

Selection and adaptation components of infant mortality

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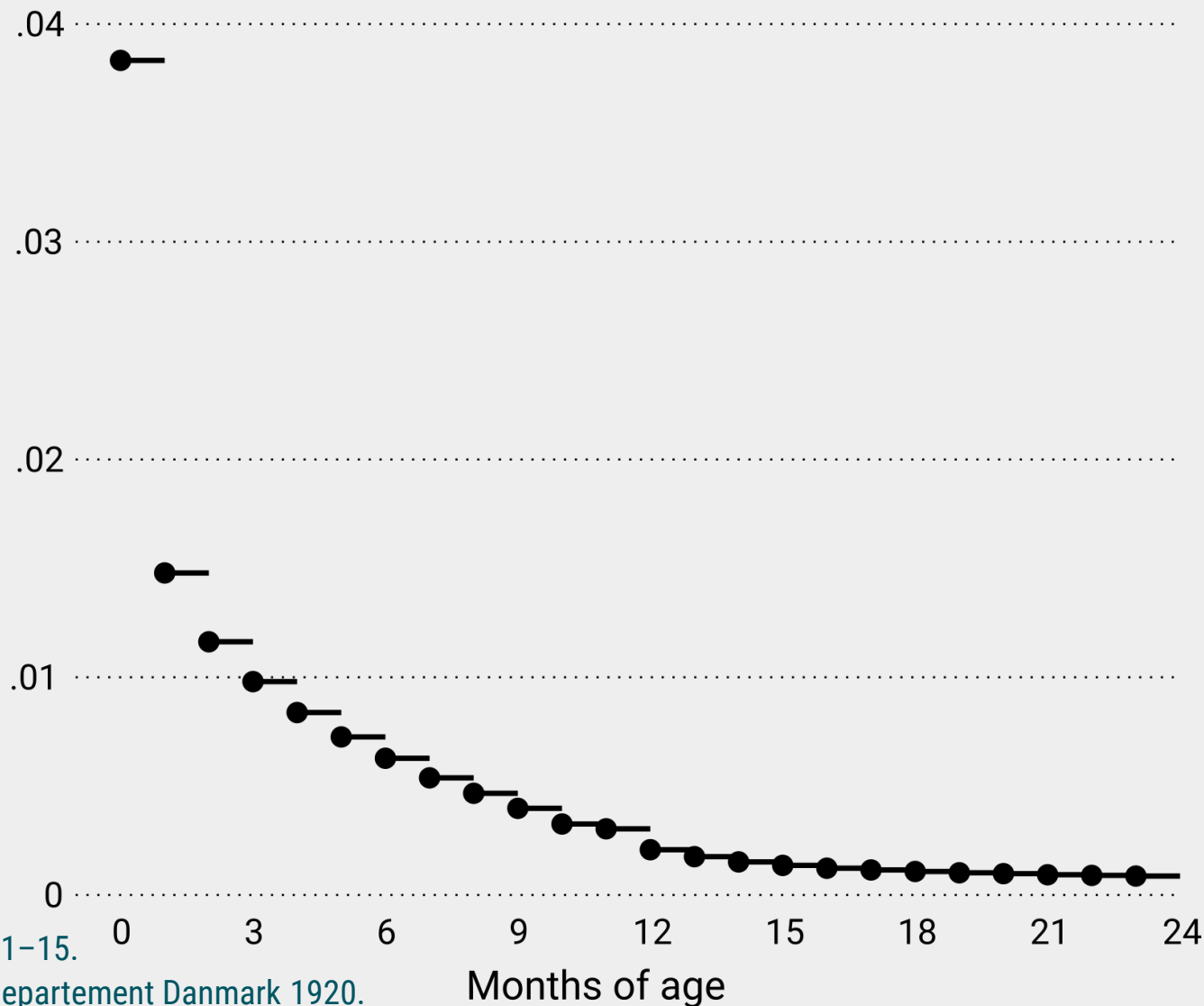
Max-Planck Odense Center on the
Biodemography of Aging



Department of Public Health
University of Southern Denmark

The age pattern of early life mortality

Probability to die
within 30 days
 ${}_1q_x$



Danish males born 1911-15.

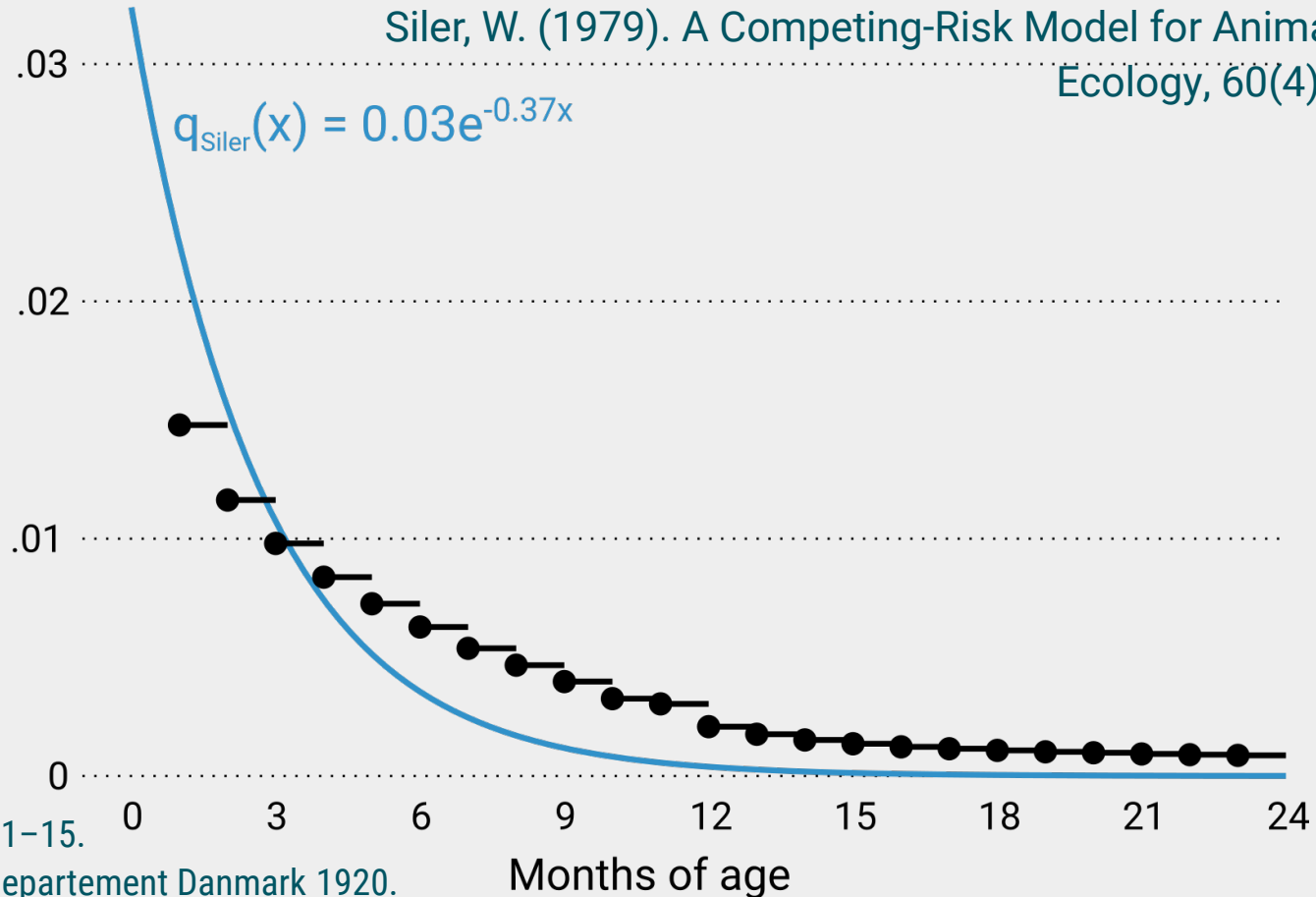
Raw data: Statistiske Departement Danmark 1920.

Mortality decline as growth and adaptation

Probability to die
within 30 days
 ${}_1q_x$

*"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."*

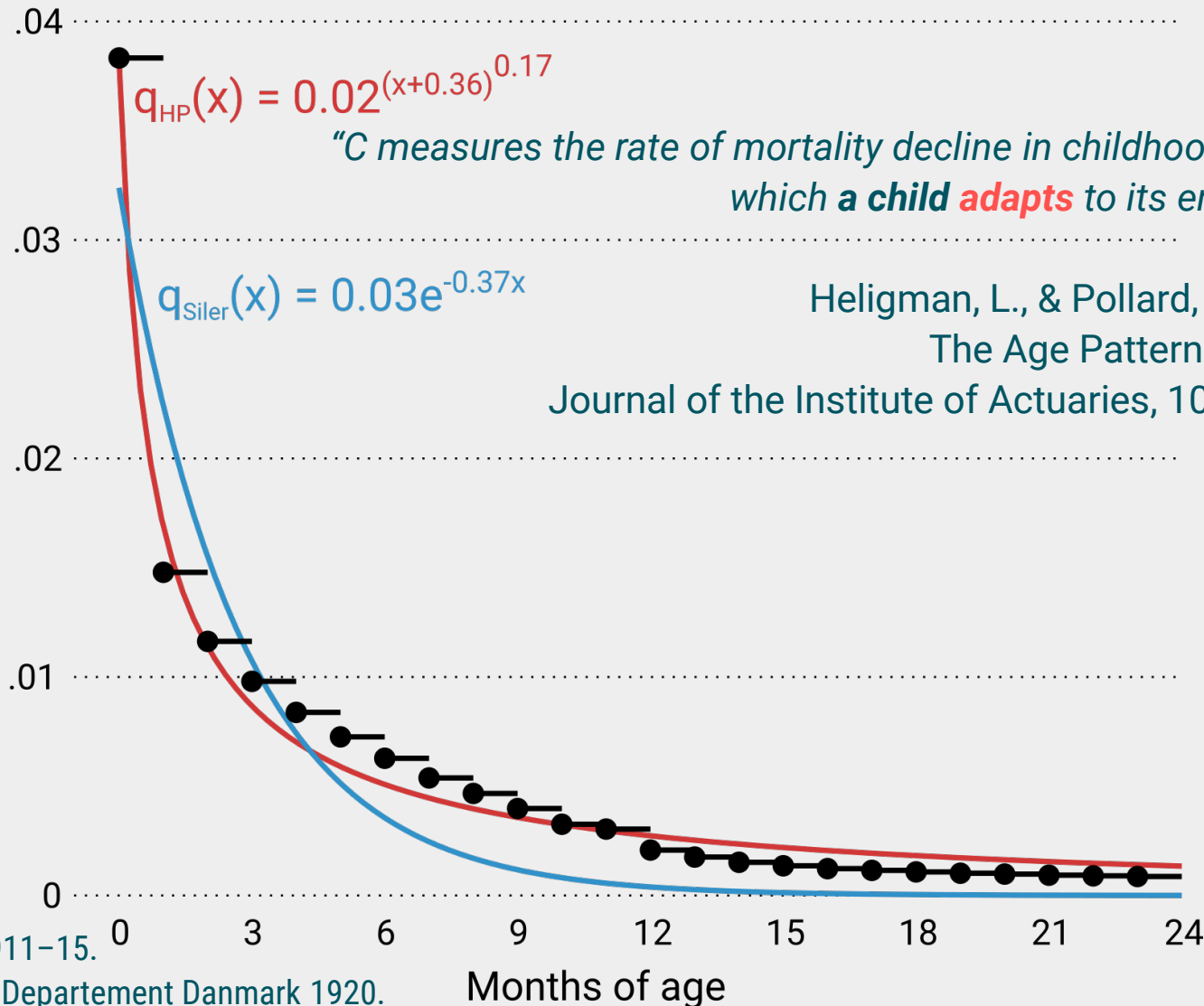
Siler, W. (1979). A Competing-Risk Model for Animal Mortality.
Ecology, 60(4), 750–757.



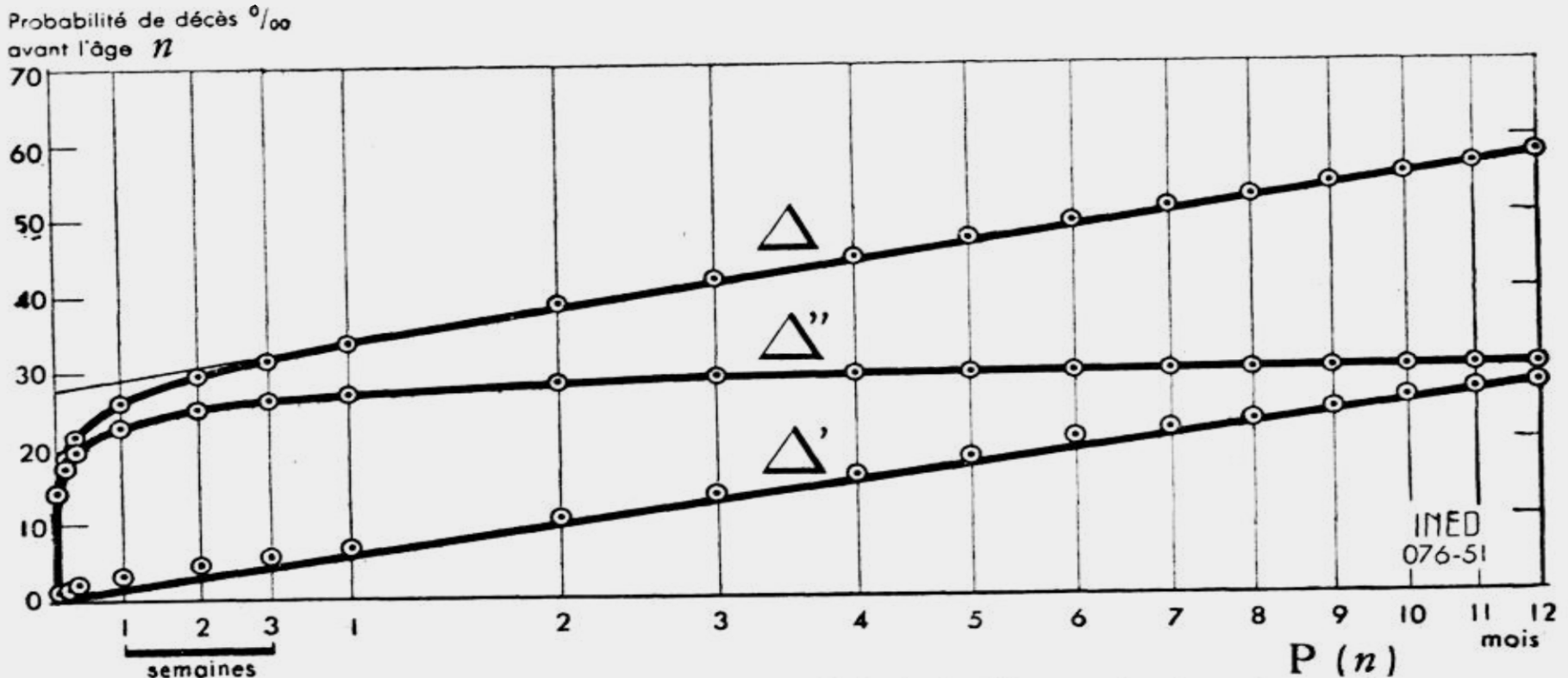
Mortality decline as growth and adaptation

Probability to die
within 30 days

${}_1q_x$



Mortality decline as mortality selection



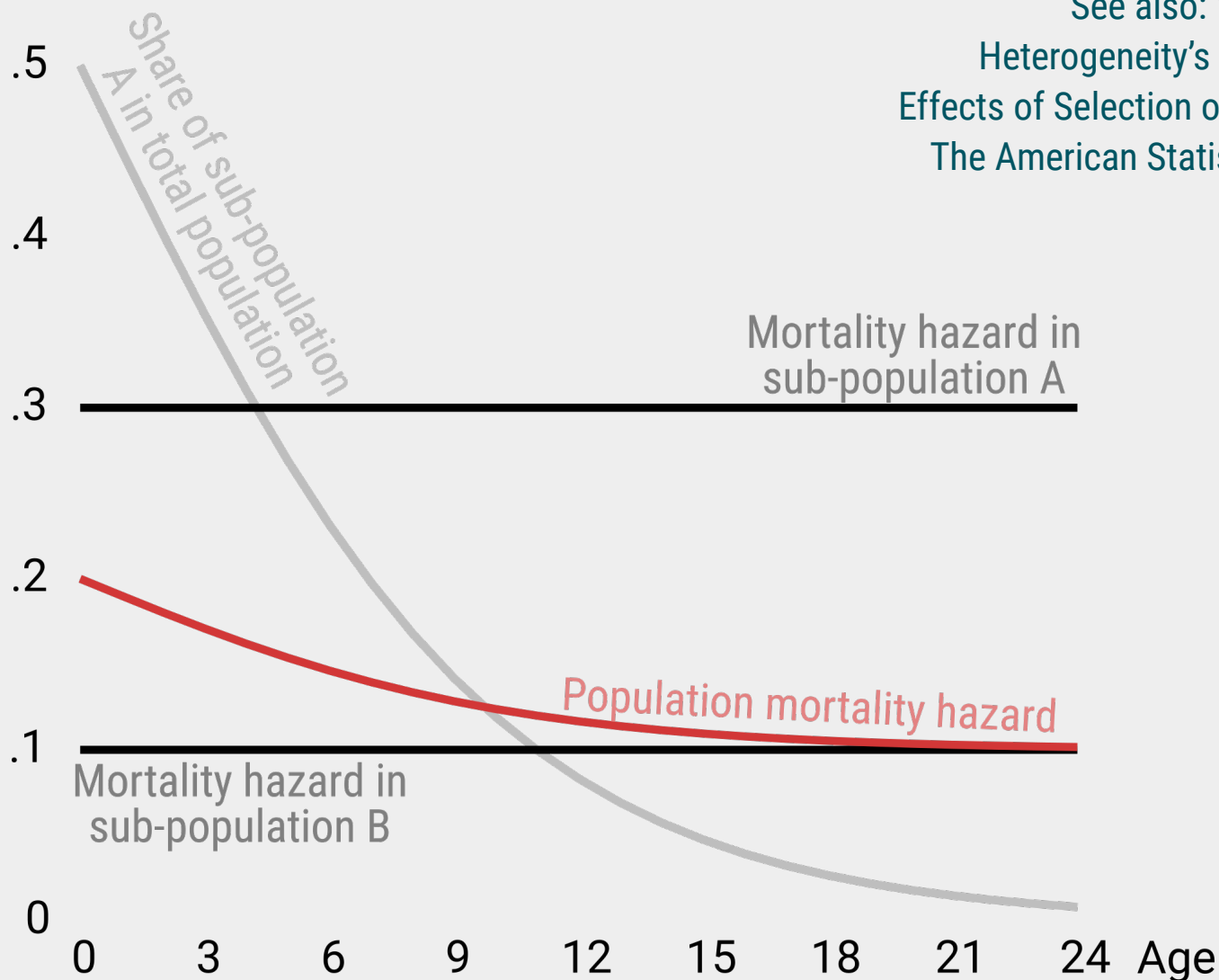
GRAPHIQUE n° 8. — Séparation des mortalités infantiles endogène et exogène.
(schéma observé aux États-Unis en 1932).

Bourgeois-Pichat, J. (1951). La mesure de la mortalité infantile.

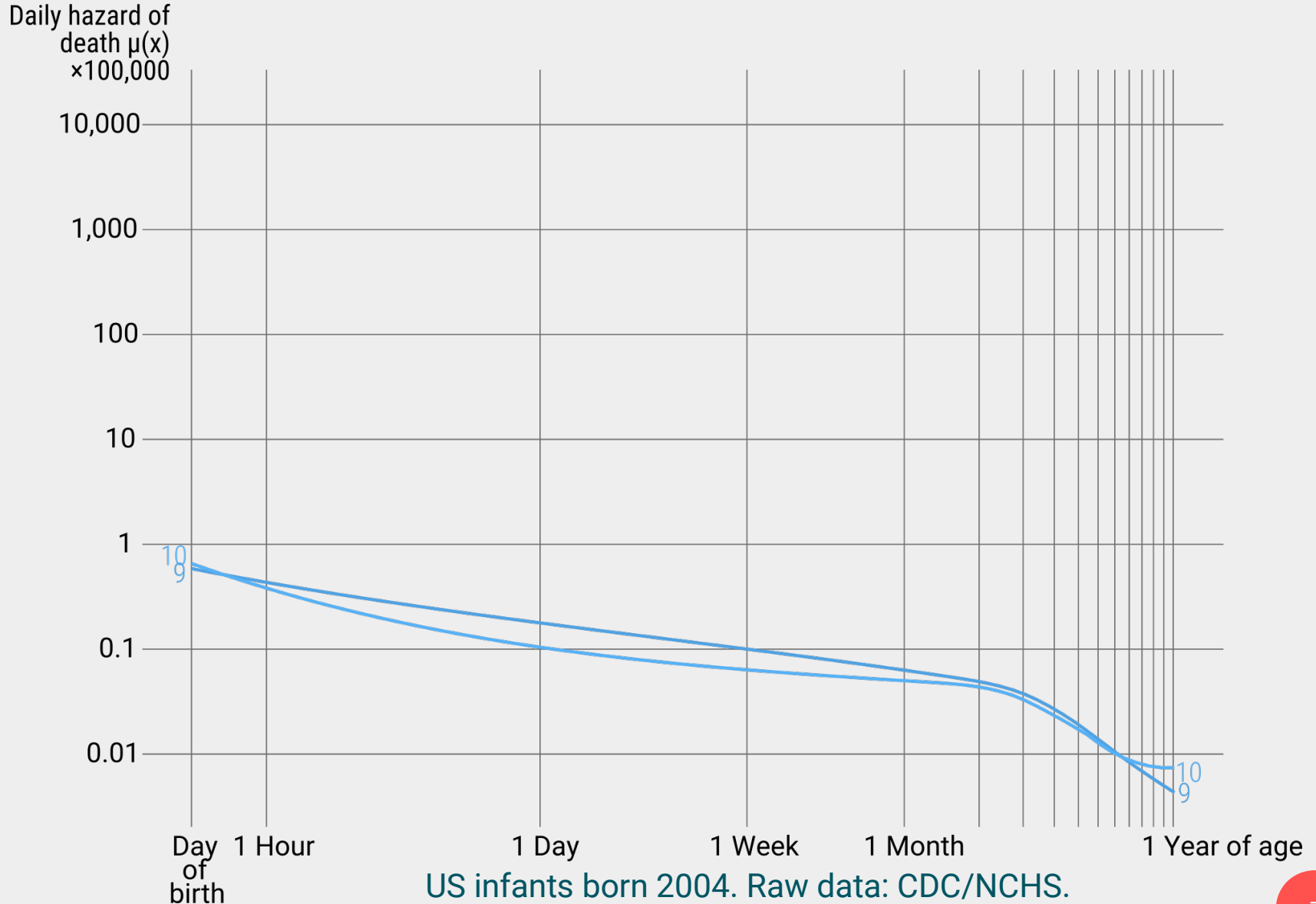
II. Les causes de décès. Population, 6(3), 459-480.

Mortality decline as mortality selection

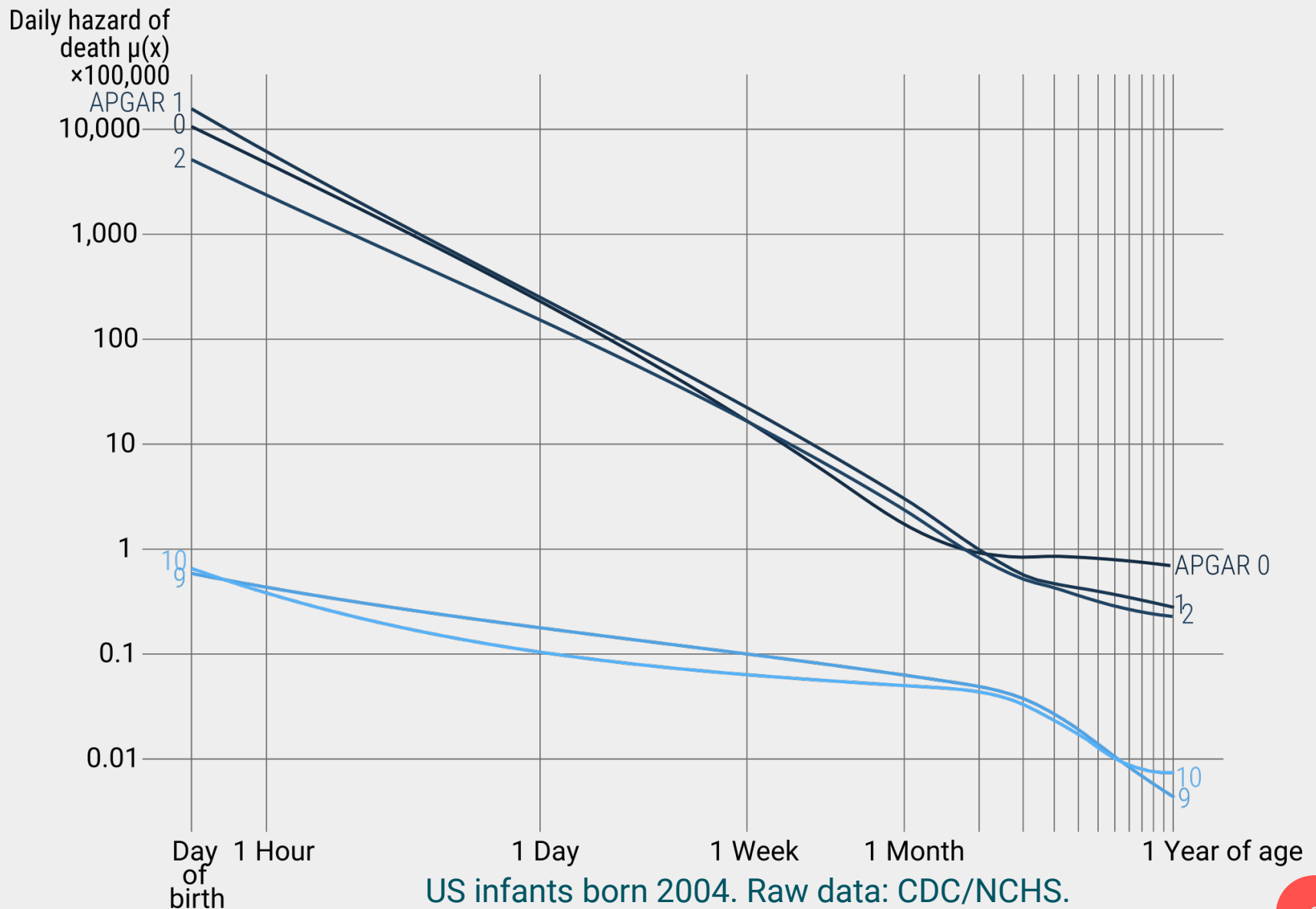
See also: Vaupel & Yashin (1985).
Heterogeneity's Ruses: Some Surprising
Effects of Selection on Population Dynamics.
The American Statistician, 39(3), 176–185.



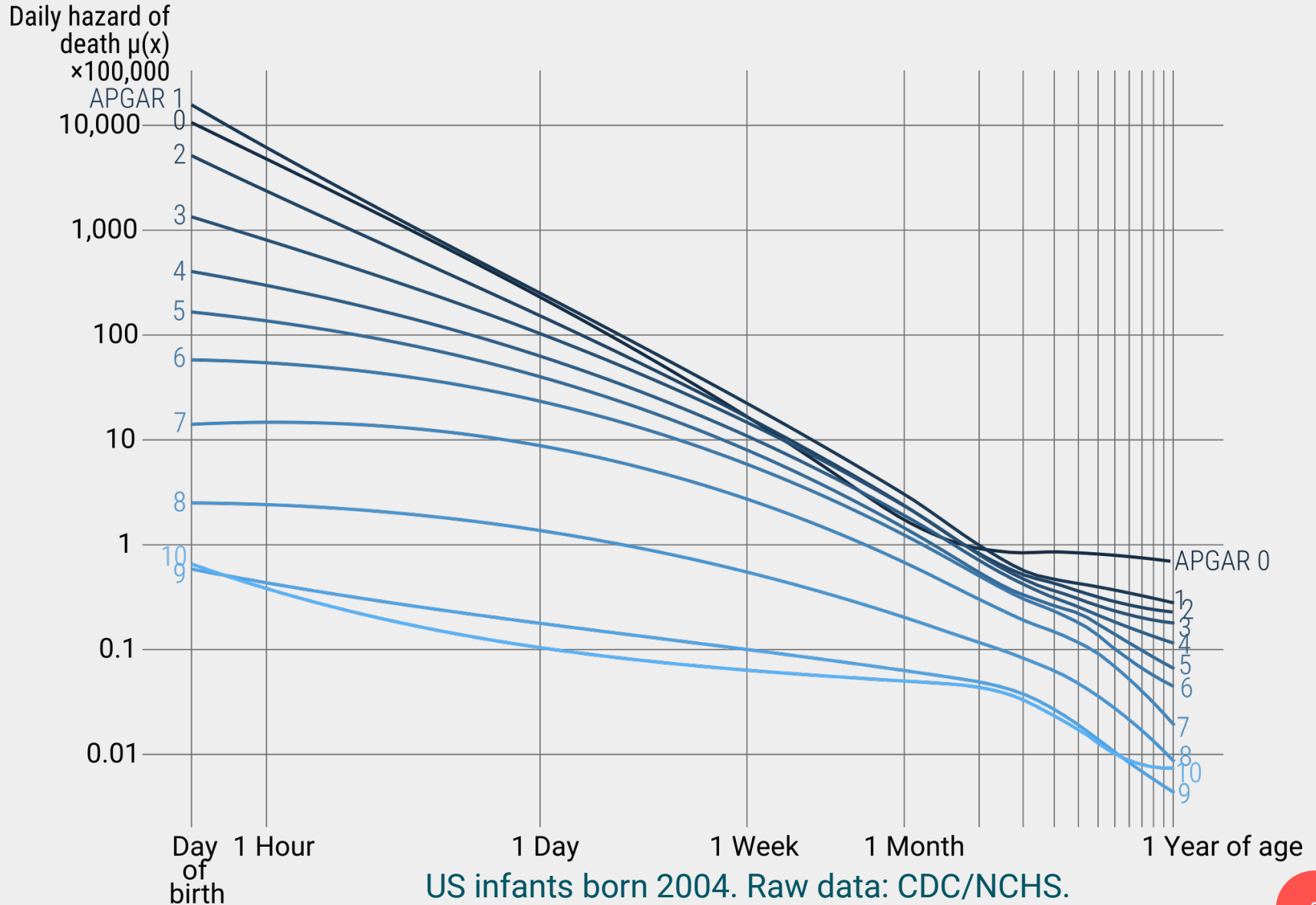
A demonstration of mortality selection



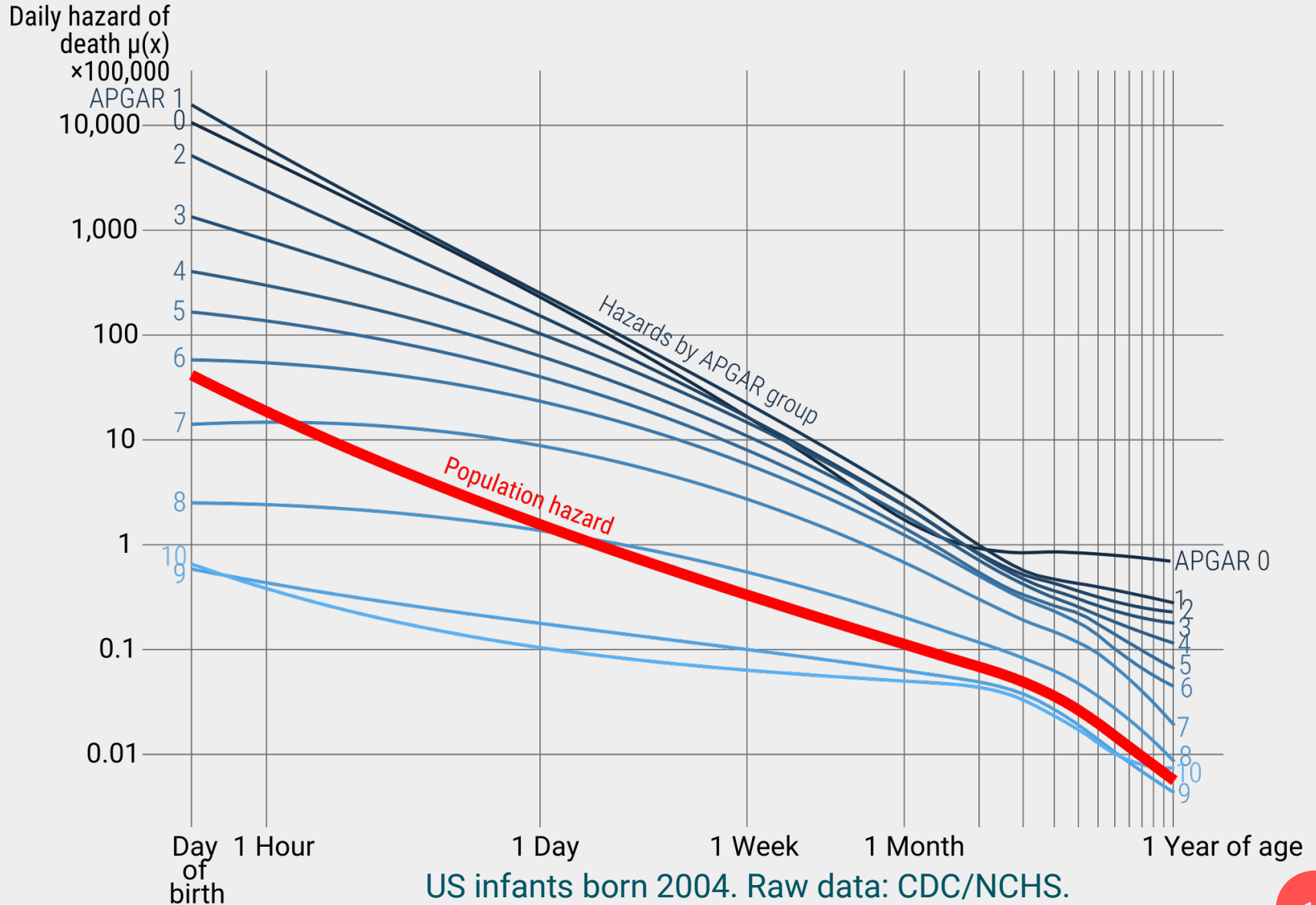
A demonstration of mortality selection



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.

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

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.

Co-variance based decomposition

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

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

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

Individual level data on births and infant deaths

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

PRINT NAME OF DECEASED For use by physician or institution		CERTIFICATE OF DEATH				STATE FILE NUMBER	
1. DECEASED'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		6. DATE OF BIRTH (Month, Day, Year)		7. BIRTHPLACE City and State or Foreign Country	
8. WAS DECEASED EVER IN U.S. ARMED FORCES? (Yes or no)		9a. PLACE OF DEATH (Check only one; see instructions on other side) <input type="checkbox"/> Hospital <input type="checkbox"/> Inpatient <input type="checkbox"/> Outpatient <input type="checkbox"/> D.O.A. <input type="checkbox"/> Other _____ <input type="checkbox"/> Nursing Home <input type="checkbox"/> Residence <input type="checkbox"/> Other (Specify)					
9b. FACILITY NAME (If not institution, give street and number)		9c. CITY, TOWN, OR LOCATION OF DEATH		9d. COUNTY OF DEATH			
10. MARITAL STATUS—Married, Never Married, Widowed, Divorced (Specify)		11. SURVIVING SPOUSE (If wife, give maiden name)		12a. DECEASED'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	
14. INSIDE CITY LIMITS? (Yes or no)		15. ZIP CODE		16. WAS DECEASED OF HISPANIC ORIGIN? (Specify No or Yes—if yes, specify Cuban, Mexican, Puerto Rican, etc.) <input type="checkbox"/> No <input type="checkbox"/> Yes Specify:		17. RACE—American Indian, Black, White, etc. (Specify) 18. DECEASED'S EDUCATION (Specify only highest grade completed) Elementary/Secondary ED-12 College (1-4 or >+)	
19. FATHER'S NAME (First,Middle,Last)		20. MOTHER'S NAME (First,Middle,Maiden Surname)					
21. INFORMANT'S NAME (Type/Print)		22. MAILING ADDRESS (Street and Number or Rural Route Number, City or Town, State, Zip Code)					
23a. METHOD OF DISPOSITION <input type="checkbox"/> Burial <input type="checkbox"/> Cremation <input type="checkbox"/> Removal from State <input type="checkbox"/> Donation <input type="checkbox"/> Other (Specify)		23b. PLACE OF DISPOSITION (Name of cemetery, crematory, or other place)		23c. LOCATION—City or Town, State			
24. SIGNATURE OF FUNERAL SERVICE LICENSEE OR PERSON ACTING AS SUCH		25. LICENSE NUMBER (if licensed)		26. NAME AND ADDRESS OF FACILITY			
27a. Complete items 27a-c only when certifying physician is not available at time of death to certify cause of death.		27b. To the best of my knowledge, death occurred at the time, date, and place stated. Signature and Title ▶		27c. LICENSE NUMBER		27d. DATE SIGNED (Month,Day,Year)	
28. TIME OF DEATH		29. DATE PRONOUNCED DEAD (Month,Day,Year)		30. WAS CASE REFERRED TO MEDICAL EXAMINER/CORONER? (Yes or no)		Approximate Interval Between Onset and Death	
29. PART I. Enter the disease, 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) Sequentially list conditions, if any, leading to immediate cause. Enter UNDERLYING CAUSE Disease or injury that initiated events resulting in death LAST		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. _____					
PART II. Other significant conditions contributing to death but not resulting in the underlying cause given in Part I.		31a. Was AN AUTOPSY PERFORMED? (Yes or no)		31b. WERE AUTOPSY FINDINGS AVAILABLE PRIOR TO COMPLETION OF CAUSE OF DEATH? (Yes or no)			
32. MANNER OF DEATH <input type="checkbox"/> Natural <input type="checkbox"/> Pending Investigation <input type="checkbox"/> Accident <input type="checkbox"/> Could not be Determined <input type="checkbox"/> Suicide <input type="checkbox"/> Homicide		33a. DATE OF BLUJRY (Month,Day,Year)		33b. TIME OF BLUJRY		33c. BLUJRY AT WORK? (Yes or no)	
		33d. PLACE OF BLUJRY—At home, farm, store, factory, office building, etc. Specify		33e. LOCATION (Street and Number or Rural Route Number, City or Town, State)		33f. DESCRIBE HOW BLUJRY OCCURRED	
34. CERTIFIER (Check only one) <input type="checkbox"/> CERTIFYING PHYSICIAN (Physician certifying cause of death when another physician has pronounced death and completed item 27) To the best of my knowledge, death occurred due to the cause(s) and manner as stated. <input type="checkbox"/> PRONOUNCING AND CERTIFYING PHYSICIAN (Physician both pronouncing death and certifying 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. <input type="checkbox"/> 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.		35. SIGNATURE AND TITLE OF CERTIFIER		35. LICENSE NUMBER		35. DATE SIGNED (Month,Day,Year)	
36. NAME AND ADDRESS OF PERSON WHO COMPLETED CAUSE OF DEATH ITEM 27 (Type/Print)		37. REGISTRAR'S SIGNATURE					
		38. 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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Analysis pipeline

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1. Raw data
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Analysis pipeline

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3760921	1986	11483525199483525199999	11410845001221088991278914451101301345209644411
3760922	1986	11483525199483525199999	1138864580122109991012799123351013212516021130330311
3760923	1986	11483525199483525199999	1141084580122107991012689101121618131121450186664411
3760924	1986	11483525199483525199999	1141084580122107991012689101121618131121450186664411
3760925	1986	11483525199481272799999	1132966453612210557073228812327999999900061300110111
3760926	1986	11483525199483525199999	1140674536122109990013010424591419912178043130330311
3760927	1986	11483525199483525199999	1140674536122109990013010424591419912178043130330311
3760928	1986	11483525199483525199999	1140674536122109990013010424591419912178043130330311
3760929	1986	11483525199483525199999	11140845361221099910178912310

```
# 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

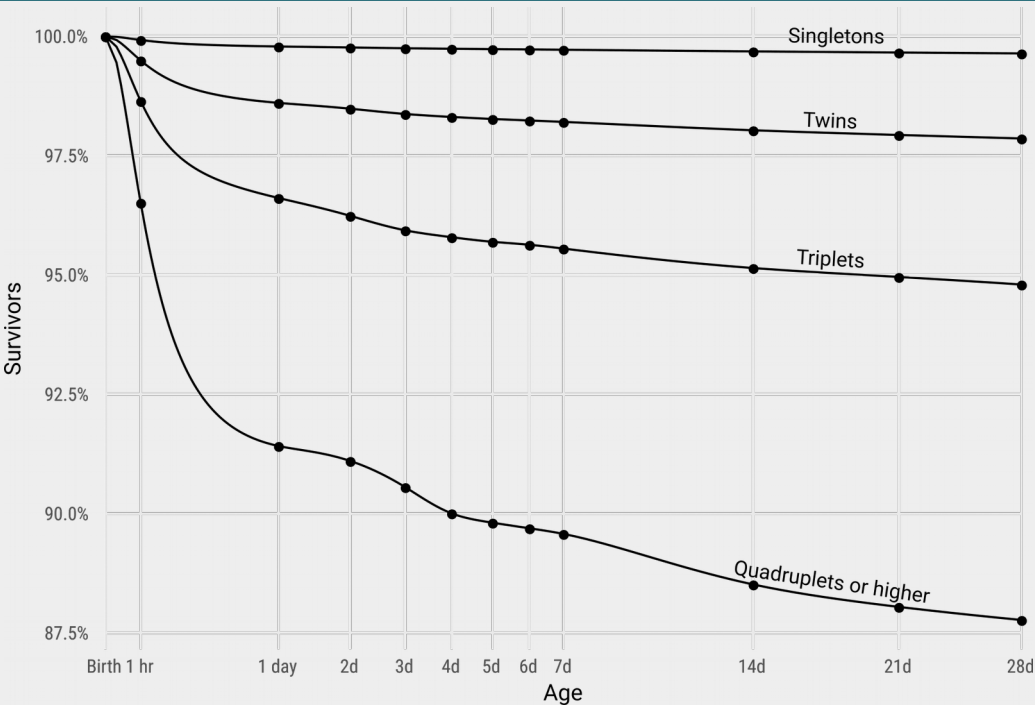
1 row = 1 birth

```
# A tibble: 48 x 8
  plurality x      nx      Nx      nEx      nDx      nCx      lx
  <fctr> <dbl> <dbl>      <dbl>      <dbl> <dbl> <dbl>      <dbl>
1 Single 0      1 24286661 24277179 18964 0 1.00000000
2 Single 1      23 24267697 557776841 33060 0 0.9992192
3 Single 24     24 24234637 581570016 5106 0 0.9978579
4 Single 48     24 24229531 581462280 3872 0 0.9976477
5 Single 72     24 24225659 581384904 2576 0 0.9974883
6 Single 96     24 24223083 581330496 1958 0 0.9973822
7 Single 120    24 24221125 581287452 1629 0 0.9973016
8 Single 144    24 24219496 581249520 1532 0 0.9972345
9 Single 168    168 24217964 4067862420 8439 0 0.9971714
10 Single 336    168 24209525 4066702104 5646 0 0.9968239
# ... with 38 more rows
```

3. Neonatal life-tables

first 28 days of life cut in 12 intervals, *stratified*

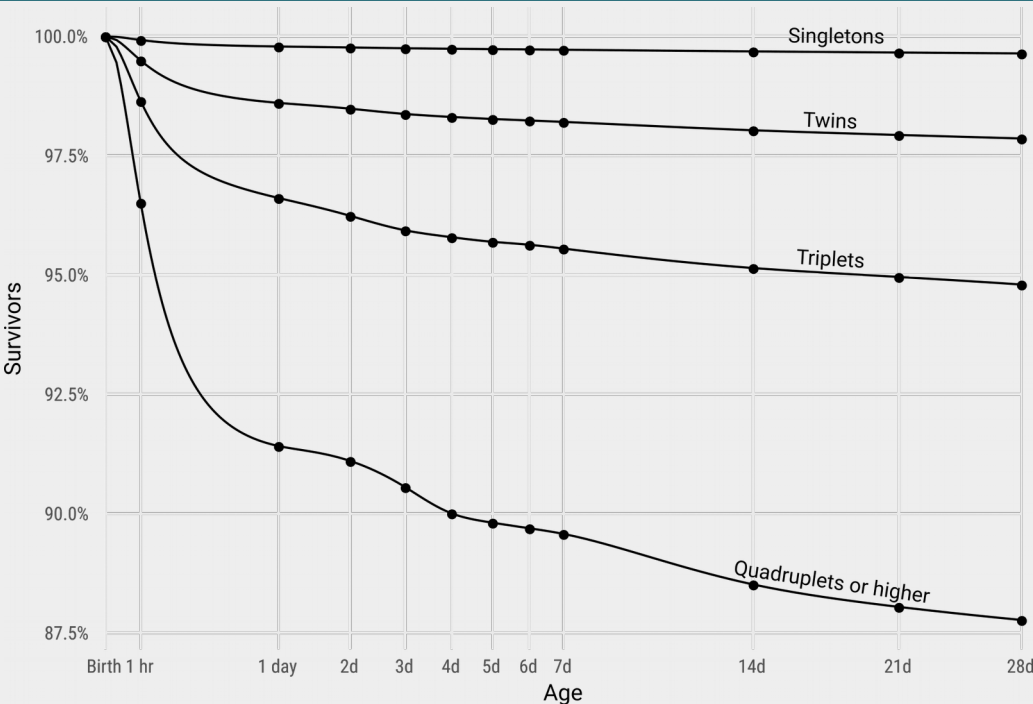
Analysis pipeline



4. Spline interpolation of life-tables

Hyman filtered cubic splines, *stratified*

Analysis pipeline



4. Spline interpolation of life-tables

Hyman filtered cubic splines, *stratified*



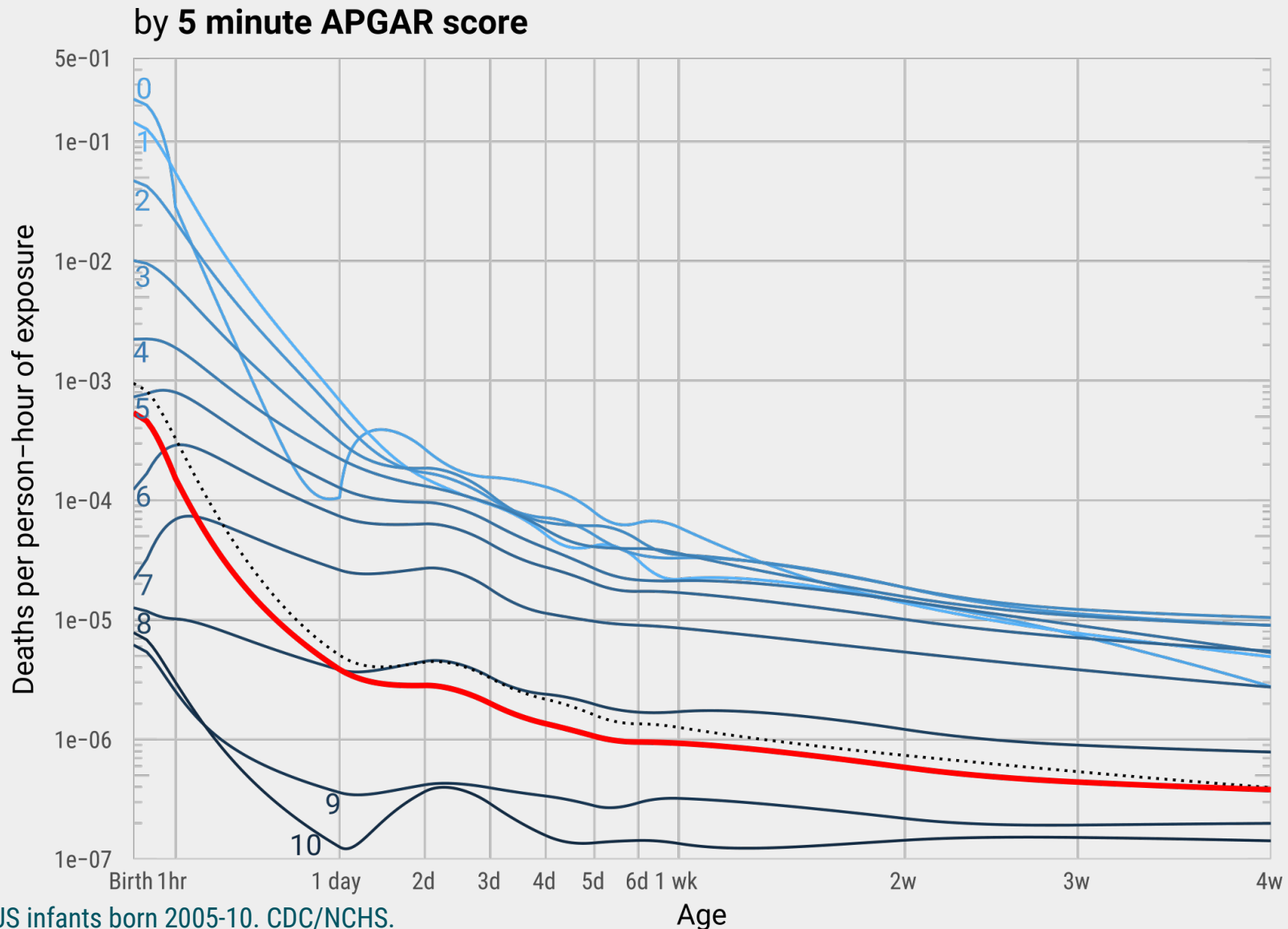
5. Vaupel-Zhang decomposition

results integrated for ease of interpretation

A tibble: 11 x 7

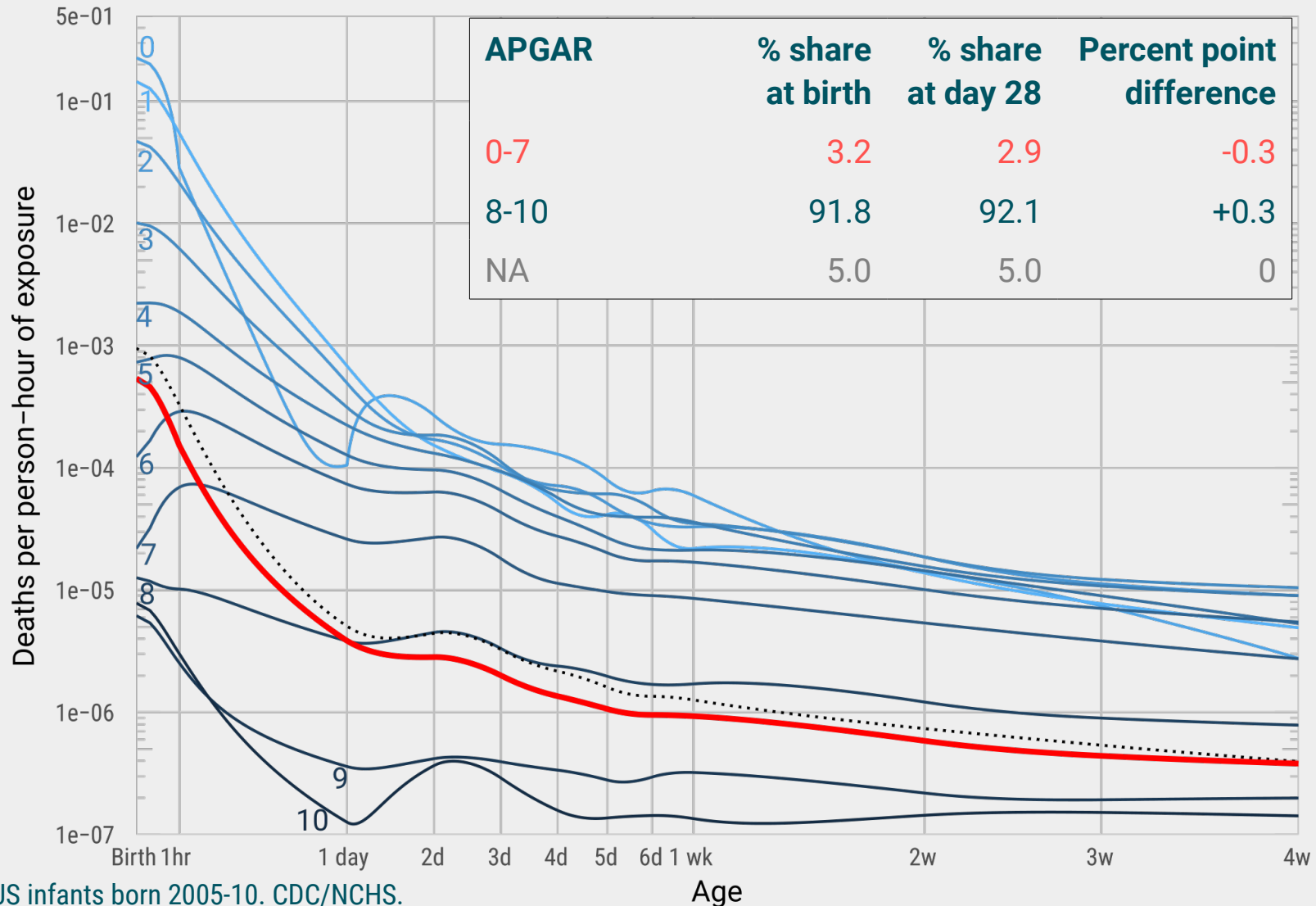
	x	nx	diff_mux	diff_direct	p_direct	diff_compos	p_compos
	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
1	0	1	-3.372577e-04	-3.371456e-04	0.9996677	-1.120566e-07	3.322581e-04
2	1	23	-1.872115e-04	-1.871751e-04	0.9998055	-3.641661e-08	1.945213e-04
3	24	24	-1.458869e-06	-1.458637e-06	0.9998411	-2.318351e-10	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

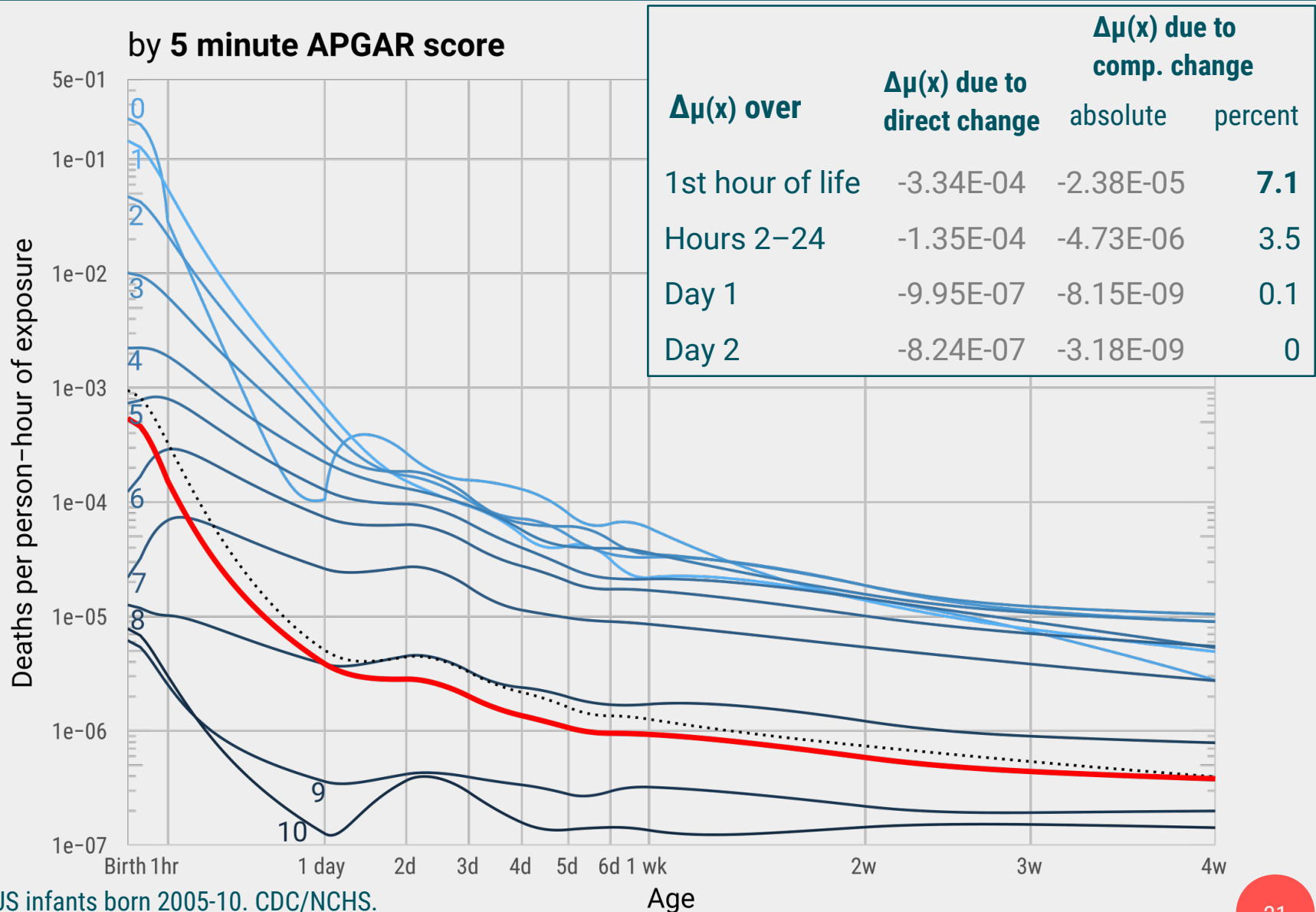


Decomposing the neonatal mortality age decline

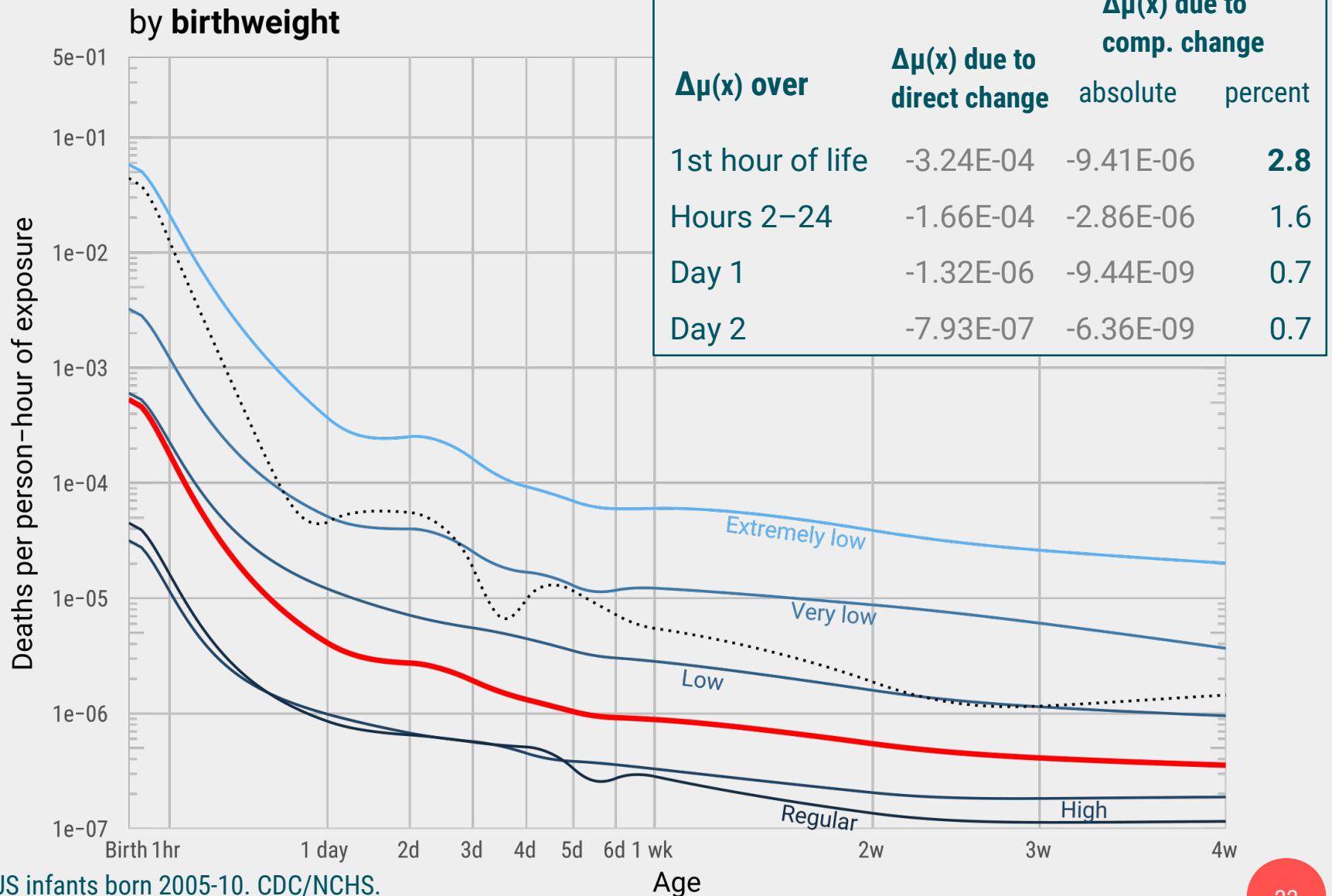
by 5 minute APGAR score



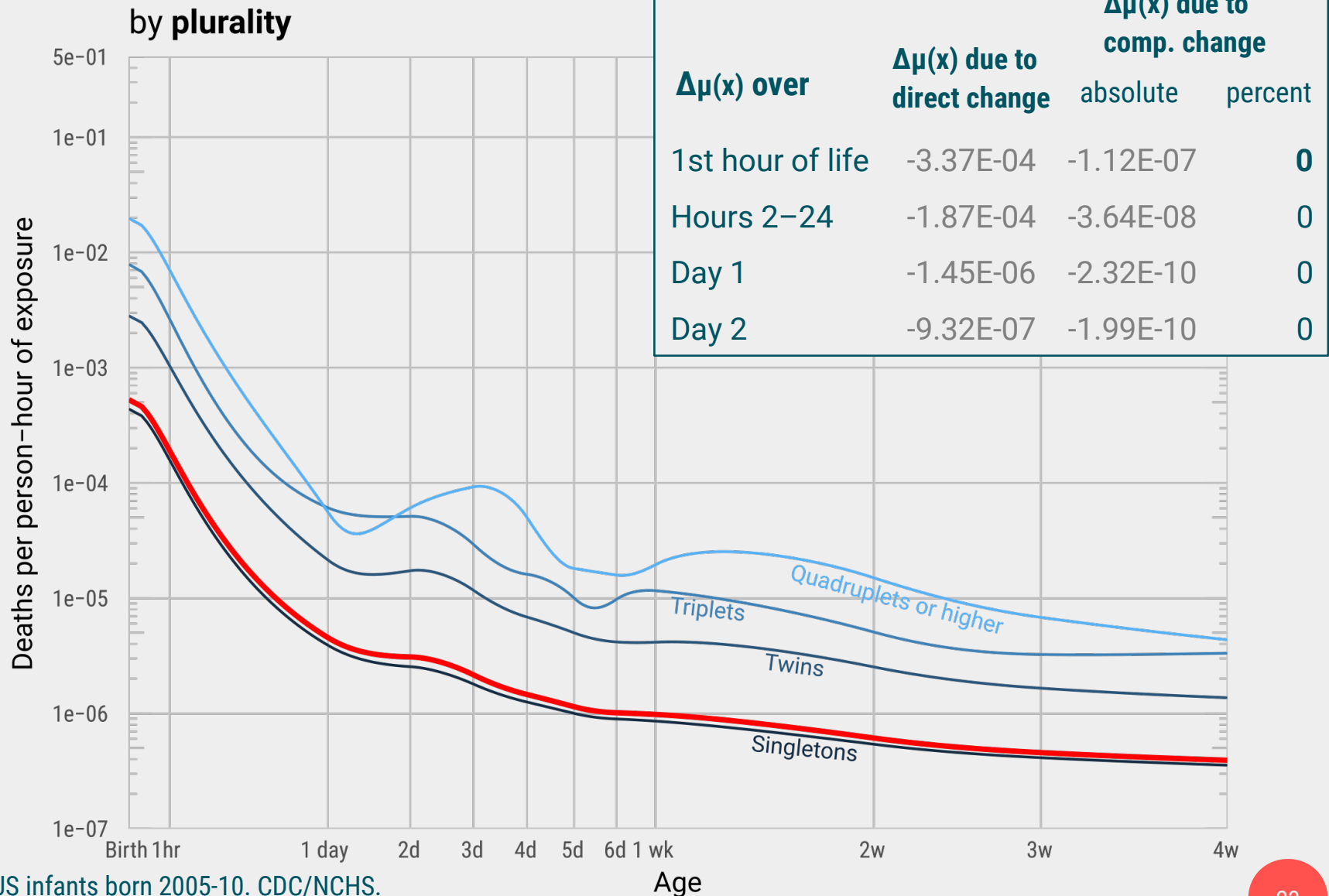
Decomposing the neonatal mortality age decline



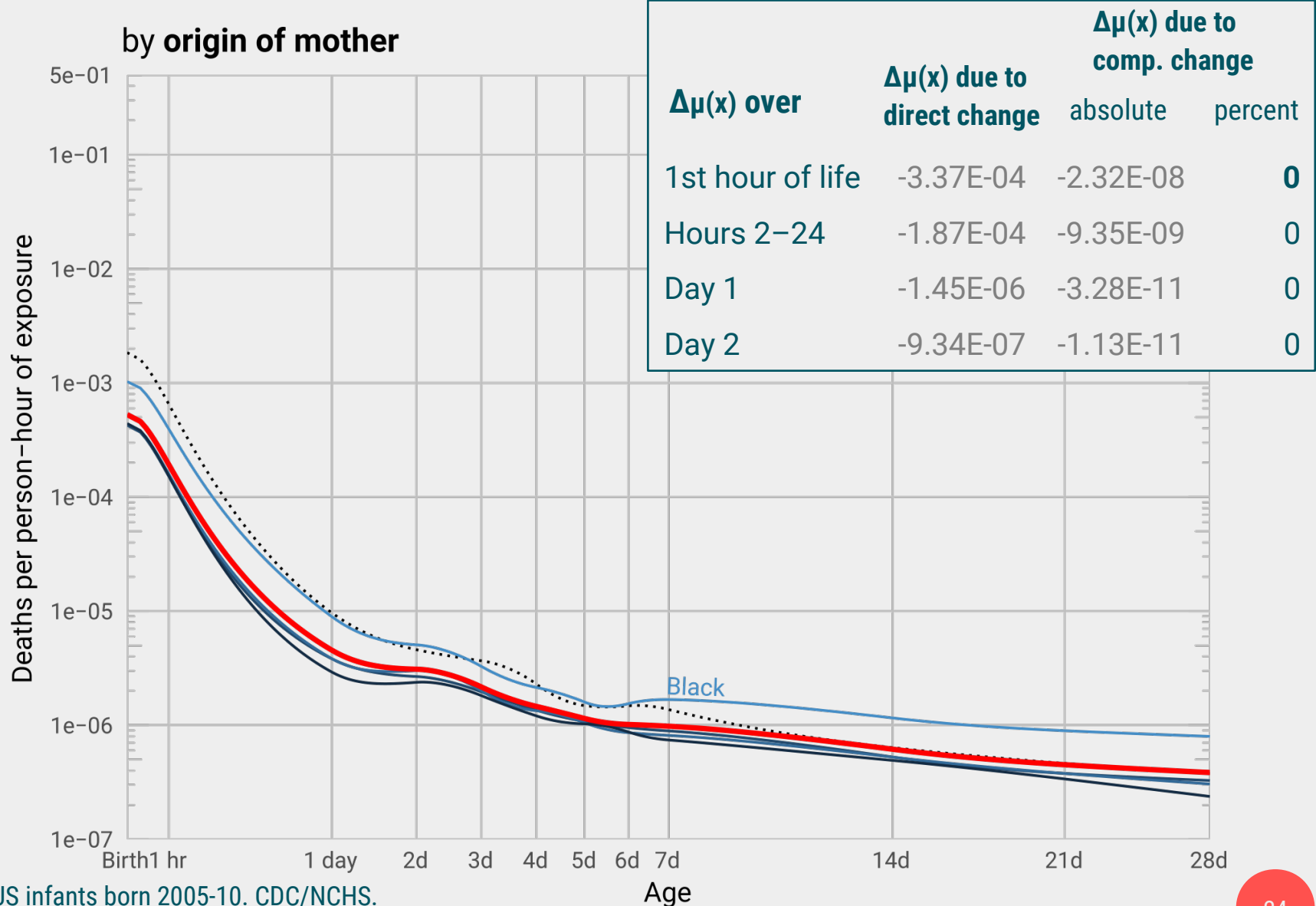
Decomposing the neonatal mortality age decline



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

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.

More on this project
github.com/jschoeley/imort_select

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