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# Adult Mortality Differentials: Estimates from Costa Rican Widowhood

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# What is known about adult mortality levels and determinants in poor countries?

- **Levels and trends:**
  - **Mortality converging with OECD in most countries.**
  - **Elderly mortality differentials smaller than for children?**
- **Determinants: Stylized facts still unknown**
  - **Suggestion of small SES differentials, but few studies.**
  - **Little evidence on role of health care sector.**
  - **Female widowhood dangerous in Bangladesh. Generalizable?**

# Adult Longevity Data in Developing Countries

- **Vital Statistics:**
  - Unreliable in many less developed countries
  - Age mis-reporting at older ages
- **Census:**
  - Indirect mortality estimation techniques using survivorship of parents, sibing, spouses
- **Longitudinal micro-data scarce:**
  - Bangladesh, Mexico, Taiwan, China
  - Few countries, still limited covariates

# Key Research Question: I

**Can widowhood data from individual-level surveys be used to study adult mortality correlates?**

- **Hill (1977 Pop Studies): Can use widowhood to estimate adult mortality *levels*.**
- **Our previous work: Census Brass questions useful for studying child survival correlates. (Large samples, less omitted variables bias.)**

**Hypothesis: Female widowhood differentials can inform male mortality differentials.**

- **Tests: Are geographic correlations between mortality and widowhood high? Are correlates similar?**

# Key Research Question: II

## How does Costa Rica achieve *Good Health at Low Cost*?

- **Life expectancy equal to or better than U.S.:**

**Age-60 life expectancy (1995-2000)**

| | Costa Rica | US-whites |
|---|---|---|
| Men | 20.7 | 19.6 |
| Women | 23.2 | 23.2 |

- **Adult male mortality lower than the U.S. since 1960's, especially cardiovascular and lung cancer. Infectious diseases comprise 30% of mortality decline since 1970.**

- **But per capita income 1/5 of U.S., per capita health care expenditures 1/10 of U.S.**

# Hypotheses for Costa Rican good outcomes

- **Caldwell: Female education, public health, access to health care facilitated by national health insurance.**
  - **But: little evidence.**
  - **E.g., education: Our cohort studies and our ecological estimates find few effects. If true would be important, given emphasis on equalizing access to care.**

# Outline

- **Theory: STELLA simulation modeling of mortality and widowhood rates and transitions**

- **Data: Costa Rican vital statistics and census**

- **Methods: County- vs. individual-level modeling**

- **Results: Does widowhood provide useful information for inferring mortality differentials?**

# Complicated Relationship Between Widowhood and Mortality

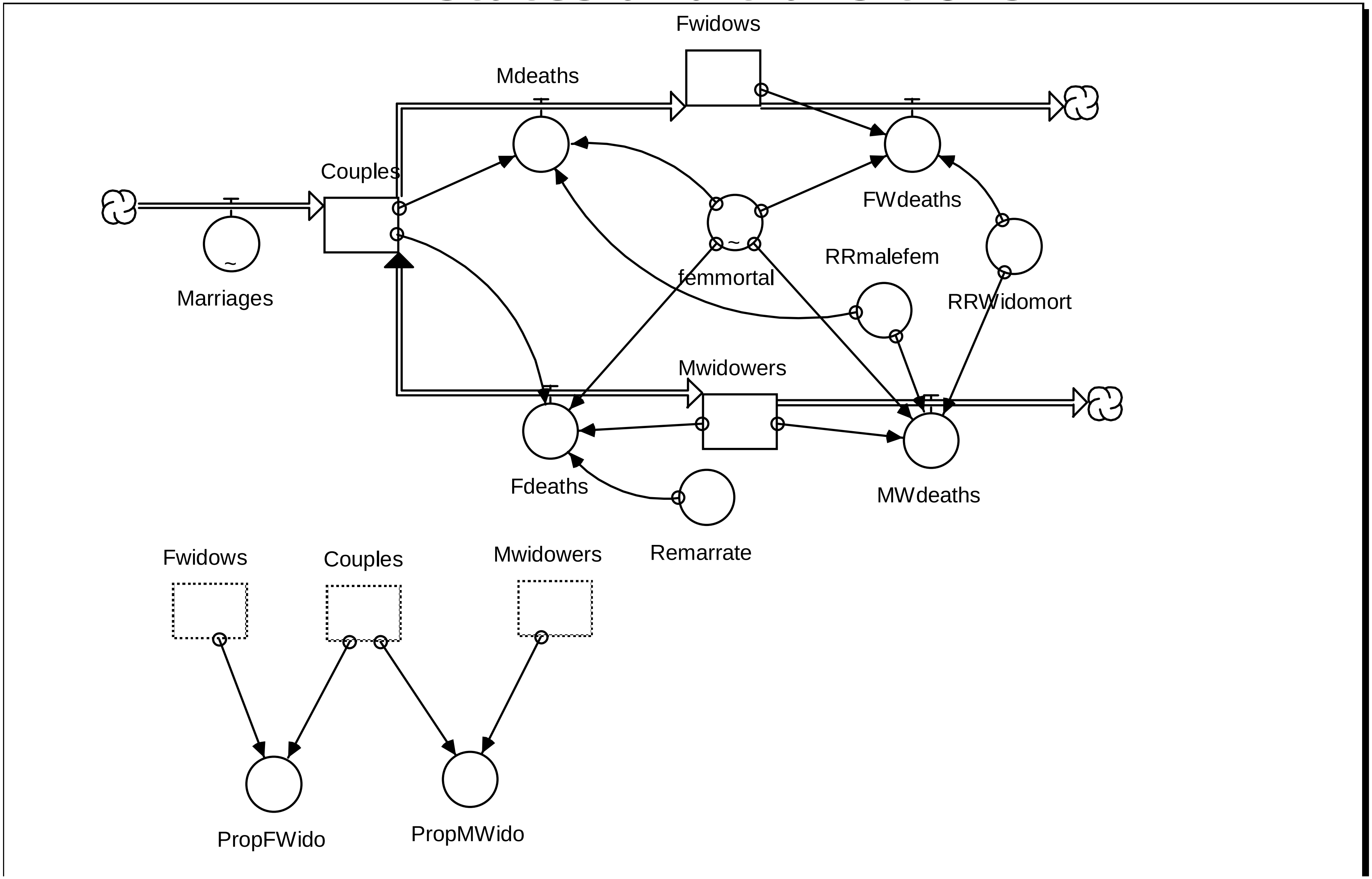
- **Couples' joint survival states are censored at the death of the second spouse**

- **Widowhood may not be observed if re-marriage has occurred**

- **Duration of widowhood may be unmeasured**

- **Key characteristics of the dead partner may be unobserved.**

# Fig 1. STELLA model of marital and mortality states and transitions



# STELLA Modeling Equations

Couples(t) = Couples(t - dt) + (Marriages - Mdeaths - Fdeaths) * dt

Mdeaths = femmortal*RRmalefem*Couples

Fdeaths = femmortal*Couples-Remarrate*Mwidowers

Fwidows(t) = Fwidows(t - dt) + (Mdeaths - FWdeaths) * dt

FWdeaths = femmortal*RRWidomort*Fwidows

Mwidowers(t) = Mwidowers(t - dt) + (Fdeaths - MWdeaths) * dt

MWdeaths = Mwidowers*femmortal*RRmalefem*RRWidomort

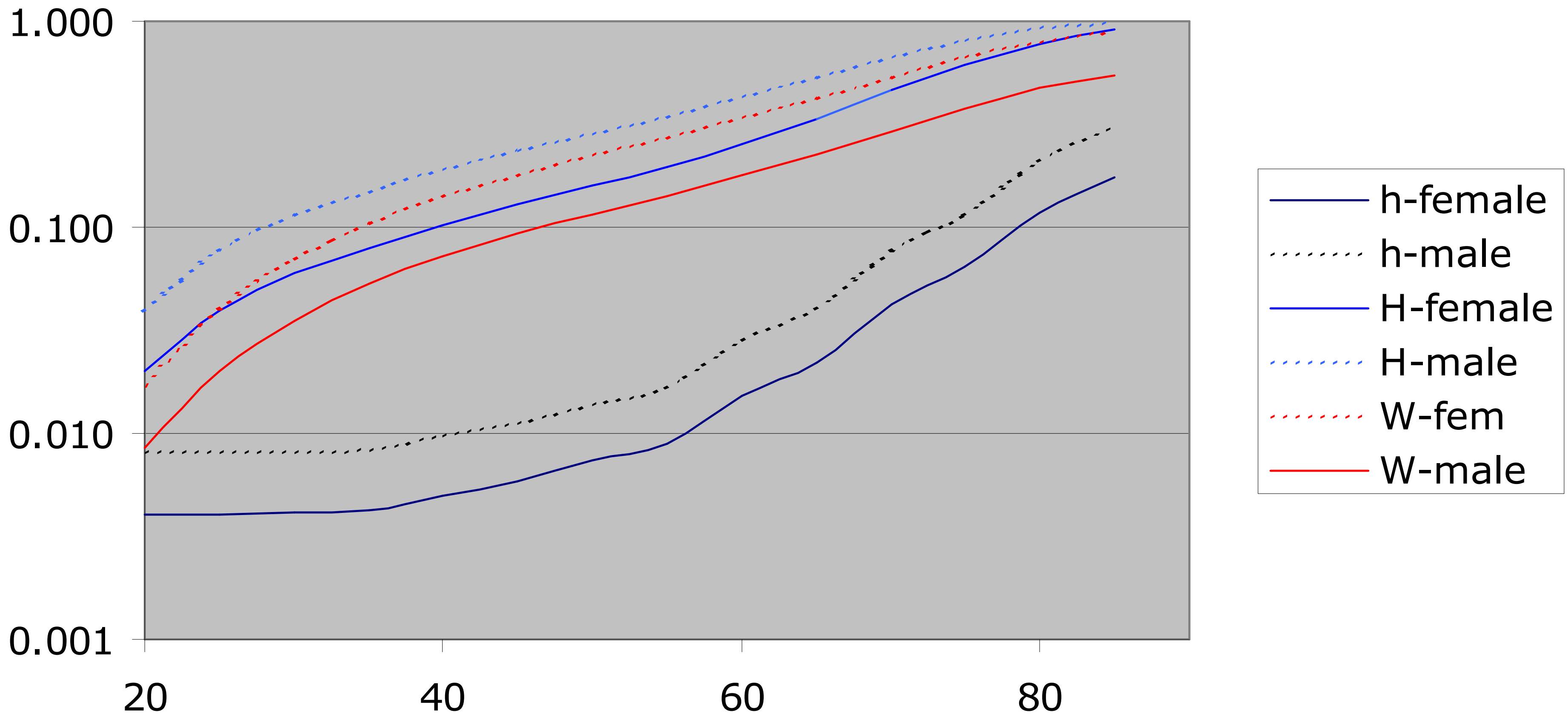
PropFWido = 1000*Fwidows/(Couples+Fwidows)

PropMWido = 1000*Mwidowers/(Couples+Mwidowers)

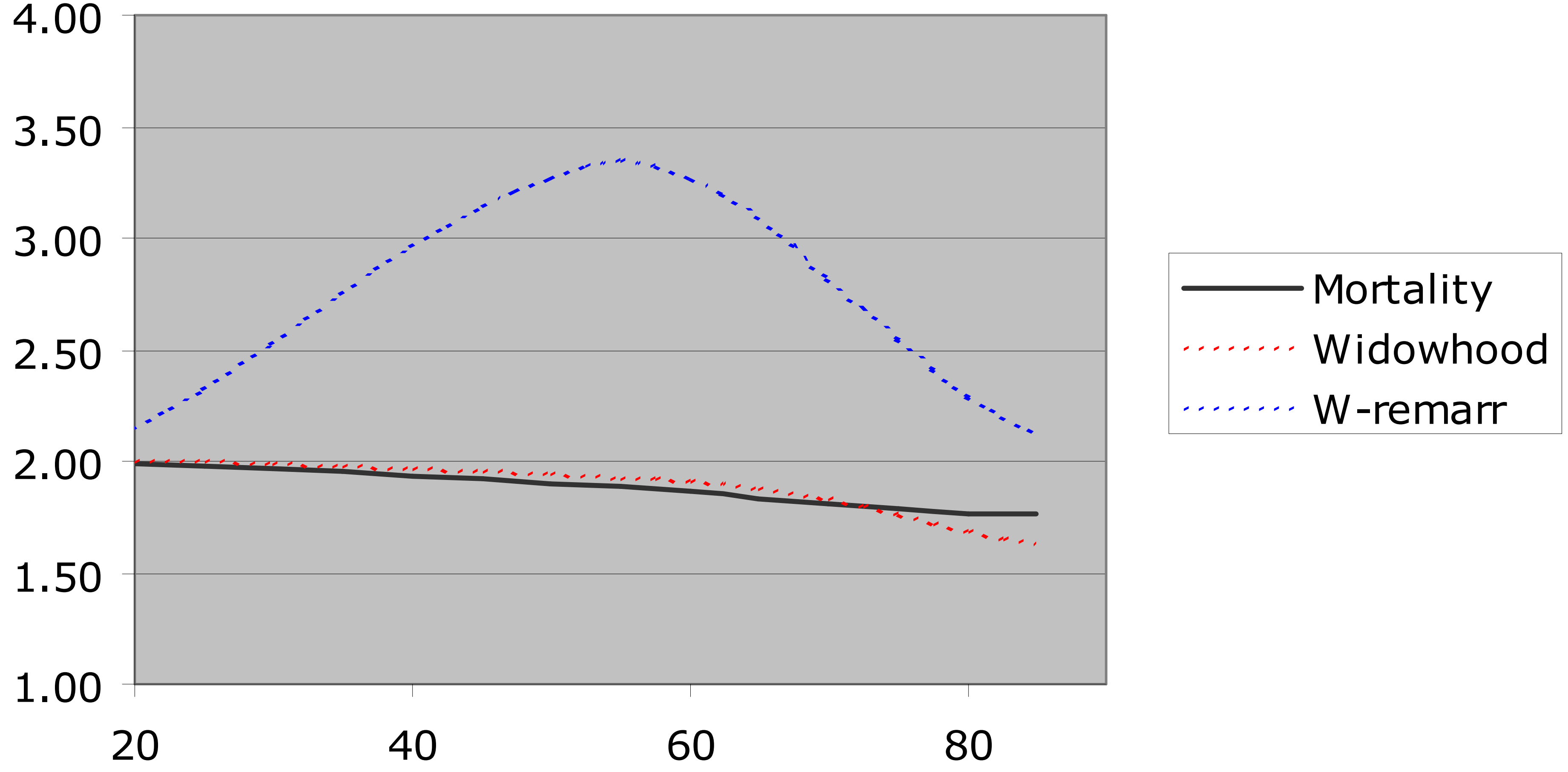
# STELLA Modeling Assumptions

- Stationarity. I.e., all cohorts are equal size and all rates (mortality, marriage, remarriage) stay constant.
- No marital dissolution because of divorce or separation.
- The marriage distribution over time or age is similar to that in Costa Rica with a mean age of 21.
- Age-specific mortality rates of women are similar to that of the Costa Rican cohort born circa 1920.
- Husbands have mortality relative risk (RR) of 2.0 with respect to wives at all ages. This RR considers both higher male mortality and about a 5-year age difference.
- Widows and widowers have a mortality RR = 1.5 with respect to married individuals of the same sex and age.

**Fig 2. Mortality and widowhood rates (logs)**



# Fig 3. Male/female rate ratio RR=2.0



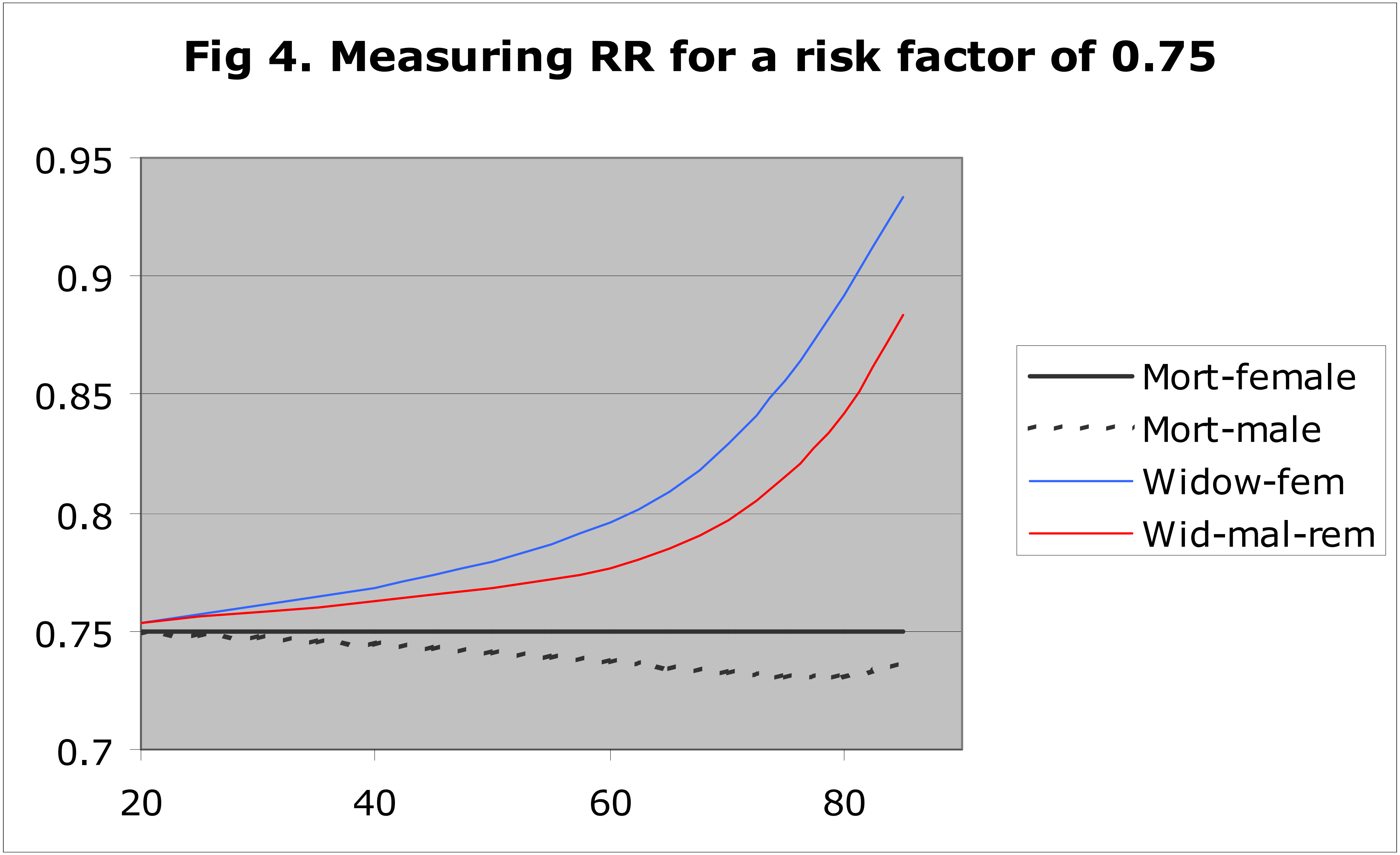


Fig 4. Measuring RR for a risk factor of 0.75
0.95
0.9
0.85
0.8
0.75
0.7
20
40
60
80
Mort-female
Mort-male
Widow-fem
Wid-mal-rem

# Data Sources

- **100% microsamples of 1973, 1984 censuses**
  - **Widowhood measured only if not re-married**
  - **Woman’s education, insurance, demographics**
  - **Household wealth, sanitation, etc.**
- **Vital Statistics mortality by age, sex, county**
- **99 “counties” that are unit of observation in aggregate analyses**

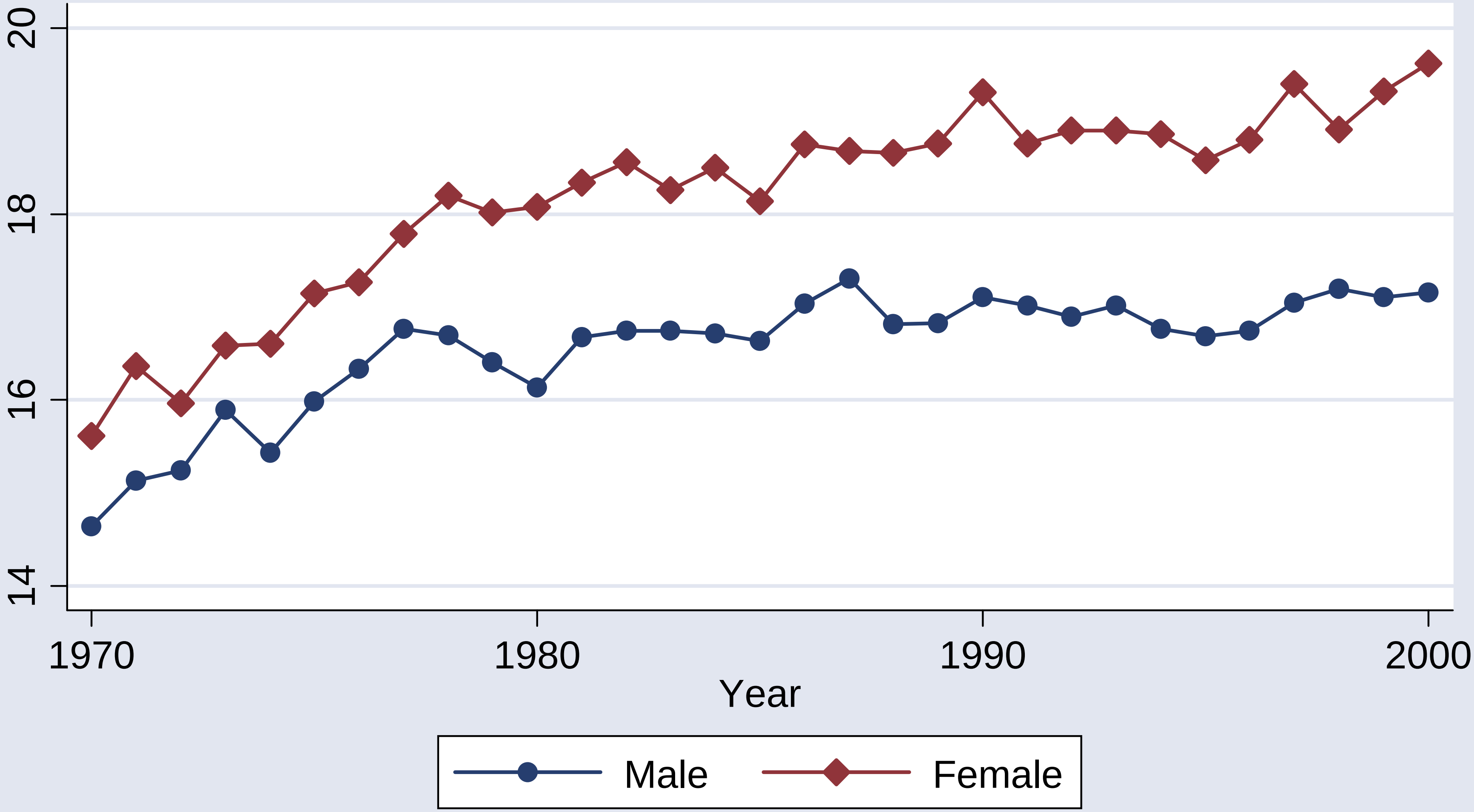
# Data Quality Issues

- **Mortality:**
  - **1984 census slightly over-estimates child mortality, though 1973 OK. Unclear whether mis-reporting differs by observables.**

- **Widowhood:**
  - **Measured only at time of census (check marital histories in Mexico MHAS.**
  - **Civil unions common: use only ever married?**
  - **Duration of widowhood unobserved (model).**
  - **Dead spousal characteristics unobserved (test assortative mating)**

Life expectancy at age 65

Costa Rica

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Source: CCP, http://www.ccp.ucr.ac.cr/observa/CRindicadores/evida.htm

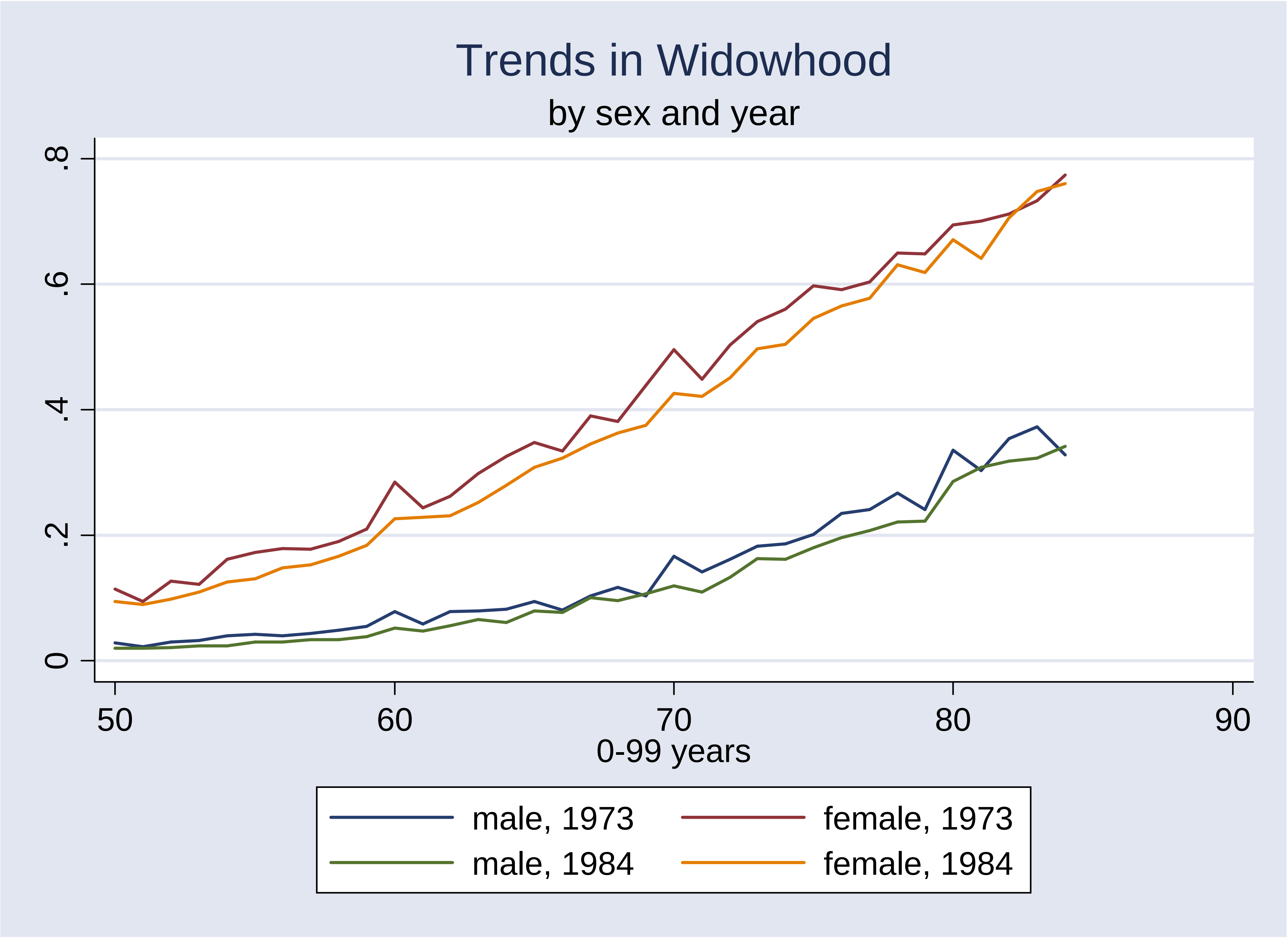
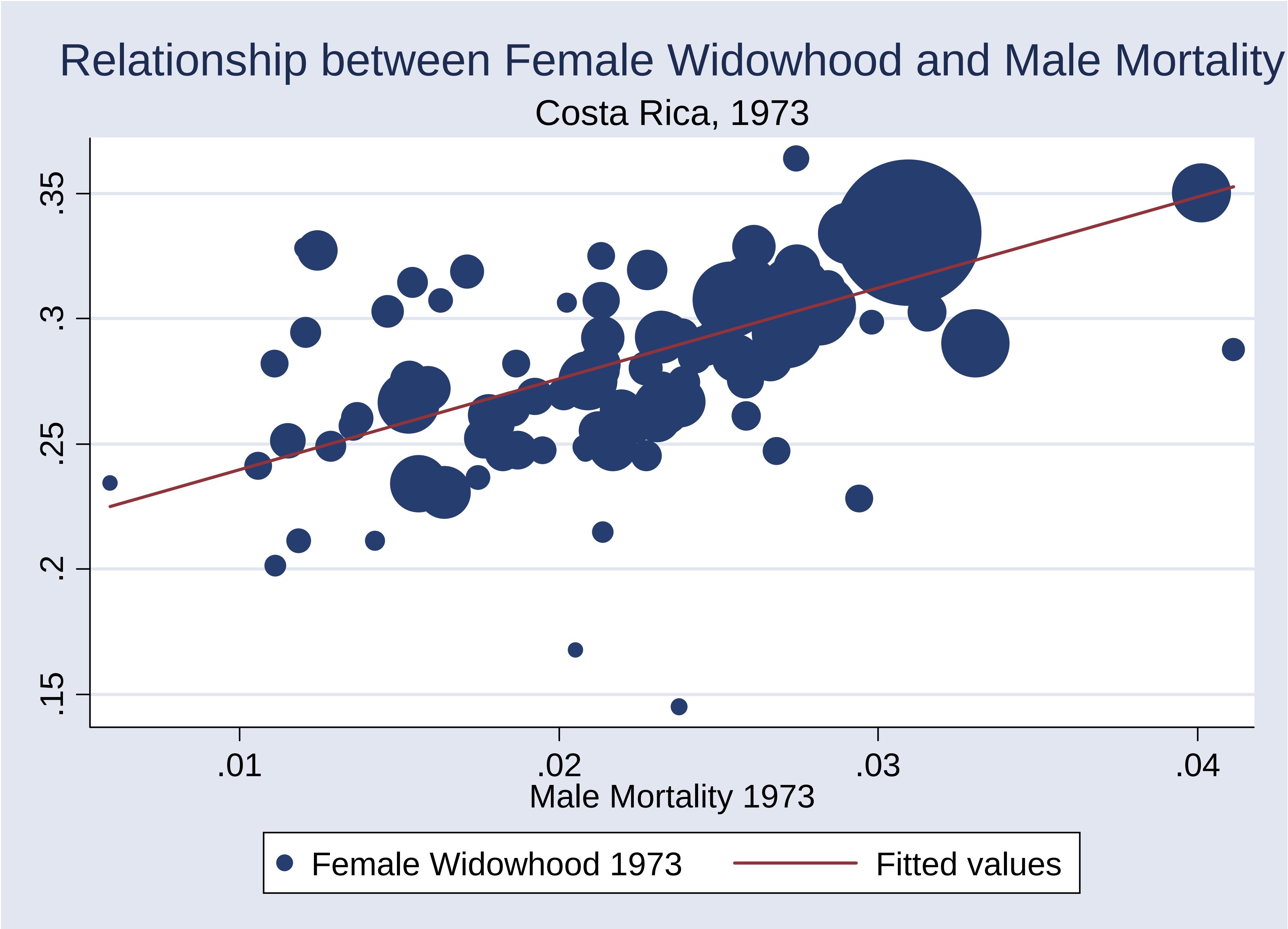
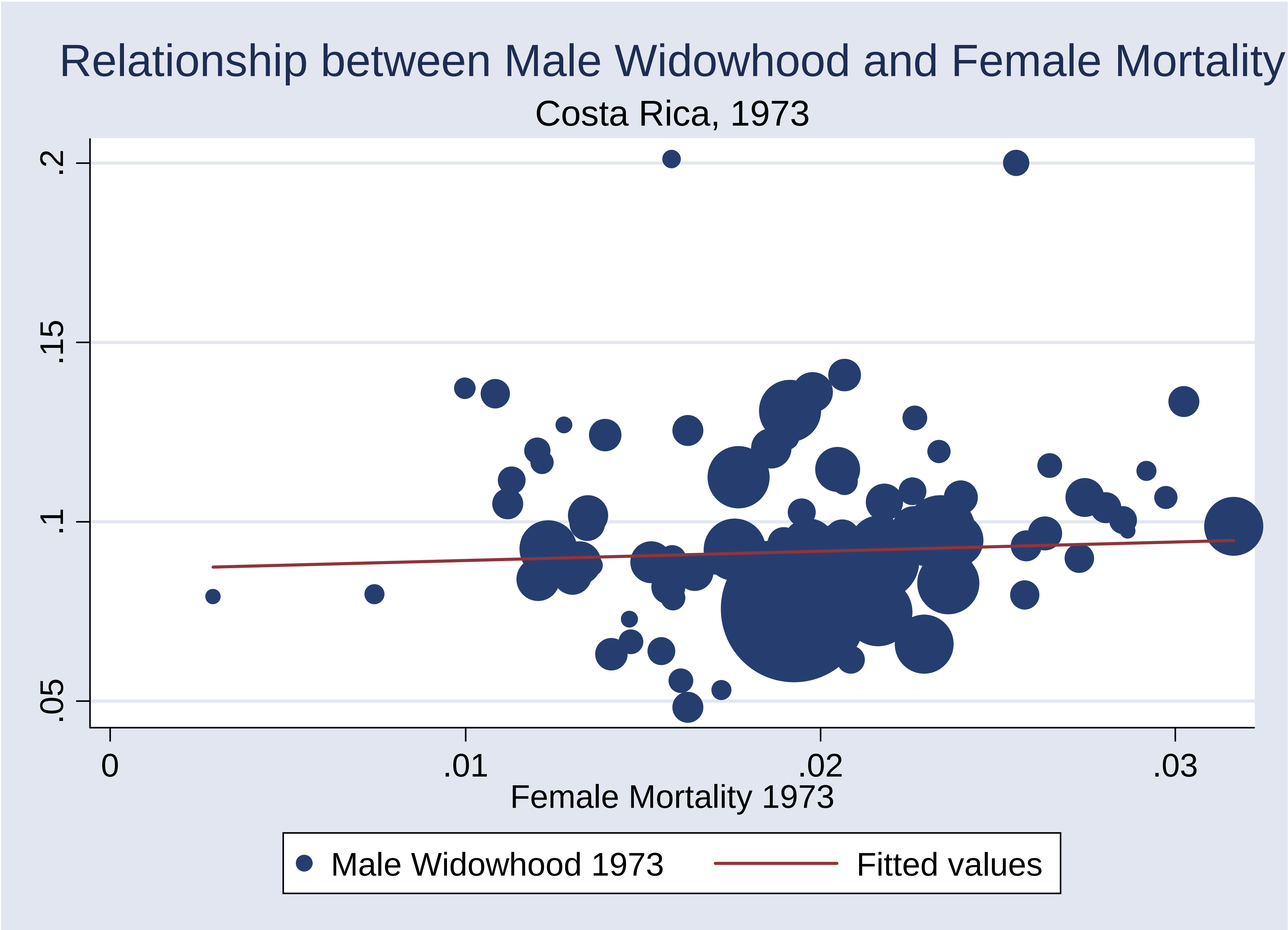

Trends in Widowhood
by sex and year
0
.2
.4
.6
.8
50
60
70
80
90
0-99 years
male, 1973
female, 1973
male, 1984
female, 1984

Table 1. Male, Female Correlations between Widowhood and Mortality

| | | | Mortality | | | |
|---|---|---|---|---|---|---|
| | | | 1973 | | 1984 | |
| | | | Female | Male | Female | Male |
| Mortality | | | | | | |
| | 1973 | Female | 1.00 | | | |
| | | Male | 0.35 | 1.00 | | |
| | 1984 | Female | 0.56 | 0.32 | 1.00 | |
| | | Male | 0.34 | 0.75 | 0.40 | 1.00 |
| Widowhood | | | | | | |
| | 1973 | Female | 0.15 | **0.68** | 0.15 | 0.61 |
| | | Male | **0.02** | -0.20 | 0.05 | -0.30 |
| | 1984 | Female | 0.32 | 0.71 | 0.24 | **0.70** |
| | | Male | 0.17 | -0.04 | **0.22** | -0.13 |


Relationship between Female Widowhood and Male Mortality
Costa Rica, 1973
.15
.2
.25
.3
.35
.01
.02
.03
.04
Male Mortality 1973
Female Widowhood 1973
Fitted values


Relationship between Male Widowhood and Female Mortality
Costa Rica, 1973
.05
.1
.15
.2
0
.01
.02
.03
Female Mortality 1973
Male Widowhood 1973
Fitted values

Marital status by sex and year, Costa Rica

| | 1973 | | | |
|---|---|---|---|---|
| | **Female** | | **Male** | |
| | Frequency | Percent | Frequency | Percent |
| Widowed | 21,497 | 22.15 | 6,835 | 7.06 |
| Married | 47,870 | 49.32 | 66,704 | 68.94 |
| In union | 5,591 | 5.76 | 9,582 | 9.90 |
| Divorced | 1,152 | 1.19 | 593 | 0.61 |
| Single | 16,651 | 17.15 | 10,358 | 10.71 |
| Other | 4,308 | 4.44 | 2,679 | 2.77 |

3. Current Marital Status of Ever-Widowed Individuals, Mexico (MHAS

| | Female | | | | Male | | | |
|---|---|---|---|---|---|---|---|---|
| Marital status | <6 years edu | | 6+ years educ | | <6 years edu | | 6+ years edu | |
| | n | % | n | % | n | % | n | % |
| Widowed | 1257 | 90.17 | 542 | 94.43 | 357 | 70.55 | 145 | 74.36 |
| Re-married | 64 | 4.59 | 15 | 2.61 | 93 | 18.38 | 34 | 17.44 |
| In Union | 40 | 2.87 | 10 | 1.74 | 41 | 8.10 | 10 | 5.13 |
| Other (Divorced | 33 | 2.37 | 7 | 1.22 | 15 | 2.96 | 6 | 3.08 |

# Regression Specifications

- Aggregated county-analyses:

$$m_c = \beta X_c + \gamma XZ_c + \mu_c + \varepsilon_c$$

$$m_{c,84} - m_{c,73} = \beta(X_{c,84} - X_{c,73}) + \gamma(Z_{c,84} - Z_{c,73}) + (\mu_c - \mu_c) + (\varepsilon_{c,84} - \varepsilon_{c,73})$$

- Individual-level widowhood model:

$$Widowed_{icy} = \gamma_1 X_{icy} + \gamma_2 age_{icy} + \gamma_3 Z_{icy} + \gamma_4 CountyFixedEffect_{icy} + \varepsilon_{icy}$$

# Interpreting Education Gradients

1. **True effect of education on widow's own longevity after spouse's death. => Positive coefficient**

2. **Bias due to differential re-marriage by education. Empirically, education may reduce re-marriage rates. => positive bias**

3. **True effect of education (own or spouses) on husband's mortality. Higher educated women would be less likely to be observed as widowed.**

   **=> Negative coefficient**

Table 4: County-Level Female Widowhood and Male Mortality Regressio

| | Female Widowhood | | | | Male Mortality | | | |
|---|---|---|---|---|---|---|---|---|
| | **OLS** | | **FD** | | **OLS** | | **FD** | |
| *Education Categories* | | | | | | | | |
| *Primary ed* | -0.0794 | * | -0.1018 | * | -0.0062 | | -0.0297 | ** |
| | (.0308) | | (.0480) | | (.0053) | | (.0103) | |
| *Secondary* | -0.0921 | * | -0.1230 | | -0.0089 | | -0.0278 | |
| | (.0435) | | (.0869) | | (.0081) | | (.0143) | |
| *Insurance* | 0.0259 | | -0.0258 | | 0.0078 | | -0.0041 | |
| | (.0226) | | (.0256) | | (.0050) | | (.0037) | |
| *Central valle* | 0.0105 | | (dropped) | | -0.0002 | | (dropped) | |
| | (.0060) | | | | (.0013) | | | |
| Number of obs | 198 | | 99 | | 198 | | 99 | |

Table 6: Individual-Level Female Widowhood and Male Mortality Re

| **Variable Name** | **Female Widowhood** | | | | **Male Widowhood** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Pooled** | | **County FE** | | **Pooled** | | **County FE** | |
| *Education Categories* | | | | | | | | |
| *Primary edu* | -0.0399 | ** | -0.0387 | ** | -0.0054 | ** | -0.0056 | ** |
| | (.0027) | | (.0029) | | (.0019) | | (.0022) | |
| *Secondary e* | -0.0672 | ** | -0.0708 | ** | -0.0220 | ** | -0.0215 | ** |
| | (.0040) | | (.0039) | | (.0025) | | (.0025) | |
| *Insurance* | -0.0038 | | -0.0036 | | -0.0164 | ** | -0.0170 | ** |
| | (.0023) | | (.0032) | | (.0014) | | (.0023) | |
| *Central valle* | 0.0162 | ** | (dropped) | | 0.0022 | | (dropped) | |
| | (.0043) | | | | (.0027) | | | |
| Number of obs | 188268 | | 188268 | | 187271 | | 187271 | |

# Conclusion

- **Widowhood analyses revealed strong apparent education effects on premature male mortality; not previously observed in other Costa Rican data.**

- **Simulation suggests caution; further modeling necessary.**

- **Continuing data scarcity implies widowhood techniques have large potential scientific returns.**

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# The high life expectancy of Costa Rican elders

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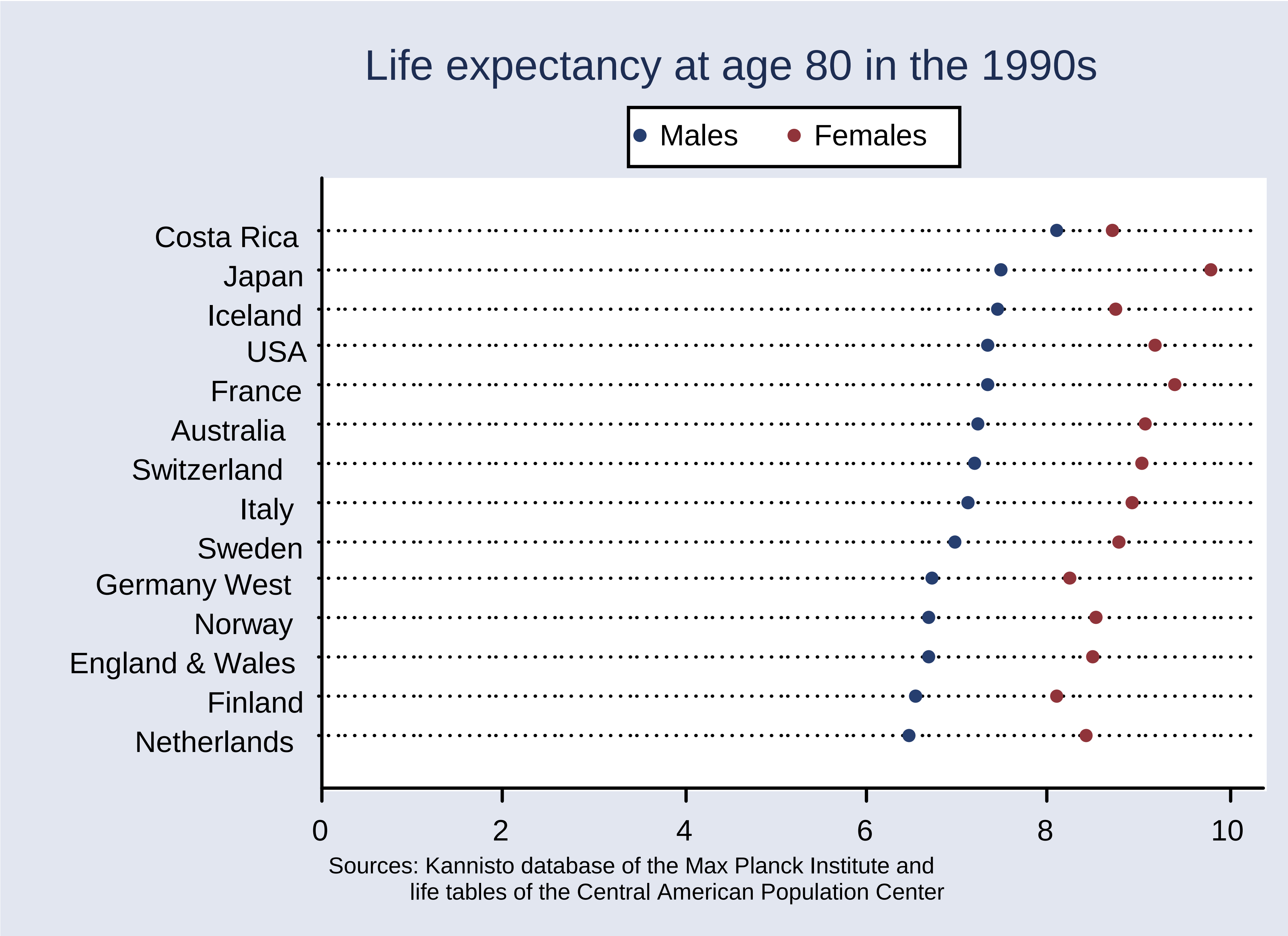
(Supported by the Wellcome Trust)


Life expectancy at age 80 in the 1990s
Males
Females
Costa Rica
Japan
Iceland
USA
France
Australia
Switzerland
Italy
Sweden
Germany West
Norway
England & Wales
Finland
Netherlands
0
2
4
6
8
10
Sources: Kannisto database of the Max Planck Institute and
life tables of the Central American Population Center

# The research questions

- Is this high longevity for real? Or due to:
  - Under registration of deaths
  - Inflated denominators by age exaggeration
- How could it be? (health expenditure per person in Costa Rica is one-tenth of the US!)

# Two data sets

- 24,000 **nonagenarians** who died in 1983-2003 or were alive, from the voting register. For looking at the data **validity issue.**

- Random **sample** of 7,200 Costa Ricans, aged 60+ from the June 2000 census. Followed until November 2003. For looking at **correlates** (only census variables)

# Methods

- Extinct cohort method to estimate mortality in the nonagenarian data set.
- Mortality model as function of age, sex and a standard set of $m_x$ rates
- Poisson regression to estimate the model
- Life tables to estimate life expectancy from the $m_x$ rates

# The mortality model

$$m_x = \alpha\, v_x\, \exp(\beta\ x)\ error$$

$m_x$ death rate at age-sex $x$

$v_x$ standard or expected death rate at $x$

$\alpha$ indicator of the general mortality level (rate ratio at x=0) compared to the standard $v_0$

$\beta$ indicator of aging-sex effects that are particular to Costa Rica (negative $\beta$ would indicate that the effect of aging is relatively smaller)

For $v_x$ we used the Kannisto (1988) average for 13 countries with valid data (ages 80 and up) and the Himes et al (1994) low mortality standard (ages 50 and up)

# Mortality correlates model:

$$m_{xi} = \alpha_{\square} v_x \, \alpha_{\square} z_i \, \exp(\beta_{\square} \, x + \beta_{\square} \, z_i \, x + error)$$

$z_i$ vector of *i* correlates (such as residence in the capital or health insurance)

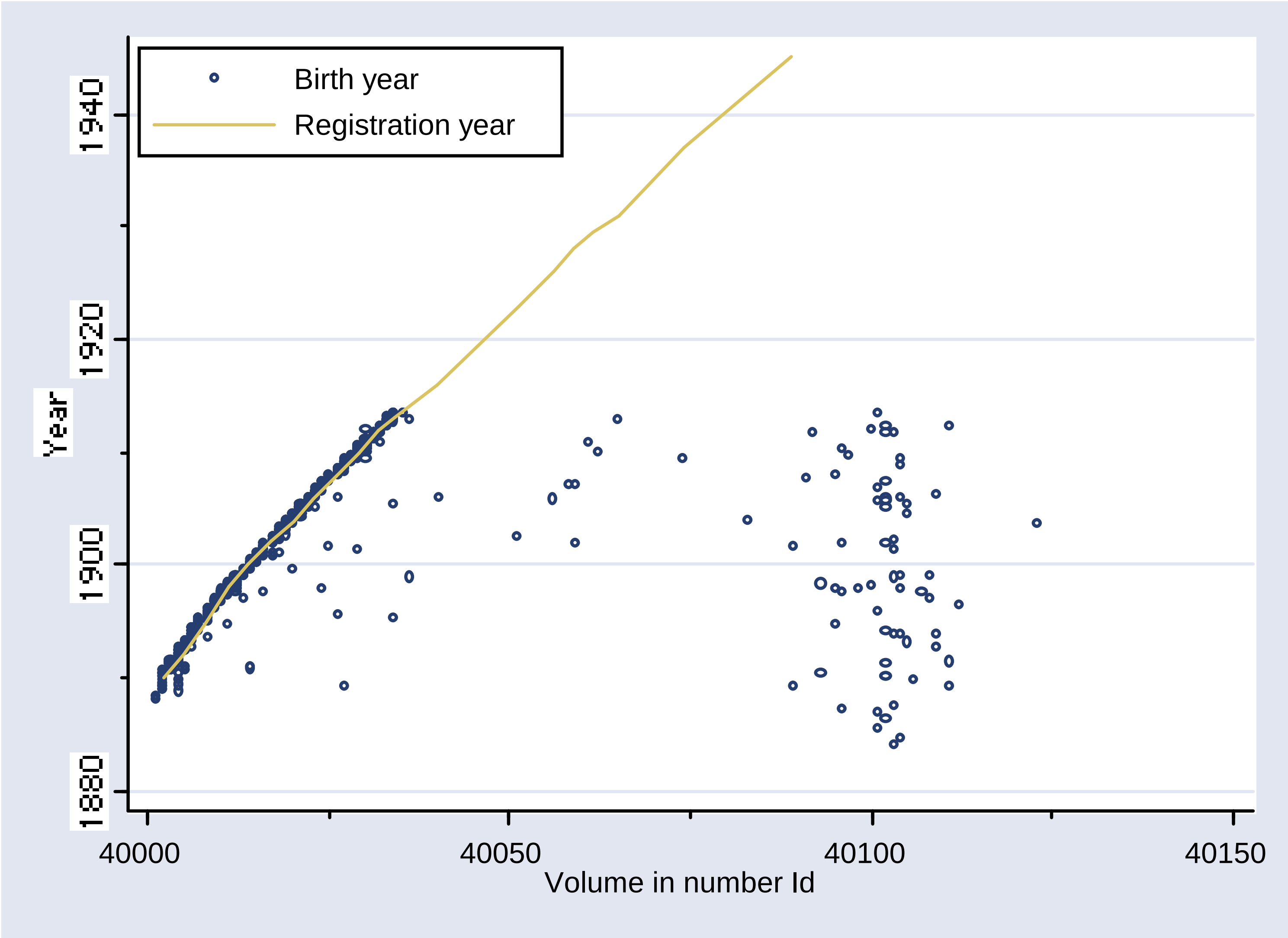
$\alpha_{\square}$ coefficients measure the general effect of the zi characteristic (at x = 0)

$\beta_{\square}$ coefficients measure the aging/sex effect specific to each characteristic *i*.

# Mortality correlates

- Disabled (26%) (at least 1 out of 10 disabilities asked in the 2000 census)
- Health insurance: Employee (55%) - voluntary (38%) - none (7%)
- Residence: Great San Jose (46%) / other
- Education: None (17%) - Elementary (67%) - Secondary+ (16%)
- Wealth (ownership of 17 conveniences in the household): low(39%) - middle (29%) - high(32%)
- Married or in a union (53%)

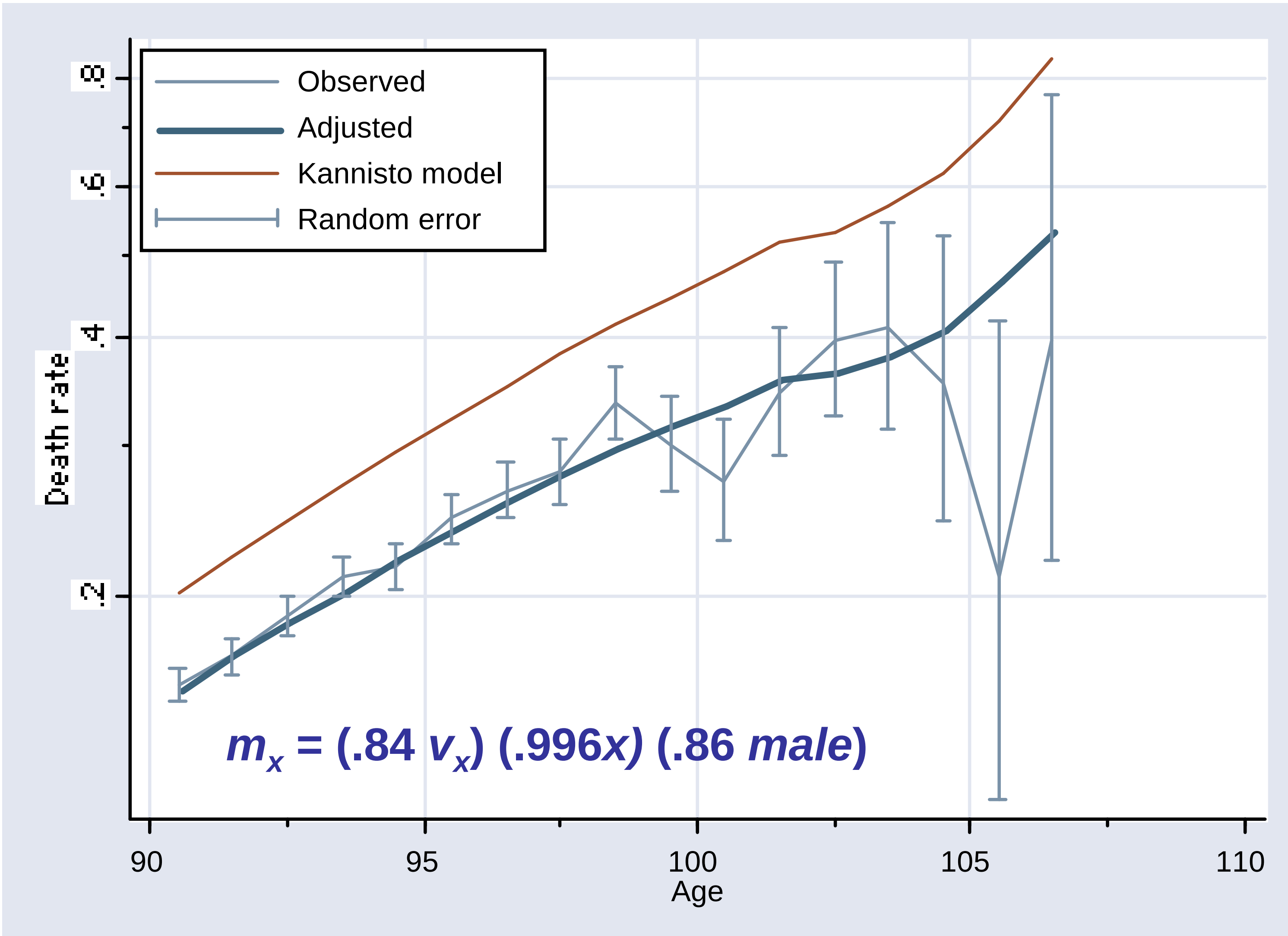
# Age validation with the ID no.

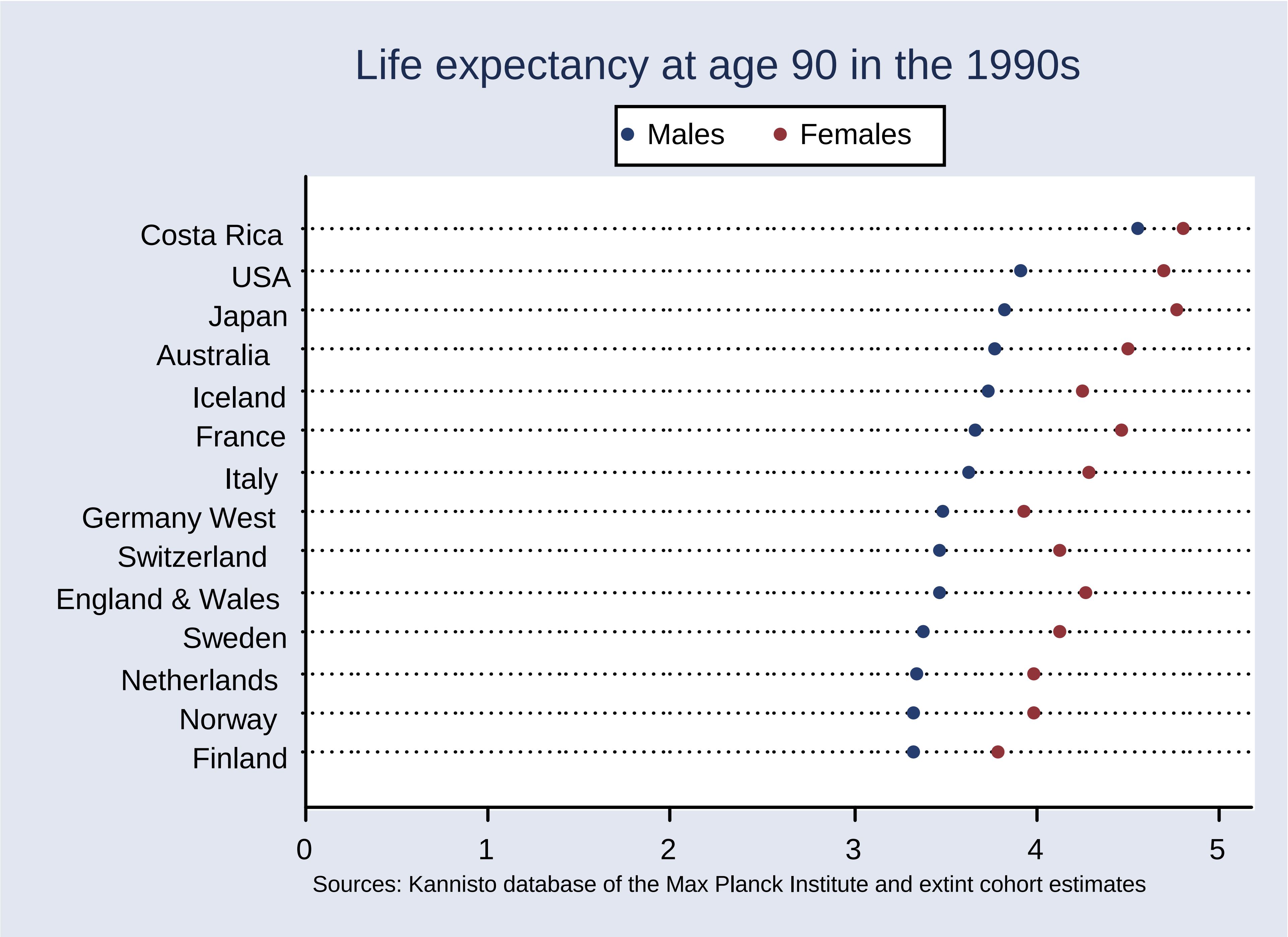


# 80%+ with validated age

| Birth decade | (N) | Timely register |
|---|---|---|
| Total | (23,954) | 83% |
| 1880 | (579) | 26% |
| 1890 | (5,369) | 79% |
| 1900 | (11,680) | 85% |
| 1910 | (6,326) | 88% |

# Low mortality rates, volatile in centenarians

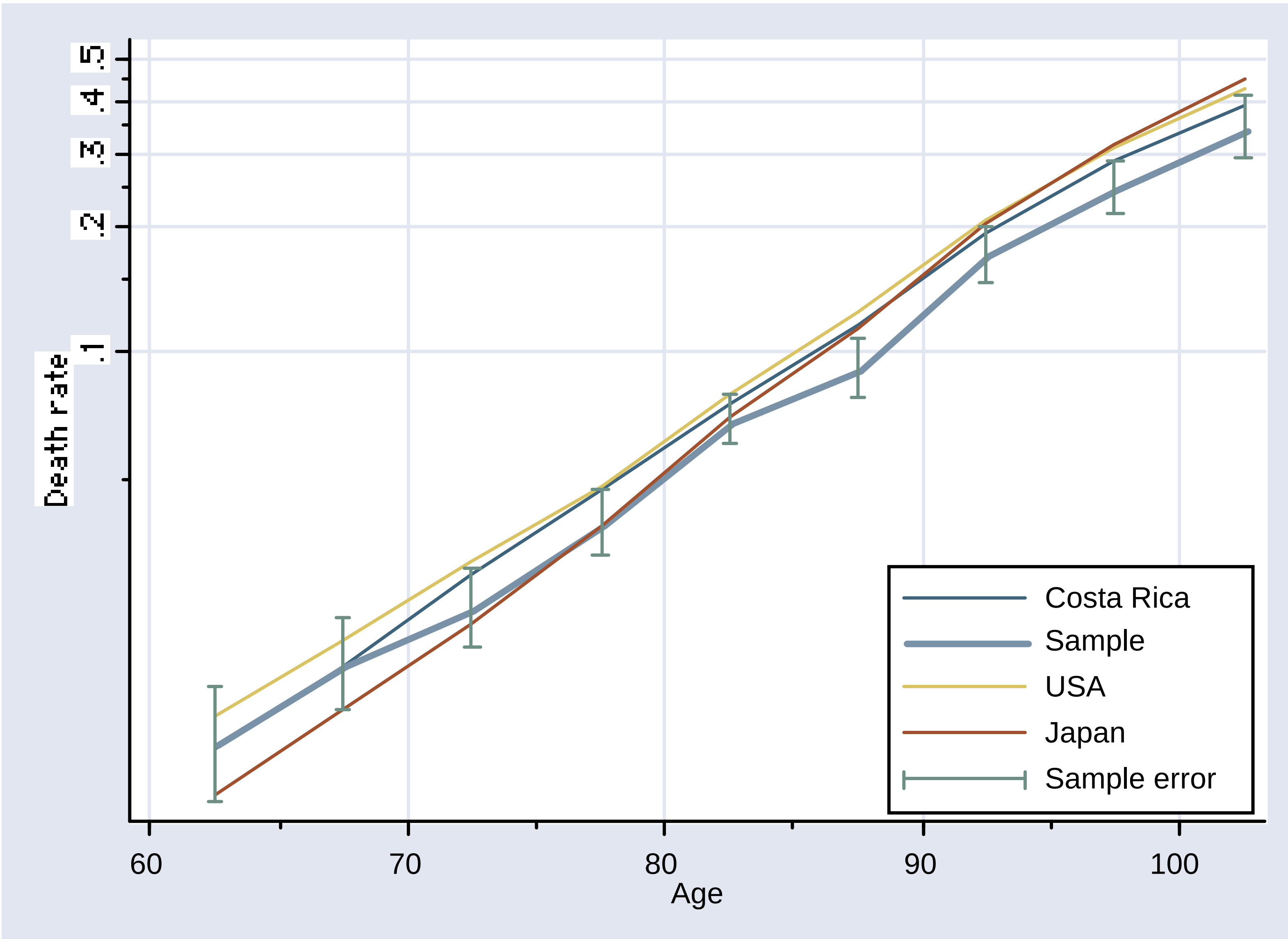




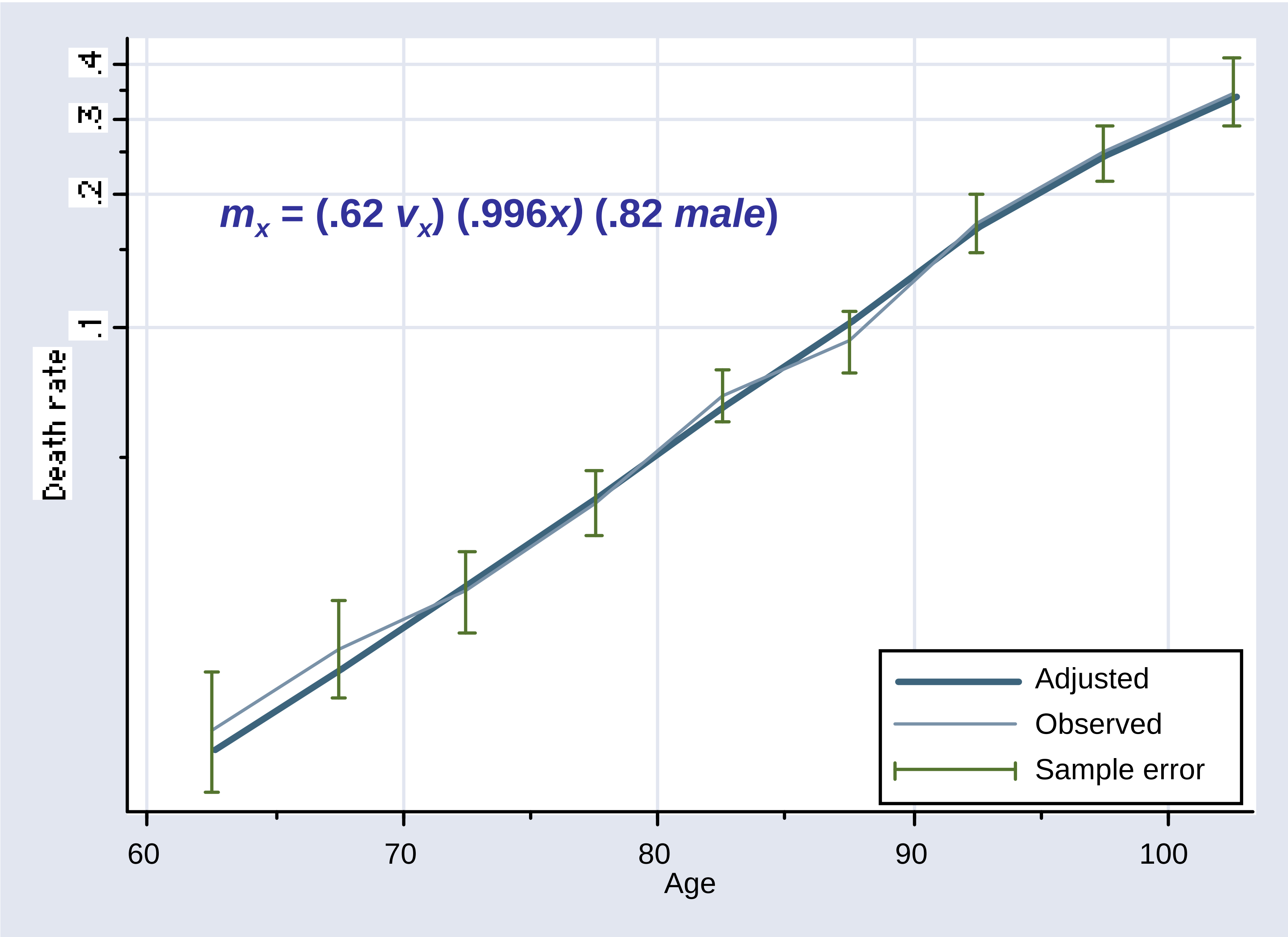
Life expectancy at age 90 in the 1990s
Males
Females
Costa Rica
USA
Japan
Australia
Iceland
France
Italy
Germany West
Switzerland
England & Wales
Sweden
Netherlands
Norway
Finland
0
1
2
3
4
5
Sources: Kannisto database of the Max Planck Institute and extint cohort estimates

# The correlates in a 7,200 sample (25,000 person/years)

# Sample confirms population estimates



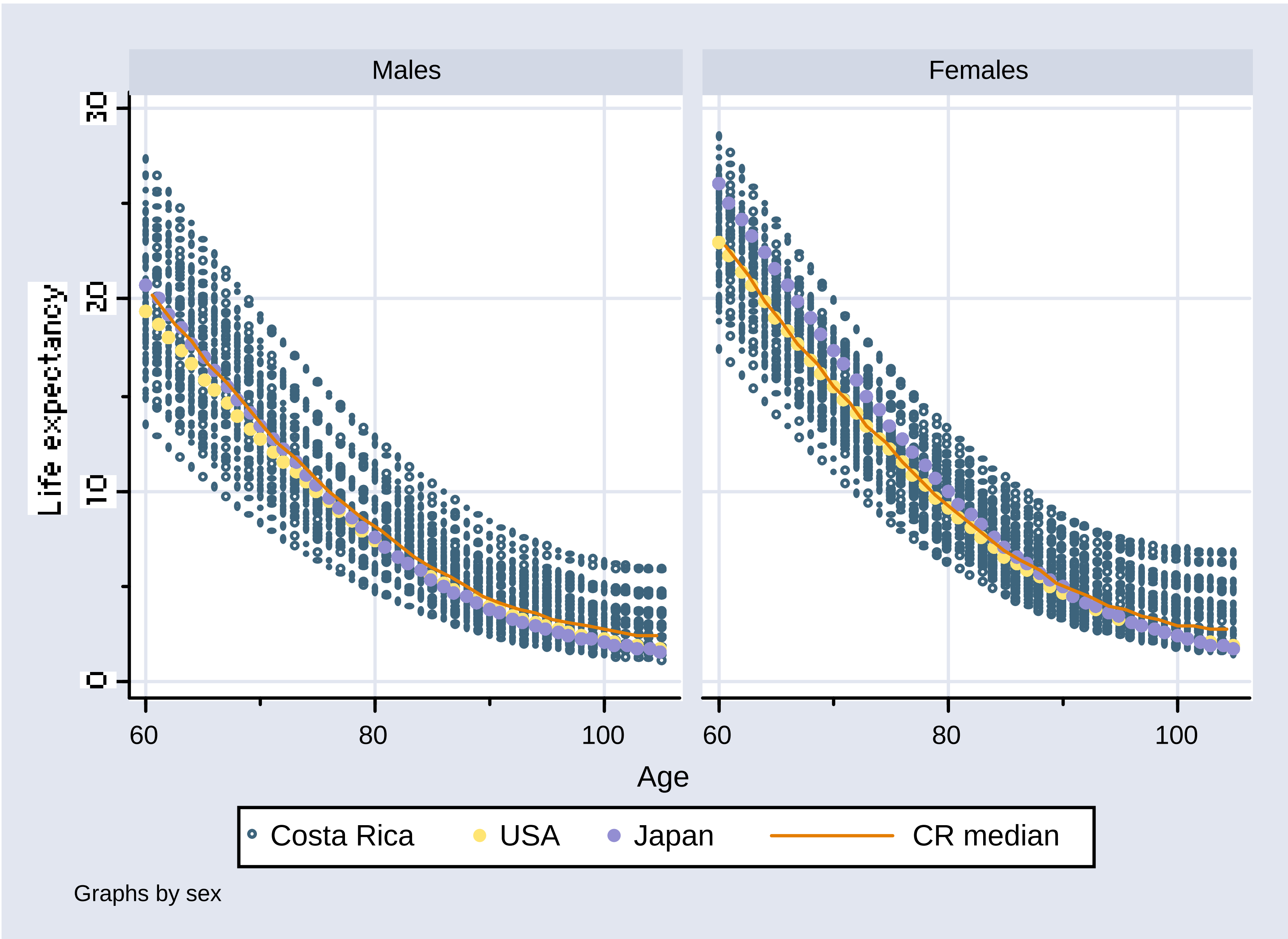
# The estimated model



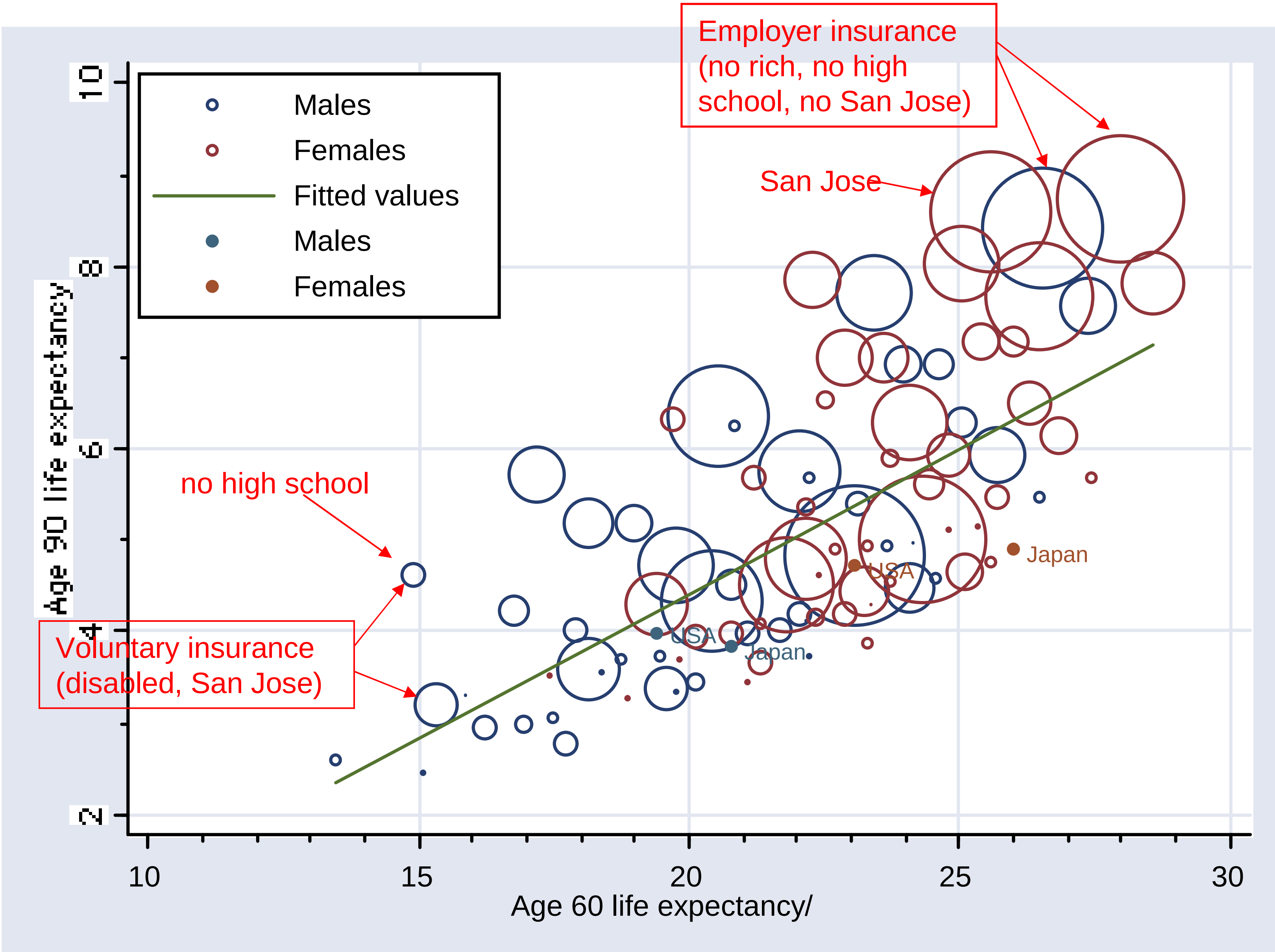
# Relative death rates

| Significant correlates | At age 60 | Age | Male |
|---|---|---|---|
| Disabled | 1.61 | 0.990 | |
| Voluntary insurance<br>No insurance | 0.95<br>0.68 | 1.022<br>1.024 | |
| High school | 1.27 | --- | |
| High wealth | 0.70 | 1.014 | |
| San Jose residence | 1.61 | 0.988 | 1.35 |
| Late registration | 0.68 | 1.012 | |

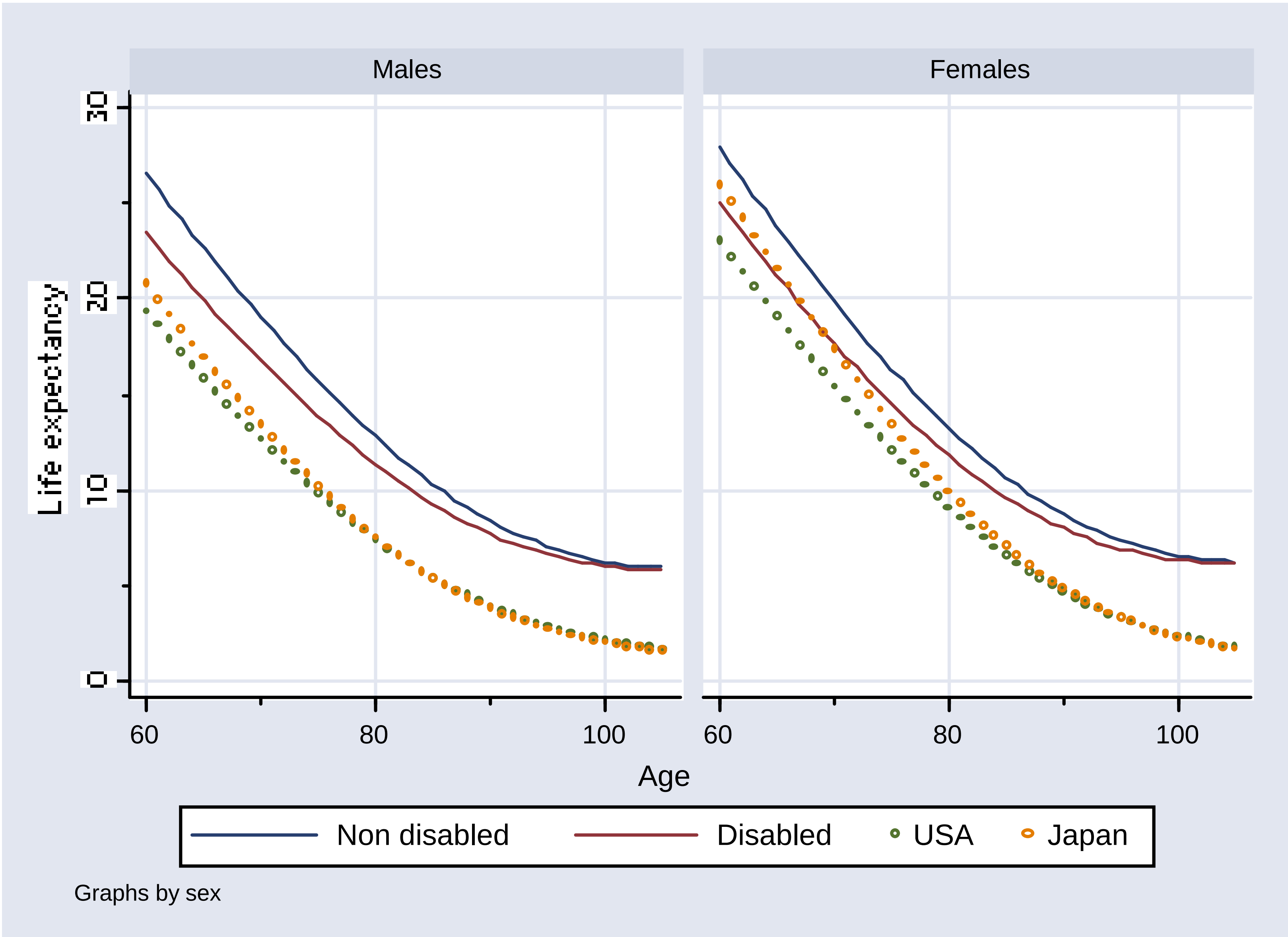
# Life expectancy by age



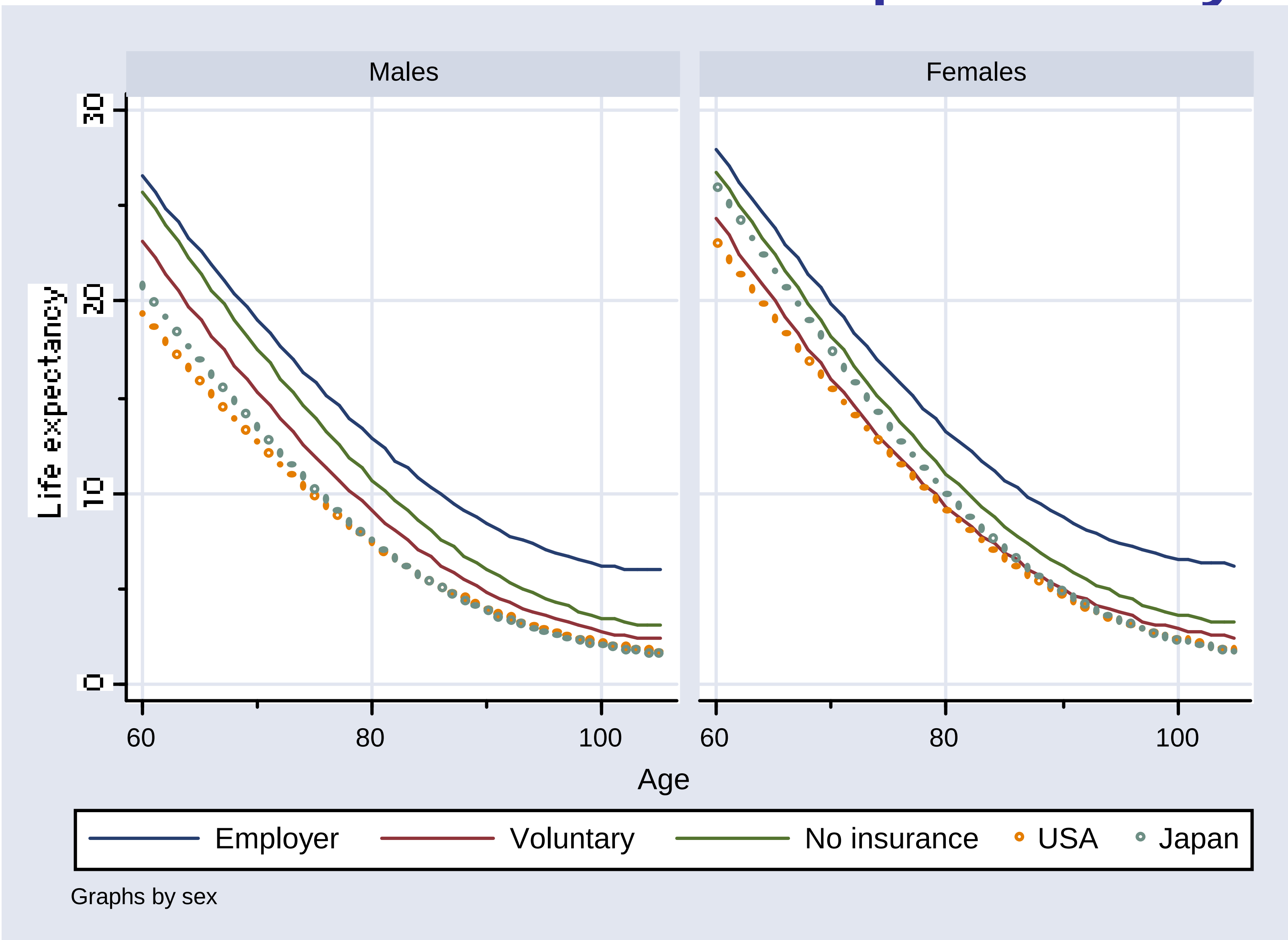
# Life expectancy at ages 60 and 90 in all 192 groups



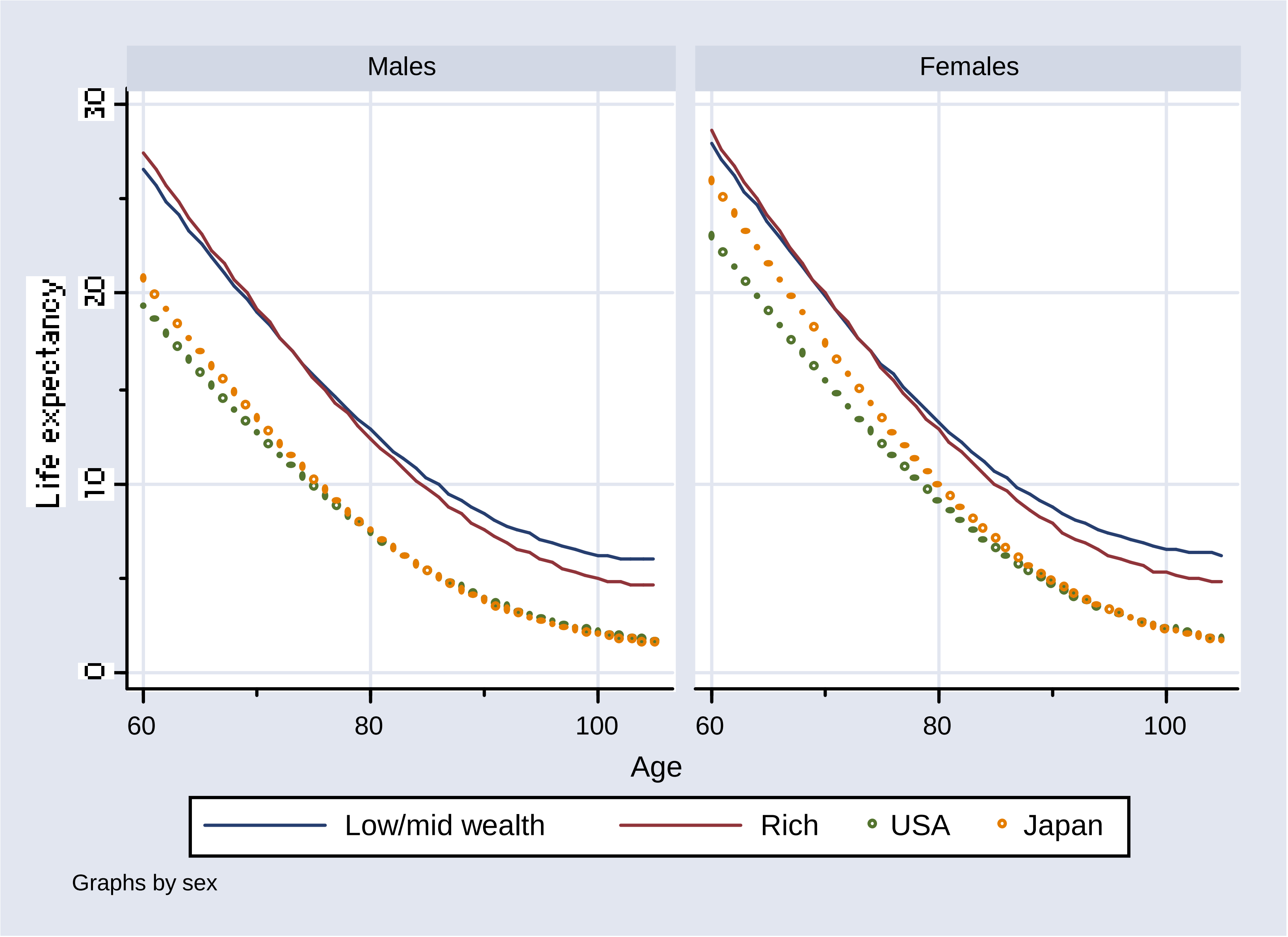
# Disability & life expectancy



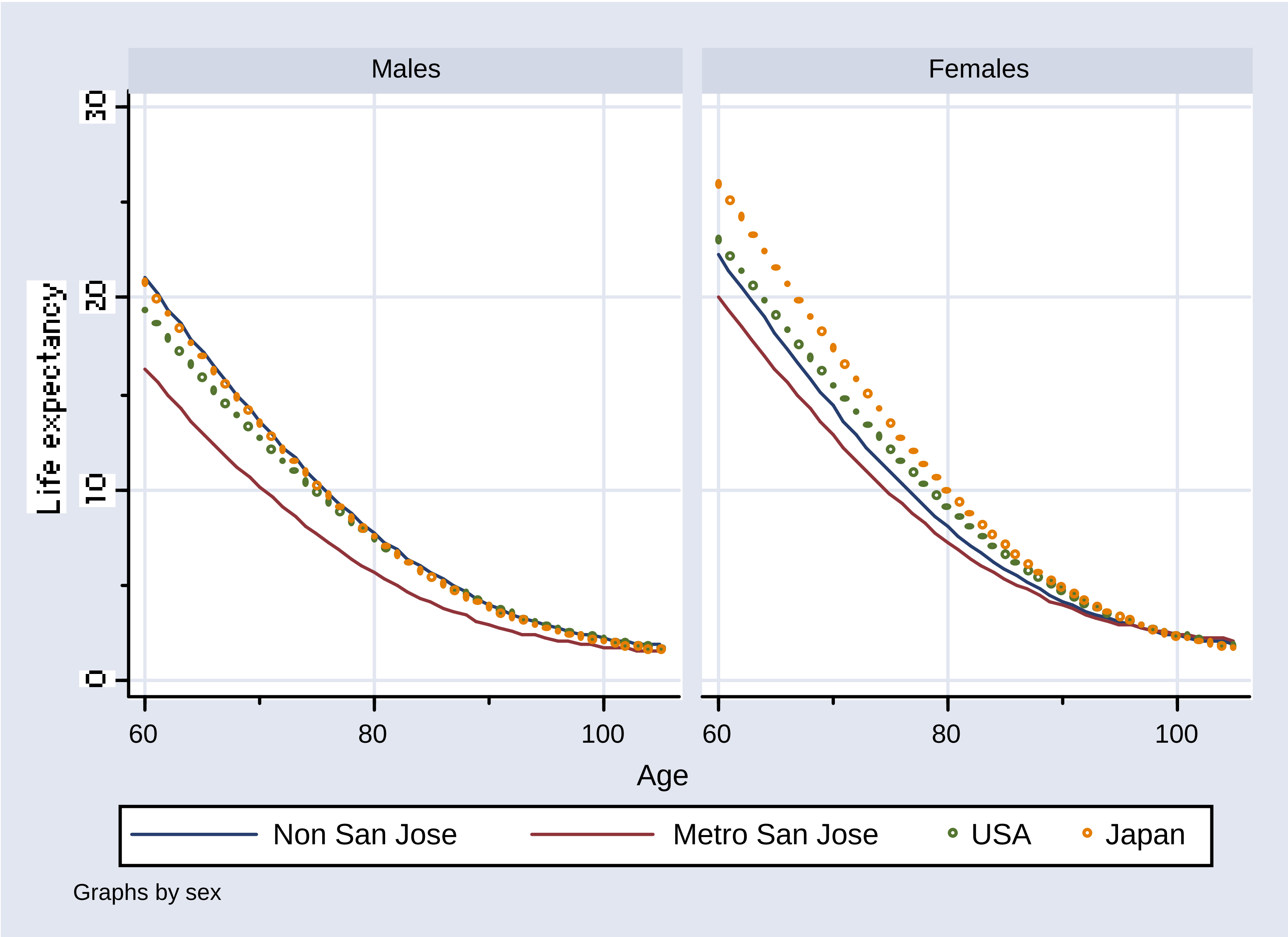
# Insurance & life expectancy



# Wealth & life expectancy



# San Jose residence & LE



# Age 60 life expectancy by education and residence

## (Non disabled men, employee insurance, low/mid wealth)

| Education | No SJ | San Jose | Total |
|---|---|---|---|
| < high school | 26.6 | 20.6 | 24.2 |
| High School | 24.0 | 18.2 | 20.2 |
| Total | 26.3 | 20.1 | 23.6 |

# Conclusions

- Can you believe that elderly Costa Rican men have one of the highest life expectancy in the world?
- Having employer-provided health insurance is an important factor for the high longevity in CR
- Modernity (education, wealth, and living in the capital) may actually reduce life expectancy of the elderly…

More research is needed!

Thank you