

LONGEVITY IN THE 21ST CENTURY: THE TUG OF THE PAST

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Potential value of this work(?)

- ▣ Importance of cohort compositional changes by health related traits or attributes as a platform to:
 - inform projections and forecasts
 - understand nature of future trends even if we are unable to forecast them correctly

Cohort and Period Changes: I

- ▣ Object: changing composition of cohorts according to well-defined traits/attributes known to be linked to health and mortality to specify future trends

- ▣ Conditions:
 - Know how cohorts evolve under selection pressure due to the trait;
 - Know the linkage between the traits and health and mortality;

Cohort and Period Changes: II

- Period changes (not linked to cohorts; affecting all cohorts the same way) may also be important (emergence of new diseases; climate changes etc...)
- Period changes/shocks may alter both the changing composition of cohort by traits (selection) and the linkage between traits/attributes and health/mortality risk ...medical technology

Three cohort shifts in LAC

- ▣ Adult cohorts are changing relative to their past exposure to early conditions
- ▣ Adult cohorts are changing relative to prevalence of smoking (uptake/desistance)
- ▣ Adult cohorts changed relative to prevalence of obesity (early/adult/trajectories)

Punch line

- ▣ All three shifts imply:
 - Changes in health status associated with chronic conditions (CVD, cancer, DT2, COPD)
 - Changes in mortality that oppose resistance to improvements in longevity
 - Changes in demand for health infrastructure, service and and expenditures (DT2)

Estimation

- ▣ Identification of trait and assessment of composition of cohort by trait: past, present and near term
 - Rate of acquisition of and resistance to traits
 - force of selection due to traits

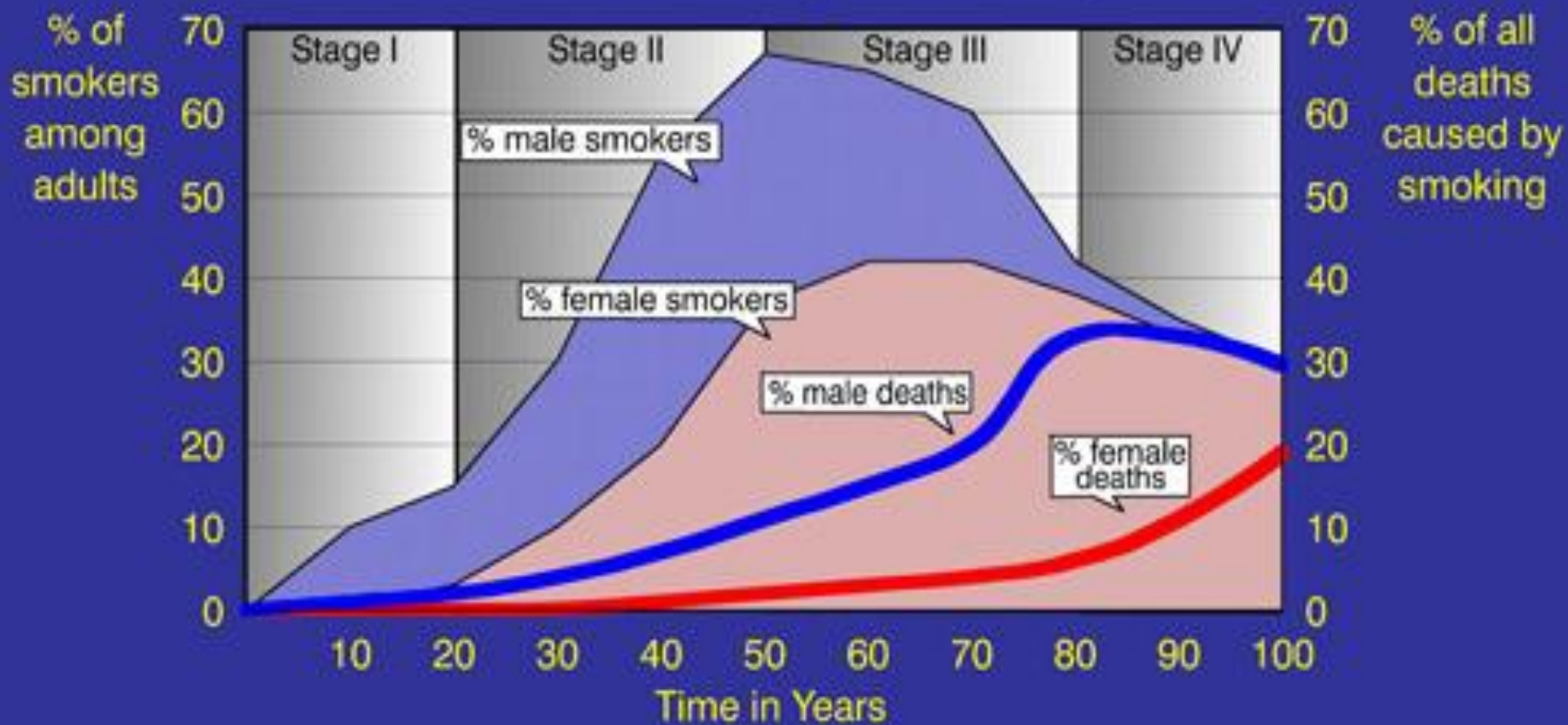
- ▣ Identification of linkage between traits and excess health/mortality risks

Changing composition by past exposure to smoking

- ▣ Past smoking and stages in the smoking epidemic:
 - Early and late stages
 - Male-female contrasts
 - Special cases Brazil, Cuba and Chile
- ▣ Selection: before age 50 is negligible
- ▣ Linkage to mortality: via lung cancer
 - Age of onset; duration; intensity

Four Stages of the Tobacco Epidemic

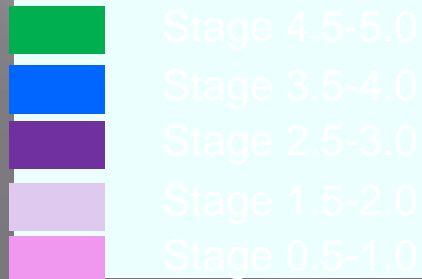
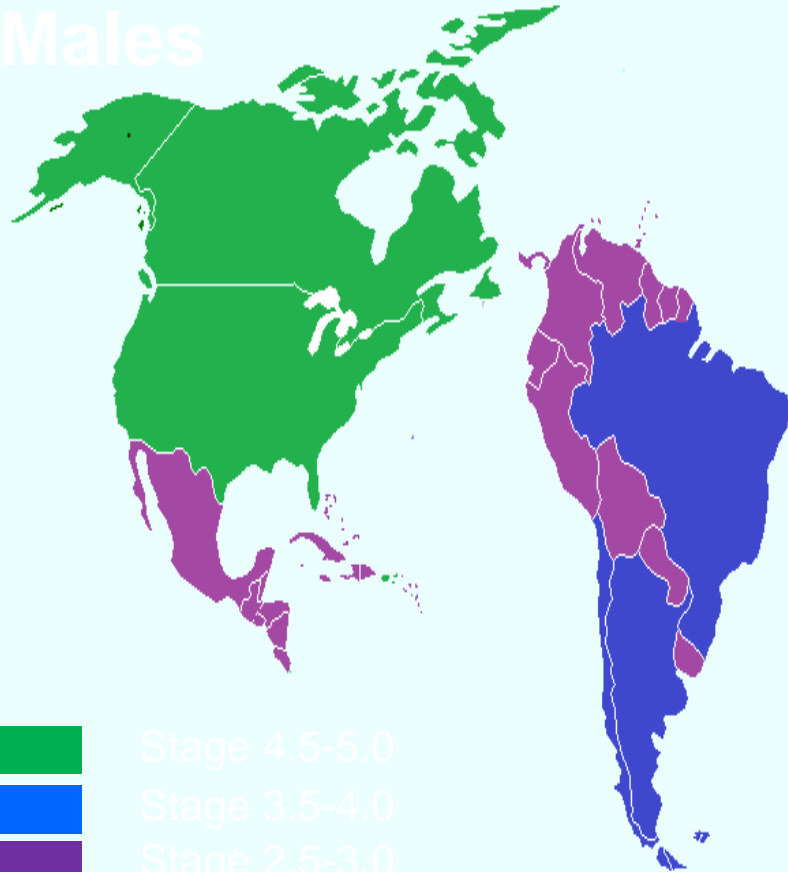
A model of the cigarette epidemic



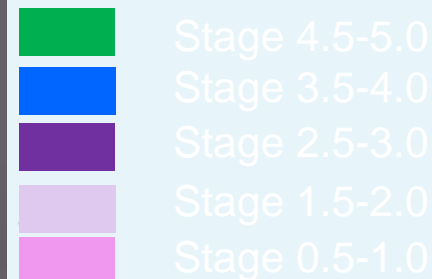
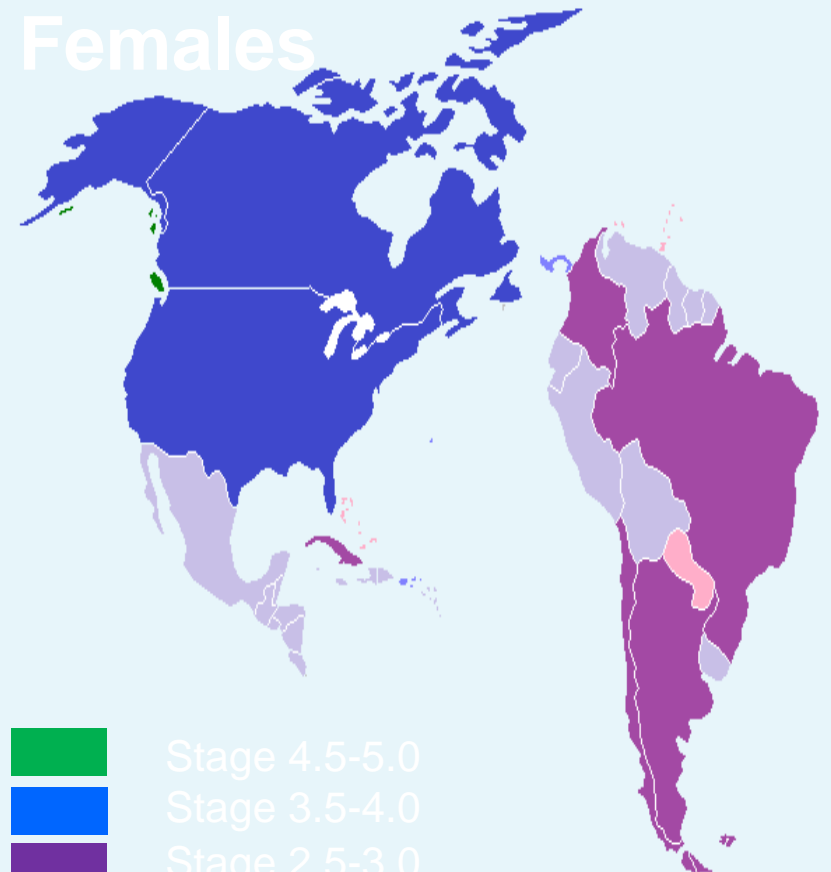
Source: Lopez et al 1994

The Americas: Stages of the Tobacco Epidemic

Males



Females



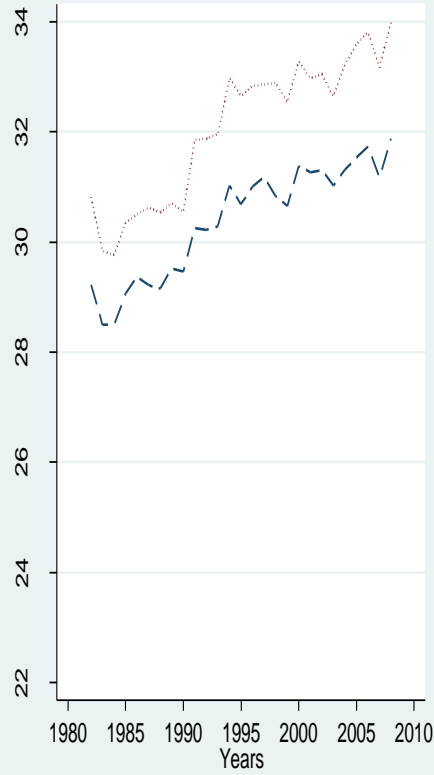
Argentina

Males



--- Observed Counterfactual

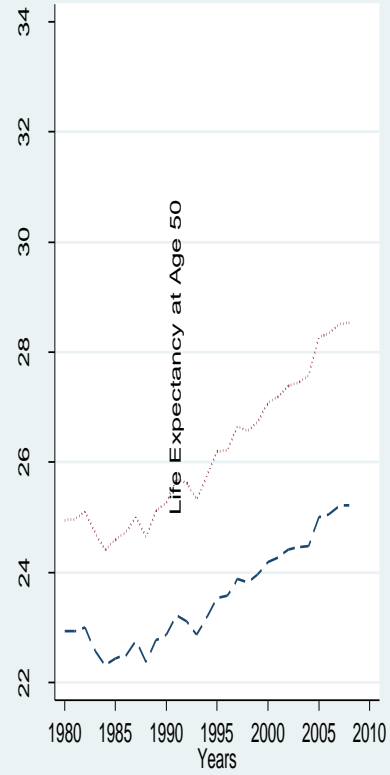
Females



--- Observed Counterfactual

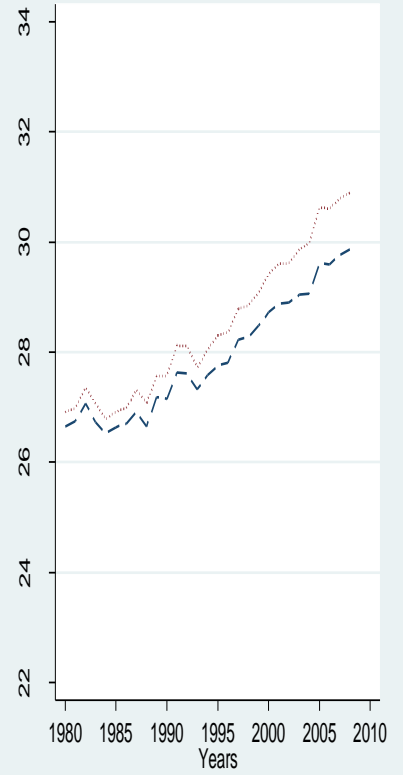
Brazil

Males



--- Observed Counterfactual

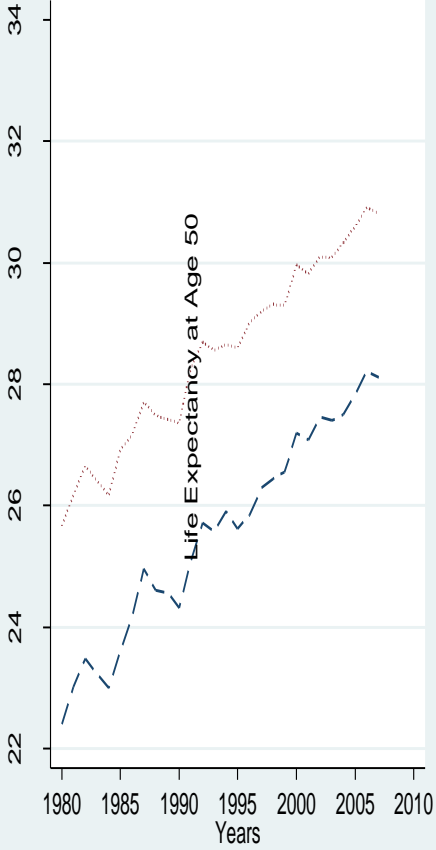
Females



--- Observed Counterfactual

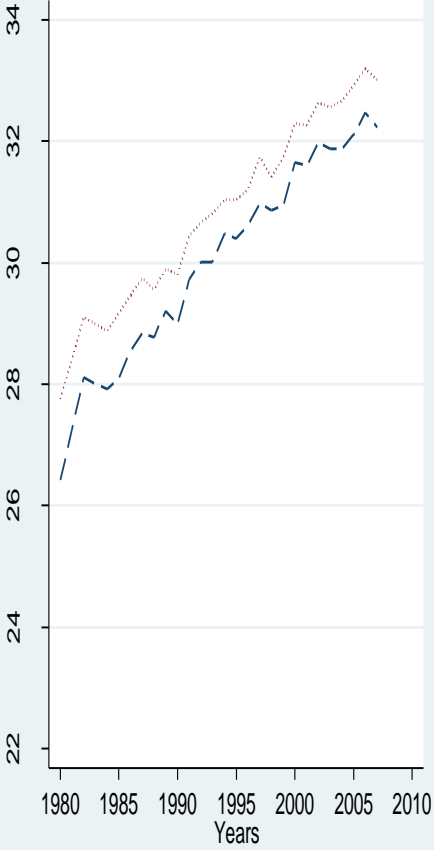
Chile

Males



--- Observed Counterfactual

Females



--- Observed Counterfactual

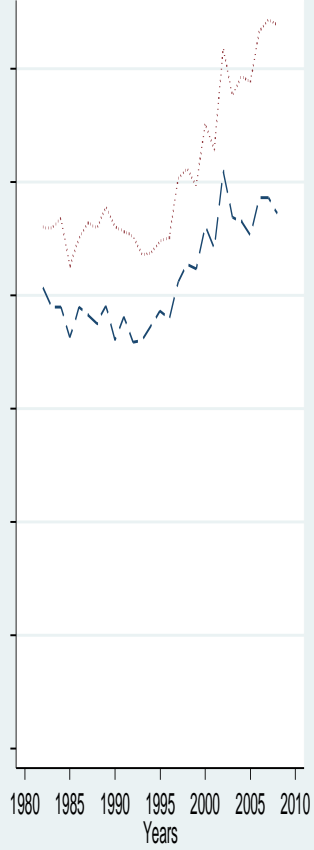
Cuba

Males



--- Observed Counterfactual

Females

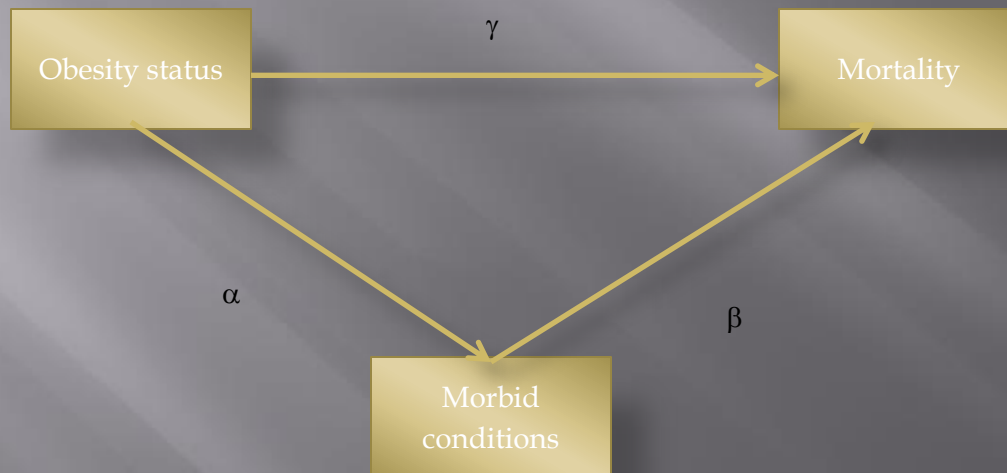


--- Observed Counterfactual

Changing composition by obesity

- ▣ Increasing obesity throughout
 - Early and late stages
 - Male-female contrasts
 - Special cases: Mexico
- ▣ Selection: before age 50 is minor
- ▣ Linkage to mortality: via DT2, CVD, cancer, cognitive decline
 - Age of onset; duration; trajectories

Figure 4: Relations between obesity, diseases and mortality



The case of Mexico

- ▣ Ten year risk of developing DT2 given obesity at the outset
- ▣ Risk of DT2 (cancer; heart) given DT2
- ▣ Overall mortality excess due to obesity

Recent estimates

INTERMEDIATE RISKS

- ▣ Risk of DT2 given obesity
 - 1.44-1.56 obese
 - 1.36-1.42 overweight

- ▣ Risk of mortality given DT2
 - 1.70

OVERALL IMPACT ON MORTALITY AT AGES OVER 50

- ▣ Losses between 3 and 4 years of life at age 50

- ▣ About 9-14% of $E(50)$

Changing composition by early exposures

- Trait: Type/extent of exposure to early diseases and poor nutrition
- Strong and weak conditions
 - Depend on regime of mortality decline
- Selection before 50: substantial
- Linkage to mortality: via DT2, CVD, COPD, some cancers (liver; gastrointestinal)
 - Age of onset; duration; trajectories

Types of frailty

- Standard: established at birth, invariant and invariant effects on mortality. If you believe in this you can also believe in:
- Barker: established in the age interval (-1,5), invariant but with time varying effects
 - Effects on mortality before age 5 and on mortality above age 60

Figure 2b: Life expectancy at age 60 under alternative scenarios
Guatemala

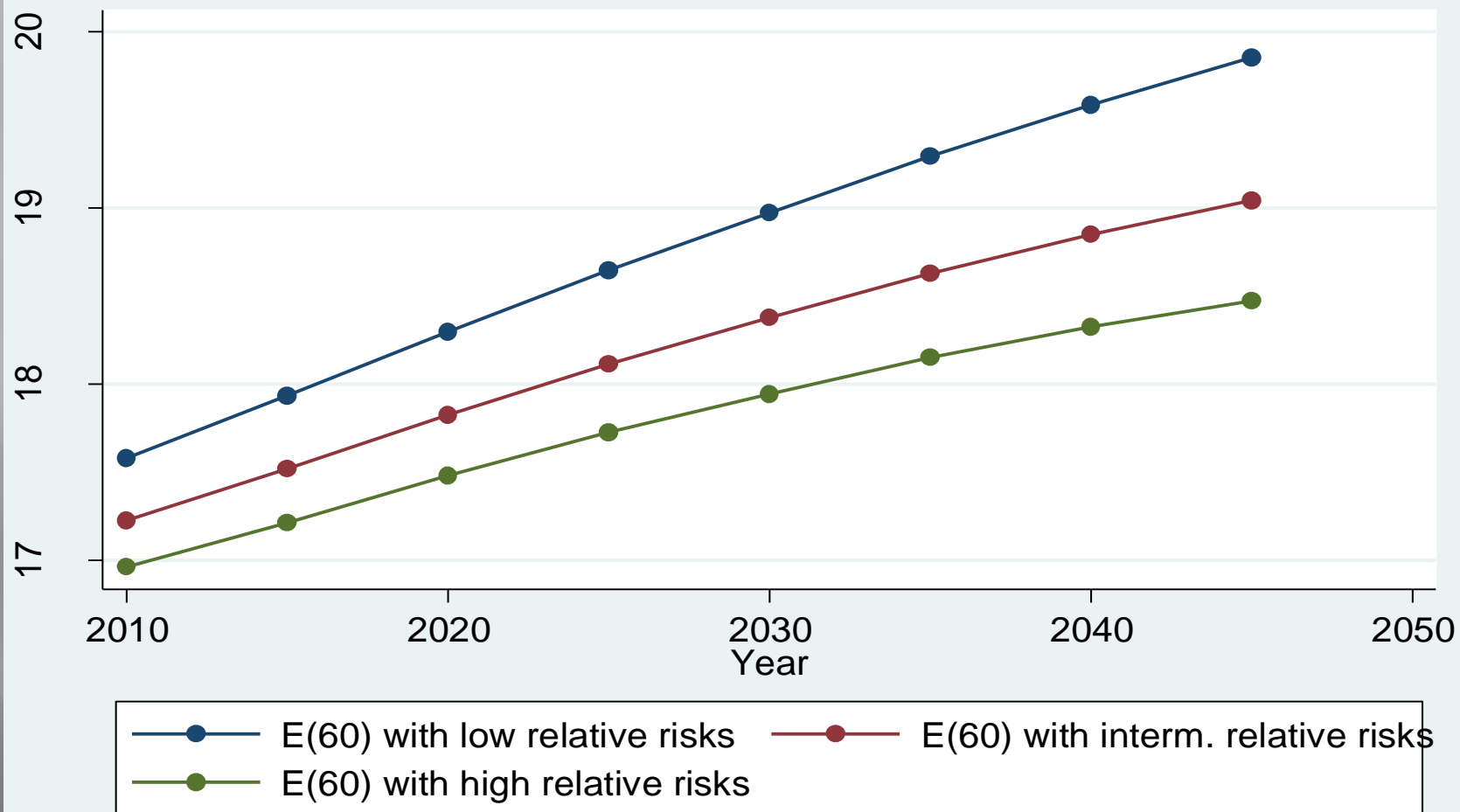
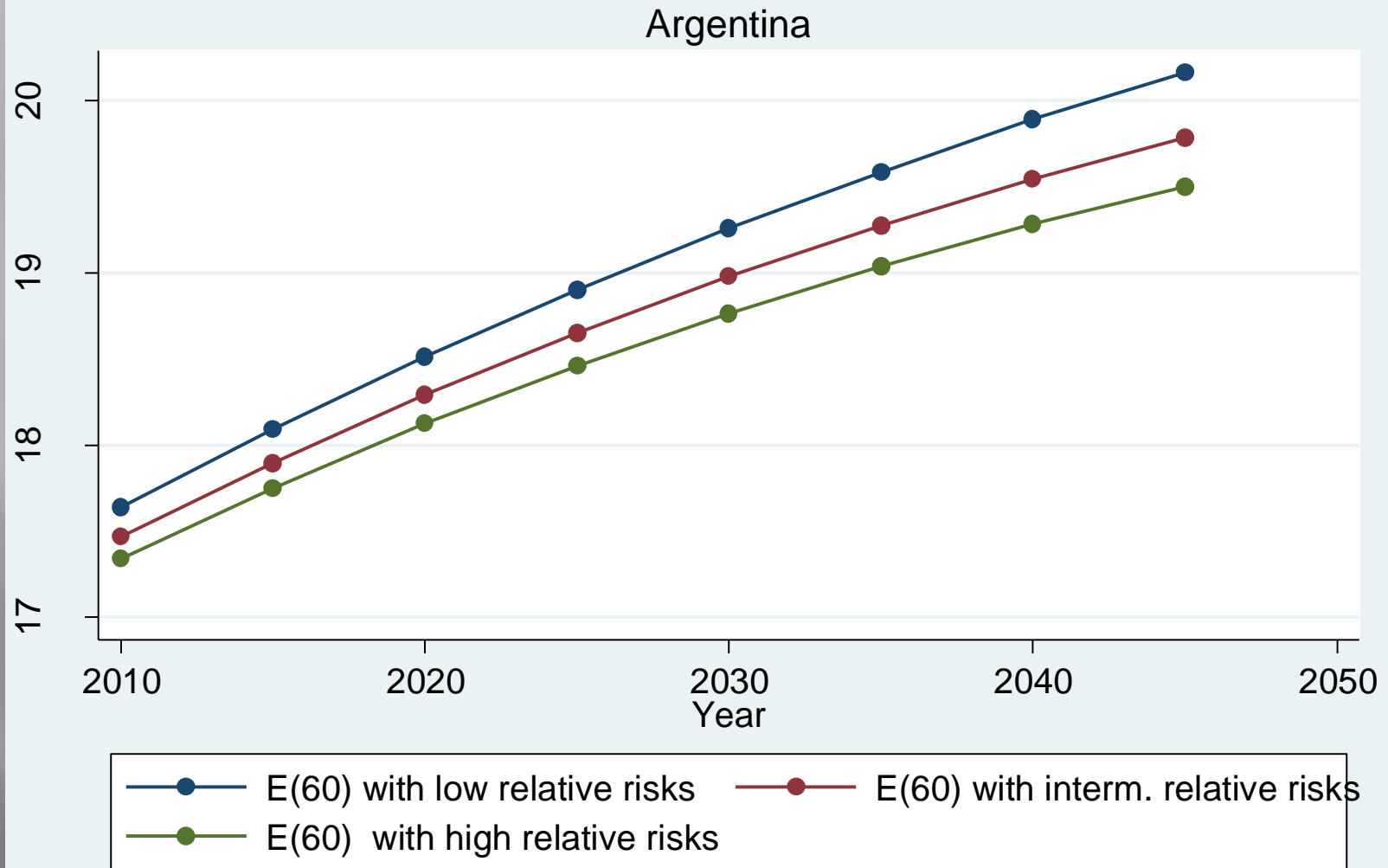


Figure 2a: Life expectancy at age 60 under different scenarios.....



CONCLUSIONS

- ▣ Strength of estimates is variable
 - Stronger for smoking and obesity
 - Weaker for early conditions
- ▣ Estimates are absurdly conservative
- ▣ Ignore interactions between traits
 - Excess mortality due to smoking AND obesity
- ▣ Assumes no changes in medical technology
 - What if new lung cancer therapy that leads to final remission?
- ▣ Need to generate similar estimates for other regions
 - Other countries may be worse than obesity in Mexico or smoking in Cuba

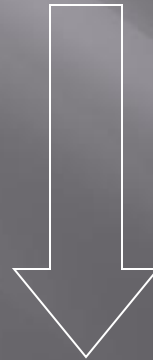
END

Early Conditions

**Nutritional
Status**

**Particular
Diseases**

**Recurrent
Infections**



**Heart and
Pulmonary
Diseases**
Diabetes

**Heart and
Liver
Diseases**
**Stomach
Cancer**

**Coronary
Artery
Diseases**

Early Conditions

**Nutritional
Status**



**Heart and
Pulmonary
Diseases**
Diabetes

Barker and Osmond 1986

Barker et al 1989a, 1989b, 1989c

Barker 1994, 1998

Fowden and Forhead 2004

Gluckman and Hanson 2006

Godfrey et al 2007

Palloni and McEniry 2007

Kaijser et al 2008

Early Conditions

Particular
Diseases



Elo and Preston 1992

Go 2002

Blaser et al 2005

Heart and Liver
Diseases

Stomach Cancer

Diabetes I

Early Conditions

Recurrent
Infections

Inflammatory
Process

Fong 2000, 2004, 2005
<periodontitis/chlamydia
pneumonia>

Finch and Crimmins 2004

Crimmins and Finch 2006

McDade et al 2010

Coronary
Artery
Diseases

HOW DOES MORTALITY CHANGE

EXPOSURE

RESISTANCE

RECOVERY

**Minimize
contraction
rates**
(eradication,
vaccination)

**Minimize
sequelae**
(antibiotics,
nutrition)

**Minimize
scars**
(nutrition,
therapies)

Mortality regimes and Barker effects

Mortality Decline	Early-late health connection		
	Nutritional Status	Diseases	Recurrent Infections
Standards of living	(++)	(+)	(+)
Public Health	(+)	(++)	(++)
Medical Innovations	(?)	(?)	(?)

Within Cohort Relation between Early and Late Mortality: Western Europe and North America

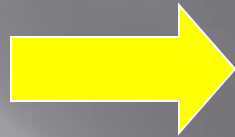
Mortality Decline	Early-late health connection		
	Nutritional Status	Particular diseases	Recurrent Infections
Standards of living	(++)	(+)	(+)
Public Health	(+)	(++)	(++)
	(?)	(?)	(?)

Within Cohort Relation between Early and Late Mortality:LAC

Mortality Decline	Early-late health connection		
	Nutritional Status	Particular diseases	Recurrent Infections
Standards of living	(++)	(+)	(+)
Public Health	(+)	(+)	(+)
Medical Innovations	(?)	(?)	(?)

The scenario in LAC countries

**Medical
improvements
after 1940**



**Explain 40% to 60% of decline
in mortality rates in LAC
(Palloni and Wyrick 1981;
Palloni and Pinto, 2011)**

+



Within Cohort Relation between Early and Late Mortality

Mortality Decline	Type of early-late health connection		
	Nutritional Status	Particular diseases	Recurrent Infections
	(++)	(+)	(+)
	(+)	(+)	(+)
Medical Innovations	(?)	(?)	(?)

Within Cohort Relation between Early and Late Mortality

Mortality Decline	Type of early-late health connection		
	Nutritional Status	Particular diseases	Recurrent Infections
	(+)	(+)	(+)
	(+)	(+)	(+)
Medical Innovations	(+)	(+)	(+)

It depends on whether medical innovation decreases contraction rates (vaccination)

Within Cohort Relation between Early and Late Mortality

Mortality Decline	Type of early-late health connection		
	Nutritional Status	Particular diseases	Recurrent Infections
	(+)	(-)	(-)
	(+)	(+)	(+)
Medical Innovations	(-)	(-)	(-)

... or increases recovery rates (antibiotics; antiparasitic treatments)

Within Cohort Relation between Early and Late Mortality

Mortality Decline	Type of early-late health connection		
	Nutritional Status	Particular diseases	Recurrent Infections
	Scenarios most likely in LAC countries		
	(++)	(+)	(+)
Public Health	(+)	(+)	(+)
Medical Innovations	0	(-)	(-)

QUICK EXAMPLES

- ▣ **Chemotherapy
(antibiotics)
enhances expression**
 - ▣ **Rheumatic heart
fever and late adult
valve disease
(stenosis)**
 - ▣ **Helicobacterium
Pylori and colon
cancer**
 - ▣ **Chagas disease**
 - ▣ **Hepatitis A**
- ▣ **Public health
(eradicate) reduces
exposure to :**
 - ▣ **Malaria**
 - ▣ **Helic.Bacter.Pyl**
 - ▣ **Chagas**
 - ▣ **HPV**

CONJECTURE

- ▣ Cohorts born after 1940-50 and carry with them higher odds of expressing effects of early conditions or “Barker effects”: their survival was the work of medical innovations and less so of public health and improvements in nutrition
 - Increased chronic illness (metabolic; heart;respir)
 - Increased mortality
 - Increased disability
- ▣ “Increased” ...relative to a counterfactual: what they would have experienced had they not been saved by medical technology and instead had survived due other factors

Difficulties

- ▣ Counterfactual is unverifiable and we must be satisfied with irregularities in time trajectory of mortality rates
- ▣ Offsetting effects of progress in prevention treatment of chronic conditions

The standard frailty model

- Frailty ϕ with density $g(\phi)$ and time- invariant impact on force of mortality:
 - $\mu(x) = \mu_s(x) * \phi$
- Time dependent composition by ϕ
- Continuous changes in mean $\mu(x)$:
 - $\mu(x) = \mu_s(x) * E(\phi, x)$
 - Convergence of $\mu(x)$ to least frail

Barker effects – new formulation

- Early conditions in age interval $(-1.0-5.0)$ with a fixed distribution, $f(\varepsilon)$
- ε influences $\mu(x)$ for ages $x < y$ as
 - $\mu(x, \varepsilon) = \varepsilon \mu_s(x)$
- ε influences $\mu(x)$ for ages $x > 60$ as
 - $\mu(x, \varepsilon) = \lambda^* \varepsilon \mu_s(x)$ and $\lambda > 1$
- Experience of early environments (public health, medical innovations) changes cohort's distribution/composition:
 - *it increases representation of high values of ε*

Caveats

- ▣ We are assuming one source of heterogeneity, namely, early conditions or ε
- ▣ Like the standard heterogeneity models we assume fixed values initial conditions (ε or φ) .
- ▣ Unlike standard heterogeneity we are assuming time varying effects
- ▣ More interesting is to assume TWO sources of heterogeneity: standard and Barker possibly correlated. This requires working with bivariate distributions

Expression for $\mu_c(y,t)$, $y \geq 60$

$$\mu_c(y, t) = \frac{\int f(\varepsilon) \mu_s(y, \varepsilon) \varepsilon k(t) \exp[-k(t) * \Lambda_s(y, \varepsilon, \lambda)] d\varepsilon}{\int f(\varepsilon) \exp[-k(t) * \Lambda_s(y, \varepsilon, \lambda)] d\varepsilon}$$

Expression for integrated MU (net of time effects)

$$\Lambda_s(y, \varepsilon, \lambda) = \int_{\{0,60\}} \mu_s(y) \lambda \varepsilon \, d\varepsilon + \int_{\{0,60\}} \mu_s(y) \varepsilon = \lambda \varepsilon (\Lambda_s(0-y) + \Lambda_s(0-60) (1-\lambda))$$

Implications of conjecture

- ▣ $\partial \ln \mu_c(y, t) / \partial t = \partial \ln k(t) / \partial t + \partial \ln E(\varepsilon, y, t) / \partial t \geq 0$
for some pair (y, t)

- ▣ ...and because
 - $\partial \ln k(t) / \partial t < 0$ and $\partial \ln E(\varepsilon, y, t) / \partial t \geq 0$

- ▣ ...it must be the case that for some t and y :
 - $|\partial \ln k(t) / \partial t| \leq \partial \ln E(\varepsilon, y, t) / \partial t$

Special cases

- ▣ $f(\varepsilon)$ member of exponential family:
 - Exponential ****worked out***
 - Gamma ****almost there***

- ▣ If $\lambda = 1$ model becomes standard frailty model

Empirical test is difficult

- ▣ Implicated cohorts are too young
- ▣ Mortality data in most affected countries is faulty:
 - Overstatement of ages at death decreases over time
 - Completeness of death registration improves over time

Two conditions and two parameters

Poor early conditions

Early-Late mechanisms

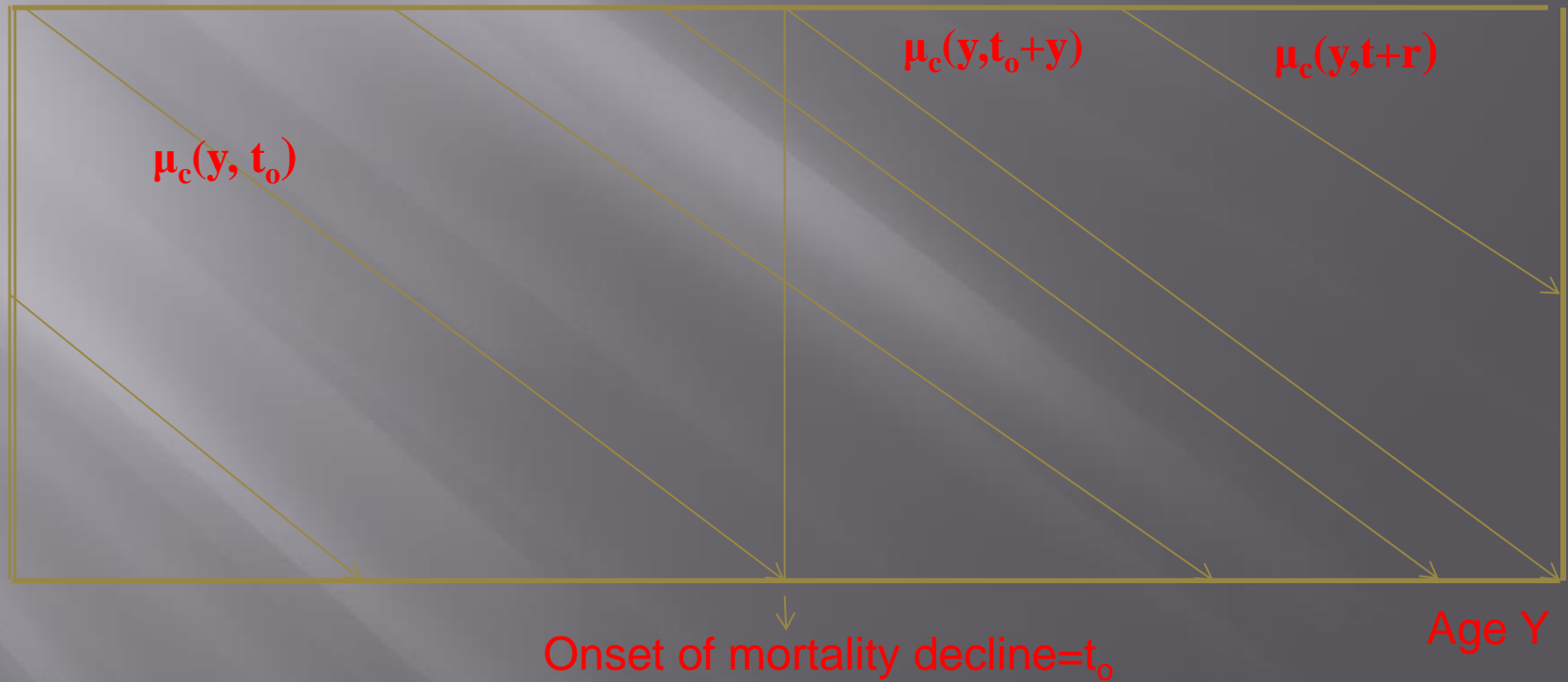
Changing distribution of 'at risk' population by early conditions over life course under changing mortality

Excess mortality at older ages

Σ

Ω

Cohorts reaching age $y > 60$ at time t :



Cohort reaching age $y > 60$ at time $t > t_0 + 60$:

$$\mu_c(y, t) = \int_{\Omega} \mu_s(y) \varepsilon^{k(t)} f(\varepsilon) \exp[-k(t) * \Lambda_s(y, \varepsilon, \lambda)] d\varepsilon / \int_{\Sigma} f(\varepsilon) \exp[-k(t) * \Lambda_s(y, \varepsilon, \lambda)] d\varepsilon$$

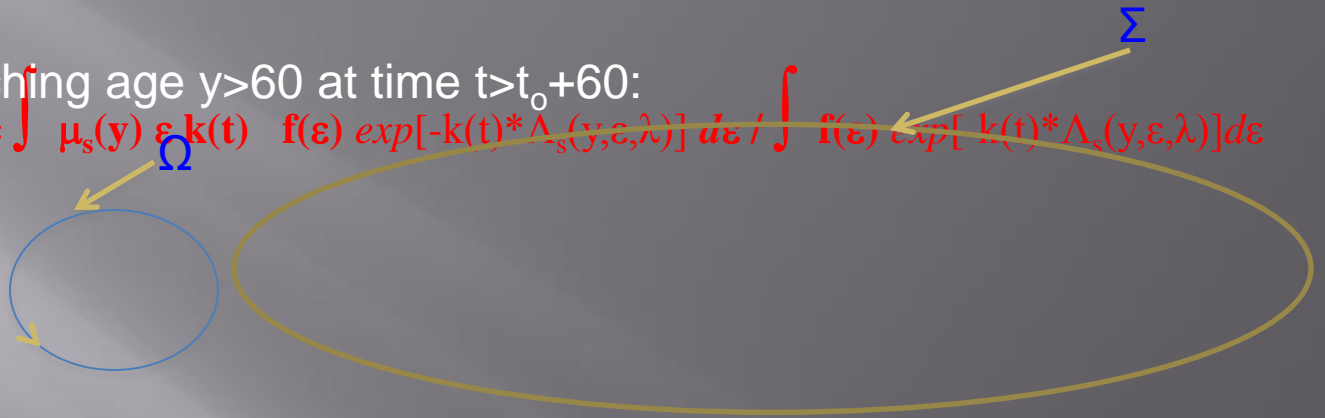


Figure 1a: Distribution of values of Epsilon (early conditions)

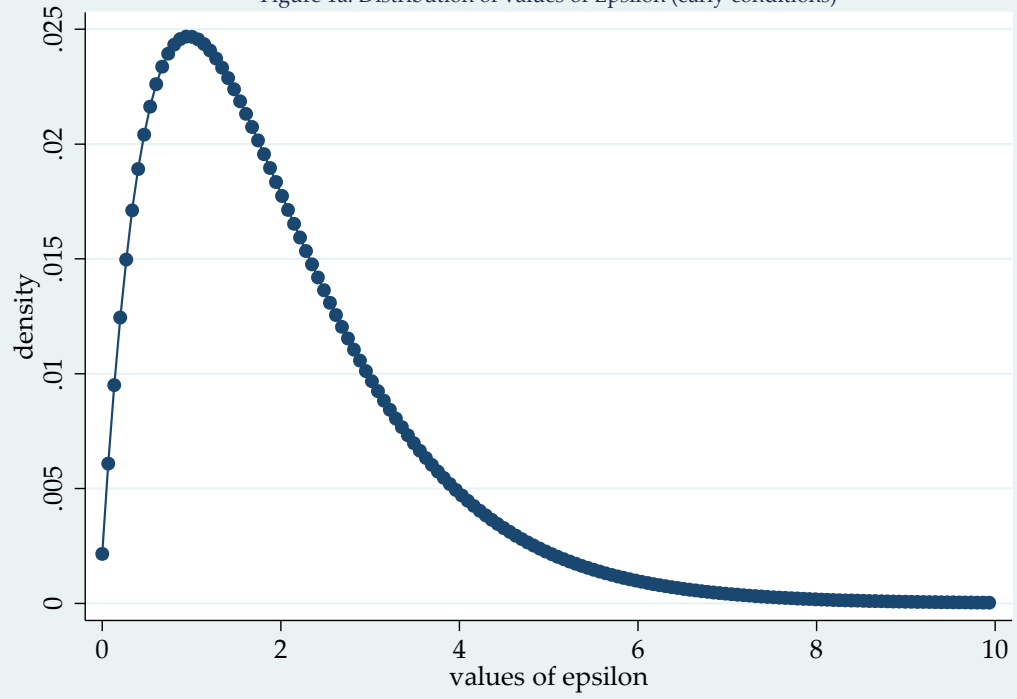


Figure 1a: Survival functions by early conditions factor
(three mortality regimes)

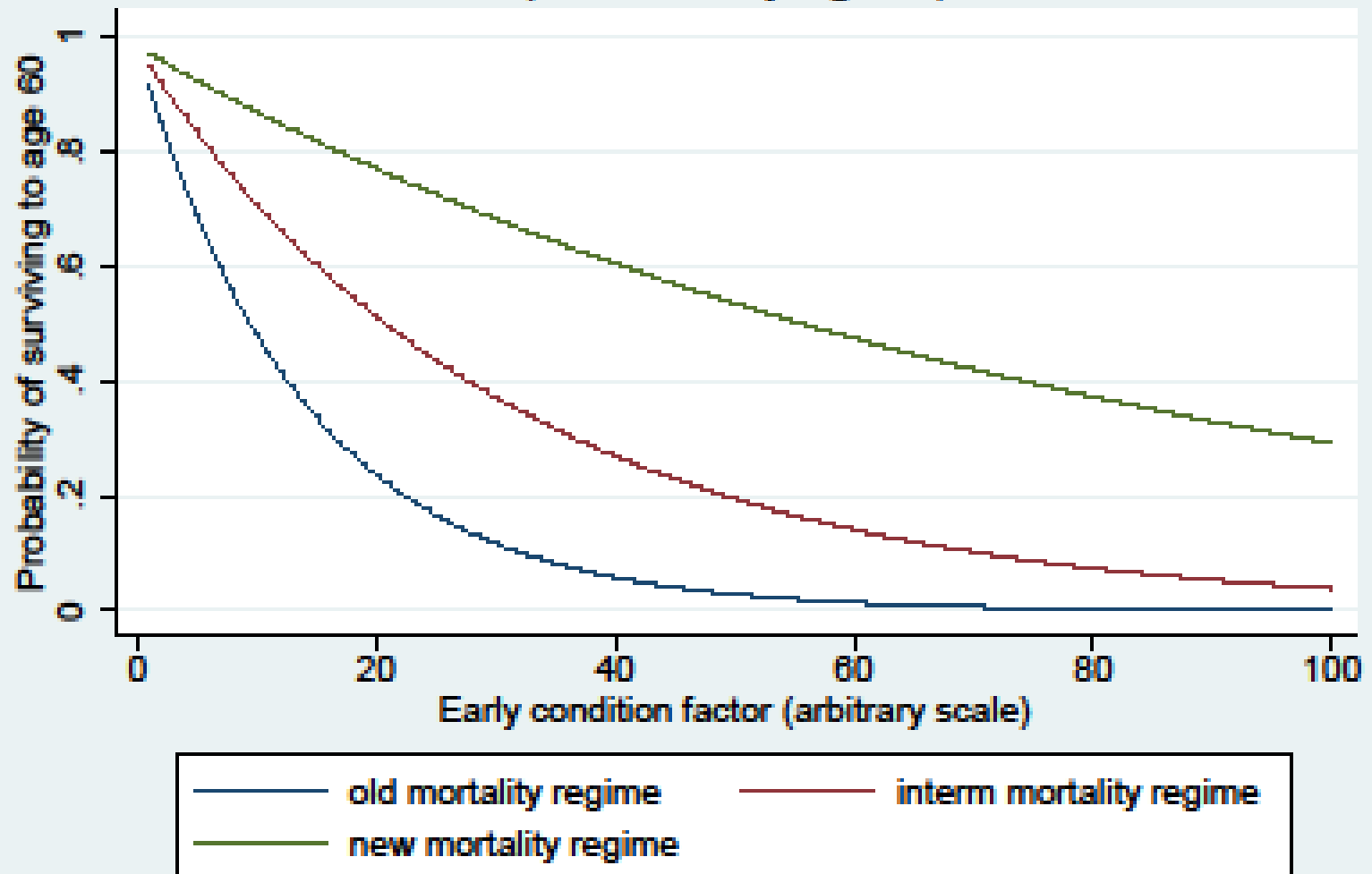


Figure 1b: Distribution at age 60 by early condition factor
(three mortality regimes)

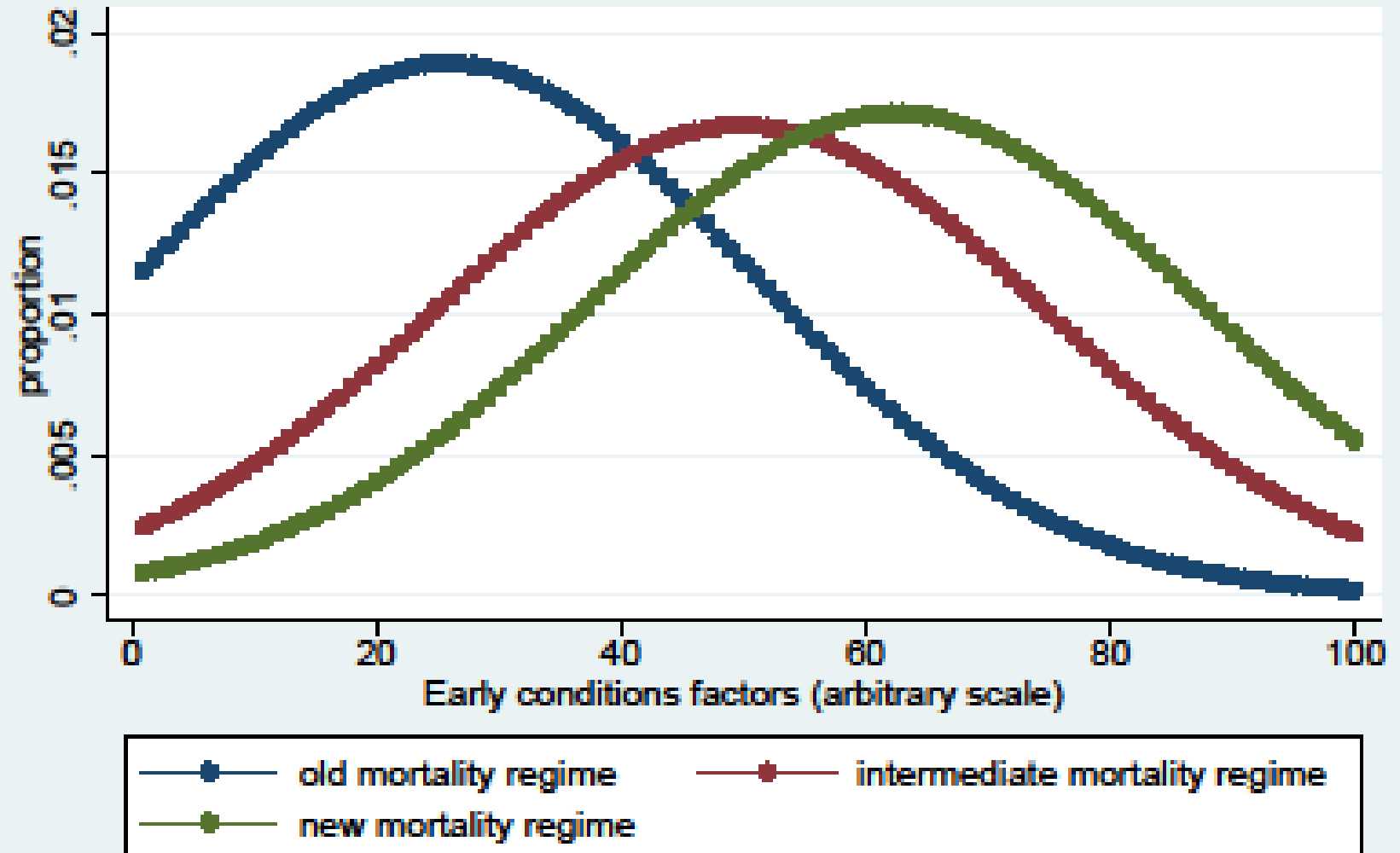


Figure 1c: Average mortality at age 60 by mortality regime

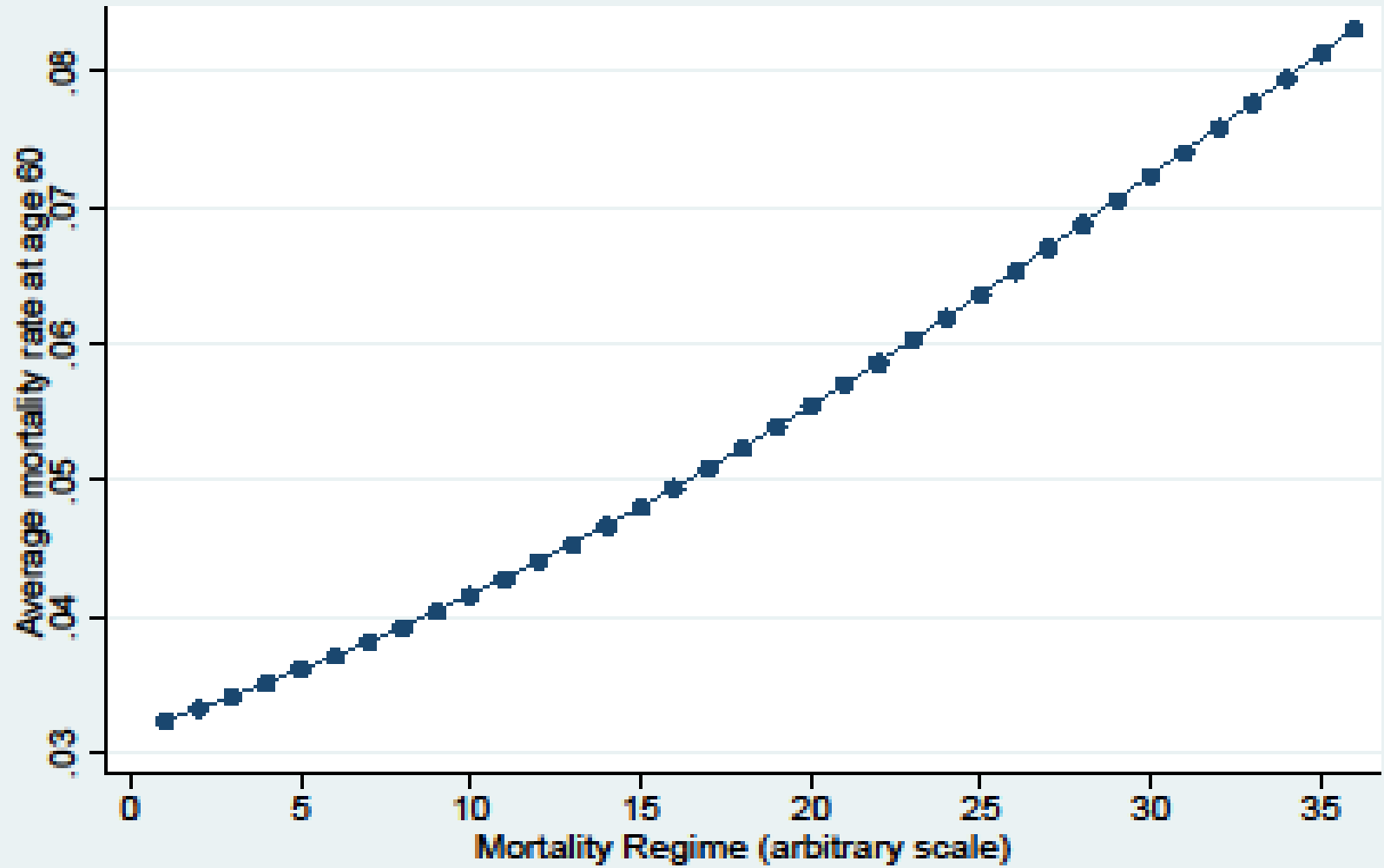
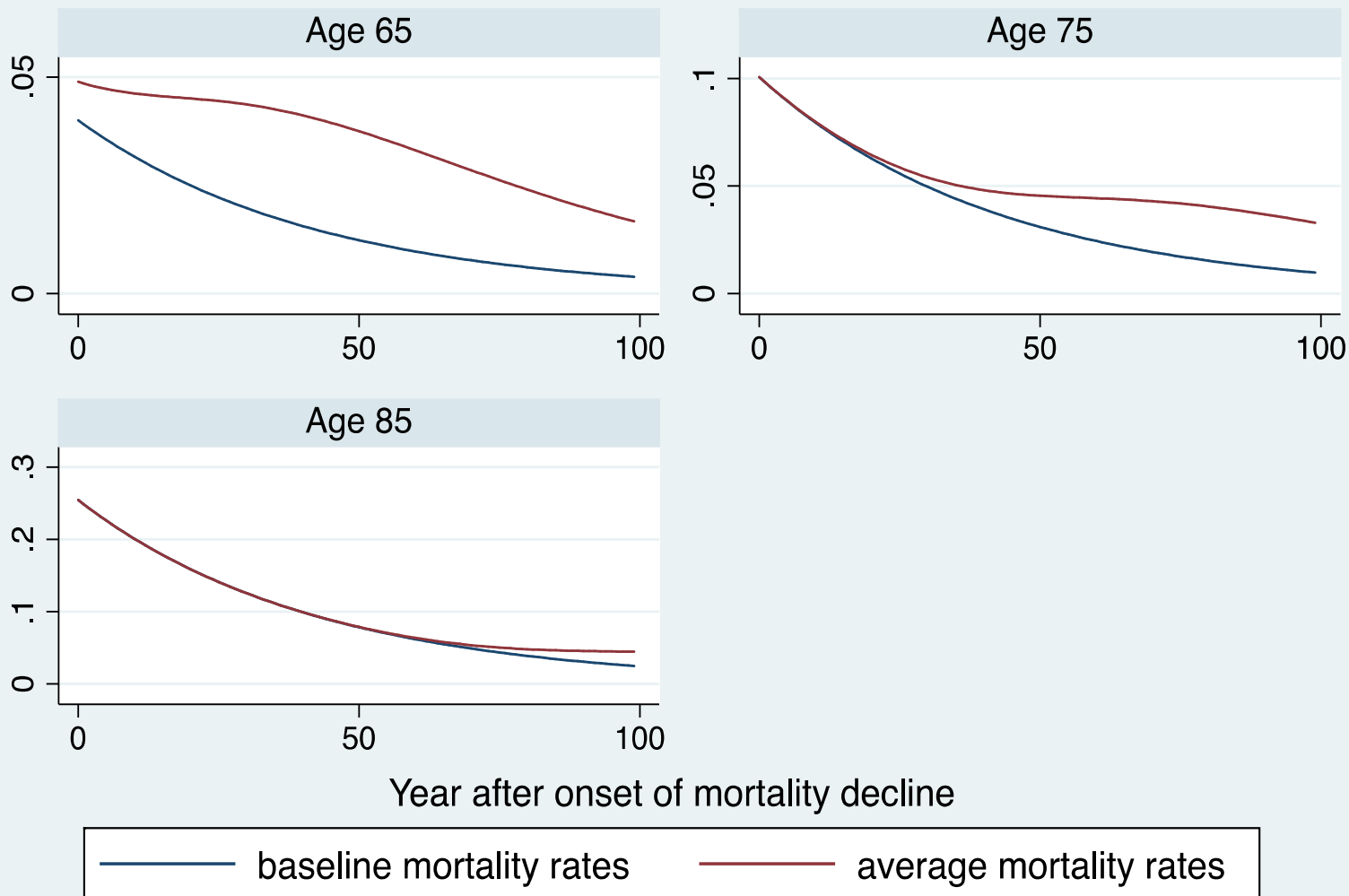
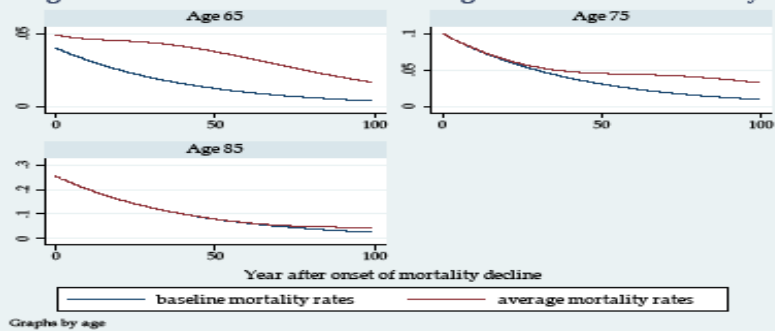


Figure 1d: Differences between average and baseline mortality



Graphs by age

Figure 1d: Differences between average and baseline mortality



Two conditions and two parameters

Poor early conditions



Early-Late mechanisms



Changing distribution of 'at risk' population by early conditions over life course under changing mortality

$\Sigma?$



Excess mortality at older ages

$\Omega?$

Estimation of “Population at Risk” (the Σ)

Counterfactual populations

Projections assuming mortality since 1950 constant

Computation of differences yields ‘saved’ population

Ages: 0-5? 0-20? 0-60?

Causes: all? Infectious Diseases?

Subsets of the ‘saved’ population

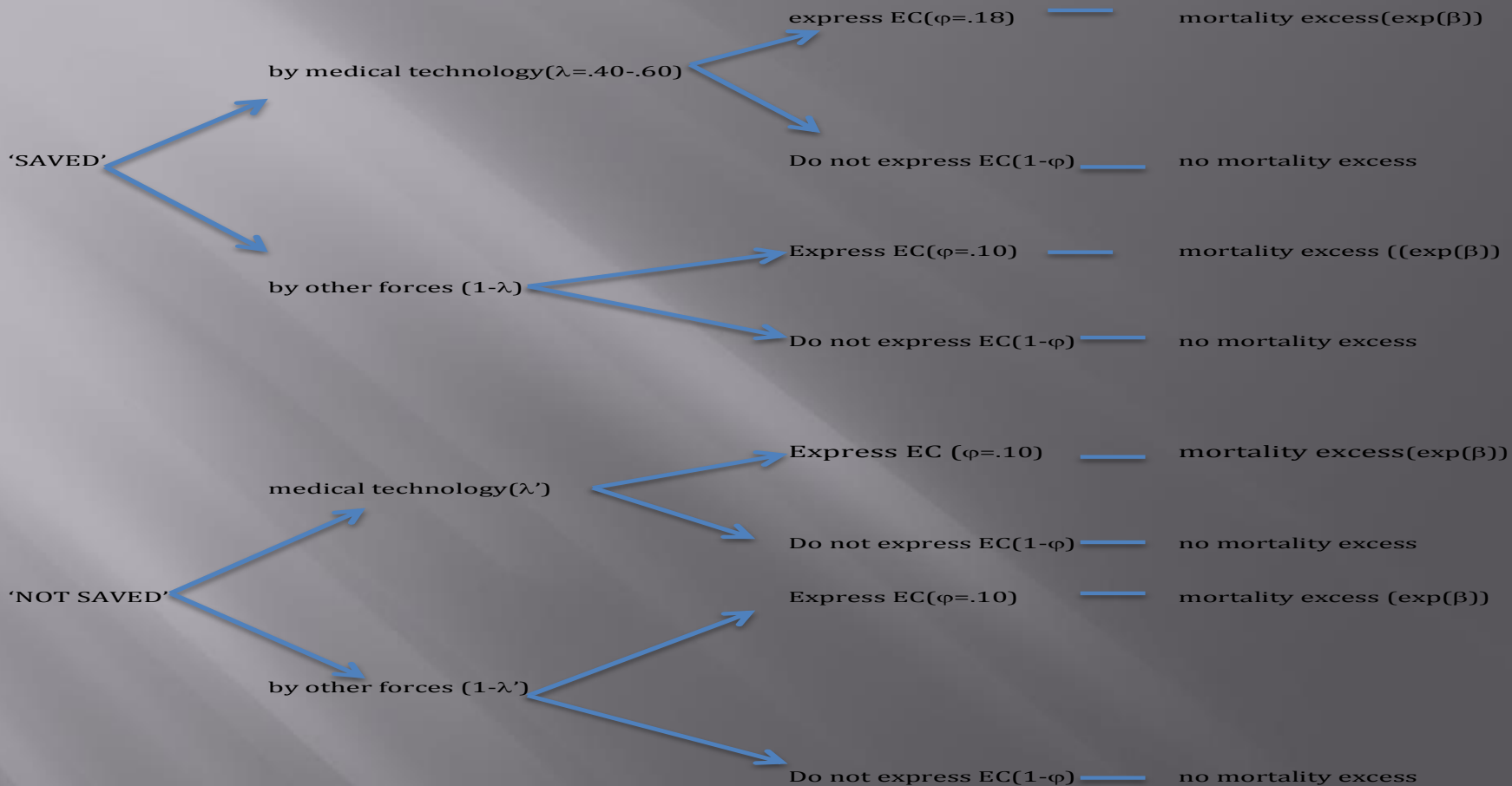
By medical technology? By standards of living?

Subsets experiencing adversity early in life

Fraction of LBW

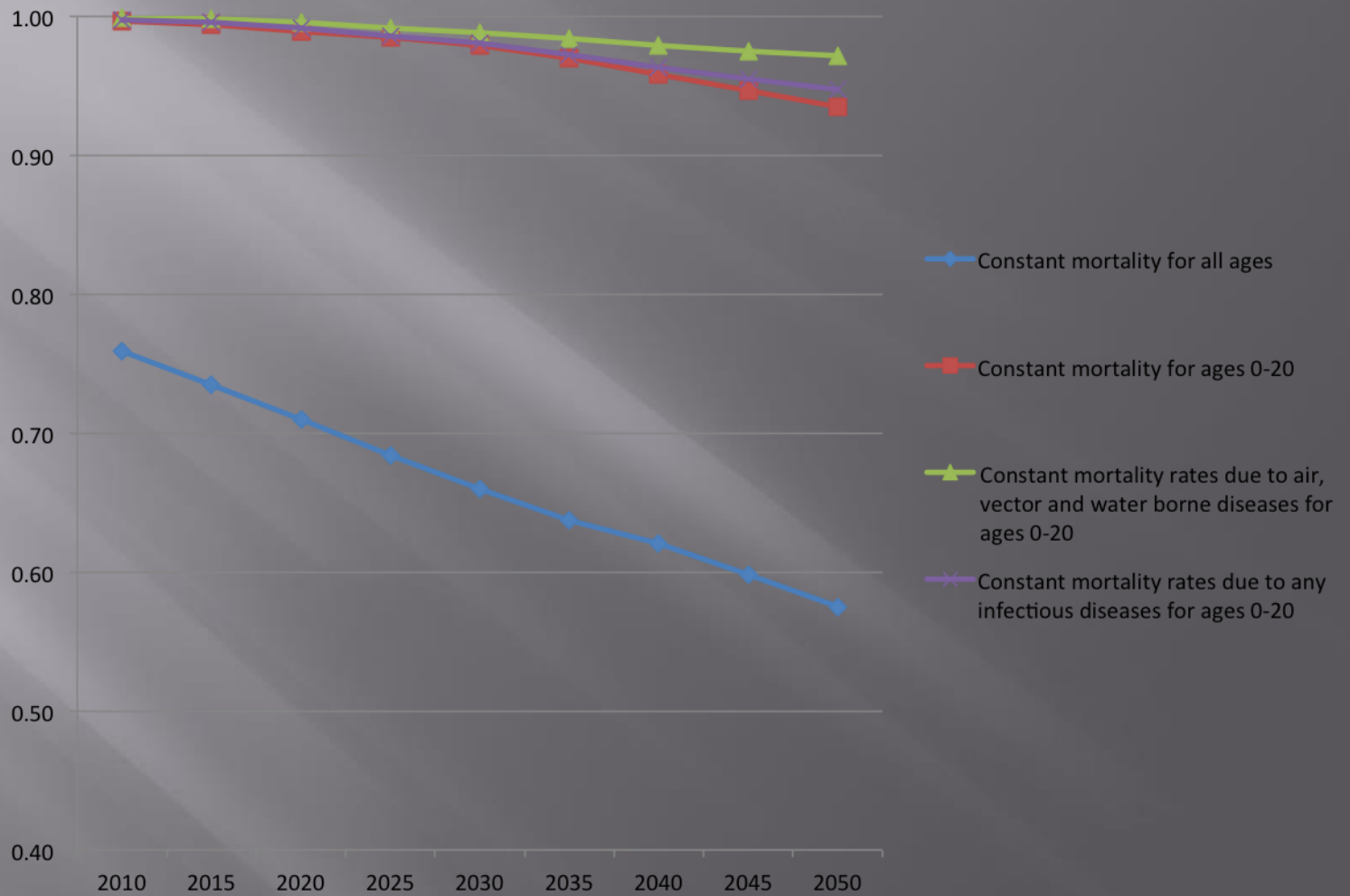
Fraction stunted (ages 0-10)

Figure 2: Components of a cohort exposed to mortality decline in LAC

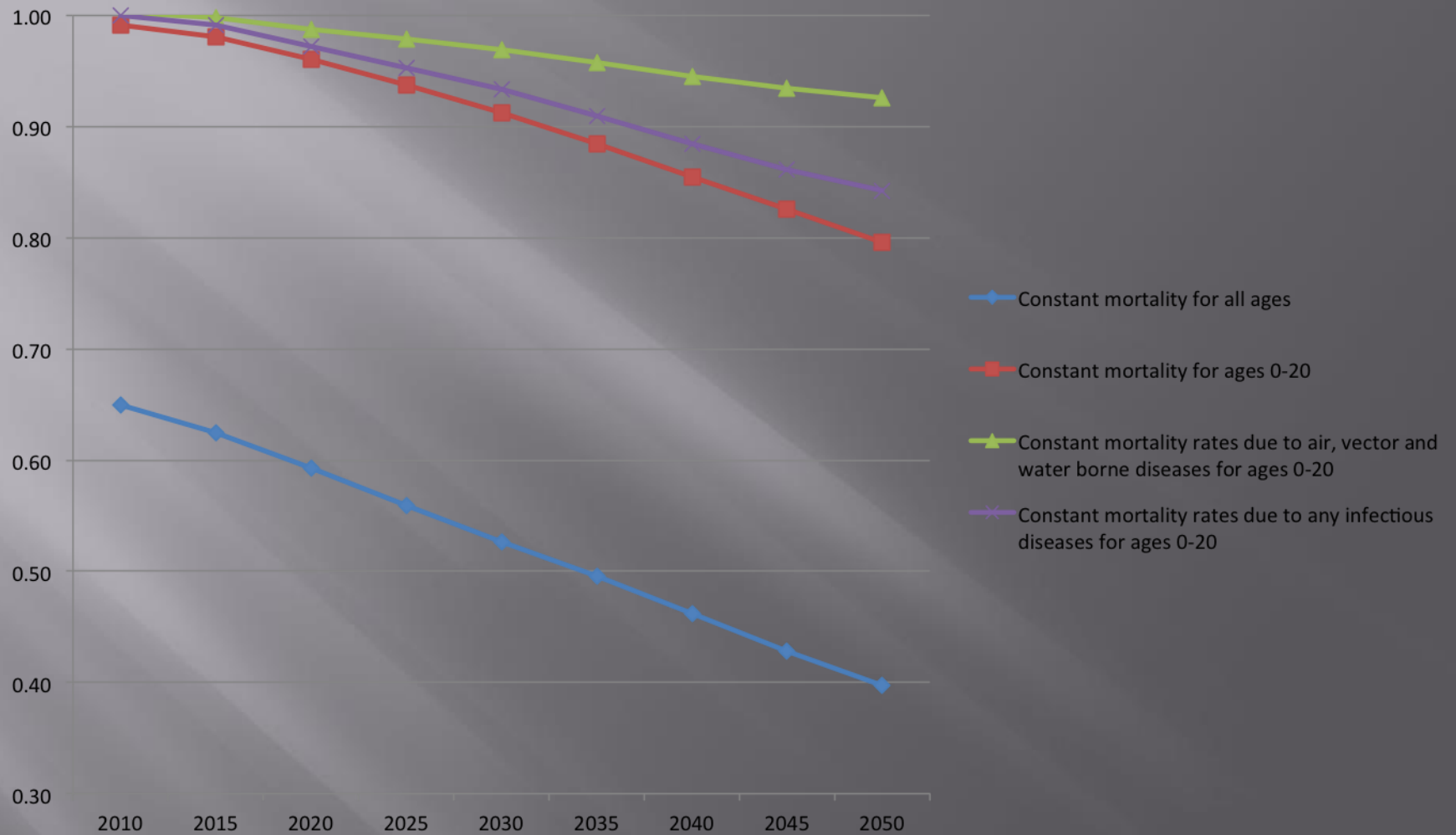


λ proportion among those 'saved' attributable to medical technology: .40 and .60
 λ' proportion among those NOT SAVED attributable to medical technology =.20
 ϕ fraction among those saved by medical technology that could manifest EC = .10 -.20
 $\exp(\beta)$ is the mortality excess due to early conditions.

Ratios of Populations over 60(Counterfactual / Observed) - Argentina



Ratios of Populations over 60(Counterfactual/ Observed) - Mexico



Ratios of Populations over 60 (Counterfactual/ Observed) - Guatemala

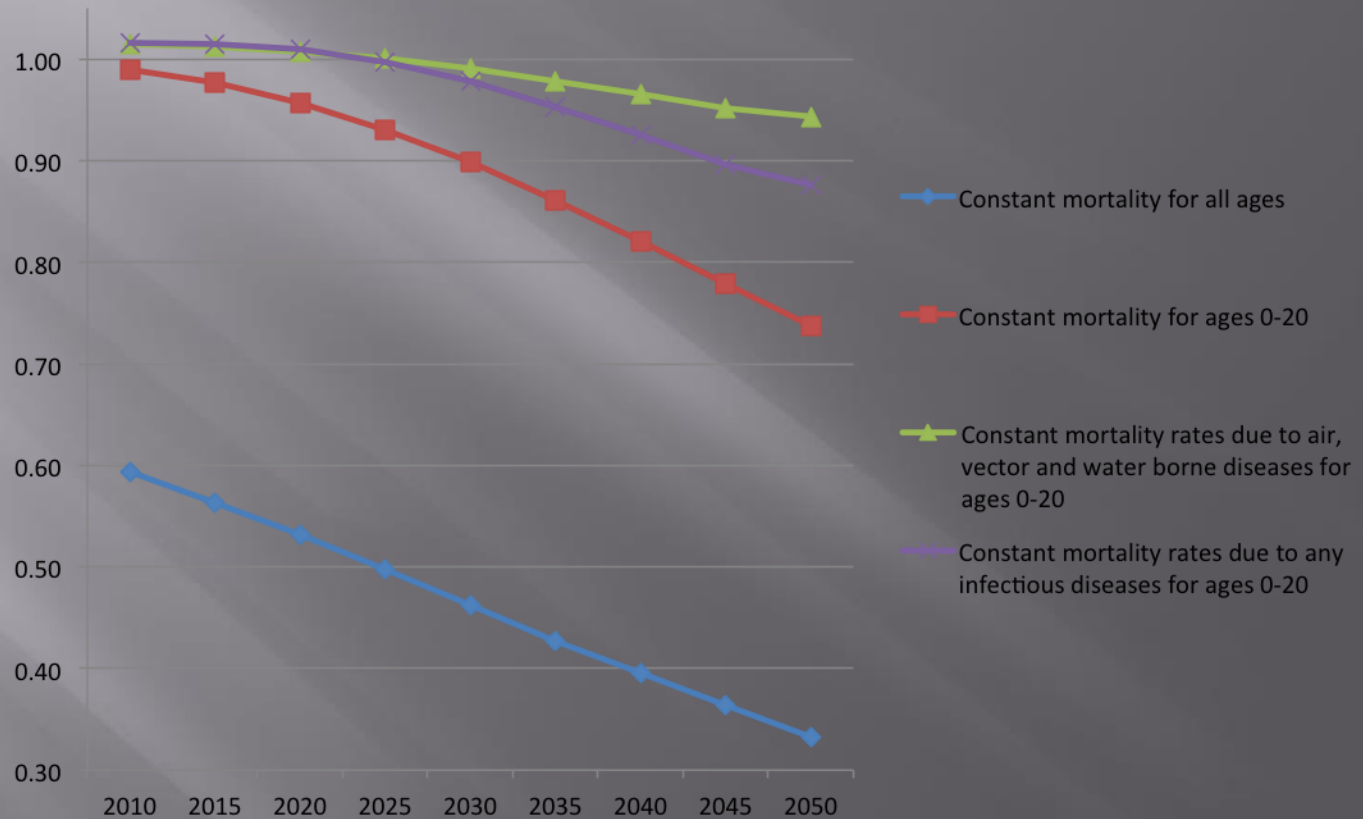
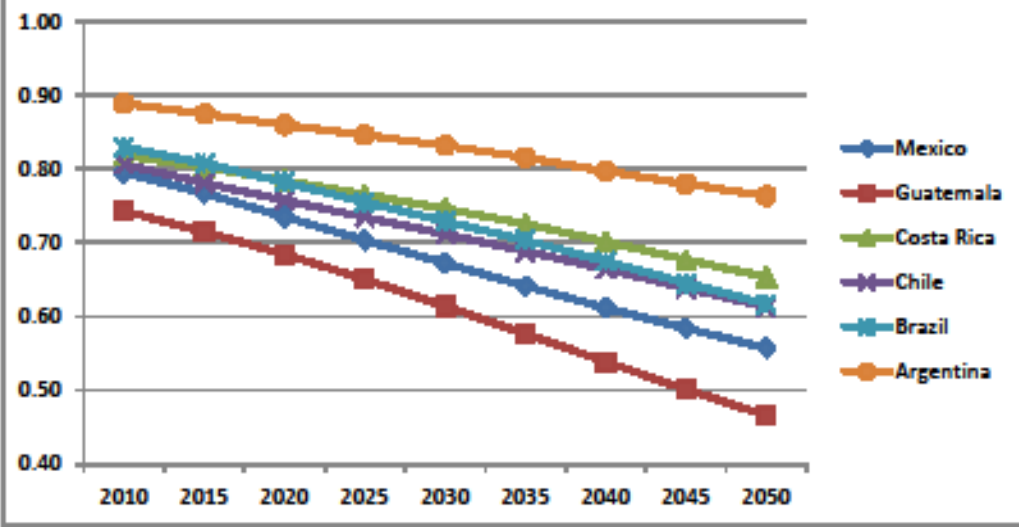


Figure 3: Ratio of the total population aged 60+ from counterfactual projections (mortality at ages 0-59 kept at 1950 levels) to the conventional projected population



Estimation of Excess Mortality Ω

Mexican Health and Aging Study (MHAS):

- MHAS I (2001) and MHAS II (2003)
- Target Population: People over **50 years old**

Puerto Rican Elderly: Health Conditions (PREHCO):

- PREHCO I (2002) and PREHCO II (2006)
- Target Population: People over **60 years old**

Costa Rican Longitudinal Study of Elderly (CRELES)

- CRELES I (2006) and CRELES II (2009)
- Target Population: People over **60 years old**

Figure 4a: Life expectancy at age 60 under different scenarios
Argentina

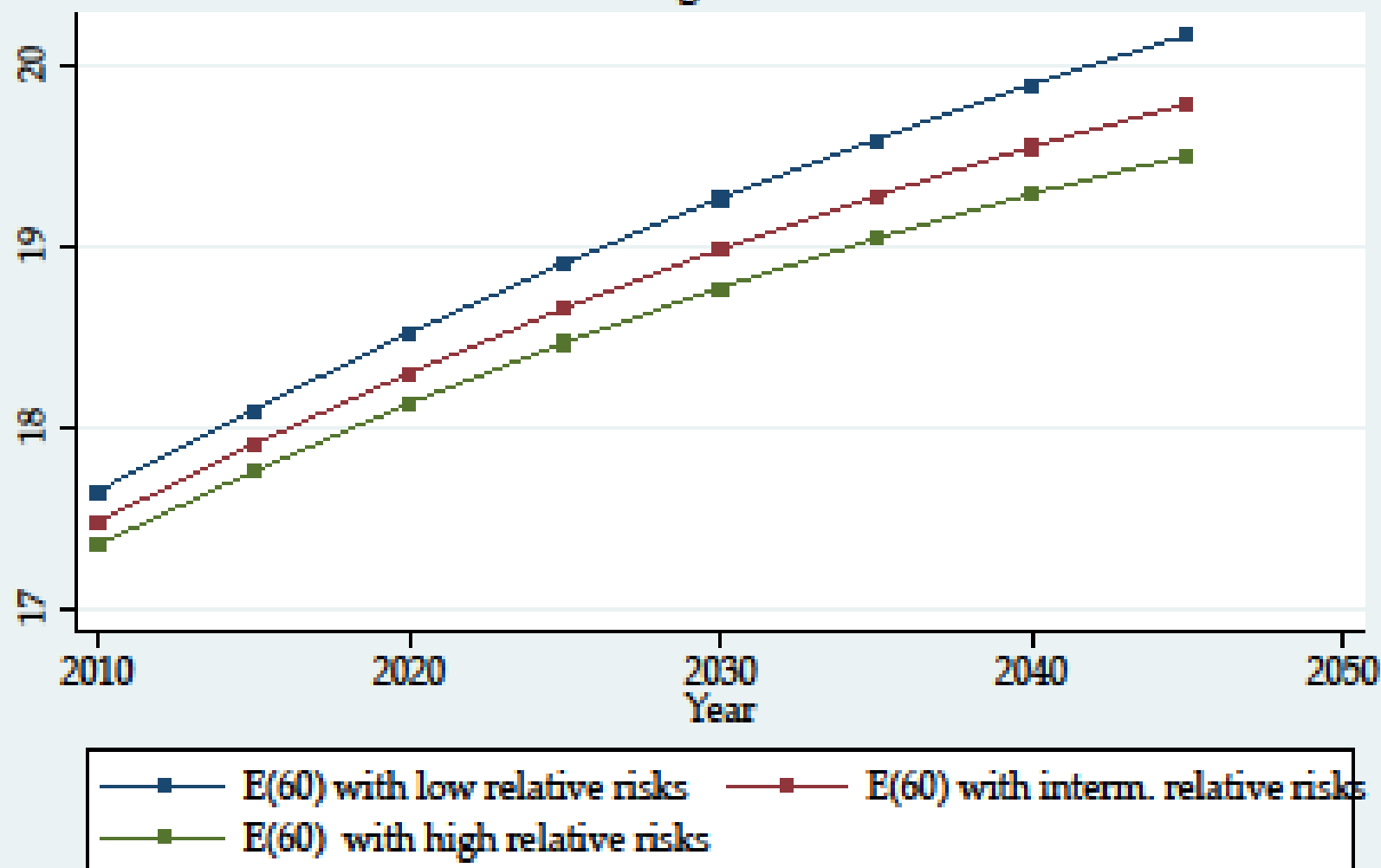
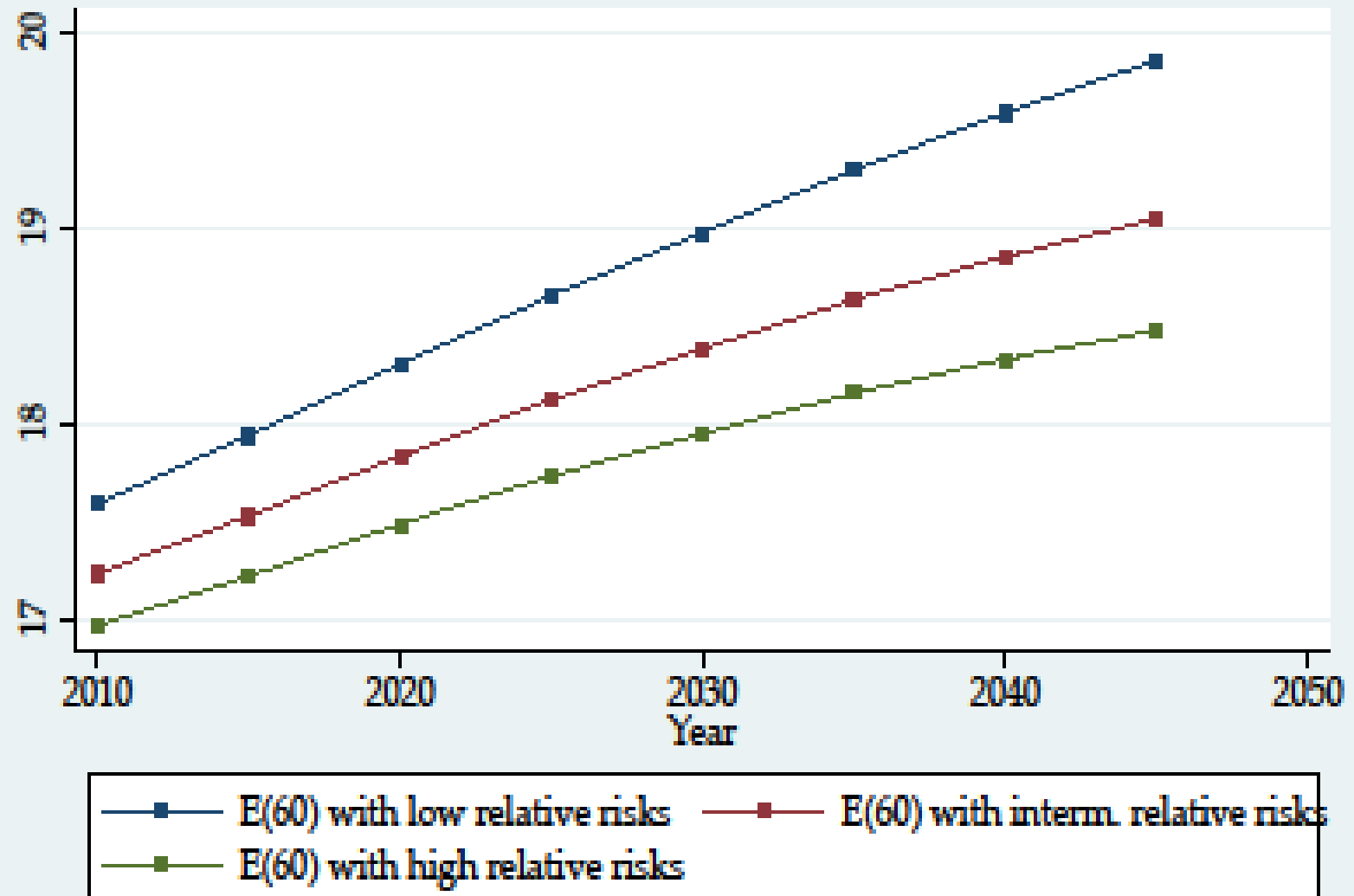


Figure 4b: Life expectancy at age 60 under alternative scenario
Guatemala



Are these differences large/small?

- ▣ Projected gains in life expectancy at age 60 between 2010 and 2050 of the order of 5 years: potential losses amount to $3/5$ of projected gains
- ▣ Gains of life expectancy at age 60 during 1980-2000 of the order of 10 years: potential losses amount to $2/5$ of past gains

One more thing

- ▣ Preliminary results using exponential and gamma show really interesting properties
- ▣ Results from a bivariate exponential (or bivariate gamma!) to treat simultaneously standard and barker frailty are low hanging fruit and delicious

thanks

You are welcome

Variables	MHAS	PREHCO
Death	0.06	0.16
Age	69	72
Sex (female)	0.53	0.60
Poor Early Conditions	0.38	0.37
Short Knee height	0.3	0.3
Polio	0.003	0.004
Rheumatic Fever	0.014	0.023
Tuberculosis	0.007	0.008
Poor general Health	0.11	0.072
Heart Diseases	0.044	0.19
Diabetes	0.17	0.28
0 yrs school.	0.33	0.06
1-5 yrs school.	0.38	0.31
6 yrs school.	0.15	0.08
7+ yrs school.	0.14	0.55
Proxy interview	0.08	0.12
<i>Total Observations (sample)</i>	<i>7,604</i>	<i>5,286</i>

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3. Estimation Procedures

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Step 1	Poor Early Conditions →	Diabetes
	Poor Early Conditions →	Heart Diseases

3. Estimation Procedures

Step 1	Poor Early Conditions →	Diabetes
Step 2	Diabetes → Heart Diseases → PEC →	Mortality Mortality Mortality (not significant)

3. Estimation Procedures

Step 1	Poor Early Conditions → Diabetes Poor Early Conditions → Heart Diseases
Step 2	Diabetes → Mortality Heart Diseases → Mortality PEC → Mortality (not significant)
Step 3	Projected Prevalence of Poor Early Conditions, Diabetes and Heart diseases 5 years ahead

3. Estimation Procedures

Step 1	Poor Early Conditions → Diabetes Poor Early Conditions → Heart Diseases
Step 2	Diabetes → Mortality Heart Diseases → Mortality PEC → Mortality (not significant)
Step 3	Projected Prevalence of Poor Early Conditions, Diabetes and Heart diseases 5 years ahead
Step 4	Future Life Expectancy and Healthy Life Expectancy consistent with projected values of PEC, diabetes, heart diseases

3. Estimation Procedures. Bounds of the Effects of PEC on LE and HLE

Bounds of the effects defined by:

- 1. Changing the Prevalence of elderly people who experienced PEC**
- 2. Changing the Effect of PEC on Diabetes and Heart Diseases**

5. Estimation Procedures. Bounds of the Effects of PEC on LE and HLE

Changes in Prevalence	
Scenario 1	
Scenario 2	
Scenario 3	

5. Estimation Procedures. Bounds of the Effects of PEC on LE and HLE

Changes in Prevalence	
Scenario 1	$PEC_{t+5} = PEC_t$
Scenario 2	
Scenario 3	

3. Estimation Procedures. Bounds of the Effects of PEC on LE and HLE

Changes in Prevalence	
Scenario 1	$PEC_{t+5} = PEC_t$
Scenario 2	$PEC_{t+5} = (1 + r)^5 \times PEC_t$ <p>$r = 0.02$ per year (estimated from the data)</p>
Scenario 3	

3. Estimation Procedures. Bounds of the Effects of PEC on LE and HLE

Changes in Prevalence	
Scenario 1	$PEC_{t+5} = PEC_t$
Scenario 2	$PEC_{t+5} = (1 + r)^5 \times PEC_t$ $r = 0.02$ per year (estimated from the data)
Scenario 3	$PEC_{t+5} = 0$

Changes in Effects of PEC Defined for Scenario 1 and 2

COUNTER-FACTUAL	EFFECT OF PEC ON	
	DIABETES	HEART DISEASES
Case 0		
Case 1		
Case 2		
Case 3		
Case 4		
Case 5		
Case 6		
Case 7		
Case 8		
Case 9		
Case 10		
Case 11		

Changes in Effects of PEC Defined for Scenario 1 and 2

COUNTER-FACTUAL	EFFECT OF PEC ON	
	DIABETES	HEART DISEASES
Case 0	Estimated Effect	Estimated Effect
Case 1		
Case 2		
Case 3		
Case 4		
Case 5		
Case 6		
Case 7		
Case 8		
Case 9		
Case 10		
Case 11		

Changes in Effects of PEC Defined for Scenario 1 and 2

COUNTER-FACTUAL	EFFECT OF PEC ON	
	DIABETES	HEART DISEASES
Case 0	Estimated Effect	Estimated Effect
Case 1	2 x Estimated Effect	Estimated effect
Case 2	4 x Estimated Effect	Estimated effect
Case 3	8 x Estimated Effect	Estimated effect
Case 4		
Case 5		
Case 6		
Case 7		
Case 8		
Case 9		
Case 10		
Case 11		

Changes in Effects of PEC Defined for Scenario 1 and 2

COUNTER-FACTUAL	EFFECT OF PEC ON	
	DIABETES	HEART DISEASES
Case 0	Estimated Effect	Estimated Effect
Case 1	2 x Estimated Effect	Estimated effect
Case 2	4 x Estimated Effect	Estimated effect
Case 3	8 x Estimated Effect	Estimated effect
Case 4		
Case 5	2 x Estimated Effect	2 x Estimated Effect
Case 6	4 x Estimated Effect	4 x Estimated Effect
Case 7	8 x Estimated Effect	8 x Estimated Effect
Case 8	16 x Estimated Effect	16 x Estimated Effect
Case 9		
Case 10		
Case 11		

Changes in Effects of PEC Defined for Scenario 1 and 2

COUNTER-FACTUAL	EFFECT OF PEC ON	
	DIABETES	HEART DISEASES
Case 0	Estimated Effect	Estimated Effect
Case 1	2 x Estimated Effect	Estimated effect
Case 2	4 x Estimated Effect	Estimated effect
Case 3	8 x Estimated Effect	Estimated effect
Case 4		
Case 5	2 x Estimated Effect	2 x Estimated Effect
Case 6	4 x Estimated Effect	4 x Estimated Effect
Case 7	8 x Estimated Effect	8 x Estimated Effect
Case 8	16 x Estimated Effect	16 x Estimated Effect
Case 9	Estimated effect	2 x Estimated Effect
Case 10	Estimated effect	4 x Estimated Effect
Case 11	Estimated effect	8 x Estimated Effect

Changes in Effects of PEC Defined for Scenario 1 and 2

COUNTER-FACTUAL	EFFECT OF PEC ON	
	DIABETES	HEART DISEASES
Case 0	Estimated Effect	Estimated Effect
Case 1	2 x Estimated Effect	Estimated effect
Case 2	4 x Estimated Effect	Estimated effect
Case 3	8 x Estimated Effect	Estimated effect
Case 4	=case 9	=case 9
Case 5	2 x Estimated Effect	2 x Estimated Effect
Case 6	4 x Estimated Effect	4 x Estimated Effect
Case 7	8 x Estimated Effect	8 x Estimated Effect
Case 8	16 x Estimated Effect	16 x Estimated Effect
Case 9	Estimated effect	2 x Estimated Effect
Case 10	Estimated effect	4 x Estimated Effect
Case 11	Estimated effect	8 x Estimated Effect

4. Results

**Poor early
conditions**



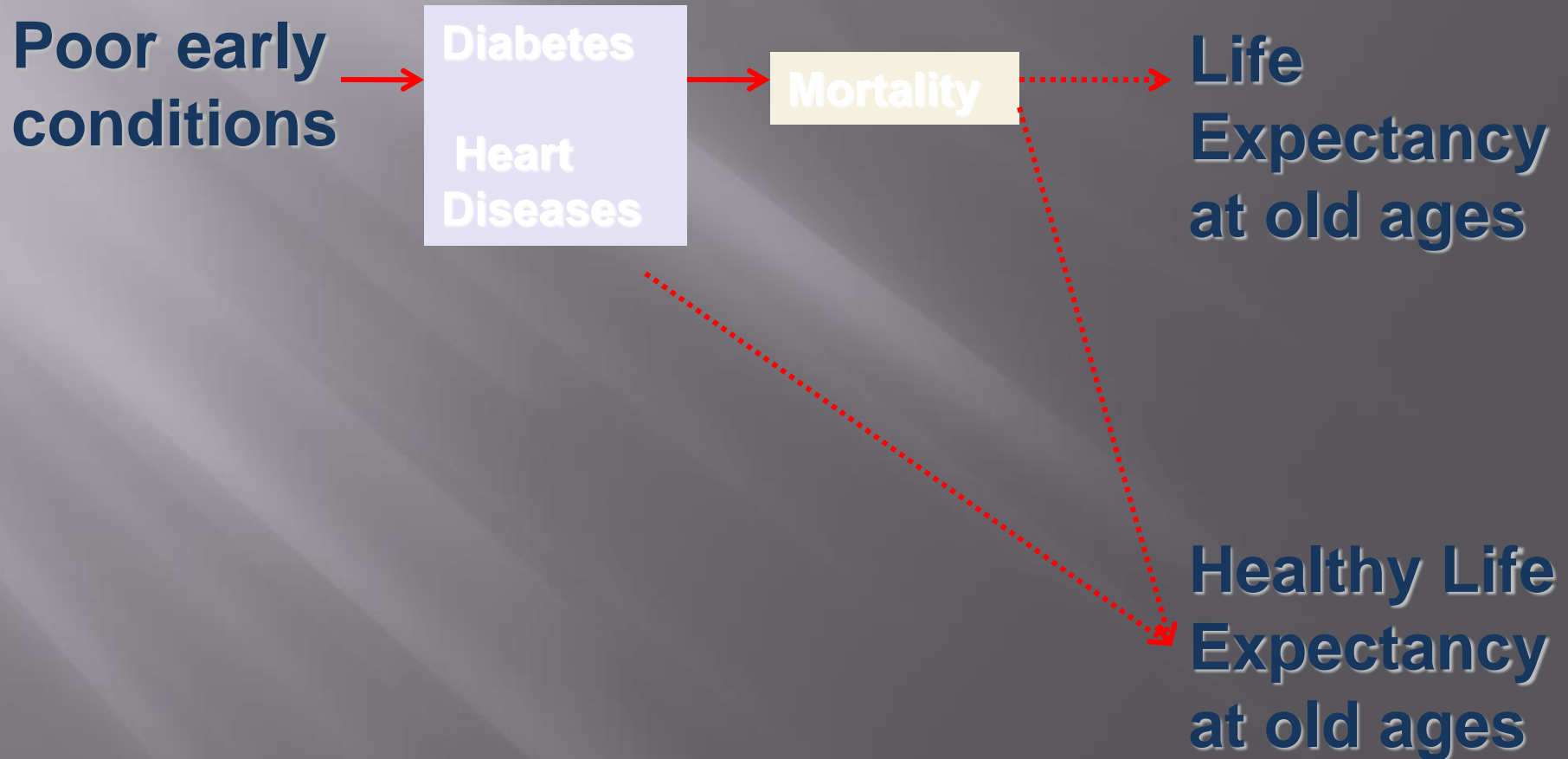
Diabetes

**Heart
Diseases**

4. Results



4. Results



Life expectancy at 60

○ Growth Rate Prev. PEC=0
□ Growth Rate Prev. PEC=.02
△ Prevalence PEC=0

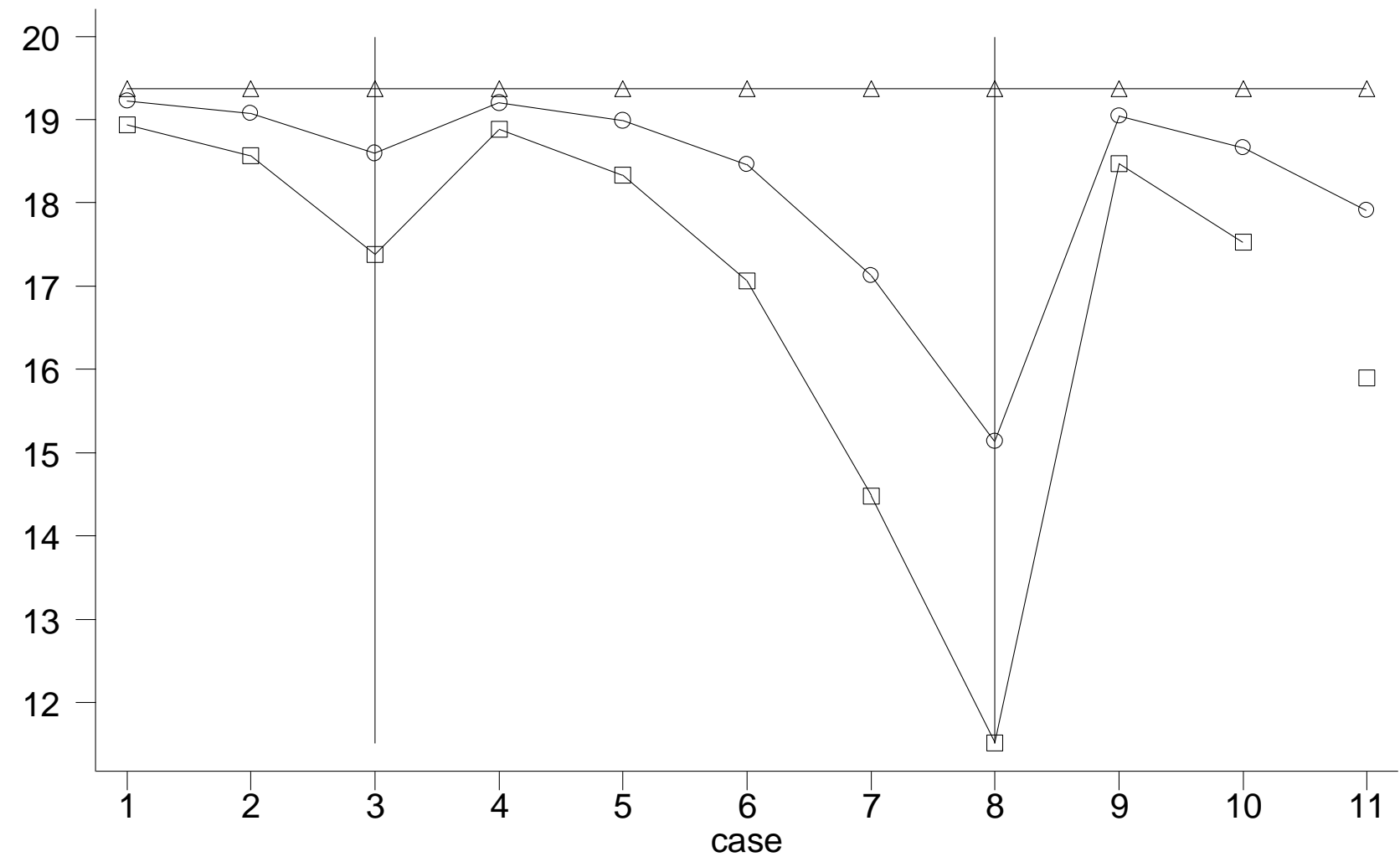


Figure 3a: Projected life expectancy at age 60-MEXICO

Life expectancy at 60

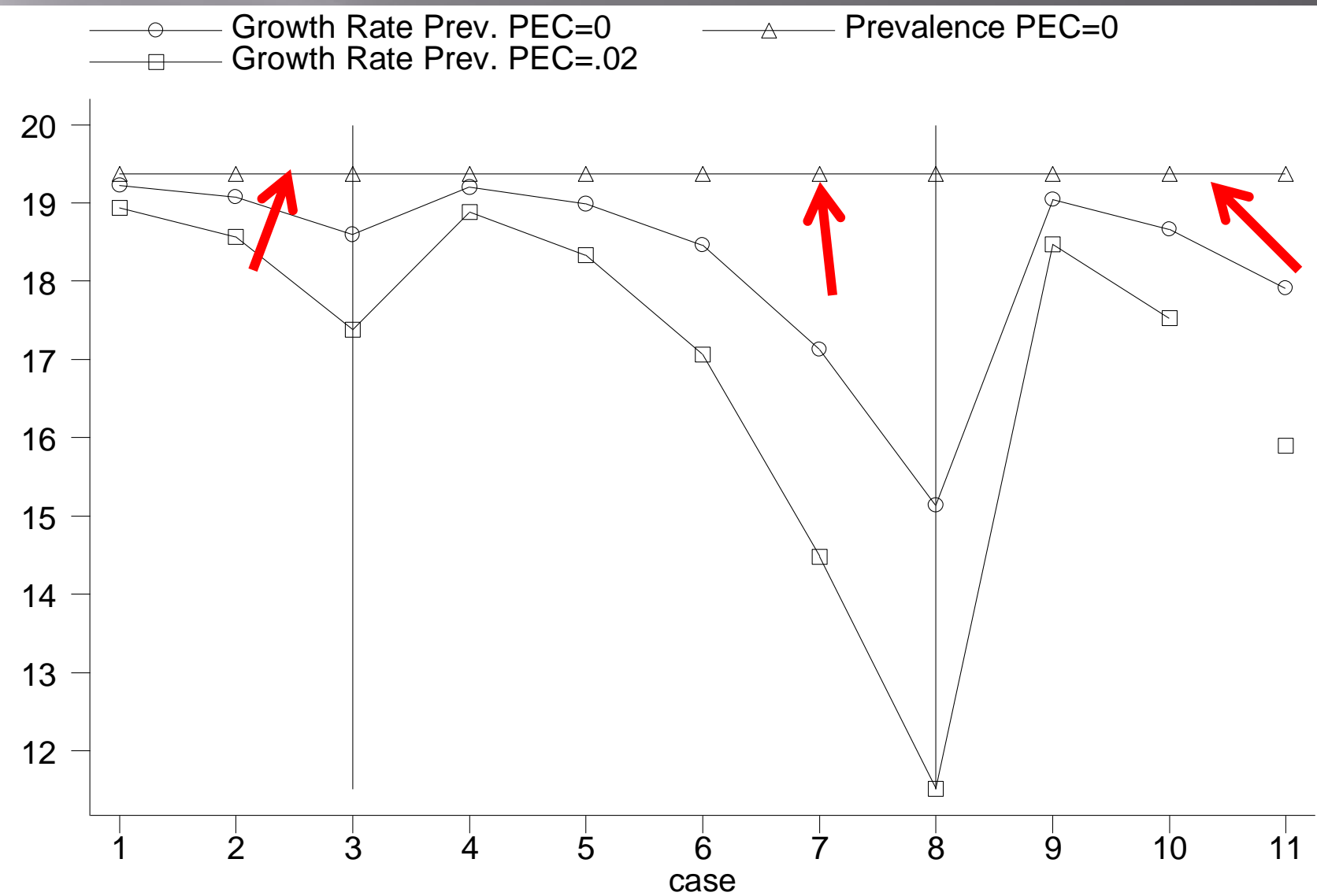


Figure 3a: Projected life expectancy at age 60-MEXICO

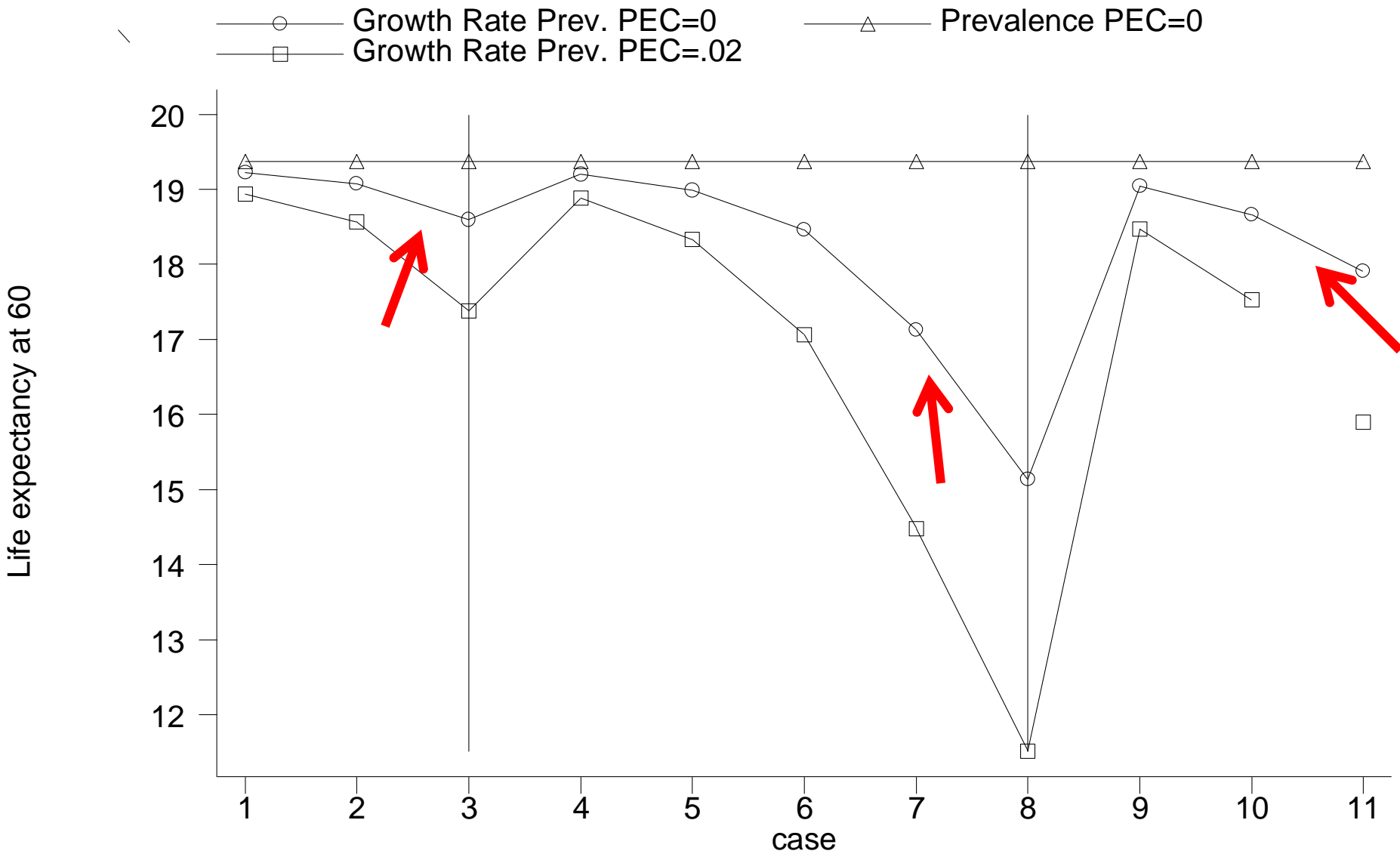


Figure 3a: Projected life expectancy at age 60-MEXICO

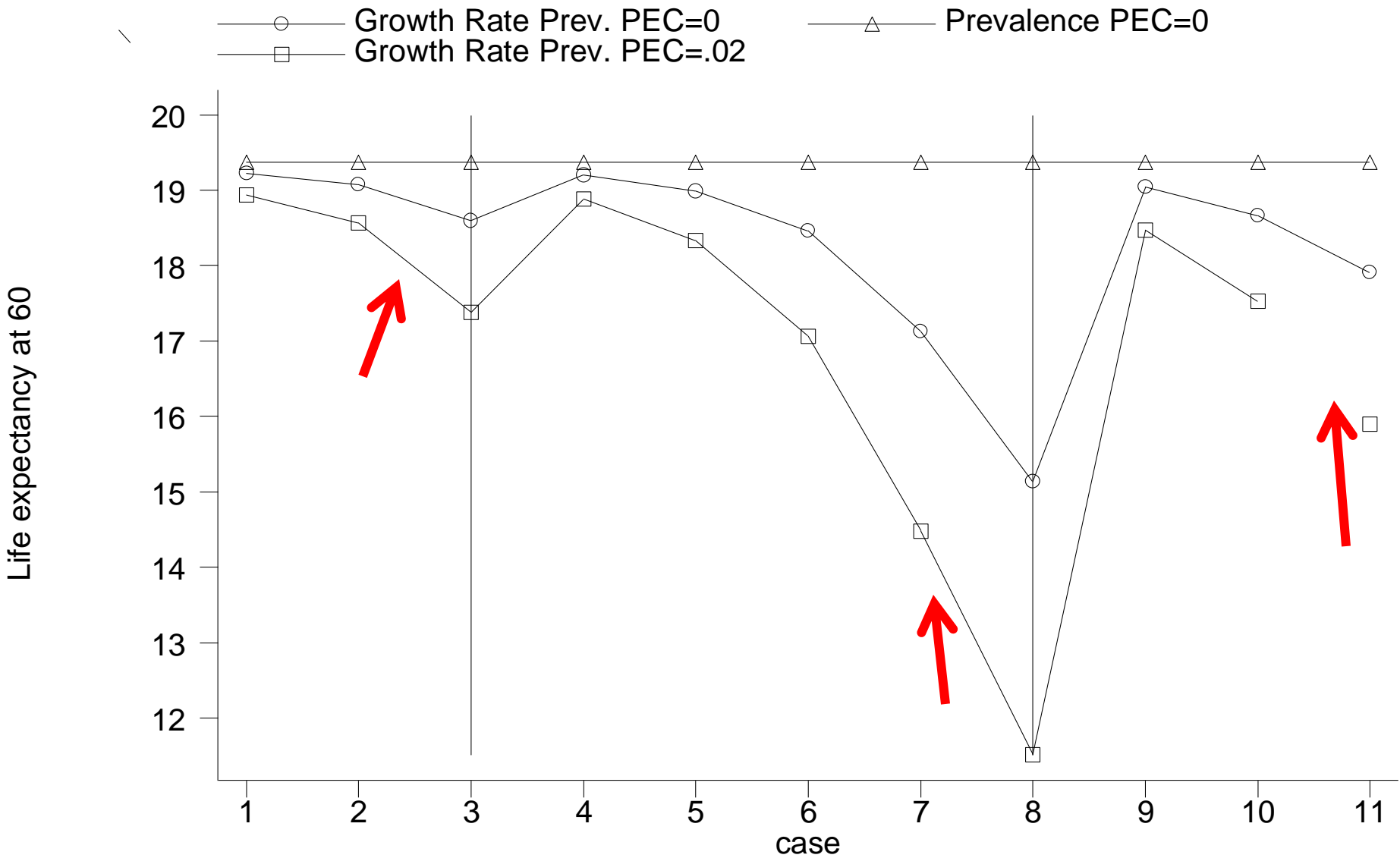


Figure 3a: Projected life expectancy at age 60-MEXICO

Life expectancy at 60

○ Growth Rate Prev. PEC=0 △ Prevalence PEC=0
□ Growth Rate Prev. PEC=.02

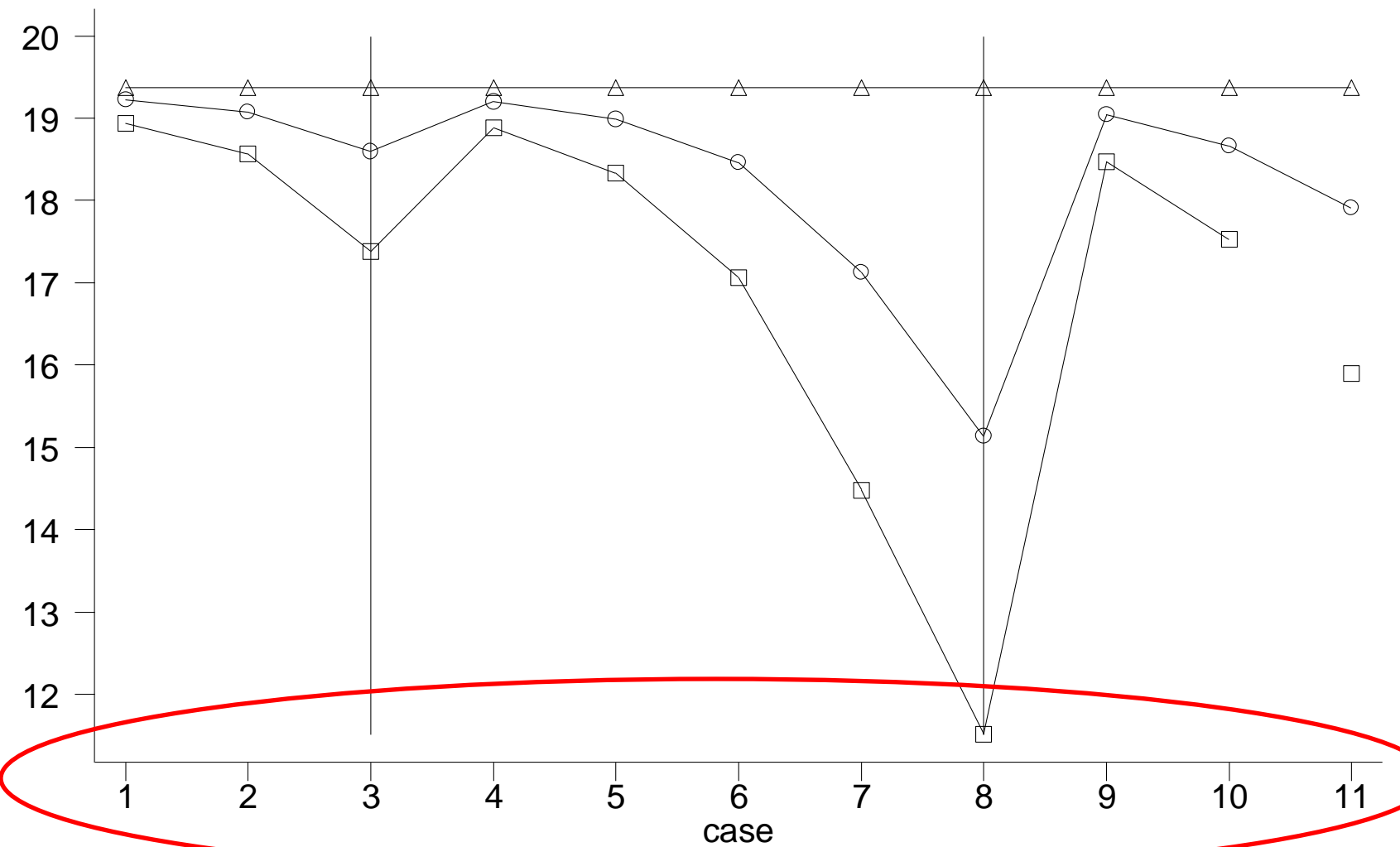


Figure 3a: Projected life expectancy at age 60-MEXICO

Life expectancy at 60

○ Growth Rate Prev. PEC=0
□ Growth Rate Prev. PEC=.02
△ Prevalence PEC=0

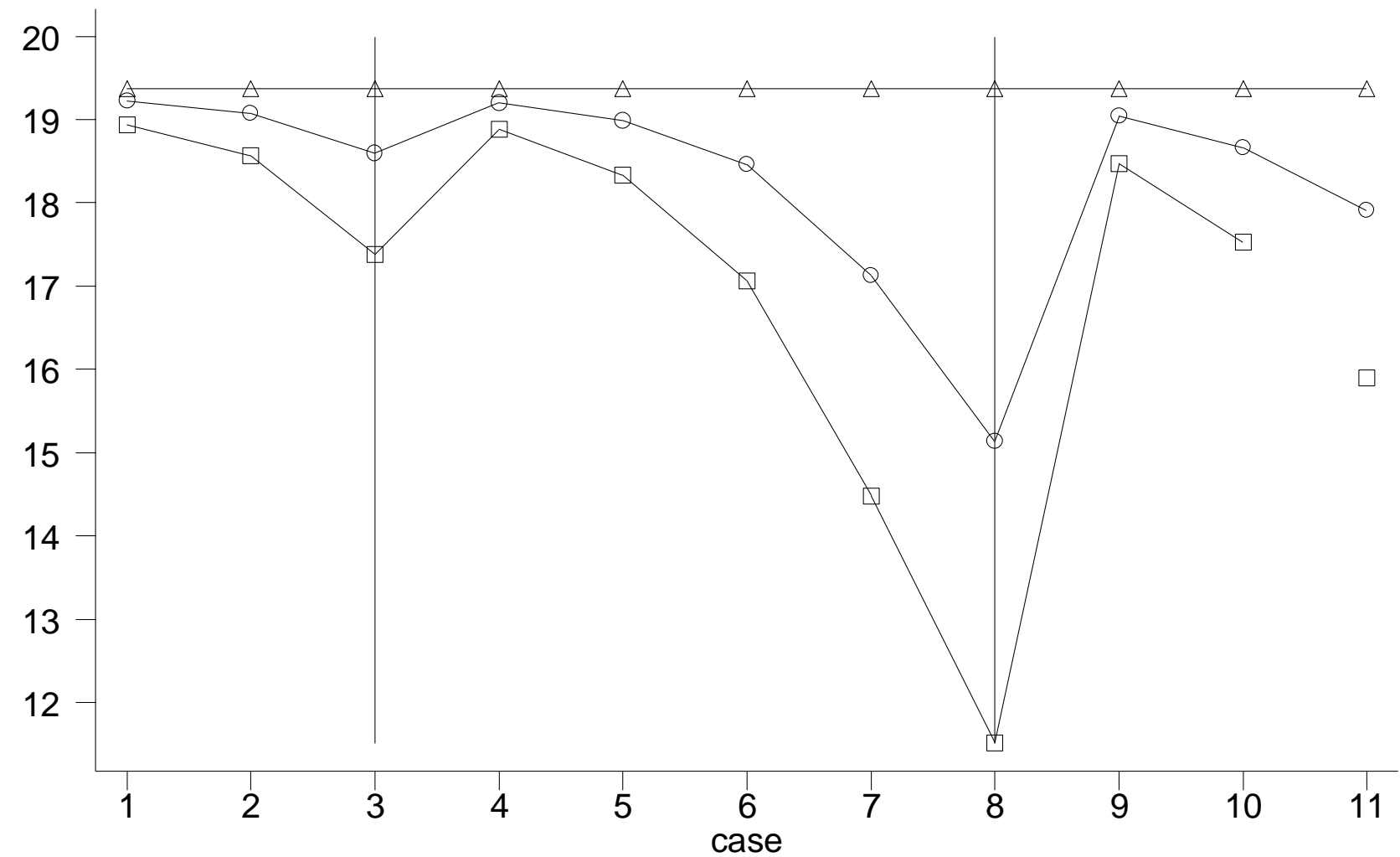


Figure 3a: Projected life expectancy at age 60-MEXICO

Life expectancy at 60

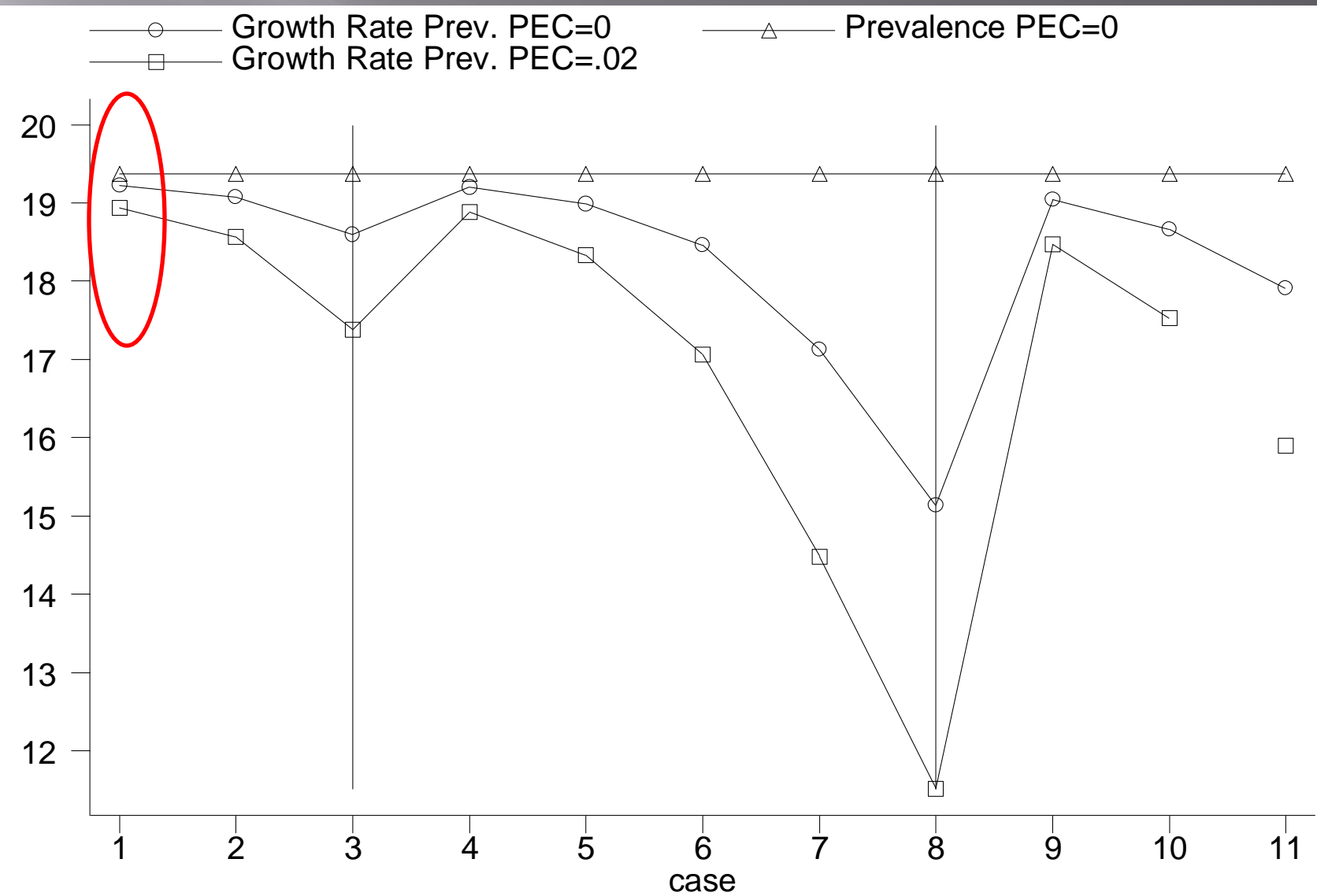


Figure 3a: Projected life expectancy at age 60-MEXICO

Life expectancy at 60

○ Growth Rate Prev. PEC=0
□ Growth Rate Prev. PEC=.02
△ Prevalence PEC=0

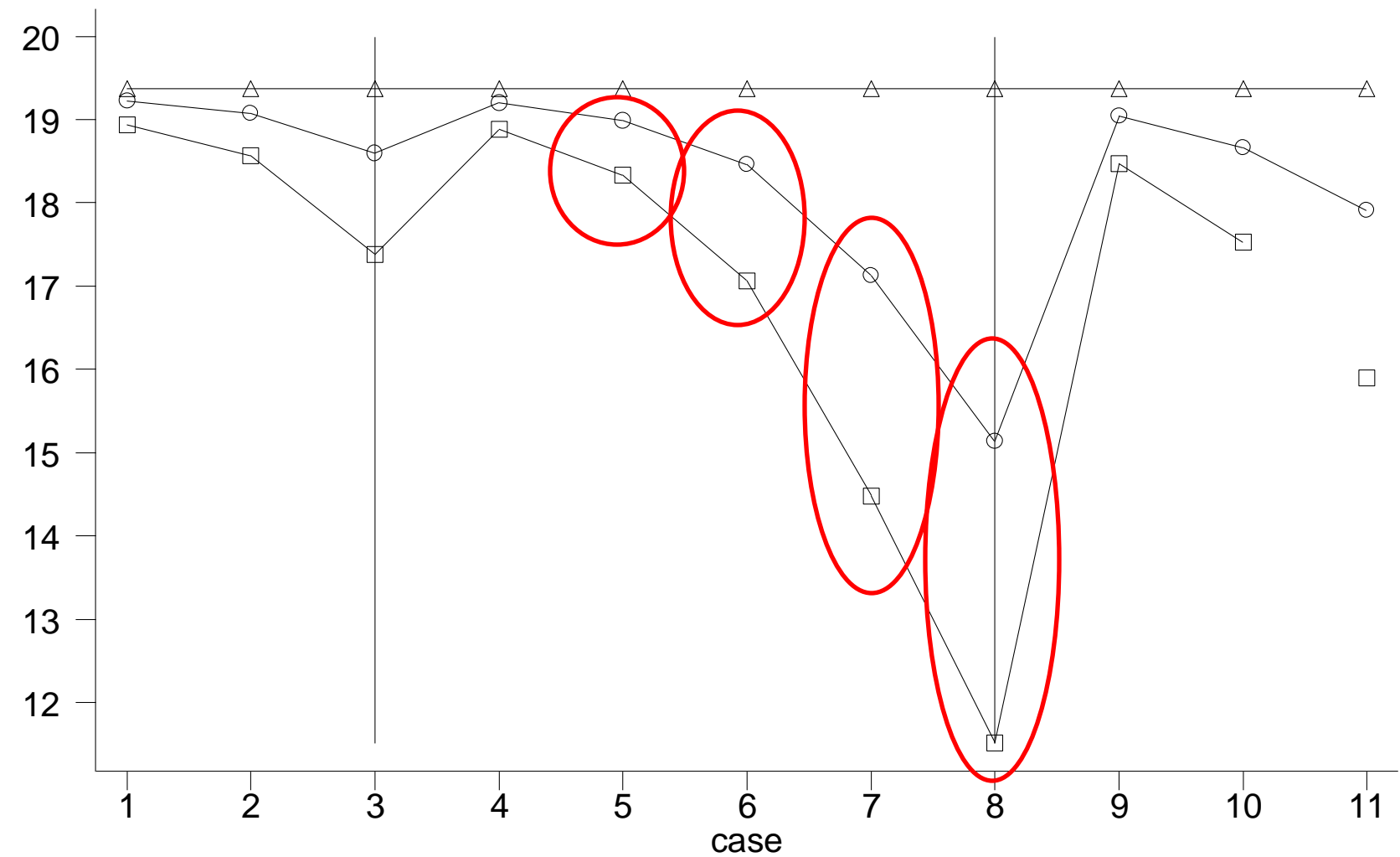


Figure 3a: Projected life expectancy at age 60-MEXICO

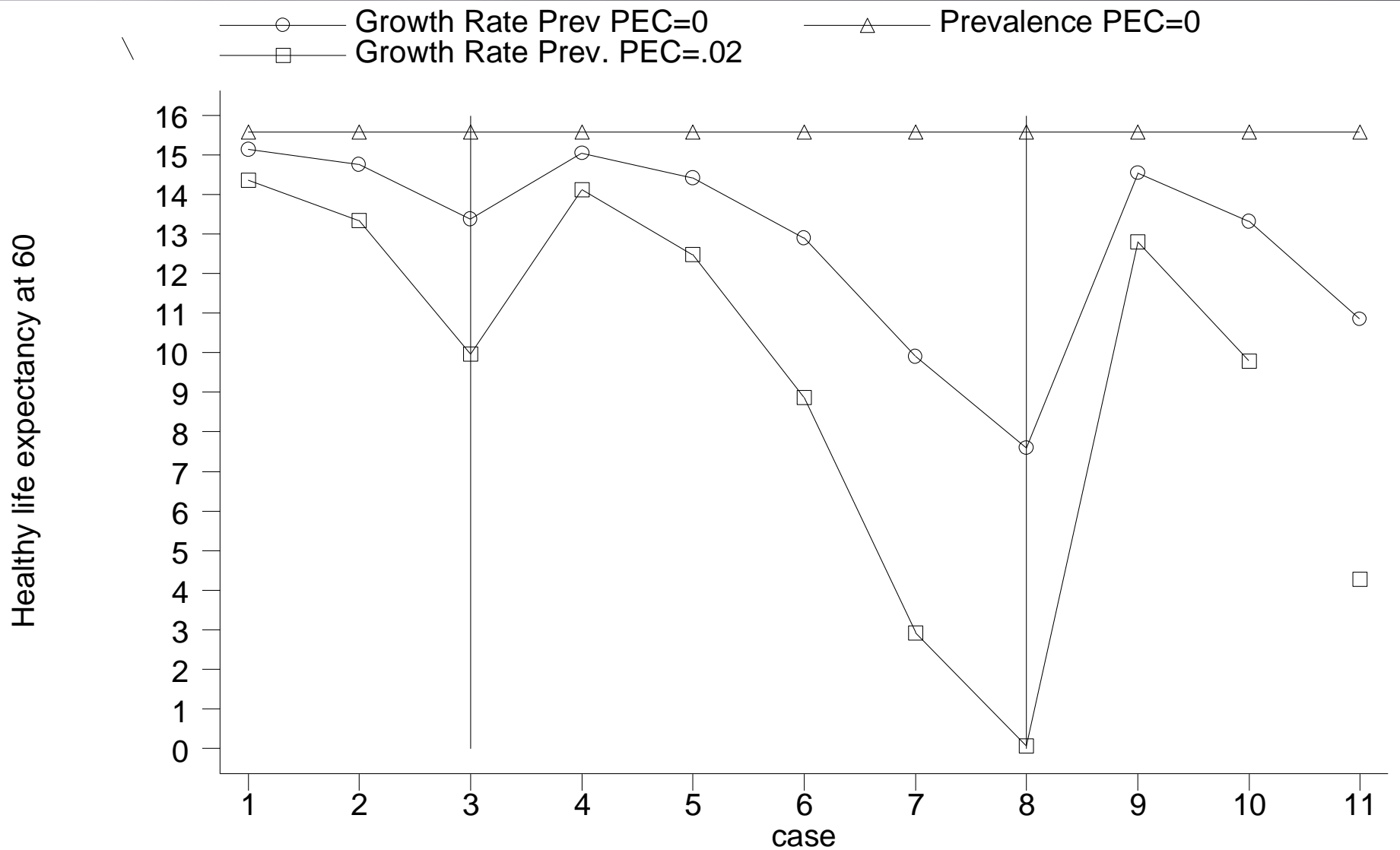


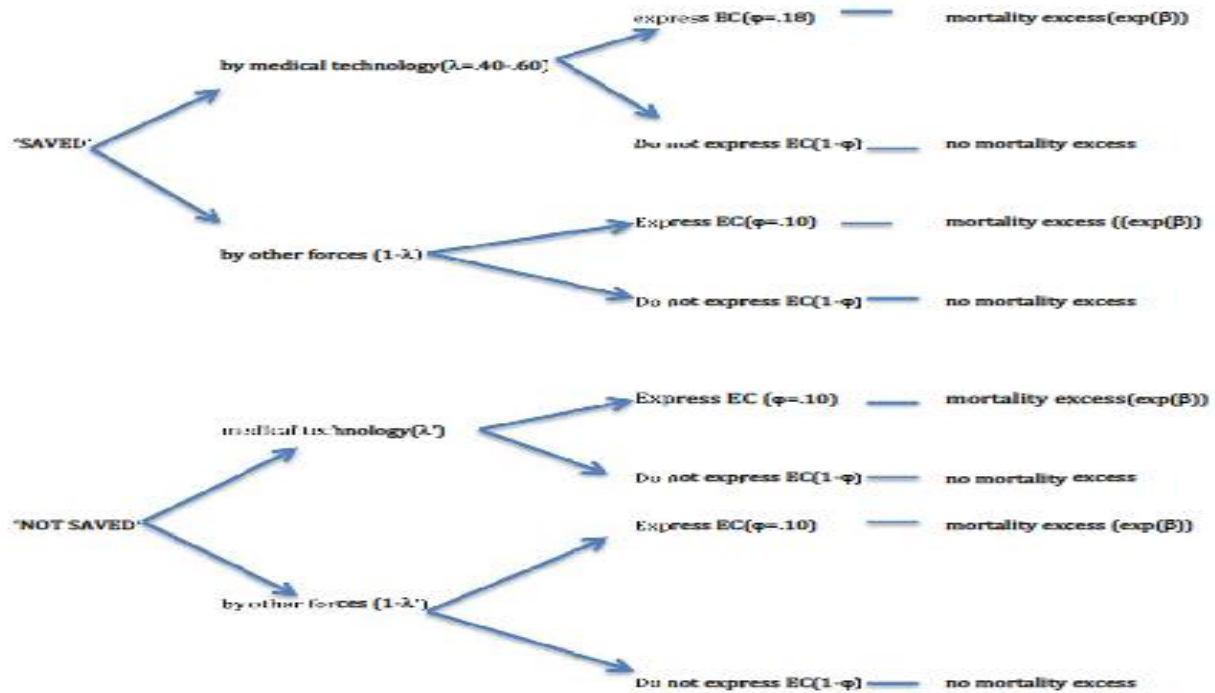
Figure 3b: Projected healthy life expectancy at age 60-MEXICO

5. Final Remarks

Our estimates of lower and upper bounds for the effects of PEC suggest:

- 1) Not even large increases in prevalence of PEC could modify substantially trend in longevity and HLE at old ages
- 2) PEC could have more than trivial consequences on longevity and HLE only if its effects on diabetes and heart disease prevalence are implausible large

Figure 2: Components of a cohort exposed to mortality decline in LAC



λ proportion among those 'saved' attributable to medical technology: .40 and .60
 λ' proportion among those NOT SAVED attributable to medical technology = .20
 ϕ fraction among those saved by medical technology that could manifest EC = .10 -.20
 $\exp(\beta)$ is the mortality excess due to early conditions.

Within Cohort Relation between Early and Late Mortality

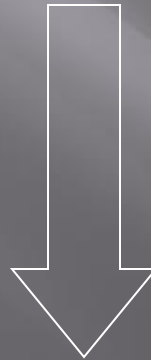
Mortality Decline	Early-late health connection		
	Nutritional Status	Particular diseases	Recurrent Infections
Standards of living	(++)	(+)	(+)
Public Health	(+)	(+)	(++)
Medical Innovations	(?)	(?)	(?)

Early Conditions

**Nutritional
Status**

**Particular
Diseases**

**Recurrent
Infections**



**Heart and
Pulmonary
Diseases

Diabetes**

**Heart and
Liver
Diseases

Stomach
Cancer**

**Coronary
Artery
Diseases**

Cohorts reaching age y at time t :

