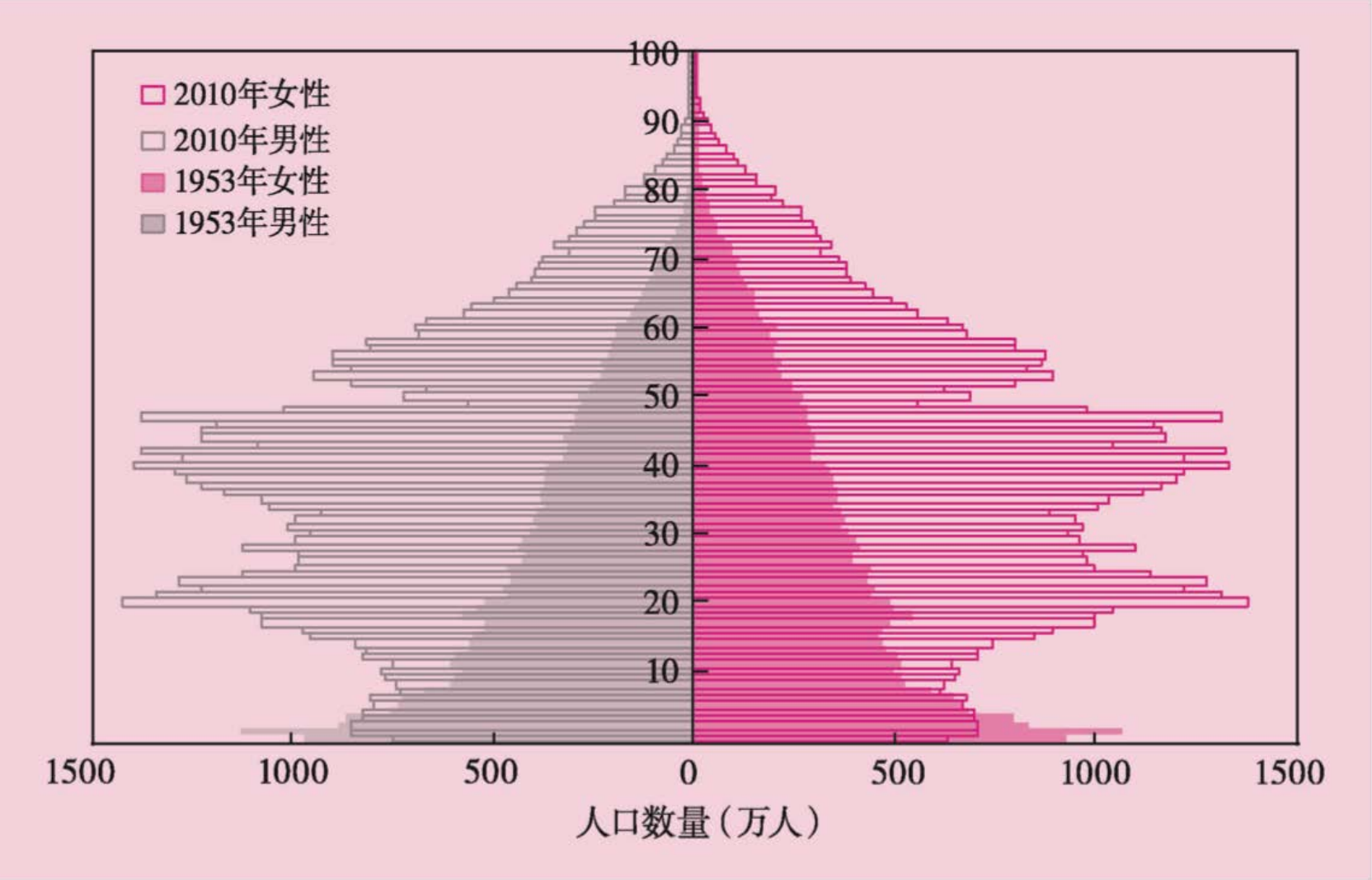


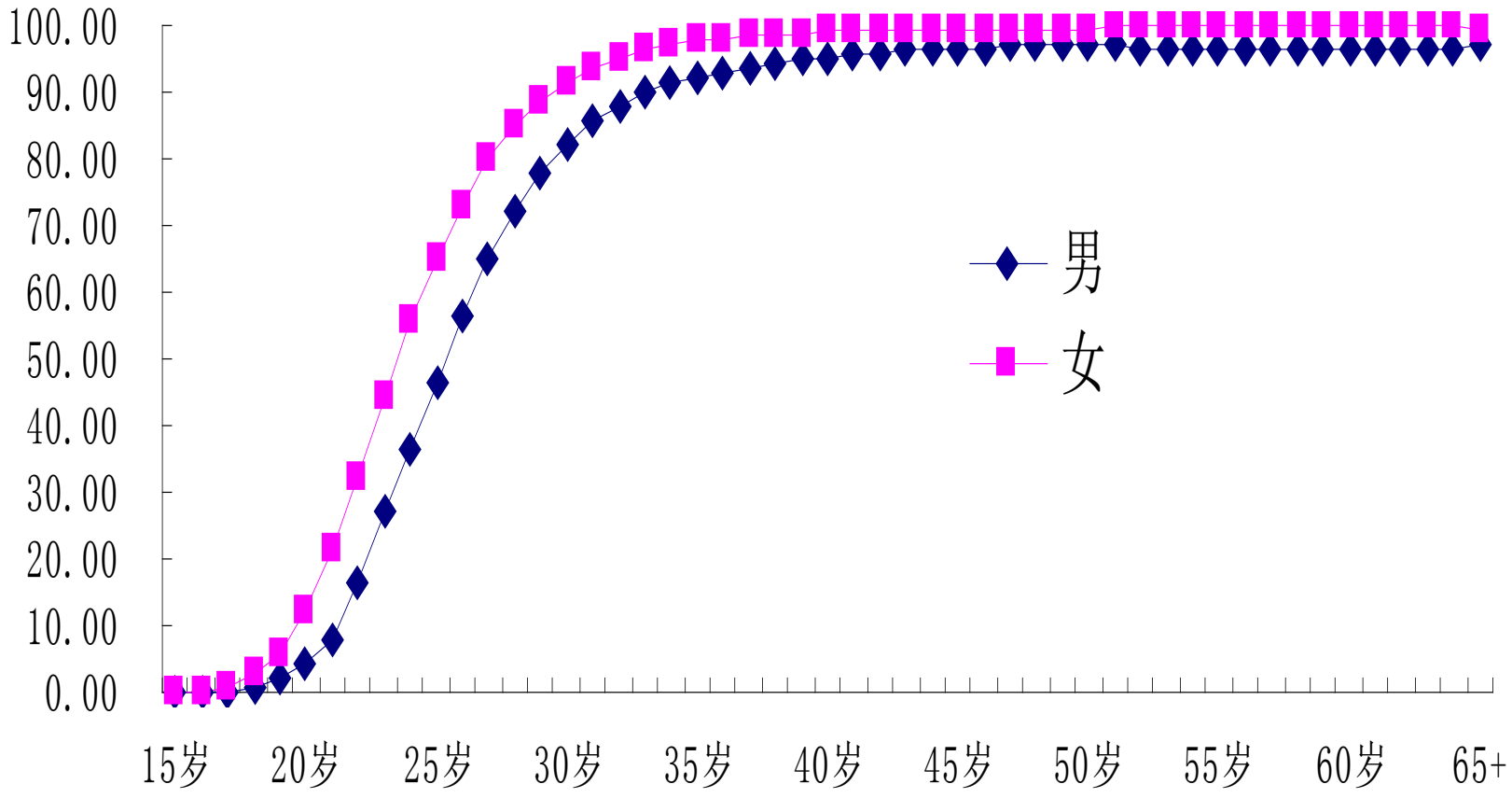
图 1　1953～2010 年人口年龄结构变化

注：1953、2010 年人口普查汇总数据。

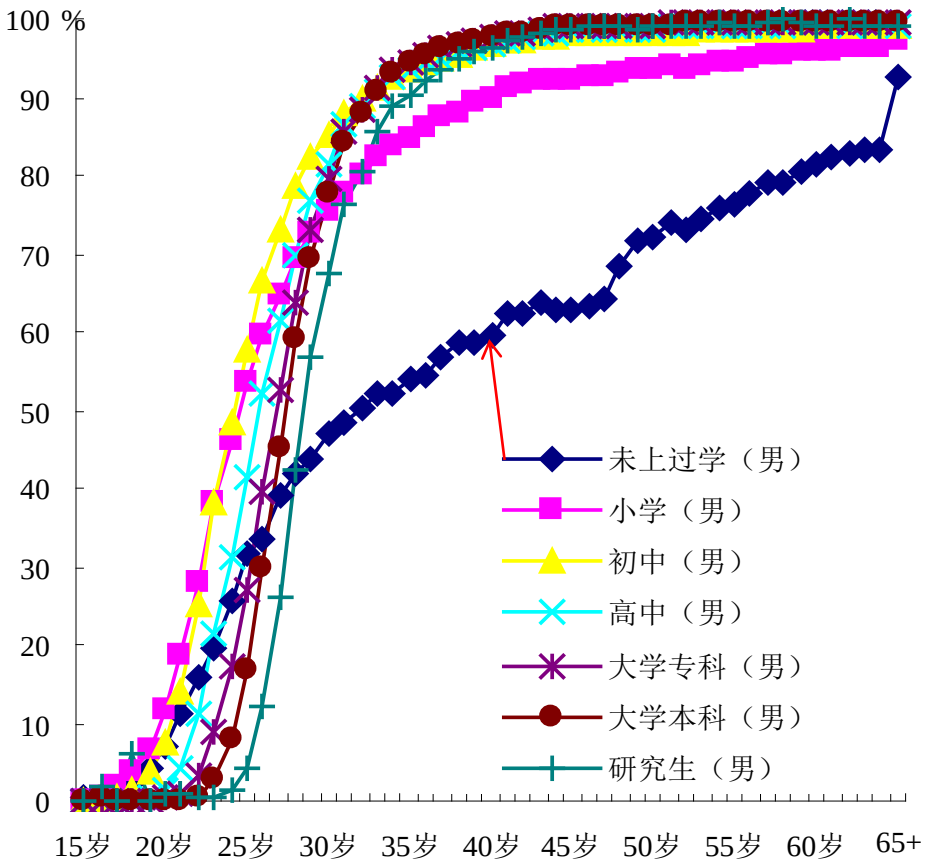
SRB:1982-2017

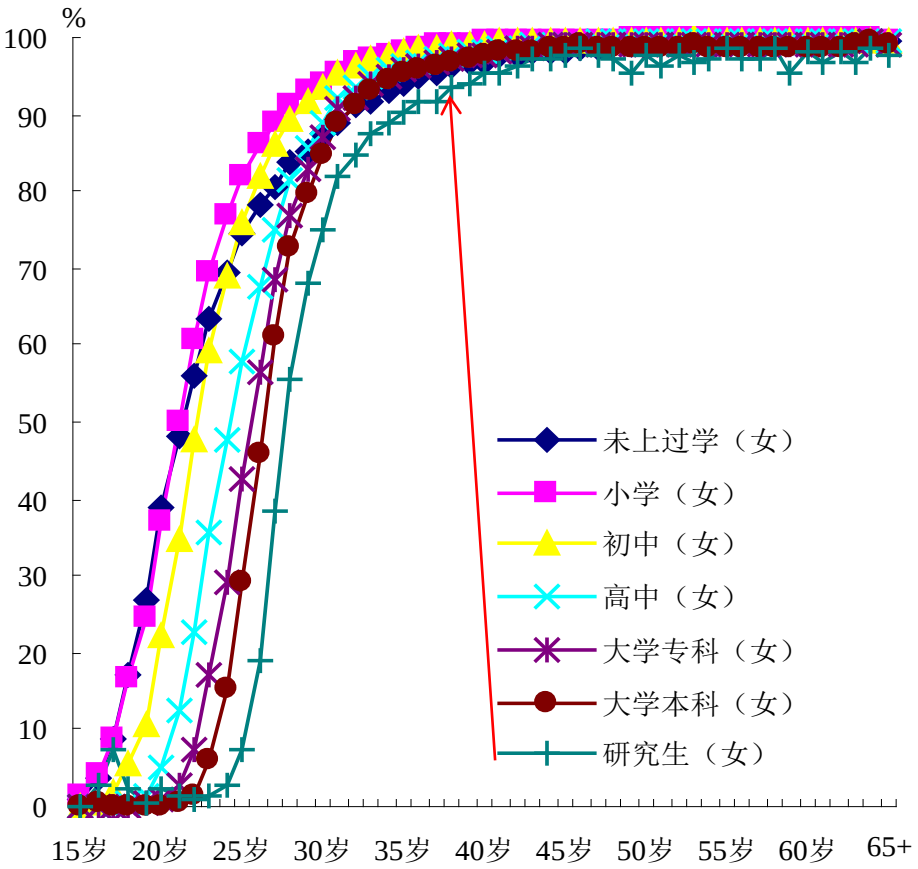
Year	SRB
1982	107.19
1990	110.92
2000	116.86
2005	120.49
2009	119.45
2010	118.06
2015	113.54
2017	113.31*

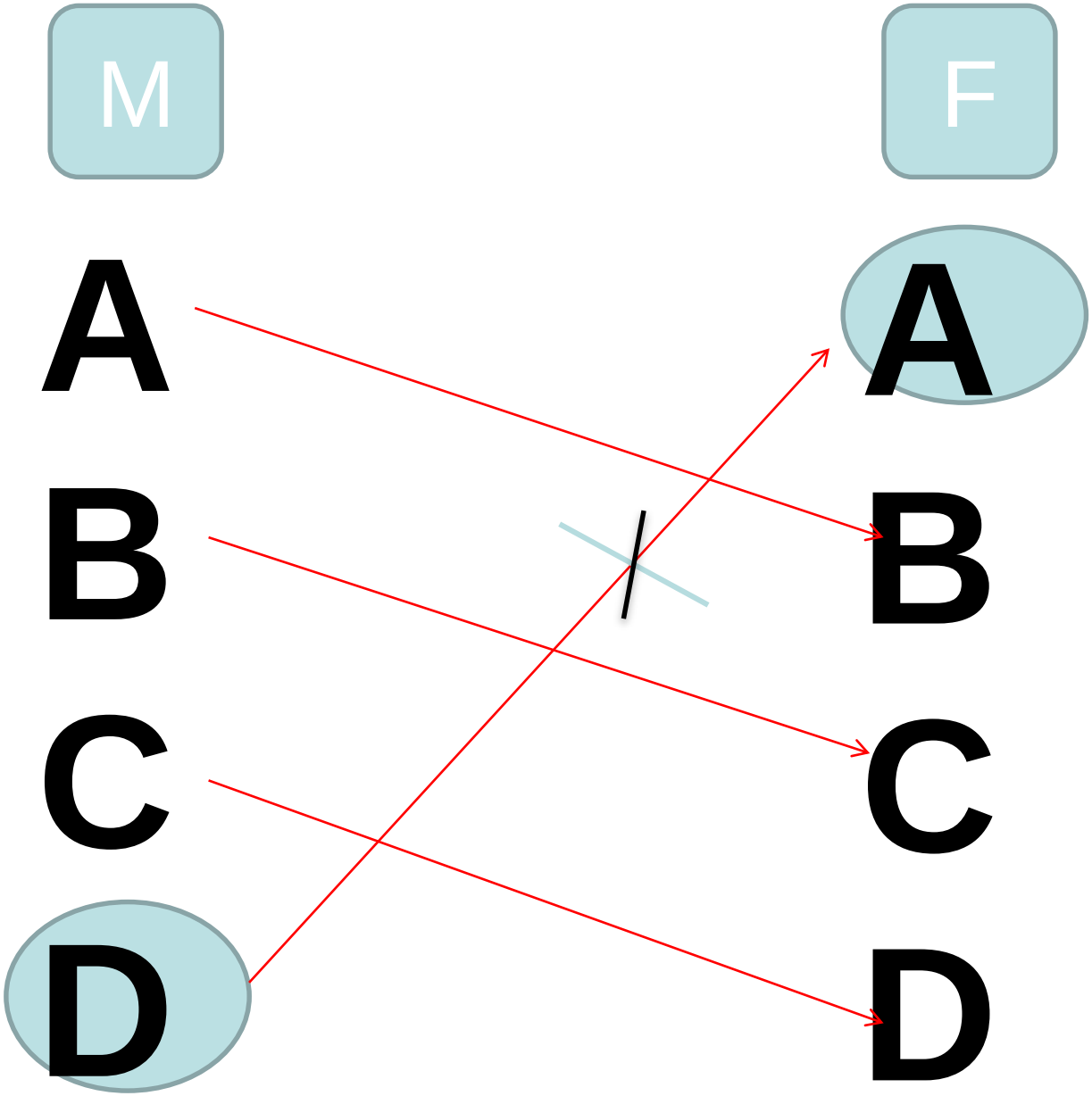
Marriage Rate of China Population Aged 15 and Above



2010 Share of China Married Male/Female Population Aged 15 and Above






M
F
A
B
C
D
A
B
C
D

Marriage Squeeze

35～59 岁男性未婚人口数量与比例

年份	35-59 岁（万人）	未婚（万人）	丧偶（万人）	离婚（万人）	无配偶（万人）	未婚比例（%）
1990	14971.10	744.19	465.96	196.12	1406.28	4.97
2000	19140.05	770.71	386.20	307.17	1464.08	4.03
2010	24637.43	1033.22	386.70	580.20	2000.12	4.19
小学及以下						
1990	9278.65	643.33	389.06	146.30	1178.69	12.70
2000	7215.42	558.43	251.48	129.58	939.49	13.02
2010	5988.30	540.12	188.45	142.62	871.20	14.55

35~59 岁男性未婚人口数量估计　单位：万人

	均值	下限	上限
2010	1042.80	957.50	1135.07
2015	1478.03	1366.61	1552.89
2020	1290.01	1201.23	1413.62
2025	1267.38	1119.40	1371.84
2030	1444.95	1314.39	1575.52
2035	1706.09	1502.40	1972.45
2040	1944.59	1690.42	2275.37
2045	2277.11	1948.08	2816.79
2050	2714.08	2327.59	3335.58

Conclusion

- As a result of SRB rises, marriage squeeze becomes increasingly severe. It is projected that male population who stay unmarried throughout lifetime (aged 35-59) will reach about 30 million by 2050, about 2.6-3.3 times that of current size.

Methods of Monitoring the Changes of Sex Ratio at Birth

Research Background

- Continuous rise in SRB
- Less effective SRB management measures
- Relevance between SRB and fertility policies
- The appearance of tipping point?
- 2005:120.49；2008：120.56 ；2009:119.45

Year	2000	2001	2002	2003	2004	2005	2006	2007
Total	116.49	116.69	118.64	117.31	115.59	*114.47*	*112.76*	110.63
City Y	132.34	133.9	131.39	123.41	118.47	*119.64*	*111.39*	109.23
City Z	125.42	120.11	126.34	126.52	123.55	*125.97*	*116.51*	115.98
City M	117.07	119.22	123.13	120.24	117.81	*114.38*	*111.5*	109.92
City YF	109.98	111.21	113.56	116.72	113.00	*110.77*	*107.65*	107.54

Research Topics and Related Researches

How’s the SRB trend determined?

- SRB represents a sensitive indicator.
- Relatively larger number of samples are required.
- High parity SRB.

Sex Ratio at Next Birth of Parity-Sex-Specific Women

	1男1女			2男1女				1男2女		
时期	MF	FM		MMF	MFM	FMM		MFF	FMF	FFM
50-59	107.2	108.75		97.95	113.22	105.68		92.35	110	92.82
60-69	104.45	108.31		101.73	99.84	101.59		111.25	109.29	117.52
70-79	104.3	104.34		106.43	105.1	101.18		99.2	113.19	113.93
80-88	108.62	104.02		98.36	106.87	100.91		125.09	103.76	118.57
平均	106.14	106.36		101.12	106.26	102.34		106.97	109.06	110.71

Source: MA Yingtong, FENG Litian, CHEN Youhua, LENG Mou, *New Theory on Sex Ratio at Birth and Its Application*, Beijing: Capital University of Economics & Business Press,1998:45-59. China's 1988 two-per-thousand-population fertility control survey raw data and revised data.

Methods of Monitoring the Changes of Sex Ratio at Birth

- **Demographic Monitoring Method**
- **Statistic Monitoring Method**

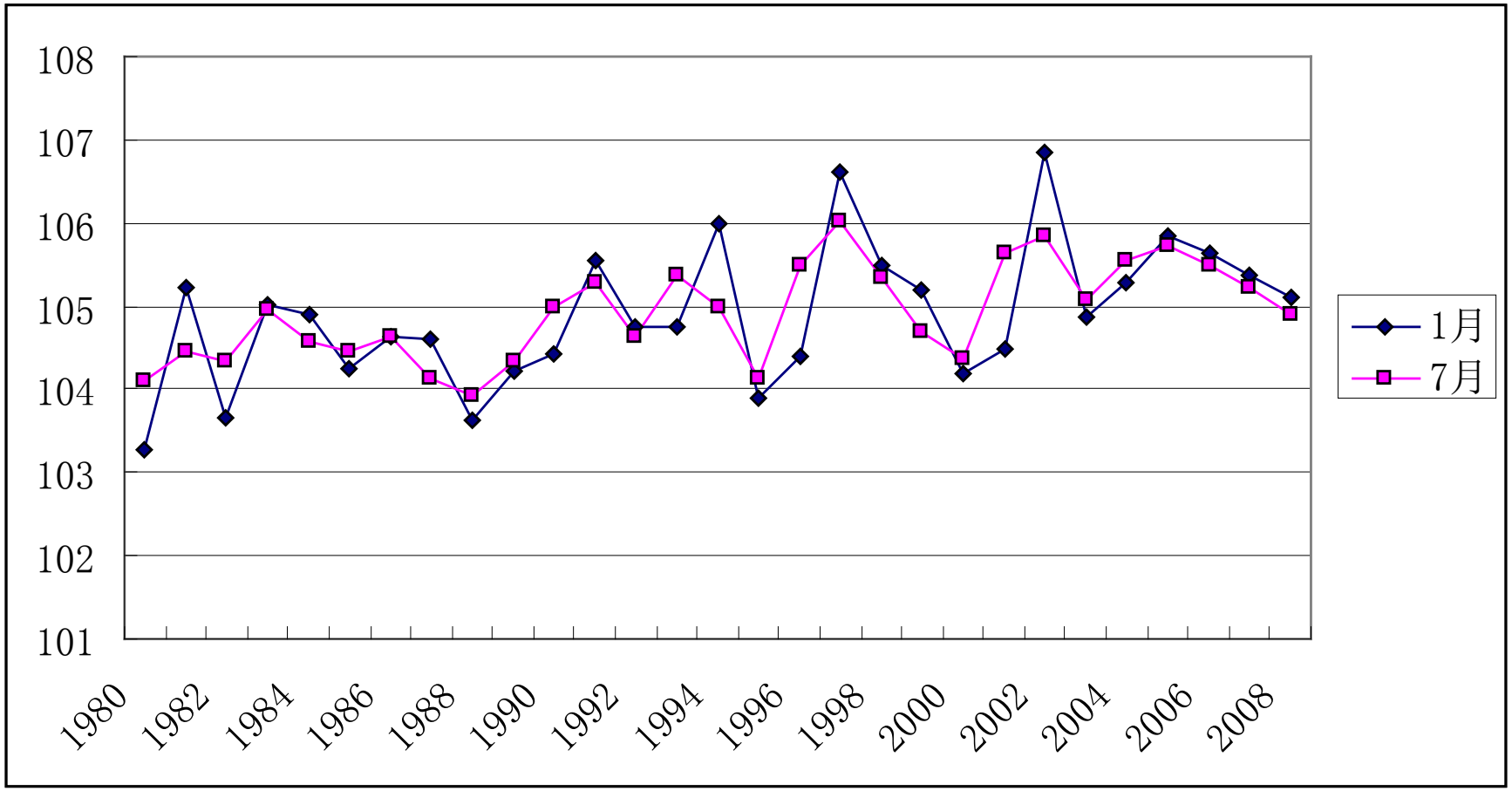
Major Sources of Empirical Research Data

- raw data of 1970, 1990, and 2000 U.S. Census; raw data of 1995 US CPS survey.
- raw data of 1982, 1990, and 2000 China Census; 2005 China 1% population survey raw data.
- 1982 China 1‰ population fertility survey raw data.

Features of SRB Changes

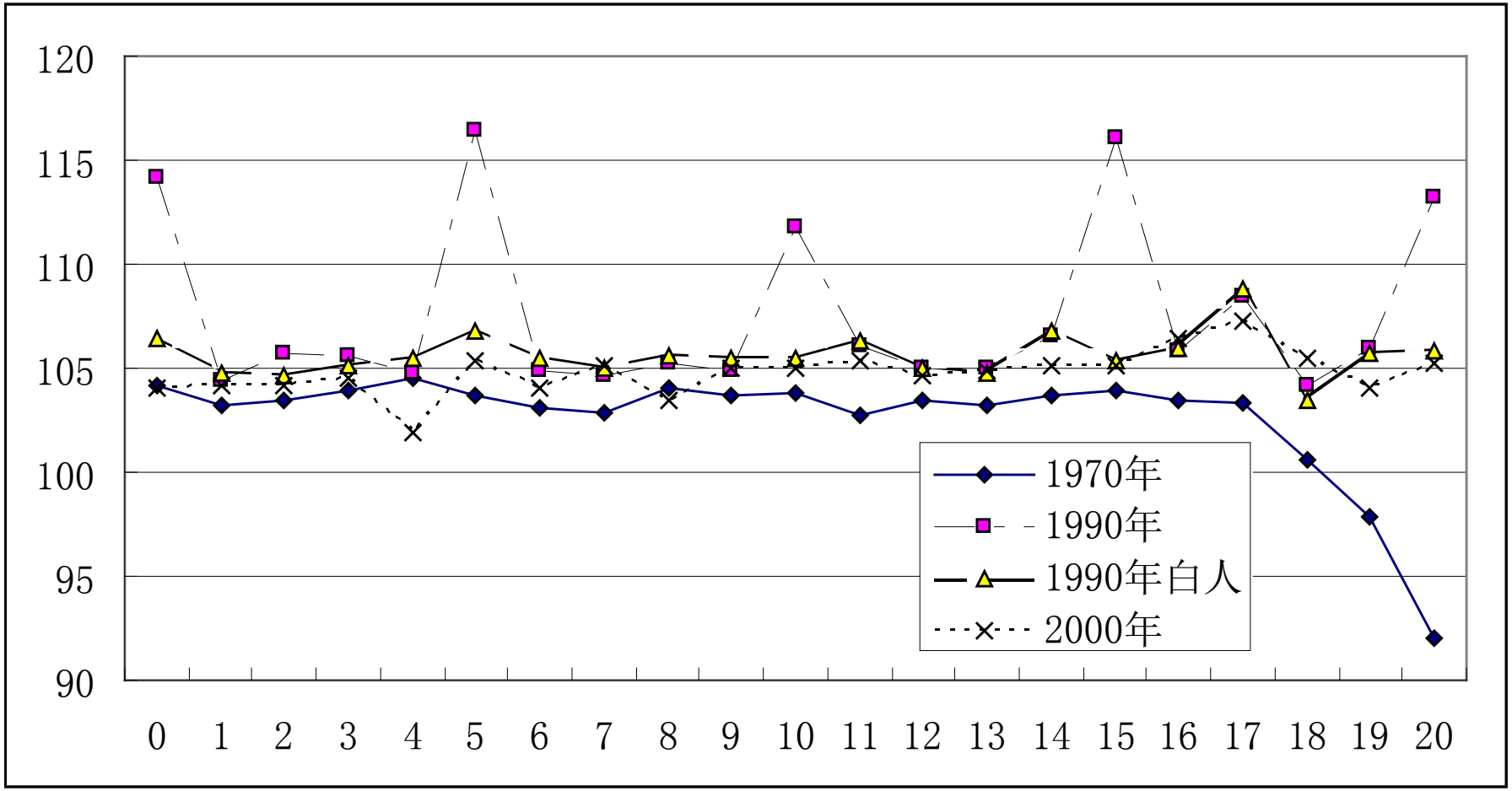
- Basic Pattern of SRB Changes: fluctuation within normal range. SRB remains stable and will not see a continuous rise.

1980-2008 Slovakia Sex Ratio of the Zero-year-old

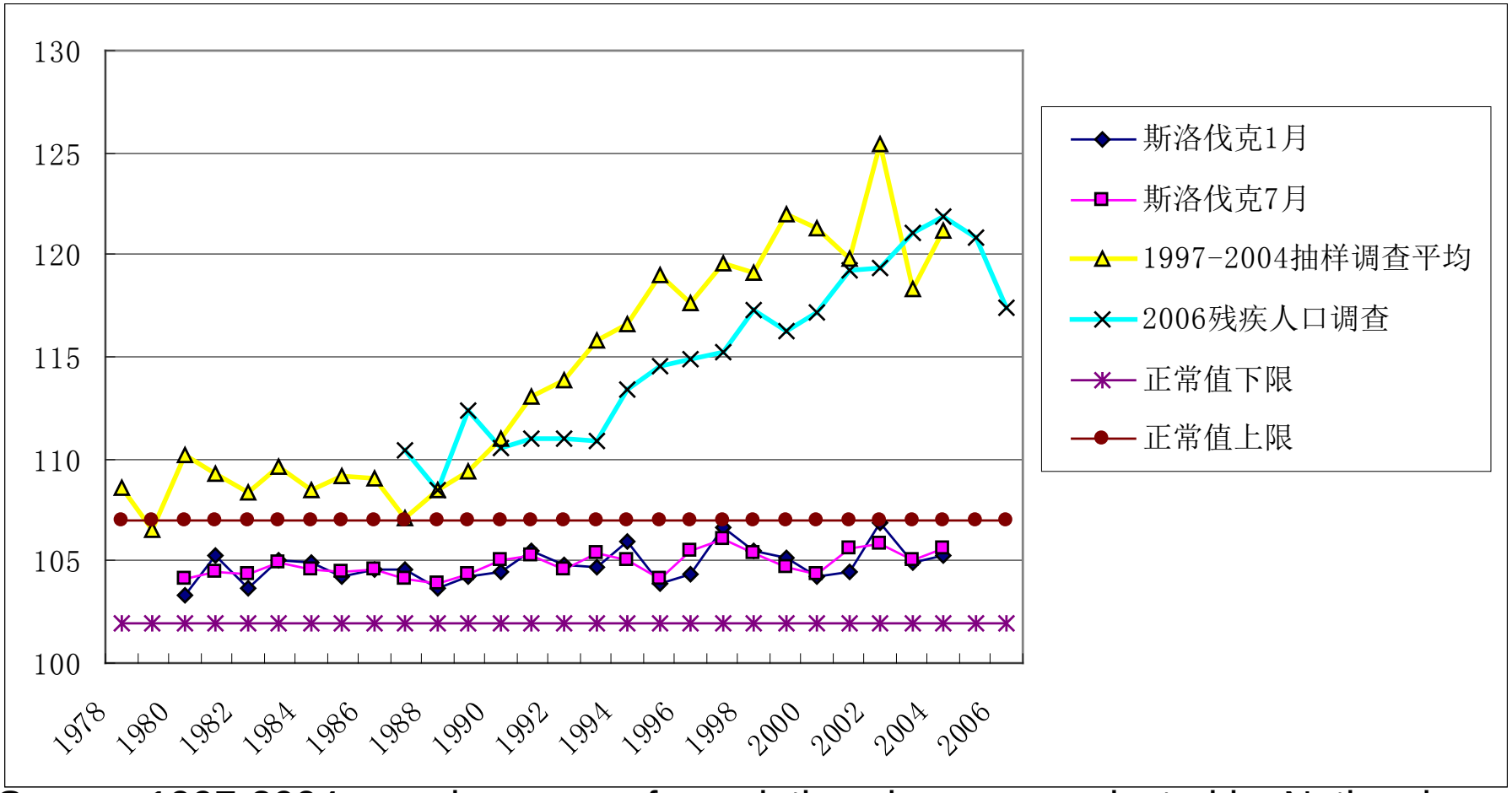


Source: calculations based on data in http://www.infostat.sk/slovakpopin/agestr.htm

Estimation of US SRB Since 1960



Source: raw data of 1970, 1990, and 2000 U.S. Census.



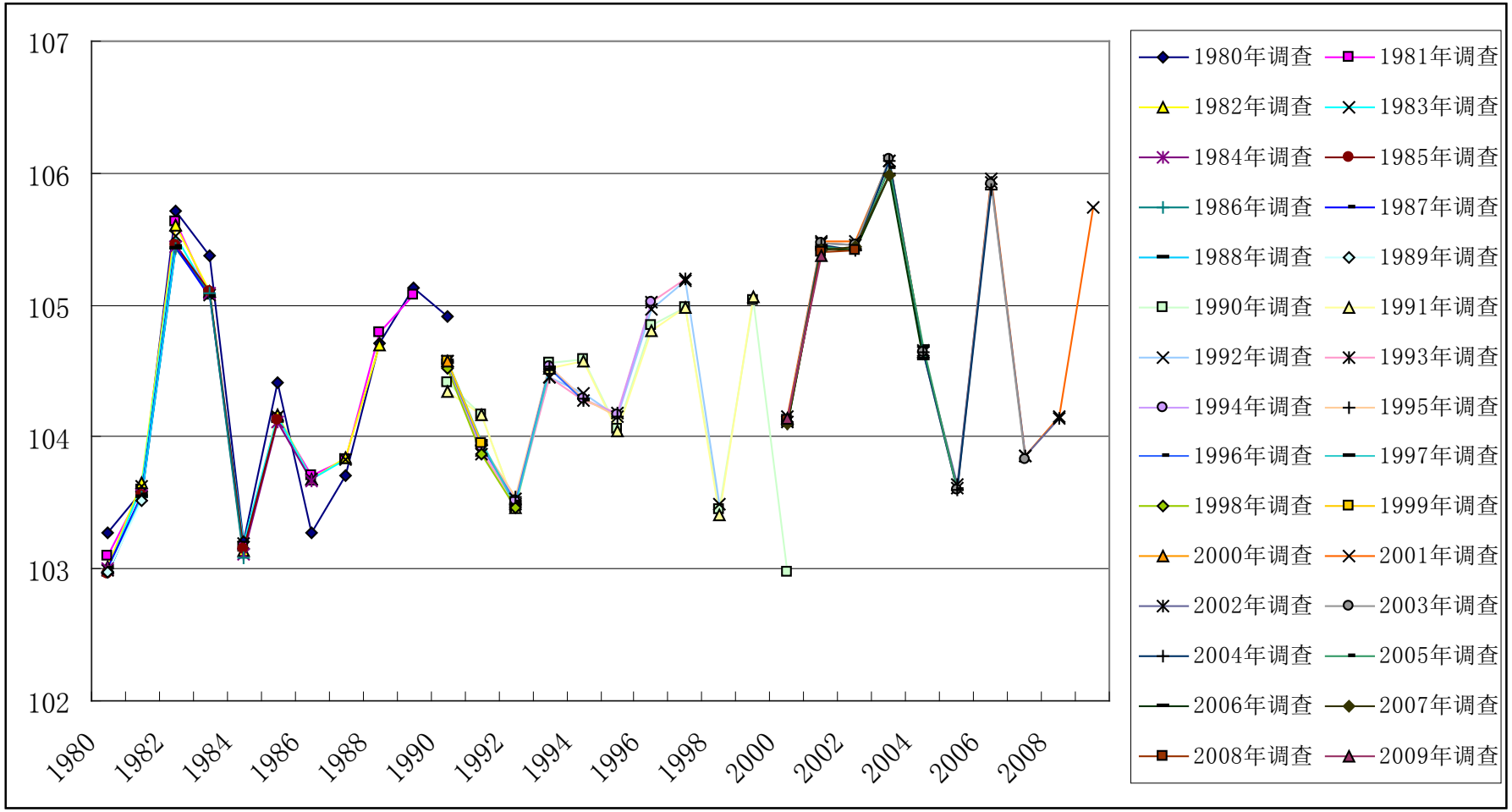
Source: 1997-2004 sample survey of population changes conducted by National Bureau of Statistics of China; 2006 sample survey of disabled population. Calculations based on data in http://www.infostat.sk/slovakpopin/agestr.htm

- e.g. Population of Slovakia grew from 4.9633 million in 1980 to 5.4122 million on Jan, 2009
- The number of the zero-year-old fell from 98,000 in 1980 to 54,000 in 2008.

Features of SRB Changes

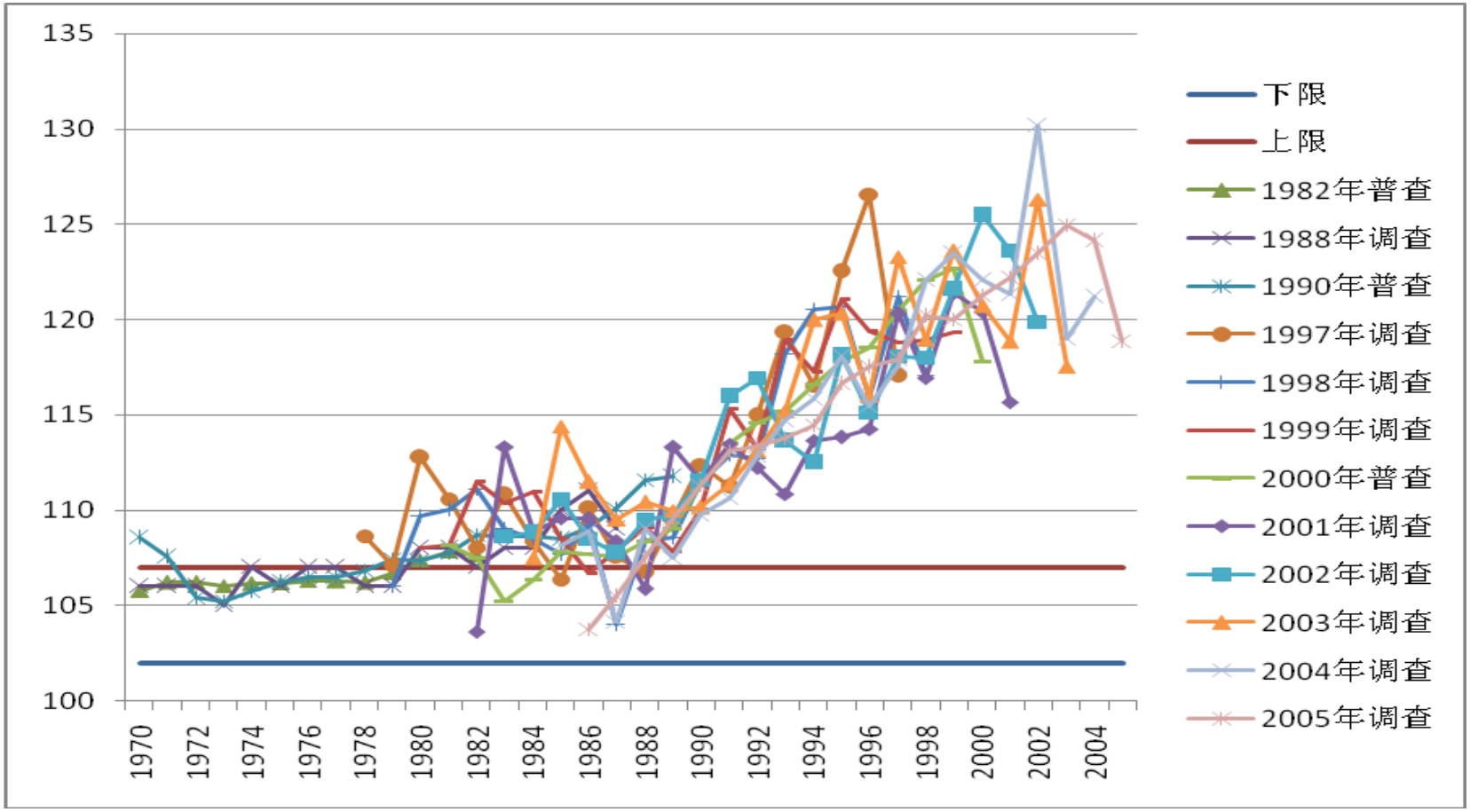
- Stability: fluctuations are very small and results of multiple surveys are pretty close to each other. With normal SRB and no artificial interference in data, SRB projections based on years of repetitive surveys are highly consistent.

1980-2009 Slovakia SRB Estimates



Source: calculations from data in http://www.infostat.sk/slovakpopin/agestr.htm.

Features of Abnormality: Inconsistent Data



Source: CHINA POPULATION & EMPLOYMENT STATISTICS YEARBOOK; 1988 two-per-thousand-population fertility control survey data; 1982, 1990 and 2000 Census; 1% population survey data of 2005 Census.

Normality: Normal Parity-Specific SRB

1995 US Parity-Specific SRB

Parity	Boy	Girl	Total	SRB
First	10959	10420	13070	105.17
Second	8508	8298	10807	102.53
Third	4132	4045	5312	102.15
Fourth	1667	1706	2020	97.71

Source: raw data of 1995 US CPS survey.

1980-1982 China Parity-Specific SRB Estimates

Parity	1980	1981	1982
First	105.1	103.97	103.63
Second	111.33	108.87	108.64
Third	111.91	112.38	112.55
Fourth	112.65	114.35	117.22
Fifth	114.94	109.86	110.43

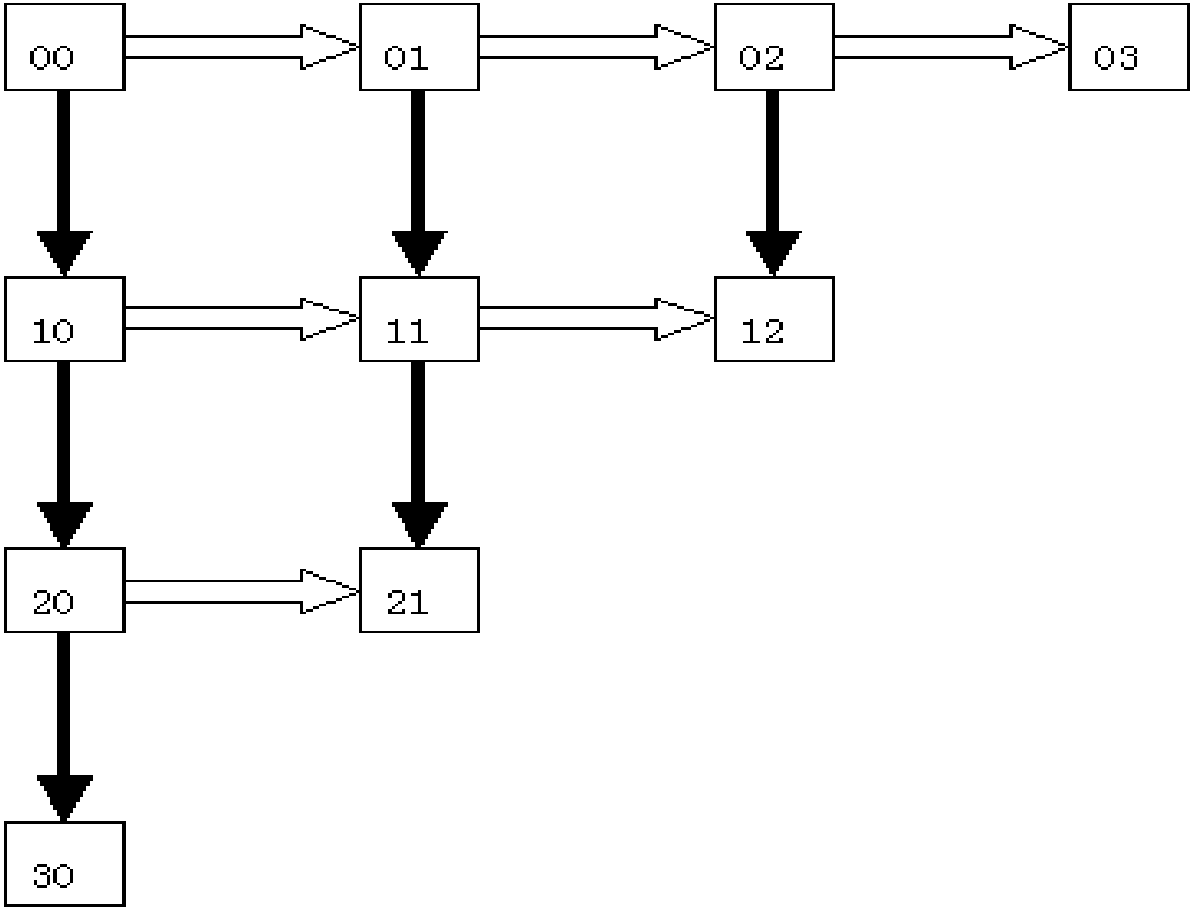
Source: survey data about mother-child match of 1982 Census.

1980-1982 China Parity-Specific SRB Estimate

Parity	1980			1981			1982		
	Total	City/town	County	Total	City/Town	County	Total	City/Town	County
1st	105.10	107.92	104.31	103.97	106.42	103.23	103.63	106.63	102.49
2nd	111.33	117.92	110.22	108.87	109.39	108.81	108.64	114.34	107.96
3rd	111.91	110.02	112.09	112.38	105.63	112.83	112.55	113.16	112.51
4th	112.65	118.64	112.25	114.35	126.06	113.75	117.22	103.60	118.05
5th	114.94	112.86	115.07	109.86	118.81	109.38	110.43	-	109.33

Source: calculations based on survey data about mother-child match of 1982 Census

Parity-Sex Progression State Spaces



Relative Error Estimates of Mother-Child Match of 1990 Census(%)

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}		**-2.94**	**-1.10**	**0.62**	**6.61**	**-1.78**
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}			**-2.50**	**-4.61**	**-2.67**	**-1.86**	
PSR_{20}	PSR_{21}	PSR_{22}				**-19.37**	**-1.28**	**-10.85**		
PSR_{30}						**-10.78**				

Relative Error＝100× (estimated sex ratio－referenced sex ratio)/referenced sex ratio
Sex ratio of 1900 Census as the reference.

1982 China Parity and Birth Sex Progression Ratio

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}	PSR_{05}		**103.63**	**113.48**	**132.60**	**151.86**	**129.43**
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}	PSR_{14}			**103.30**	**107.48**	**112.54**	**117.20**	
PSR_{20}	PSR_{21}	PSR_{22}	PSR_{23}				**94.85**	**112.33**	**106.89**	**109.73**	
PSR_{30}	PSR_{31}	PSR_{32}					**83.99**	**97.09**	**117.54**		
PSR_{40}	PSR_{41}						**83.33**				

Source: calculations based on survey data about mother-child match of 1982 Census

1981 China Parity and Birth Sex Progression Ratio

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}	PSR_{05}		**103.97**	**112.08**	**129.69**	**131.84**	**148.28**
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}	PSR_{14}			**105.29**	**107.92**	**118.59**	**108.42**	**119.70**
PSR_{20}	PSR_{21}	PSR_{22}	PSR_{23}				**95.19**	**100.45**	**103.14**	**108.52**	
PSR_{30}	PSR_{31}	PSR_{32}					**96.60**	**99.72**	**97.93**		
PSR_{40}	PSR_{41}						**86.36**				

Source: calculations based on survey data about mother-child match of 1982 Census

1980 China Parity and Birth Sex Progression Ratio

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}	PSR_{05}		**105.10**	**114.20**	**126.13**	**133.37**	**142.97**
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}	PSR_{14}			**108.42**	**108.81**	**116.69**	**129.52**	**111.83**
PSR_{20}	PSR_{21}	PSR_{22}	PSR_{23}				**98.45**	**100.99**	**100.56**	**106.73**	
PSR_{30}	PSR_{31}	PSR_{32}					**87.41**	**100.23**	**105.88**		
PSR_{40}	PSR_{41}						**85.52**				

Source: calculations based on survey data about mother-child match of 1982 Census

1970 US Parity and Birth Sex Progression Ratio of White Population

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}	PSR_{05}		**105.84**	**102.28**	**98.39**	**81.15**	**65.77**
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}	PSR_{14}			**107.96**	**105.24**	**100.91**	**90.00**	**124.02**
PSR_{20}	PSR_{21}	PSR_{22}	PSR_{23}				**113.34**	**106.63**	**103.05**	**99.34**	
PSR_{30}	PSR_{31}	PSR_{32}					**117.43**	**98.78**	**96.41**	**100.41**	
PSR_{40}	PSR_{41}						**131.89**	**108.06**			

Source: calculations based on survey data about mother-child match of 1970 US Census

1990 US Parity and Birth Sex Progression Ratio of White Population

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}	PSR_{05}		**105.86**	**104.24**	**101.55**	**94.81**
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}	PSR_{14}			**107.70**	**107.97**	**105.69**	
PSR_{20}	PSR_{21}	PSR_{22}	PSR_{23}				**105.11**	**106.05**	**107.50**	
PSR_{30}	PSR_{31}	PSR_{32}					**117.98**			

Source: calculations based on survey data about mother-child match of 1990 US Census

State and Process of Parity-Sex Progression

1990 China Parity and Birth Sex Progression Ratio

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}	PSR_{05}		104.70	147.78	219.43	214.69	218.89	260.66
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}	PSR_{14}			99.43	115.11	138.17	130.94	160.42	
PSR_{20}	PSR_{21}	PSR_{22}	PSR_{23}				76.59	88.54	115.29	119.42		
PSR_{30}	PSR_{31}	PSR_{32}					56.72	96.73	72.16			
PSR_{40}	PSR_{41}						56.45	94.44				
PSR_{50}												

Source: calculations based on 1990 China Census raw survey data.

2000 China Parity and Birth Sex Progression Ratio

PSR_{00}	PSR_{01}	PSR_{02}	PSR_{03}	PSR_{04}	PSR_{05}		105.59	209.45	353.74	365.08	366.67	266.67
PSR_{10}	PSR_{11}	PSR_{12}	PSR_{13}	PSR_{14}			88.45	130.82	169.72	166.67	75.00	
PSR_{20}	PSR_{21}	PSR_{22}	PSR_{23}				68.16	97.06	90.48	125.00		
PSR_{30}	PSR_{31}	PSR_{32}					84.21	31.82	50.00			
PSR_{40}	PSR_{41}						100.00	75.00				
PSR_{50}												

Source: calculations based on 2000 China one-per-thousand-population survey data.

2005 China Parity and Birth Sex Progression Ratio

PSR_{00}	**PSR_{01}**	**PSR_{02}**	**PSR_{03}**	**PSR_{04}**	**PSR_{05}**		**110.93**	**189.73**	**341.38**	**261.54**	**233.33**	
PSR_{10}	**PSR_{11}**	**PSR_{12}**	**PSR_{13}**	**PSR_{14}**			**78.82**	**115.29**	**177.78**	**160.00**		
PSR_{20}	**PSR_{21}**	**PSR_{22}**	**PSR_{23}**				**45.98**	**35.29**	**62.50**			
PSR_{30}	**PSR_{31}**	**PSR_{32}**					**100.00**	**75.00**				
PSR_{40}	**PSR_{41}**											
PSR_{50}												

Source: calculations based on 2005 China one-per-thousand-population survey data.

Parity and Birth Sex Progression Ratio

	PSR_{00}	Samples	PSR_{11}	Samples	PSR_{22}	Samples
1982, China	**103.63**	**51328**	**107.48**	**8484**	**106.89**	**1351**
1981, China	**103.97**	**48760**	**107.92**	**7458**	**103.14**	**1231**
1980, China	**105.10**	**48618**	**108.81**	**9509**	**100.56**	**1436**
1990, China	**101.62**	**49877**	**109.80**	**6999**	**102.78**	**292**
1989, China	**103.40**	**63600**	**109.34**	**8267**	**152.45**	**361**
1988, China	**103.30**	**69695**	**105.22**	**8451**	**115.15**	**426**
2000, China	**105.59**	**81515**	**130.82**	**1655**	**90.48**	**80**
2005, China	**110.93**	**16828**	**115.29**	**338**	**62.50**	**13**
2000, China	**102.53**	**54712**	**103.31**	**10568**	**105.49**	**824**
1990, US Whites	**105.86**	**35737**	**107.97**	**7512**	**107.50**	**498**
1989, US Whites	**106.37**	**45653**	**105.84**	**8779**	**101.79**	**563**
1988, US Whites	**104.80**	**45910**	**102.25**	**8252**	**106.78**	**488**
1970, US	**105.59**	**58626**	**104.83**	**14854**	**106.50**	**3211**
1969, US	**104.33**	**59856**	**103.42**	**14412**	**102.68**	**3178**
1968, US	**106.55**	**59051**	**103.04**	**14509**	**104.85**	**3419**

Conclusion

- SRB Changes: instability → abnormality.
- Parity-Specific SRB Changes: instability →abnormality.
- Changes of SRB State Spaces:
- (1) Diagonal instability → abnormality,
- (2) Progression births of girls—male preference→ abnormality.

Statistic Monitoring Method of SRB Changes

- **Probability analysis of SRB changes**

$$P(X = x) = \binom{n}{x} p^x (1-p)^{n-x}$$

$$\sum_{x=0}^{n} P(X = x) = \sum_{x=0}^{n} \binom{n}{x} p^x (1-p)^{n-x} = 1$$

Probability Estimates of SRB Ranges

地区	0 岁	0 岁	>107	>110	>120	>130
	男孩（人）	女孩（人）				
北京	37	37	36.38%	28.07%	20.80%	10.03%
天津	39	35	54.71%	45.45%	36.43%	20.79%
河北	324	257	97.50%	94.81%	70.68%	35.40%
山西	184	189	16.26%	11.68%	2.17%	0.22%
内蒙	106	99	47.25%	41.73%	18.19%	7.09%
辽宁	159	135	77.68%	70.11%	43.10%	19.02%
吉林	87	81	46.96%	40.88%	19.80%	9.45%
黑龙江	147	125	74.86%	70.83%	42.82%	18.08%
上海	44	39	54.46%	54.46%	37.16%	22.11%
江苏	282	229	94.00%	88.50%	58.85%	25.26%
浙江	218	175	92.92%	87.83%	63.94%	32.45%
安徽	274	218	96.14%	92.00%	69.16%	34.20%
福建	163	119	97.63%	95.93%	84.73%	66.44%
江西	249	175	99.81%	99.53%	95.74%	79.93%
山东	424	368	84.92%	72.78%	27.26%	4.03%
河南	555	395	100.00%	99.99%	99.17%	87.52%
湖北	211	152	99.14%	98.51%	90.79%	72.14%
湖南	323	244	99.37%	98.45%	87.38%	58.47%
广东	377	269	99.96%	99.89%	97.44%	82.07%
广西	303	245	95.29%	90.84%	61.87%	26.00%
海南	4	5	16.05%	16.05%	16.05%	16.05%
重庆	120	112	47.41%	37.16%	16.22%	6.52%
四川	391	311	98.15%	95.61%	71.59%	31.11%
贵州	283	287	14.75%	8.34%	0.85%	0.05%

Bayesian Analysis for SRB Changes

Prior Mean Value: $\bar{\theta} = \frac{1}{n}\sum_{i=1}^{n}\theta_i$ Prior Variance: $S_{n\theta}^2 = \frac{1}{n}\sum_{i=1}^{n}\left(\theta_i - \bar{\theta}\right)^2$

Beta Distribution Mean: $E(\theta) = \frac{a}{a+b}$

Beta Distribution Variance: $Var(\theta) = \frac{ab}{(a+b)^2(a+b+1)}$

Moment Method Estimates for Super Parameters of a and b by Solving Equations:

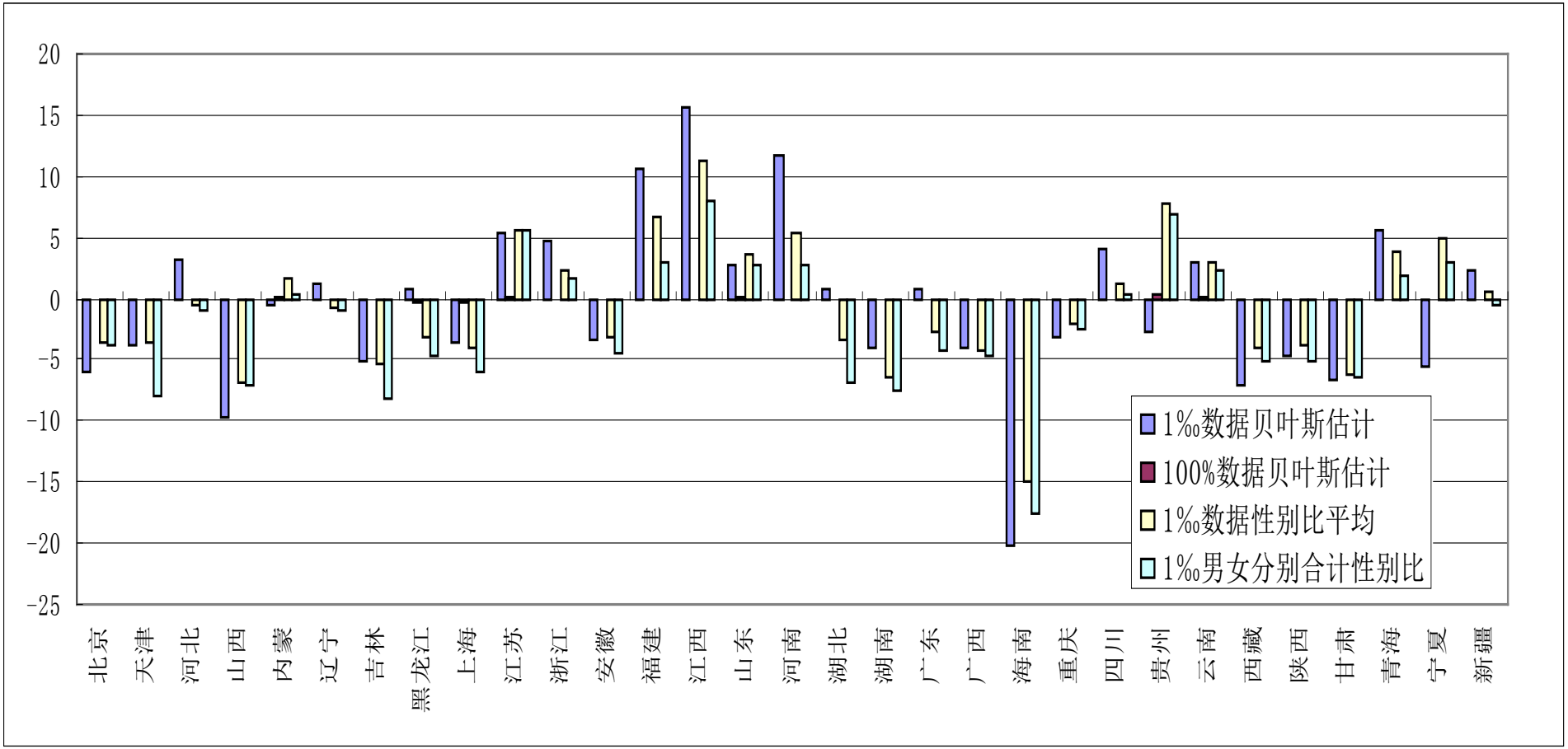
$$\frac{\hat{a}}{\hat{a}+\hat{b}} = \bar{\theta} \qquad \frac{\hat{a}\hat{b}}{\left(\hat{a}+\hat{b}\right)^2\left(\hat{a}+\hat{b}+1\right)} = S_{n\theta}^2$$

$$\hat{a} = \bar{\theta}\left[\frac{\left(1-\bar{\theta}\right)\bar{\theta}}{s^2{}_{n\theta}} - 1\right] \qquad \hat{b} = \left(1-\bar{\theta}\right)\left[\frac{\left(1-\bar{\theta}\right)\bar{\theta}}{s^2{}_{n\theta}} - 1\right]$$

Bayesian Estimation:

$$\hat{\theta}_B = \frac{a+x}{a+b+n}$$

Error Analysis of SRB Estimations by Different Methods with Small Samples



Comparison of Results of Error Estimations by Different Methods with Different Samples (%)

方法 / 数据	1‰数据			1%数据			100%数据
	贝叶斯估计	性别比平均	男女分别合计性别比	贝叶斯估计	性别比平均	男女分别合计性别比	贝叶斯估计
历史数据	5.8263	5.0980	6.7689	2.6336	3.3197	4.3176	0.1290
仿真数据	2.1876	2.6940	2.9399	1.9873	2.6954	2.9403	

$$err = \left(100 * \sum_{i=1}^{n} \frac{\left| SRB_{ri} - SRB_{ei} \right|}{SRB_{ri}} \right) \Big/ n$$

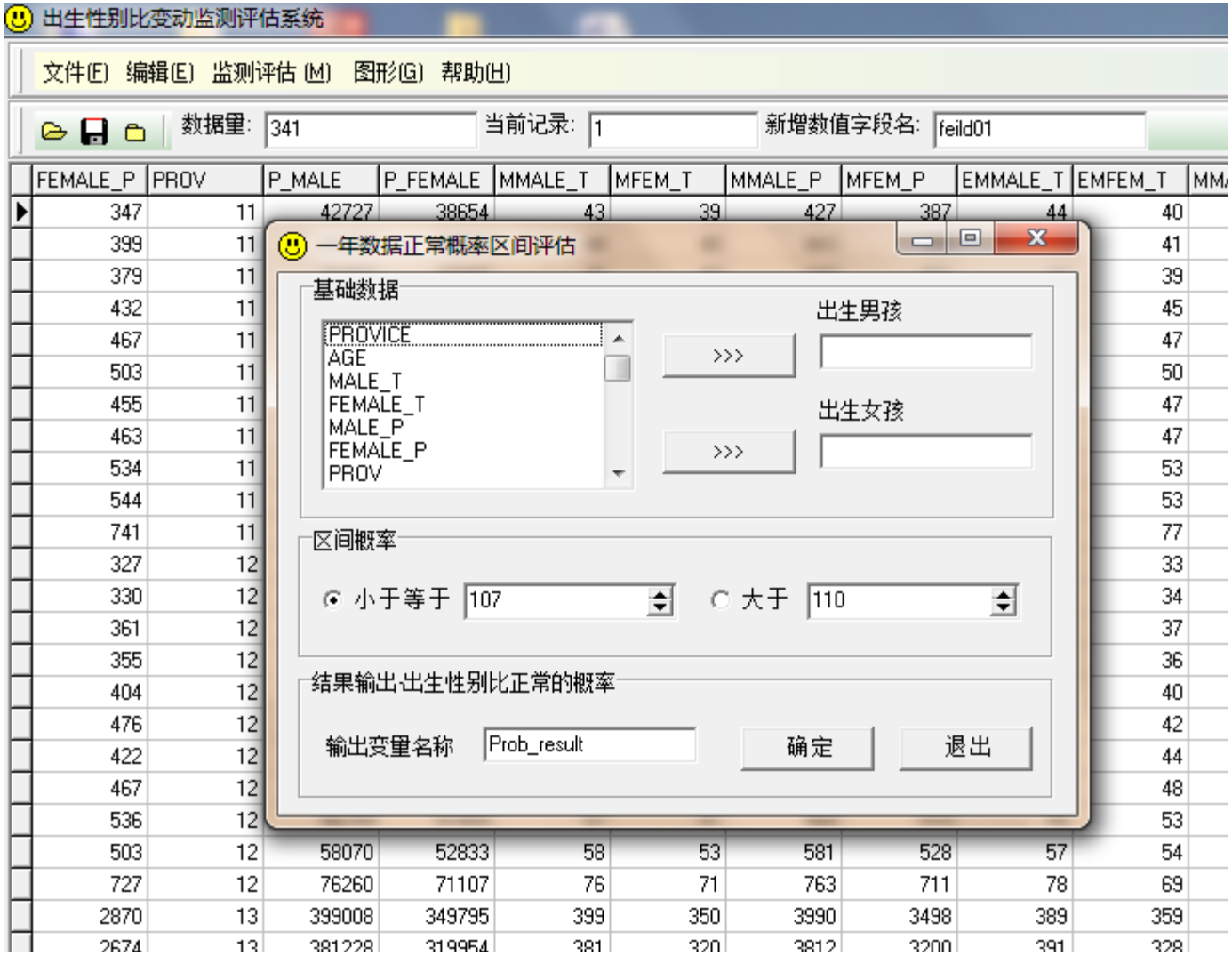
Conclusion

- Small samples could also generate relatively accurate SRB estimations.
- New indicators and methods could be developed to monitor or evaluate SRB.

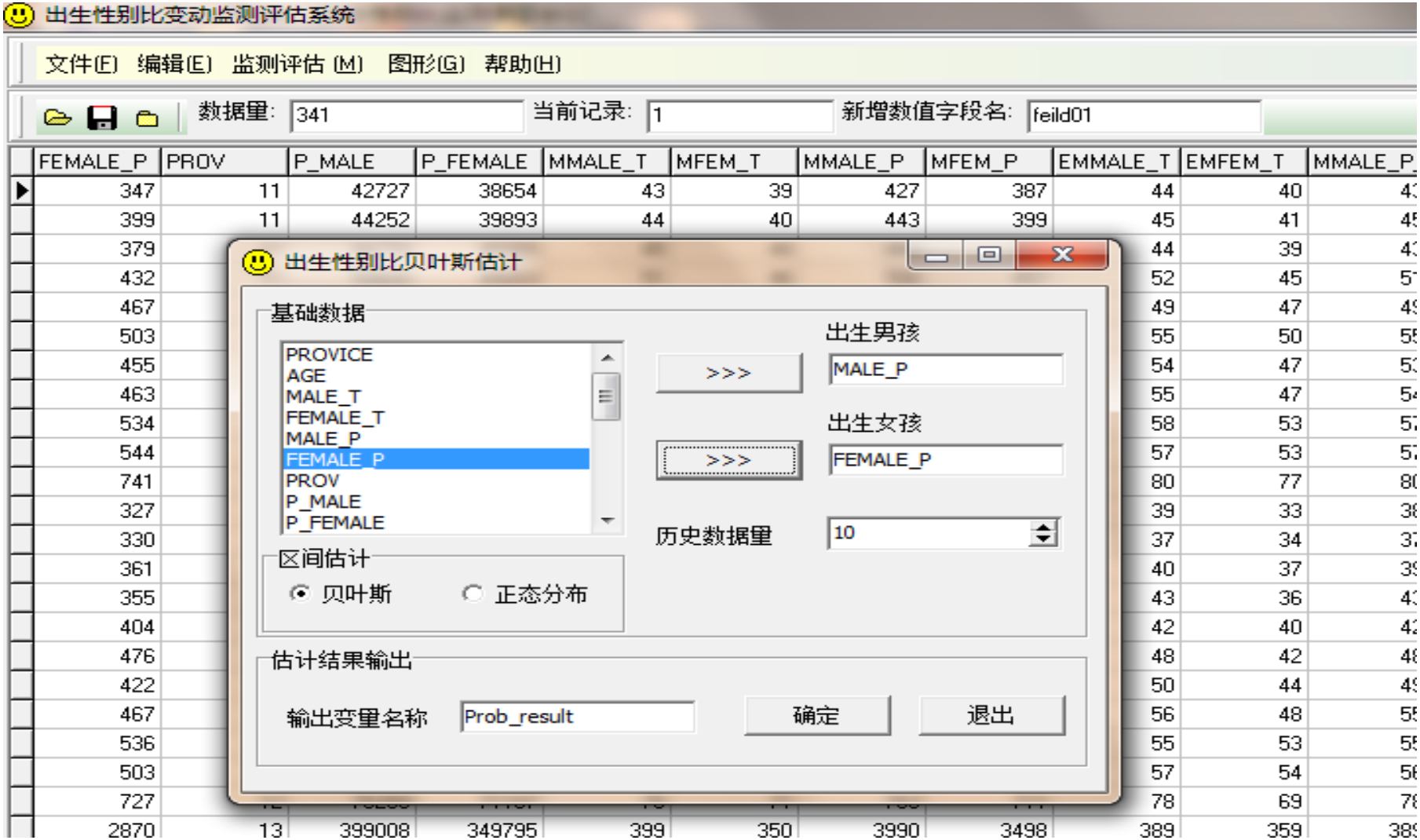
Promotion of Monitoring and Evaluation Methods

- Brochure or software: convenient, fast and easy to use.
- Pre-alarming: yellow, orange and red.

Software of Range Estimation



Bayesian Estimation Software



Conclusion & Discussion

- First, normal SRB is relatively stable, as is shown by stable indicators regarding parity or non-parity, and families with sons only, families with daughters only, or families with both sons and daughters. However, abnormal SRB often has instable indicators. Therefore, during the process of monitoring SRB, the shift from stability to instability and partial stability to complete instability must be identified.
- Second, changes could vary as some indicator might be sensitive to some aspects, but not to the other aspects. For example, families with both sons and daughters may not see changes in birth sex progression ratio, while families with daughters only may see notable changes. Therefore, a holistic analysis and approach should be adopted in monitoring SRB changes.
- Third, when the SRB is normal, results of repetitive surveys or interval estimations of the SRB of the same period are usually highly consistent, with only small fluctuations. Despite small amounts of samples, there will be no big difference between surveys. However, when the SRB is abnormal, it is difficult for data at the same period in different surveys to correspond to each other, and survey results often greatly vary from one another. Therefore, repetitive surveys are important for understanding the essence and features of problems during the process of monitoring SRB.
- Fourth, demographic statistics indicator system is designed to research laws of SRB changes in depth. As the determination and innovation of indicators are the process of concluding laws, the stability of indicators and flexibility of surveys should be taken into consideration.
- Fifth, many indicators could be analyzed and constructed based on raw data which are nevertheless not all available. Therefore, multi-channel data validation, range estimations and trend analysis are usually required to monitor SRB changes.

Thank You!