

Heterogeneous frailties and mortality selection during the first month of life

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Biodemography of Aging

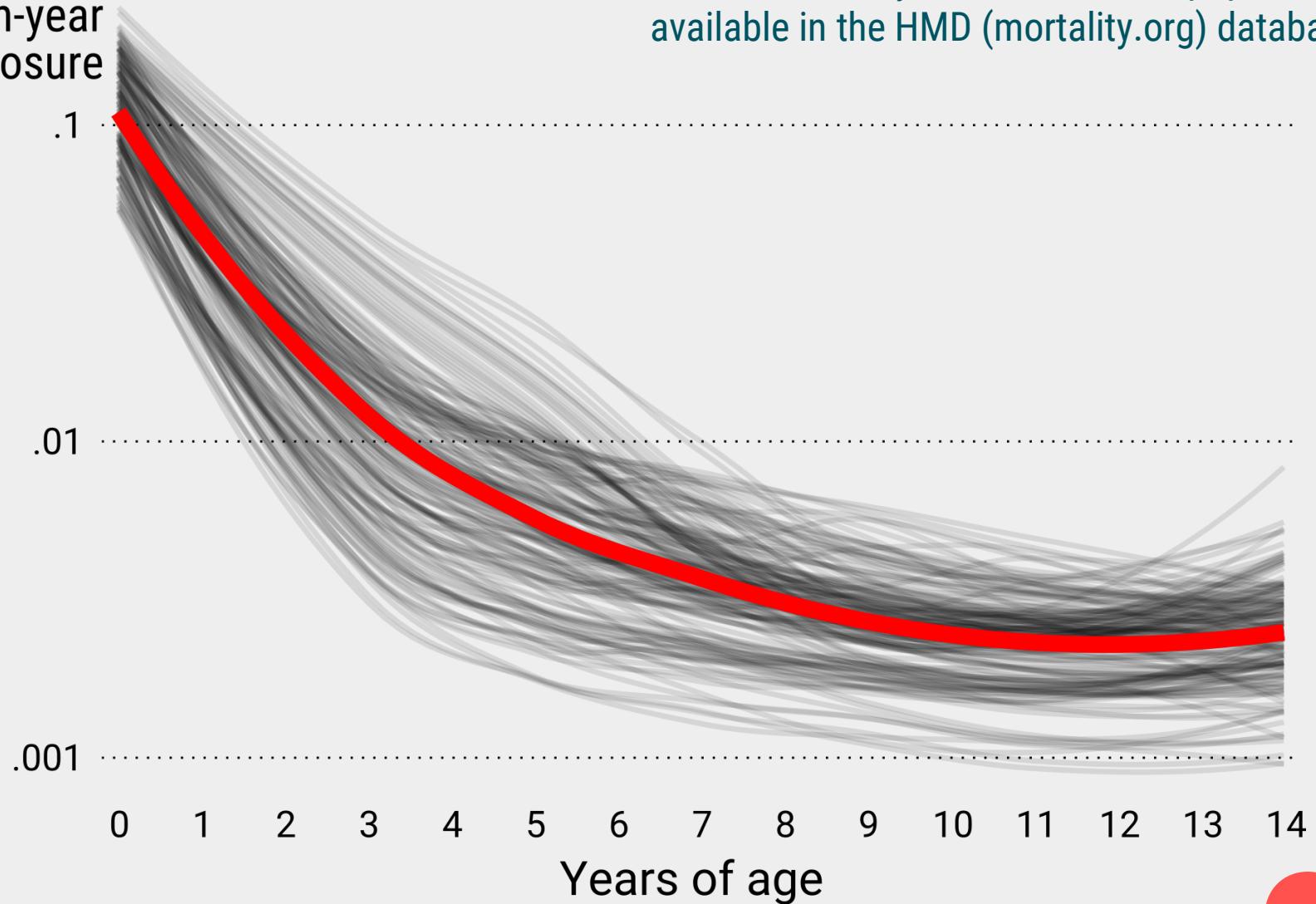


Department of Public Health
University of Southern Denmark

The age pattern of early life mortality

Deaths per
person-year
of exposure

LOESS-smoothed mortality rates for various populations
available in the HMD (mortality.org) database.

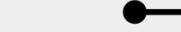


Mortality decline as growth and adaptation

Probability to die
within 30 days

.04

q_x



.03

$$q_{\text{Siler}}(x) = 0.03e^{-0.37x}$$

.02

.01

0

Danish males born 1911–15.

Raw data: Statistiske Departement Danmark 1920.

Months of age

*"While the most common use of this decreasing hazard would be to account for the hazard due to **immaturity**, it can also be used [...] for other hazards to which an animal **adjusts** successfully."*

Siler, W. (1979). A Competing-Risk Model for Animal Mortality. *Ecology*, 60(4), 750–757.

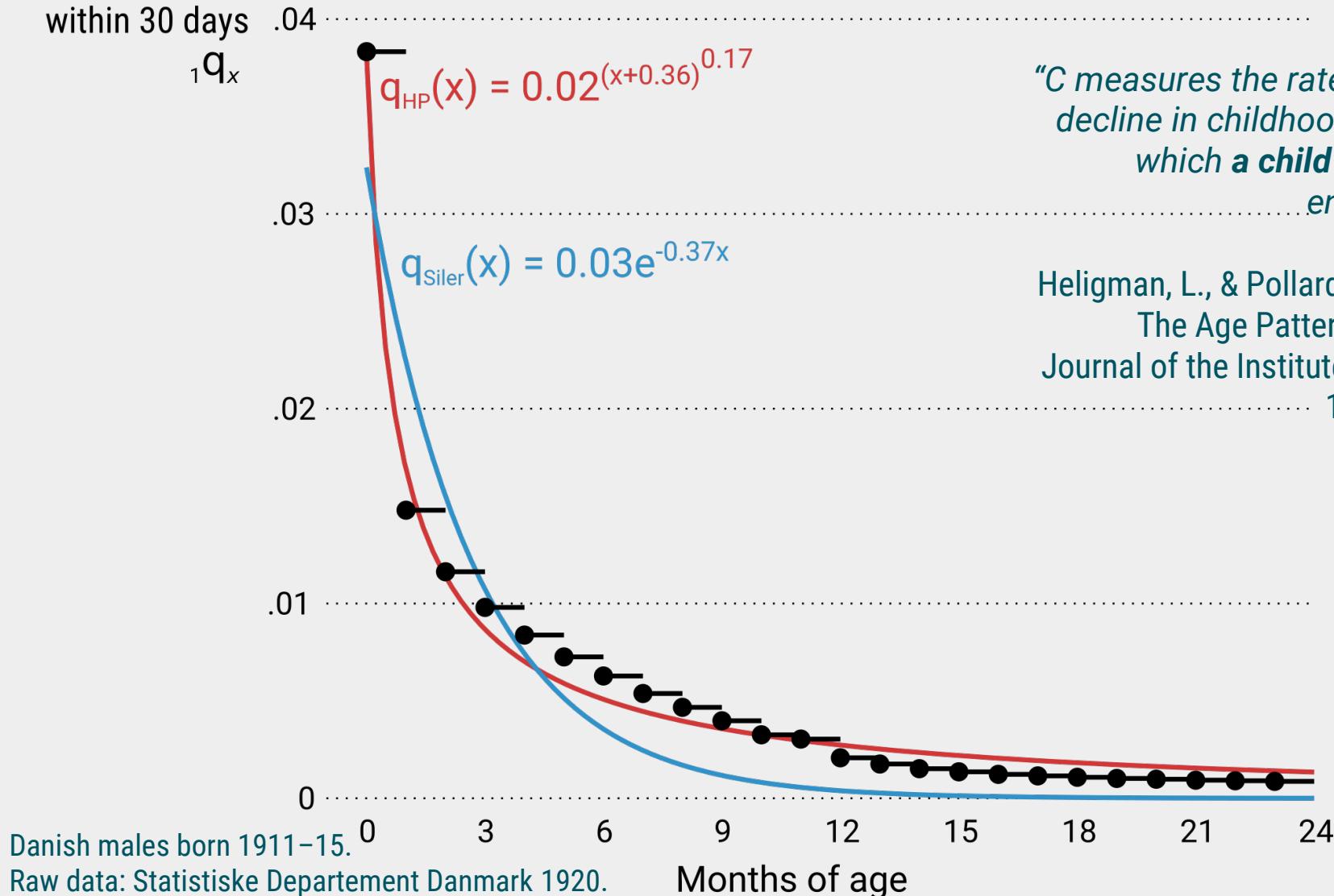
Mortality decline as growth and adaptation

Probability to die

within 30 days

$$q_x = 0.02^{(x+0.36)^{0.17}}$$

$$q_{Siler}(x) = 0.03e^{-0.37x}$$



"C measures the rate of mortality decline in childhood (the rate at which a child adapts to its environment)."

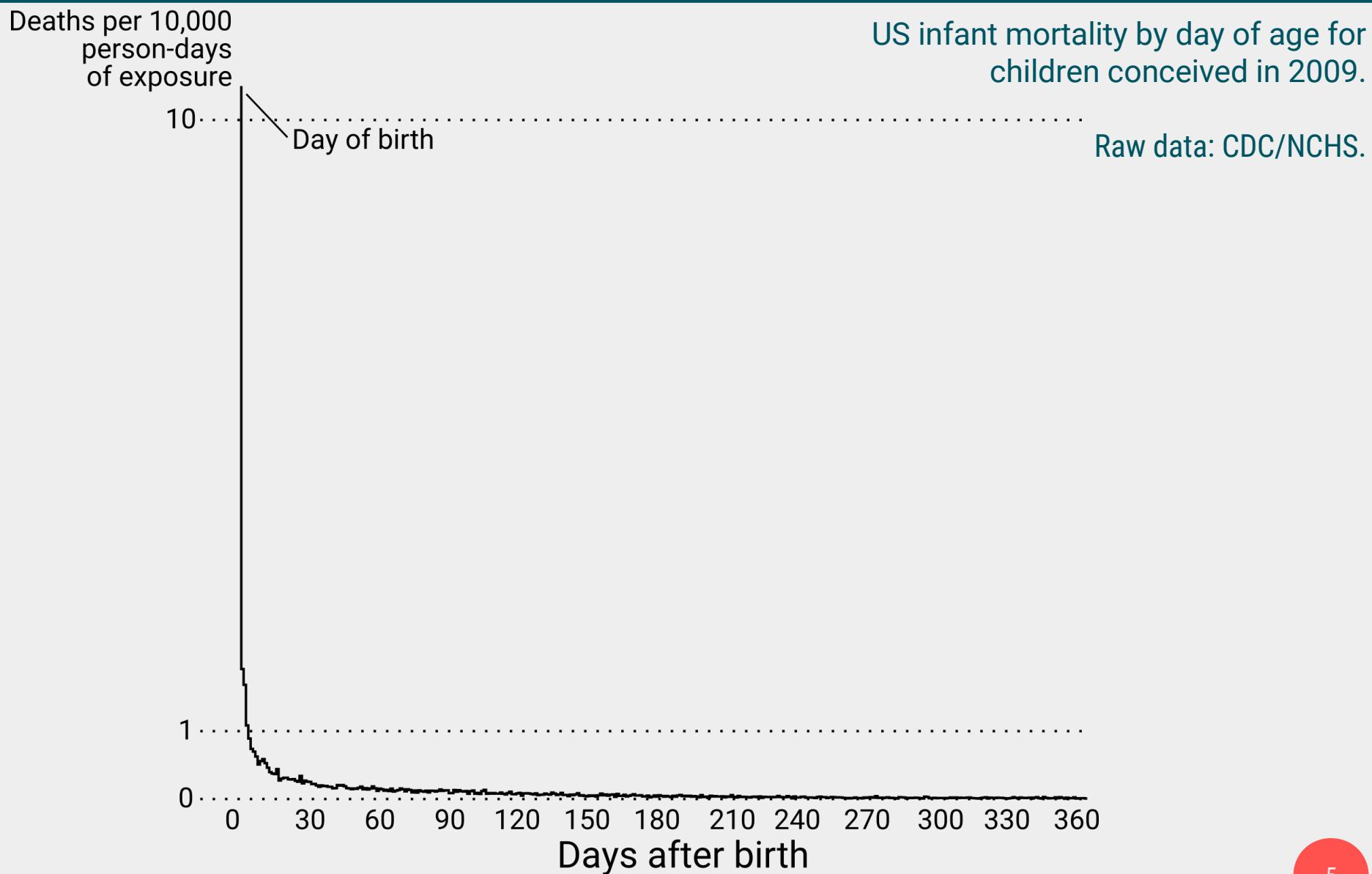
Heligman, L., & Pollard, J. H. (1980).
The Age Pattern of Mortality.
Journal of the Institute of Actuaries,
107(1), 49–80.

Danish males born 1911–15.

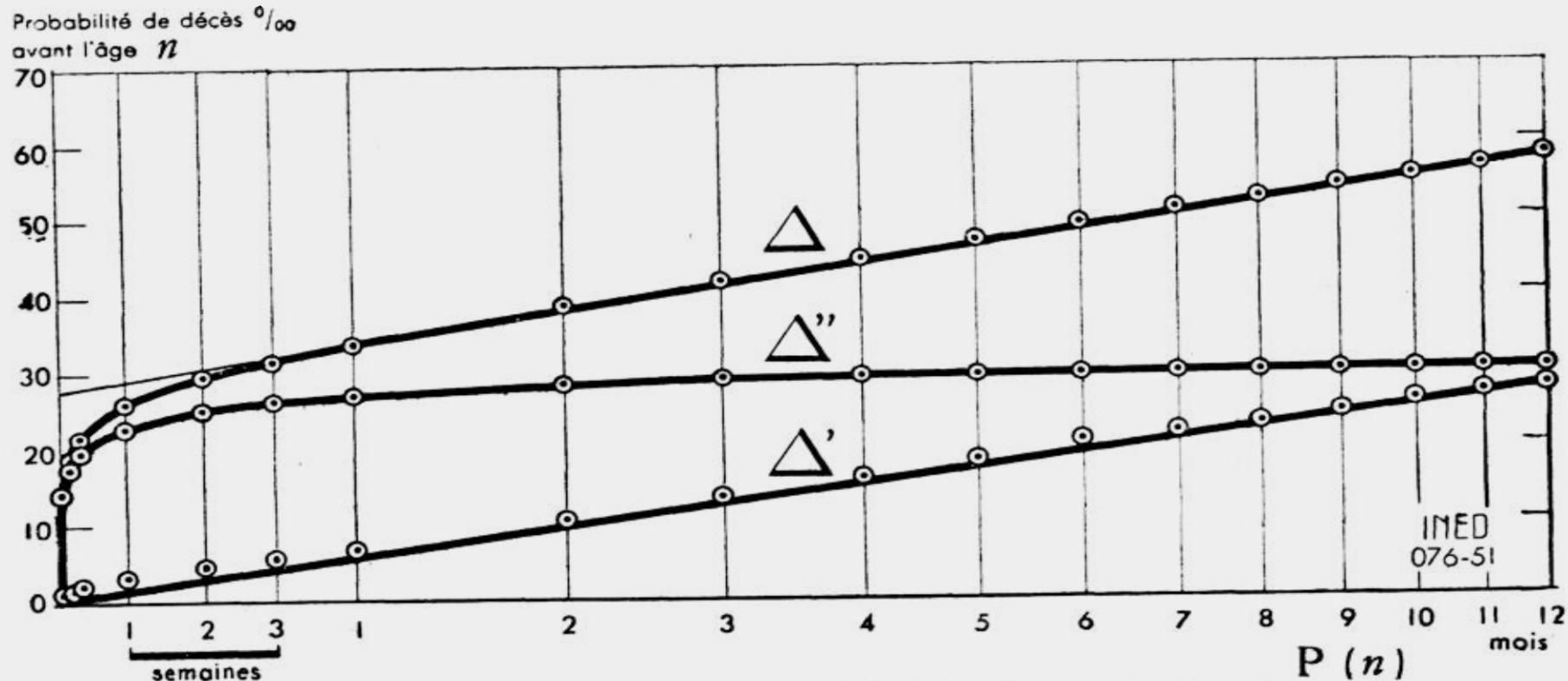
Raw data: Statistiske Departement Danmark 1920.

Months of age

Mortality decline as mortality selection



Mortality decline as mortality selection



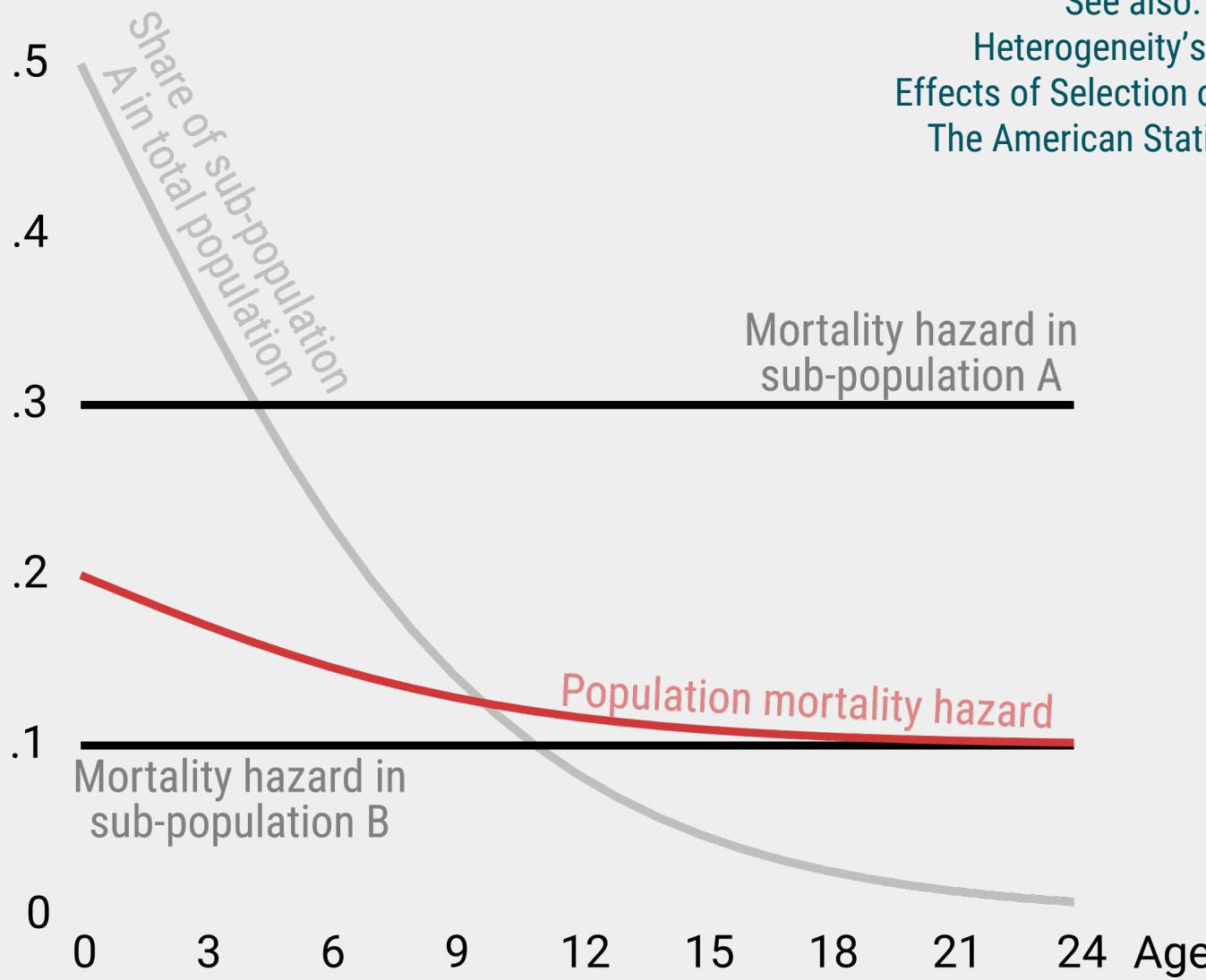
GRAPHIQUE n° 8. — Séparation des mortalités infantiles endogène et exogène.
(schéma observé aux Etats-Unis en 1932).

Bourgeois-Pichat, J. (1951). La mesure de la mortalité infantile.
II. Les causes de décès. Population, 6(3), 459–480.

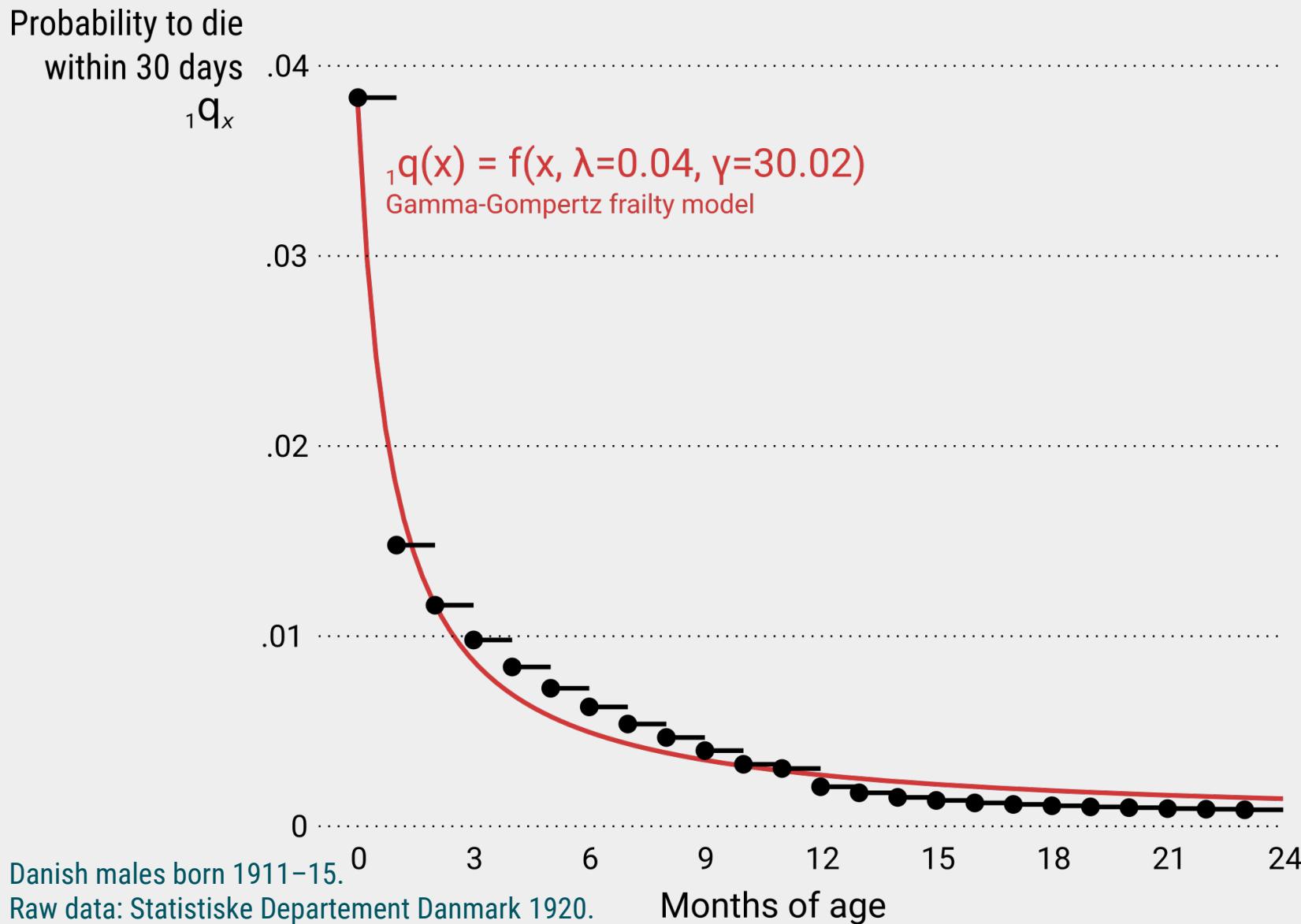
Mortality decline as mortality selection

See also: Vaupel & Yashin (1985).

Heterogeneity's Ruses: Some Surprising Effects of Selection on Population Dynamics.
The American Statistician, 39(3), 176–185.



Mortality decline as mortality selection



Overcoming guesswork by using individual level data

VITAL STATISTICS OF THE UNITED STATES: MORTALITY, 1994 TECHNICAL APPENDIX

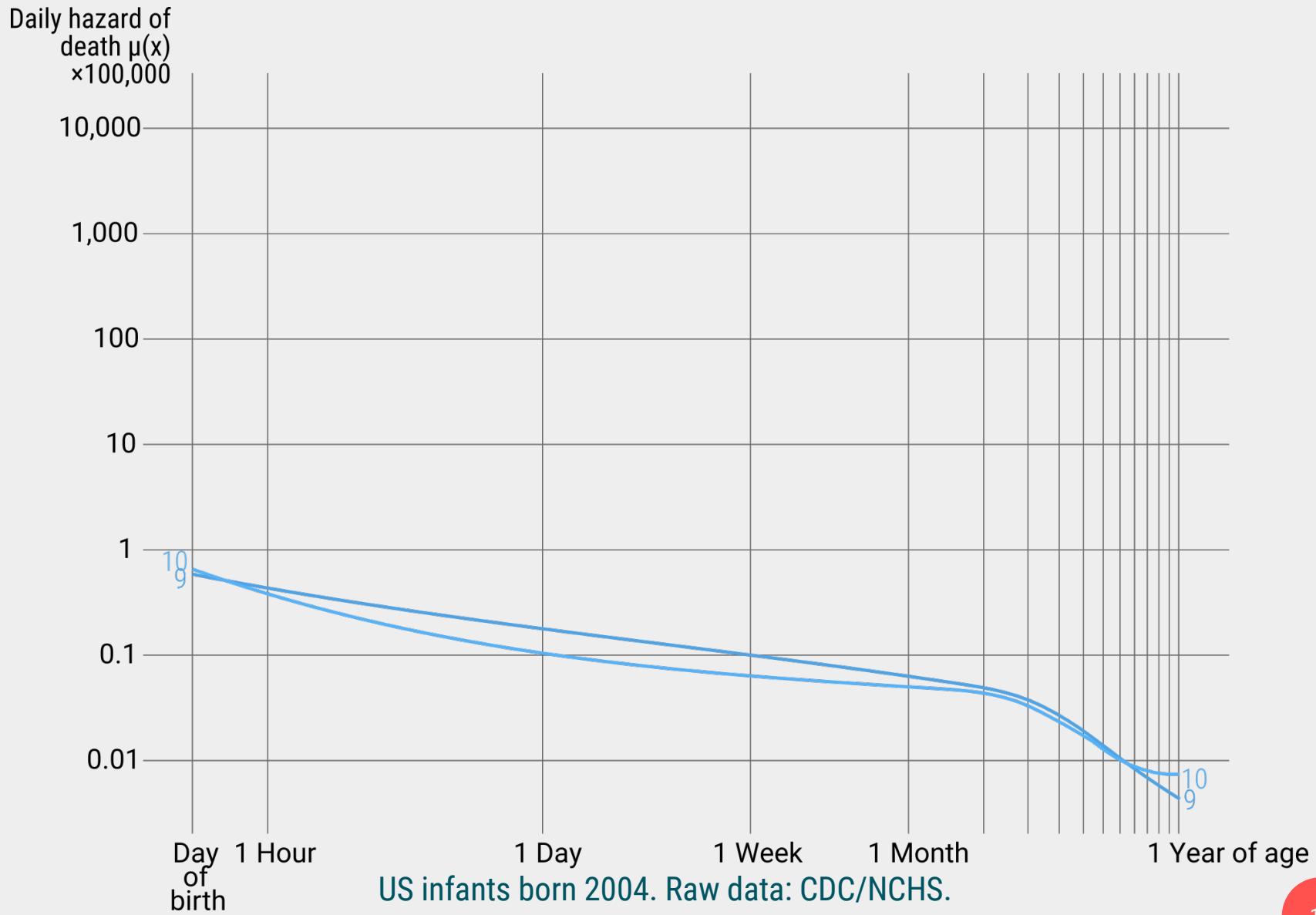
U.S. STANDARD CERTIFICATE OF DEATH											
LOCAL FILE NUMBER		STATE FILE NUMBER									
1. DECEDENT'S NAME (First, Middle, Last)											
2. SEX											
3. DATE OF DEATH (Month, Day, Year)											
4. SOCIAL SECURITY NUMBER											
5a. AGE—Last Birthday (Years)		5b. UNDER 1 YEAR		5c. UNDER 1 DAY		5d. DATE OF BIRTH (Month, Day, Year)		5e. BIRTHPLACE (City and State or Foreign Country)			
5f. PLACE OF DEATH (Check only one; see instructions on other side)											
6. WAS DECEDENT EVER IN U.S. (ARMED FORCES?)											
HOSPITAL		<input type="checkbox"/> Inpatient		<input type="checkbox"/> ER/Outpatient		<input type="checkbox"/> DGA		<input type="checkbox"/> Nursing Home <input type="checkbox"/> Residence <input type="checkbox"/> Other (Specify)			
7. FACILITY NAME (If not institution, give street and number)											
8. CITY, TOWN, OR LOCATION OF DEATH											
9. COUNTY OF DEATH											
10. MARITAL STATUS—Married, Never Married, Widowed, Divorced (Specify)											
11. SURVIVING SPOUSE (If wife, give maiden name)		12a. DECEDENT'S USUAL OCCUPATION (Give kind of work done during most of working life; Do not use retired.)		12b. KIND OF BUSINESS/INDUSTRY							
13a. RESIDENCE—STATE		13b. COUNTY		13c. CITY, TOWN, OR LOCATION		13d. STREET AND NUMBER					
13e. INSIDE CITY LIMITS? <input type="checkbox"/> Yes or no		14. WAS DECEDENT OF HISPANIC ORIGIN? (Specify No or Yes—If yes, specify Cuban, Mexican, Puerto Rican, etc.)		15. RACE—American Indian, Black, White, etc. (Specify)		16. DECEDENT'S EDUCATION (Specify only highest grade completed) Elementary/Secondary ID-121 College (1-4 or 5+)					
17. FATHER'S NAME (First, Middle, Last)		18. MOTHER'S NAME (First, Middle, Maiden, Surname)									
19a. INFORMANT'S NAME (Type/Phone)		19b. MAILING ADDRESS (Street and Number or Rural Route Number, City or Town, State, Zip Code)									
20a. METHOD OF DISPOSITION		20b. PLACE OF DISPOSITION (Name of cemetery, crematory, or other place)		20c. LOCATION—City or Town, State							
21a. SIGNATURE OF FUNERAL SERVICE LICENSEE OR PERSON ACTING AS SUCH		21b. LICENSE NUMBER (of Licensed)		22. NAME AND ADDRESS OF FACILITY							
23a. To the best of my knowledge, death occurred at the time, date, and place stated. Signature and Title ►		23b. LICENSE NUMBER		23c. DATE SIGNED (Month, Day, Year)							
24. TIME OF DEATH		25. DATE PRONOUNCED DEAD (Month, Day, Year)		26. WAS CASE REFERRED TO MEDICAL EXAMINER/CORONER? (Yes or no)							
27. PART I. Enter the diseases, injuries, or complications that caused the death. Do not enter the mode of dying, such as cardiac or respiratory arrest, shock, or heart failure. List only one cause on each line.											
IMMEDIATE CAUSE (Final disease or condition resulting in death) ►											
a. DUE TO IOR AS A CONSEQUENCE OF:											
b. DUE TO IOR AS A CONSEQUENCE OF:											
c. DUE TO IOR AS A CONSEQUENCE OF:											
d. DUE TO IOR AS A CONSEQUENCE OF:											
Approximate Interval between Onset and Death											
Part II. Other significant conditions contributing to death but not resulting in the underlying cause given in Part I.											
28a. WAS AN AUTOPSY PERFORMED? (Yes or no)		28b. WERE AUTOPSY FINDINGS ANATOMICAL PRIOR TO COMPLETION OF CAUSE OF DEATH? (Yes or no)									
29. MANNER OF DEATH		30a. DATE OF INJURY (Month, Day, Year)		30b. TIME OF INJURY		30c. INJURY AT WORK?		30d. DESCRIBE HOW INJURY OCCURRED			
30e. PLACE OF INJURY—At home, farm, street, factory, office building, etc. (Specify)		30f. LOCATION (Street and Number or Rural Route Number, City or Town, State)									
31a. CERTIFIER (Name, title, and address)											
□ CERTIFYING PHYSICIAN (Physician certifying cause of death when another physician has pronounced death and completed Item 23) To the best of my knowledge, death occurred due to the cause(s) and manner as stated.											
□ PRONOUNCING AND CERTIFYING PHYSICIAN (Physician both pronouncing death and certifying to cause of death) To the best of my knowledge, death occurred at the time, date, and place, and due to the cause(s) and manner as stated.											
□ MEDICAL EXAMINER/CORONER On the basis of examination and/or investigation, in my opinion, death occurred at the time, date, and place, and due to the cause(s) and manner as stated.											
31b. SIGNATURE AND TITLE OF CERTIFIER		31c. LICENSE NUMBER		31d. DATE SIGNED (Month, Day, Year)							
32. NAME AND ADDRESS OF PERSON WHO COMPLETED CAUSE OF DEATH ITEM 27? (Type/Phone)											
33. REGISTRAR'S SIGNATURE		34. DATE FILED (Month, Day, Year)									

The NCHS provides:

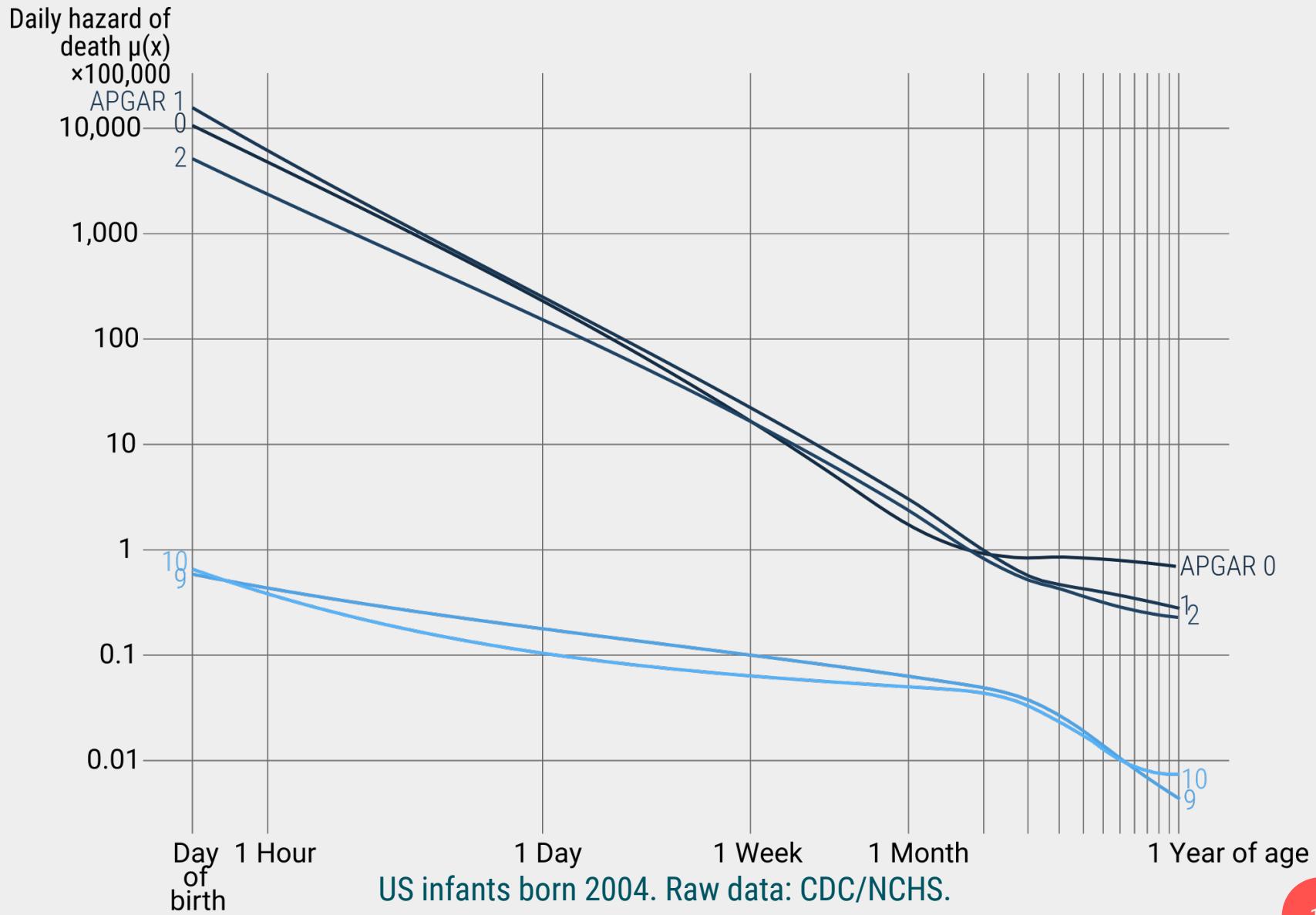
- birth certificates on ~70 million US births over period 1995–2010
- death certificates on the 439,215 infant deaths during that time

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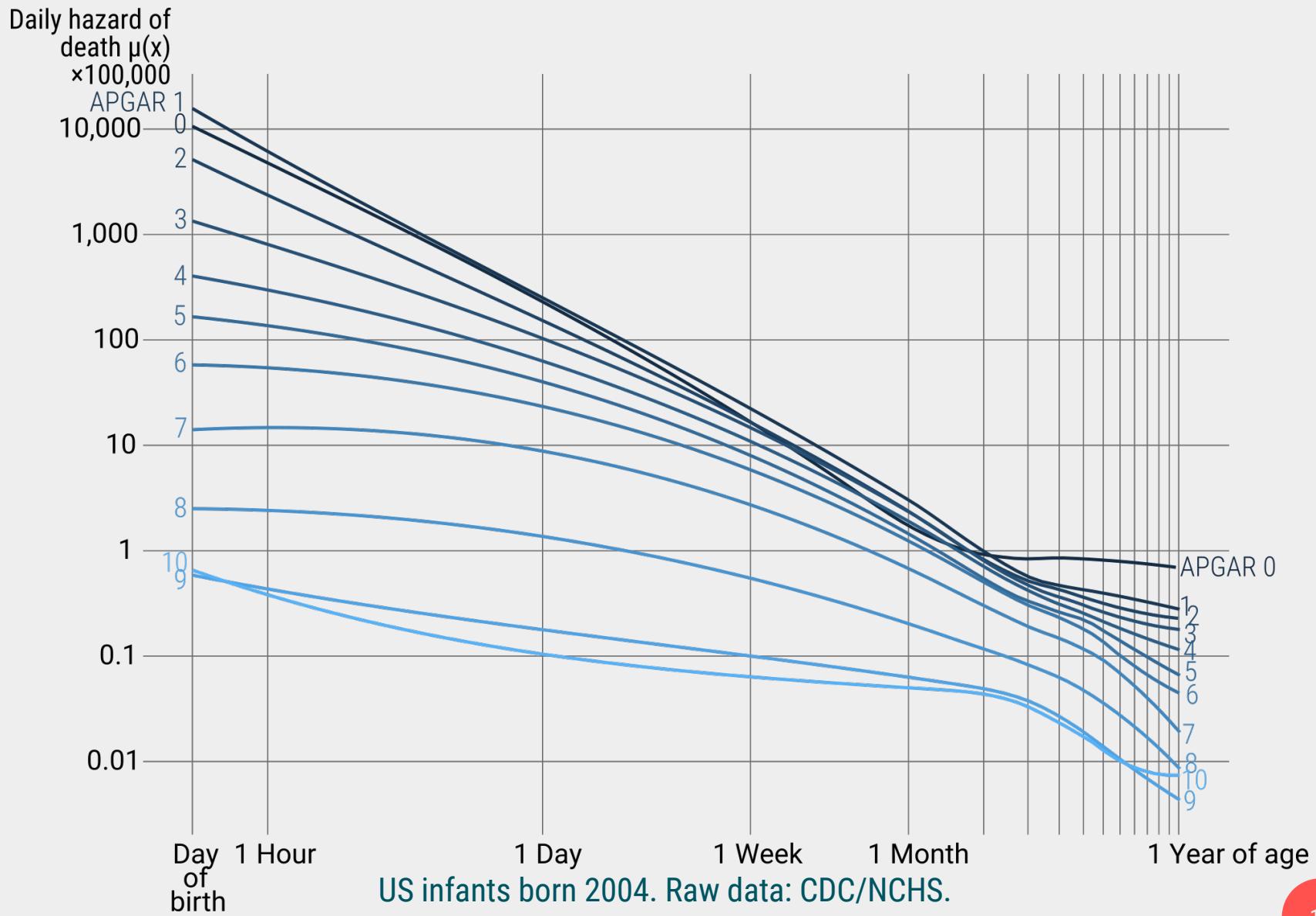
A demonstration of mortality selection



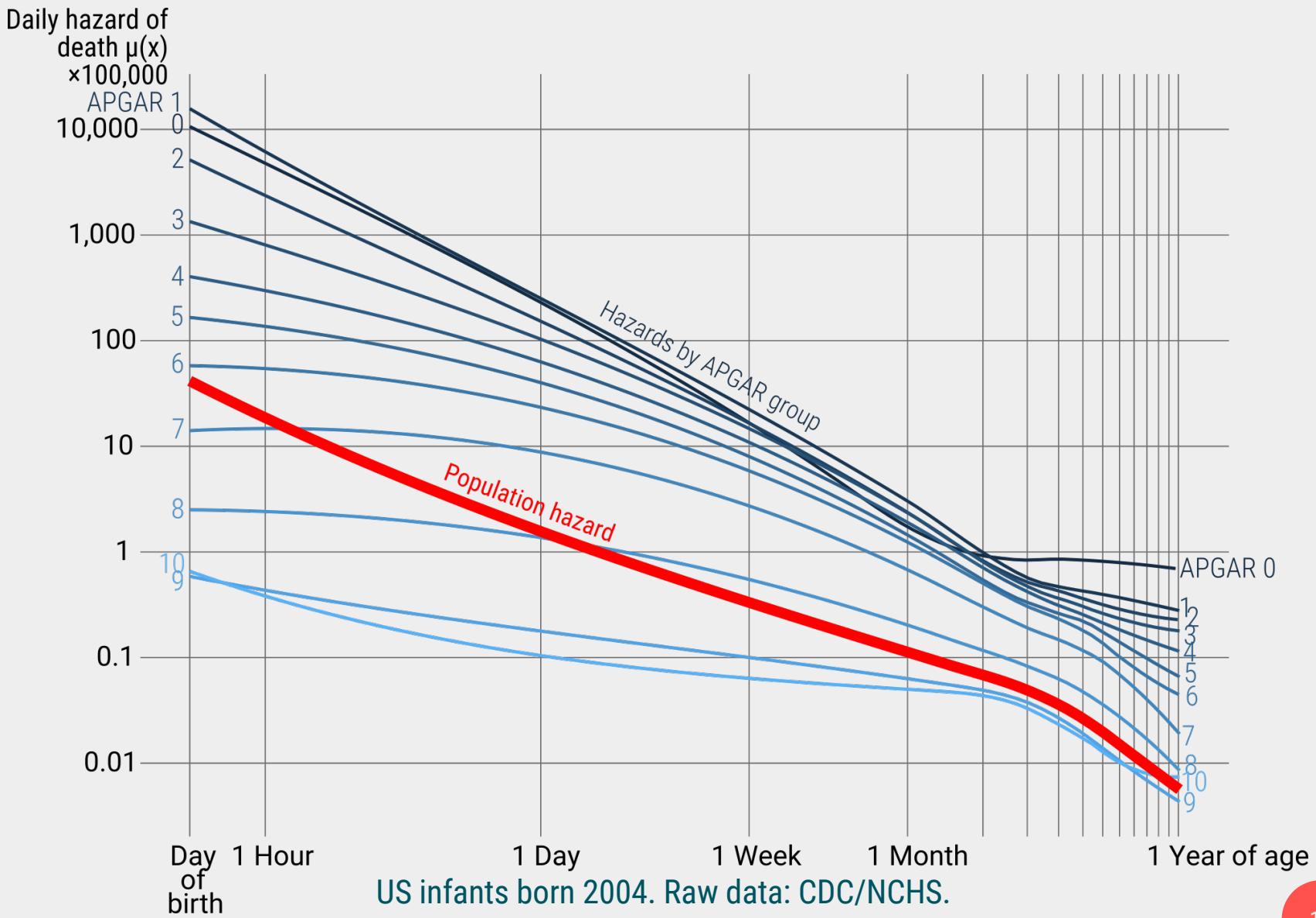
A demonstration of mortality selection



A demonstration of mortality selection



A demonstration of mortality selection



Decomposition methods

$$\text{Total difference in outcome between groups A and B} = \text{Difference due to group effect} + \text{Difference due to group composition}$$

Decomposition methods

Vaupel, J. W., & Zhang, Z. (2010). **Attrition in heterogeneous cohorts**. Demographic Research, 23(26), 737–748.

Oaxaca, R. (1973). "Male-Female Wage Differentials in Urban Labor Markets". International Economic Review. 14 (3): 693–709.

Price, G. R. (1970). **Selection and covariance**. Nature, 227(5257), 520–1.

Blinder, A. S., Ashenfelter, O., Ben-Porath, Y., Barr, N., & Oaxaca, R. (1973). **Wage Discrimination: Reduced Form and Structural Estimates**. The Journal of Human Resources, 8(4), 436–455.

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Powers, D. A., Yoshioka, H., & Yun, M.-S. (2011). **mvdcmp: Multivariate decomposition for nonlinear response models**. The Stata Journal, 11(4), 556–576.

Preston, S.H., Himes, C.L., and Eggers, M. (1989). **Demographic conditions responsible for population aging**. Demography 26(4): 691–704.

Vaupel, J.W. and Canudas-Romo, V. (2002). **Decomposing demographic change into direct vs. compositional components**. Demographic Research 7(1): 1–14.

Regression based decomposition

Vaupel, J. W., & Zhang, Z. (2010). Attrition in heterogeneous cohorts. Demographic Research, 23(26), 737–748.

Oaxaca, R. (1973). "Male-Female Wage Differentials in Urban Labor Markets". International Economic Review. 14 (3): 693–709.

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Co-variance based decomposition

Vaupel, J. W., & Zhang, Z. (2010). Attrition in heterogeneous cohorts. Demographic Research, 23(26), 737–748.

Price, G. R. (1970). Selection and covariance. Nature, 227(5257), 520–1.

$$\dot{\bar{Y}} = \dot{\bar{Y}}_z + \text{Cov}(Y_z, r_z)$$

Change in average \bar{Y} = Average change of \bar{Y} across strata z + Co-variance between \bar{Y} and relative growth rate across strata z

Preston, S.H., Himes, C.L., and Eggers, M. (1989). Demographic conditions responsible for population aging. Demography 26(4): 691–704.

Vaupel, J.W. and Canudas-Romo, V. (2002). Decomposing demographic change into direct vs. compositional components. Demographic Research 7(1): 1–14.

Co-variance based decomposition

Vaupel, J. W., & Zhang, Z. (2010). Attrition in heterogeneous cohorts. Demographic Research, 23(26), 737–748.

Price, G. R. (1970). Selection and covariance. Nature, 227(5257), 520–1.

$$\dot{\bar{\mu}} = \dot{\bar{\mu}_z} + \sigma^2_{\mu z}$$

Change in Population hazard = Average change of hazards across strata z + Variance of hazards across strata z

Preston, S.H., Himes, C.L., and Eggers, M. (1989). Demographic conditions responsible for population aging. Demography 26(4): 691–704.

Vaupel, J.W. and Canudas-Romo, V. (2002). Decomposing demographic change into direct vs. compositional components. Demographic Research 7(1): 1–14.

Analysis pipeline

1. Raw data

US births 2005-10

N = 25,143,288

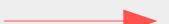
1 row = 1 birth

Analysis pipeline

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A tibble: 25,143,288 x 4

	plurality	death	survtime_h	survtime_h_width
	<fctr>	<lgl>	<dbl>	<dbl>
1	Single	TRUE	0	1
2	Single	TRUE	1	23
3	Single	TRUE	1	23
4	Single	TRUE	1	23
5	Single	TRUE	0	1
6	Single	TRUE	0	1
7	Single	TRUE	1	23
8	Single	TRUE	1	23
9	Single	TRUE	0	1
10	Twin	TRUE	0	1
# ... with 25,143,278 more rows				



2. Survival data

interval censored, stratified

1. Raw data

US births 2005-10

N = 25,143,288

1 row = 1 birth

Analysis pipeline

```
# A tibble: 25,143,288 x 4
  plurality death survtime_h survtime_h_width
  <fctr>   <lgl>     <dbl>           <dbl>
 1 Single    TRUE        0             1
 2 Single    TRUE        1            23
 3 Single    TRUE        1            23
 4 Single    TRUE        1            23
 5 Single    TRUE        0             1
 6 Single    TRUE        0             1
 7 Single    TRUE        1            23
 8 Single    TRUE        1            23
 9 Single    TRUE        0             1
 10 Twin     TRUE        0             1
# ... with 25,143,278 more rows
```

2. Survival data

interval censored, stratified

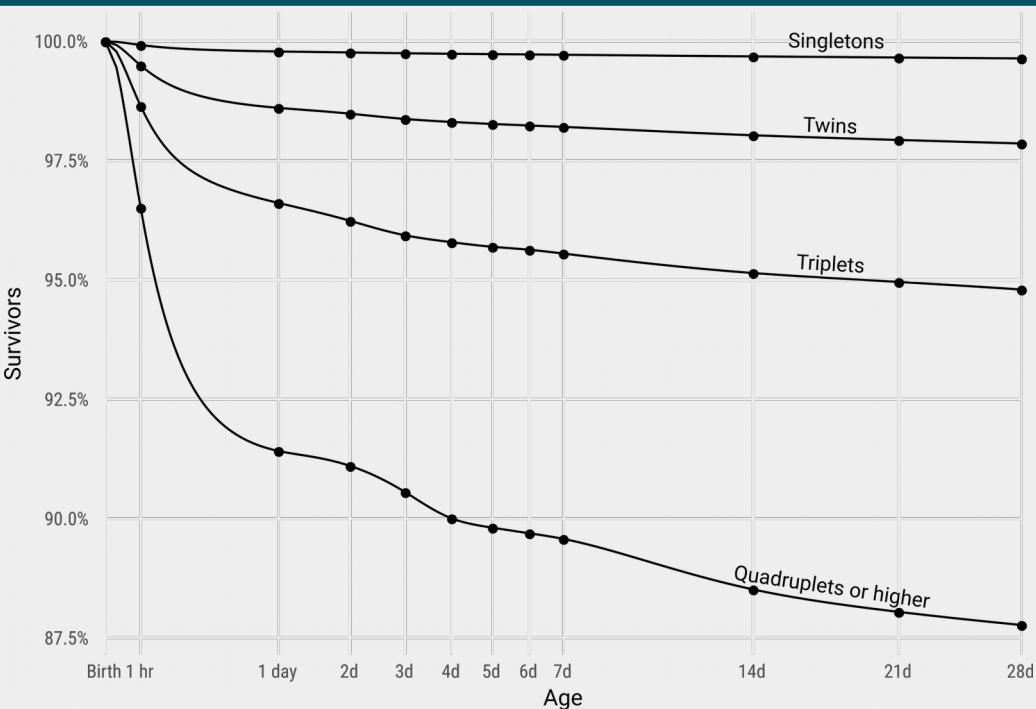
1. Raw data

US births 2005-10
N = 25,143,288
1 row = 1 birth

3. Neonatal life-tables

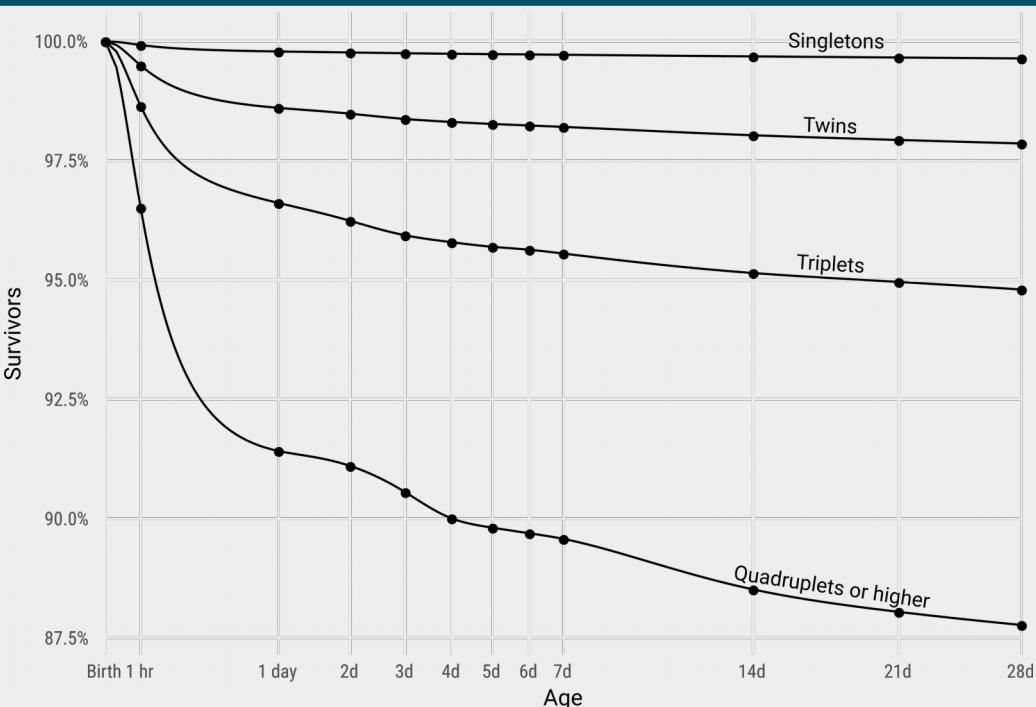
first 28 days of life cut in 12 intervals, stratified

Analysis pipeline



4. Spline interpolation of life-tables Hyman filtered cubic splines, stratified

Analysis pipeline



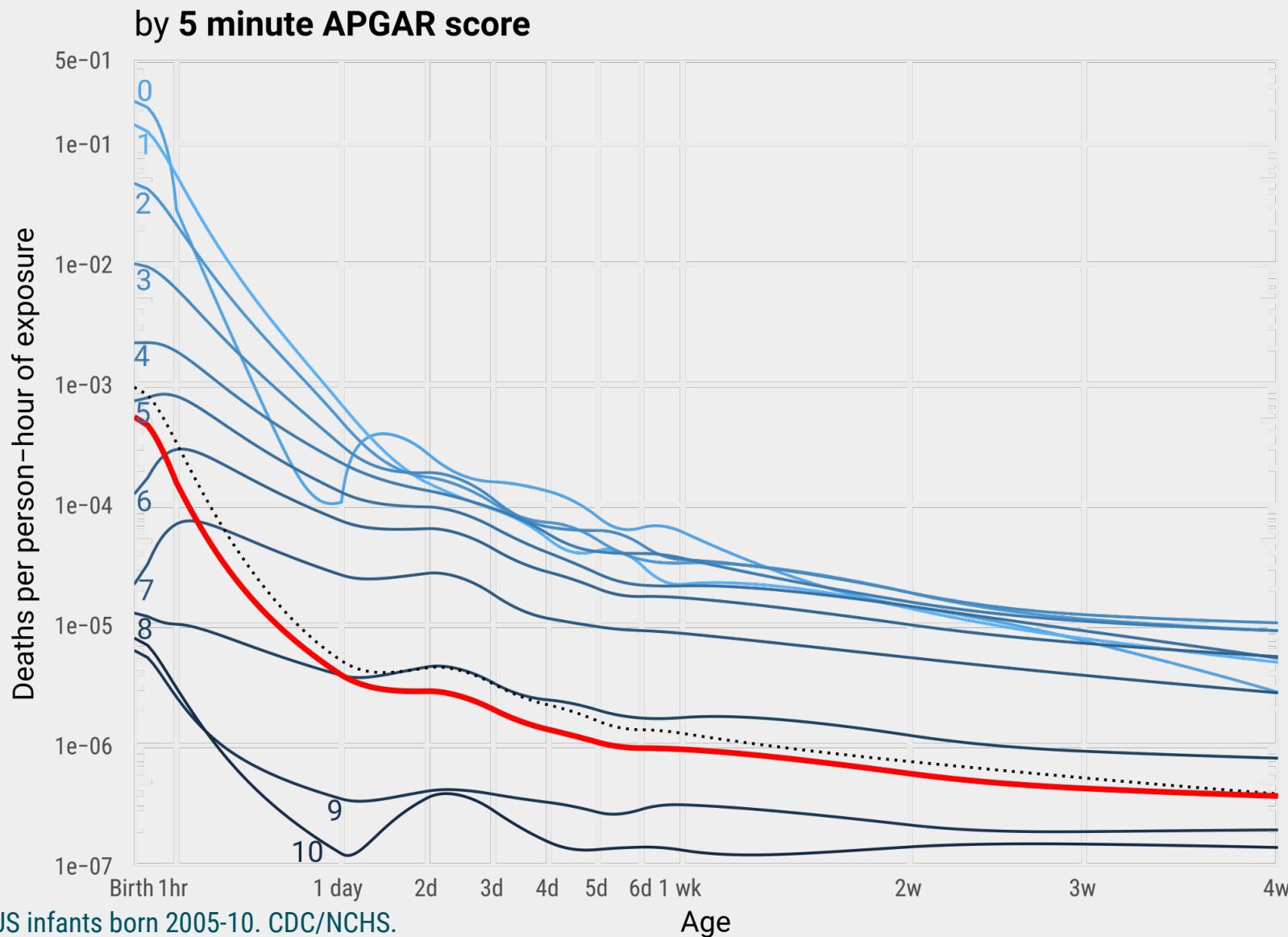
4. Spline interpolation of life-tables
Hyman filtered cubic splines, stratified



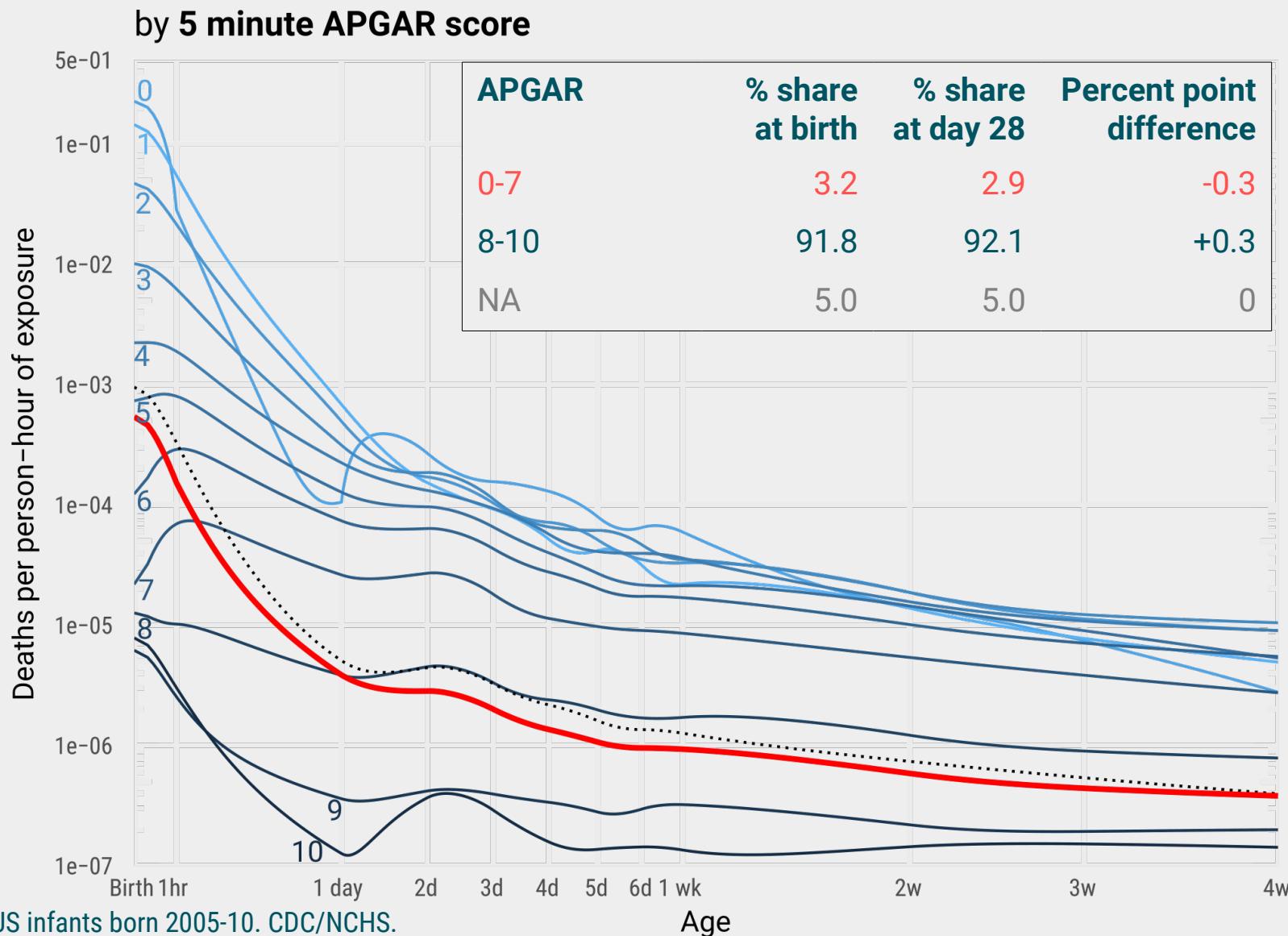
5. Vaupel-Zhang decomposition
results integrated for ease of interpretation

#	A tibble: 11 x 7	x	nx	diff_mux	diff_direct	p_direct	diff_compos	p_compos
		<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
1	0	1	-3.372577e-04	-3.371456e-04	0.9996677	-1.120566e-07	3.322581e-04	
2	1	23	-1.872115e-04	-1.871751e-04	0.9998055	-3.641661e-08	1.945213e-04	
3	24	24	-1.458869e-06	-1.458637e-06	0.9998411	-2.318351e-10	1.589143e-04	
4	48	24	-9.328814e-07	-9.326824e-07	0.9997866	-1.990316e-10	2.133514e-04	
5	72	24	-6.967401e-07	-6.966751e-07	0.9999067	-6.499963e-11	9.329108e-05	
6	96	24	-3.153042e-07	-3.152803e-07	0.9999240	-2.396879e-11	7.601798e-05	
7	120	24	-1.301809e-07	-1.301690e-07	0.9999089	-1.185915e-11	9.109745e-05	
8	144	24	-3.481738e-08	-3.480556e-08	0.9996607	-1.181328e-11	3.392928e-04	
9	168	168	-3.634319e-07	-3.633698e-07	0.9998292	-6.208683e-11	1.708348e-04	
10	336	168	-1.646642e-07	-1.646483e-07	0.9999033	-1.591812e-11	9.667023e-05	
11	504	168	-6.572048e-08	-6.571205e-08	0.9998718	-8.427150e-12	1.282272e-04	

Decomposing the neonatal mortality age decline

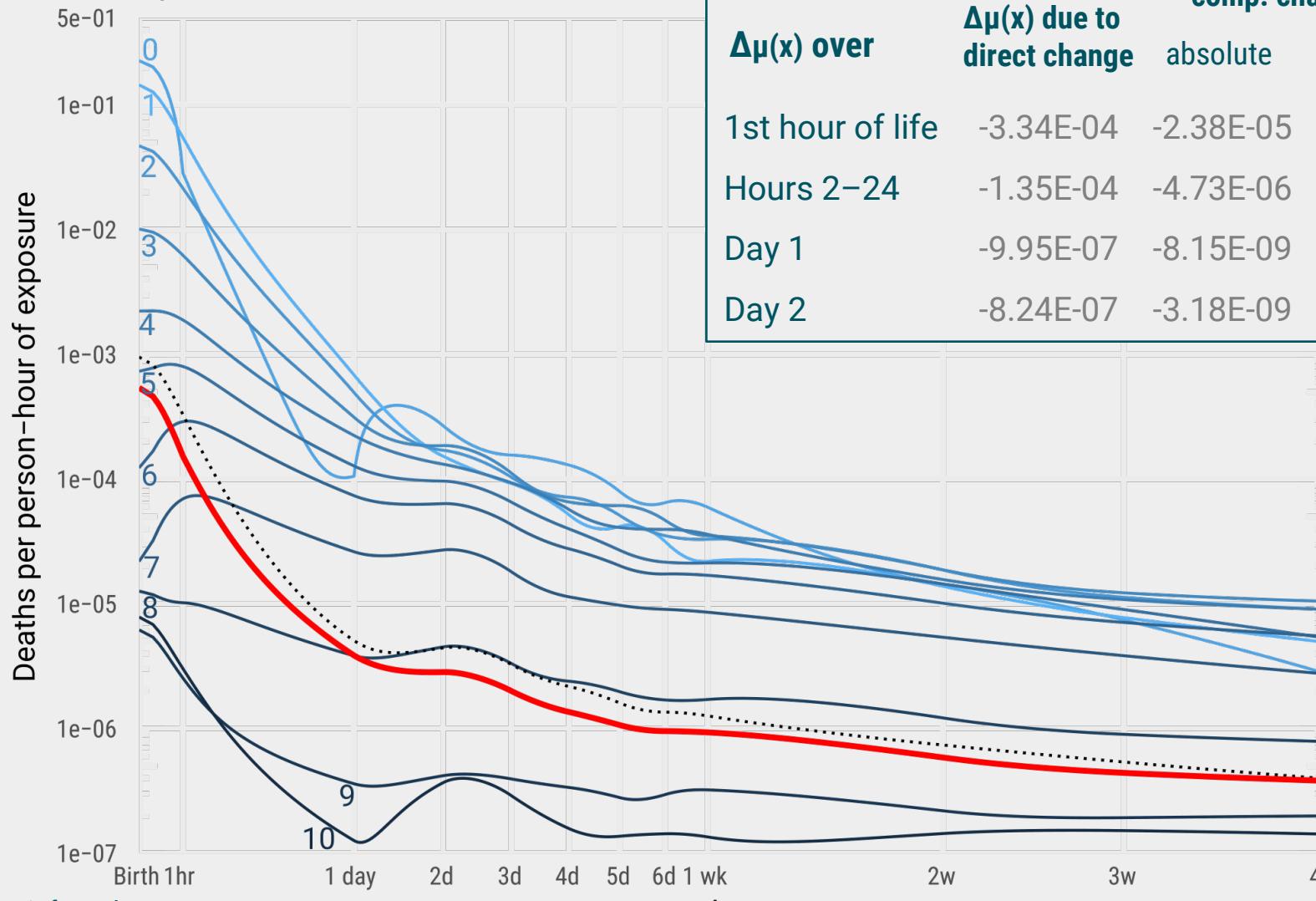


Decomposing the neonatal mortality age decline



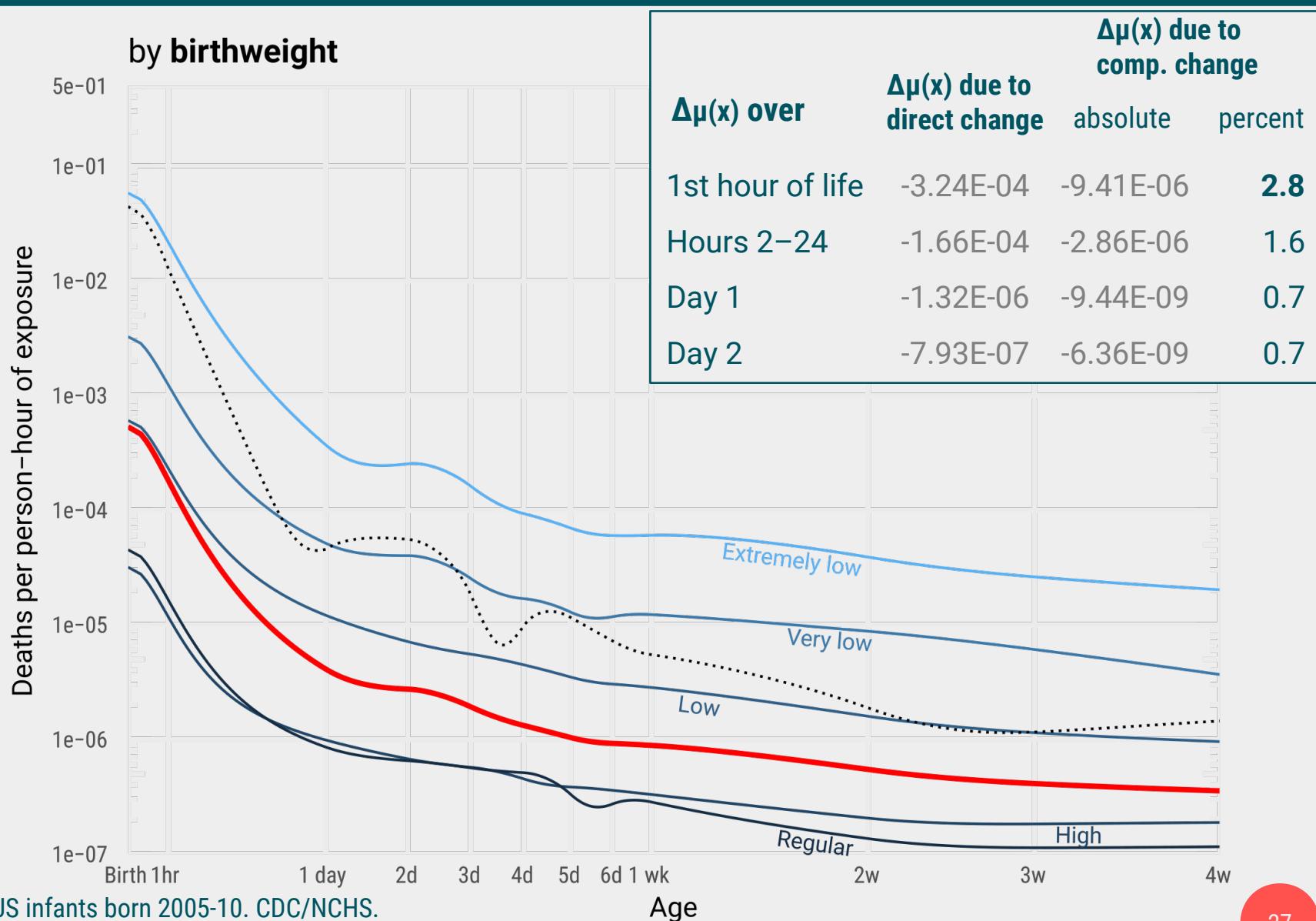
Decomposing the neonatal mortality age decline

by 5 minute APGAR score

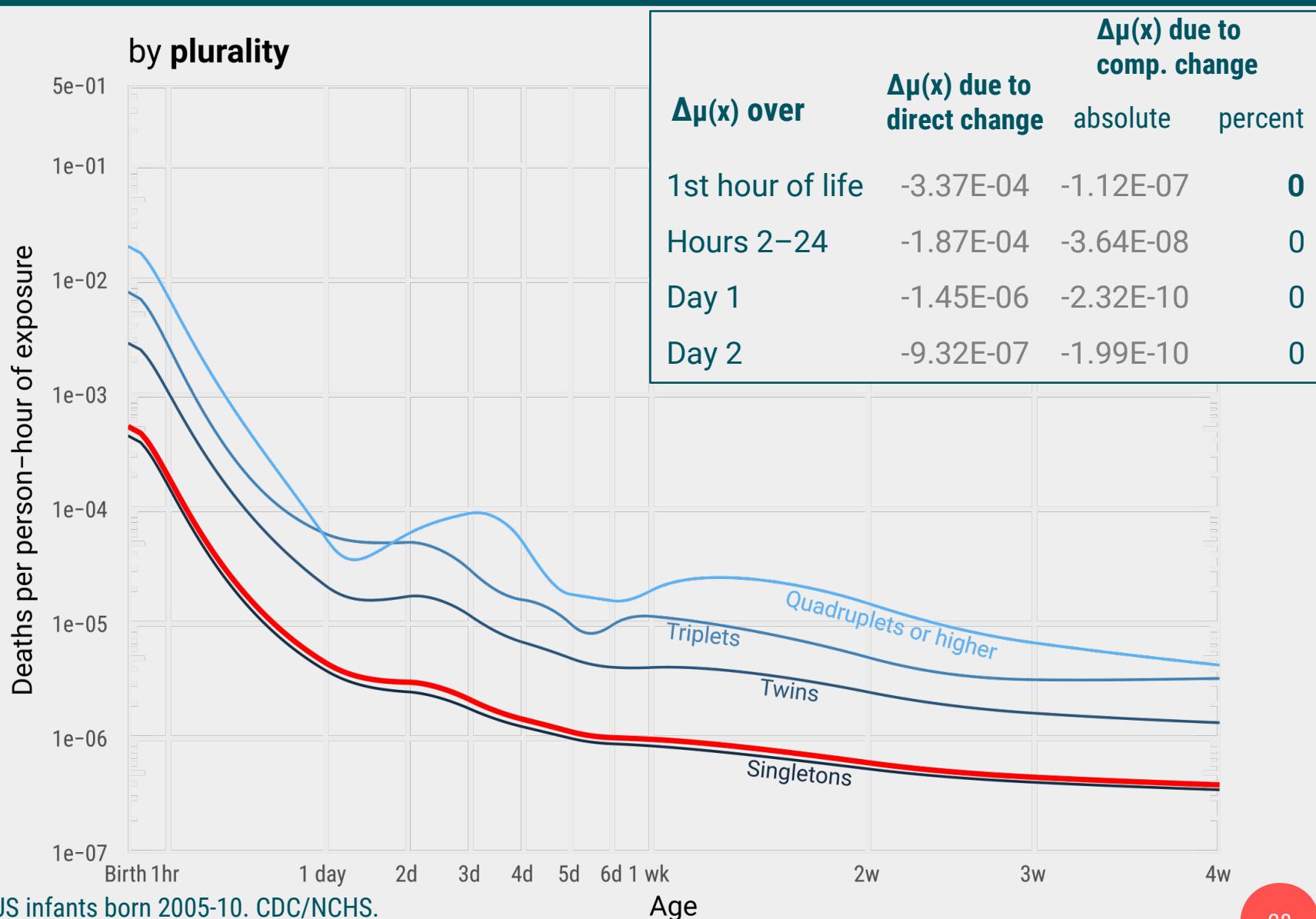


Data: US infants born 2005-10. CDC/NCHS.

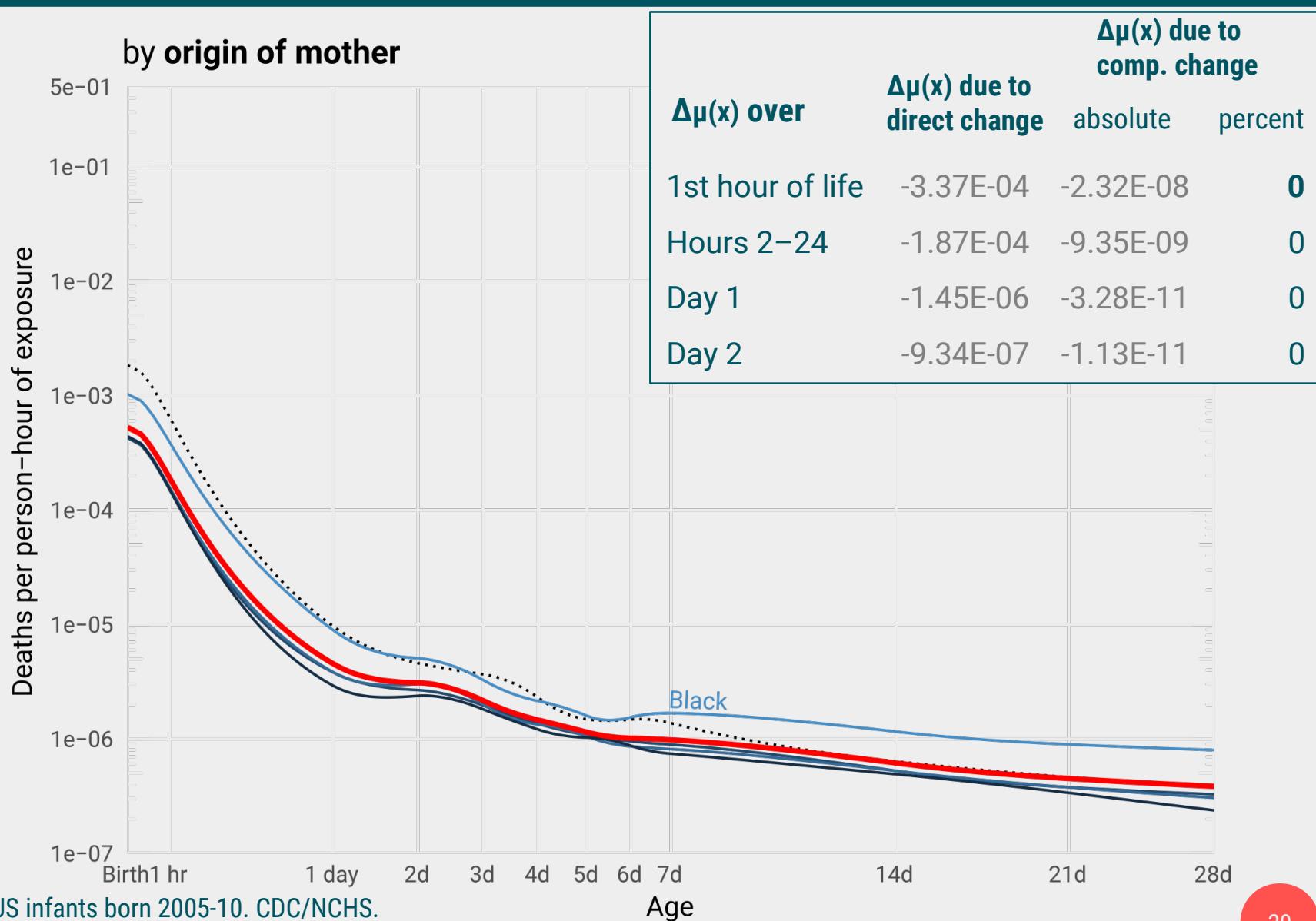
Decomposing the neonatal mortality age decline



Decomposing the neonatal mortality age decline



Decomposing the neonatal mortality age decline



Decomposing the neonatal mortality age decline

Decomposed by

APGAR score ×
Birthweight ×
Gestation at delivery ×
Birth defect ×
Birth injury ×
Plurality ×
Sex ×
Mother's resident status ×
Mother's education ×
Mother's race and origin ×
Mother's marital status ×
Mother's age ×
Alcohol or tobacco use during pregnancy

290,327 population strata / life-tables

Decomposing the neonatal mortality age decline

Decomposed by

APGAR score ×
Birthweight ×
Gestation at delivery ×
Birth defect ×
Birth injury ×
Plurality ×
Sex ×
Mother's resident status ×
Mother's education ×
Mother's race and origin ×
Mother's marital status ×
Mother's age ×
Alcohol or tobacco use during pregnancy



Changing composition along these strata explains **25 %** of the mortality Decline over the **first hour of life**.

290,327 population strata / life-tables

Conclusion

Mortality selection explains part of the mortality decline immediately after birth...

...still, most of the neonatal mortality decline over age is due to individual level effects.

My other summer project



More on this project
github.com/jschoeley/import_select

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Twitter: [@jschoeley](https://twitter.com/jschoeley)