Heterogeneous frailties and **mortality selection** during the **first month of life**

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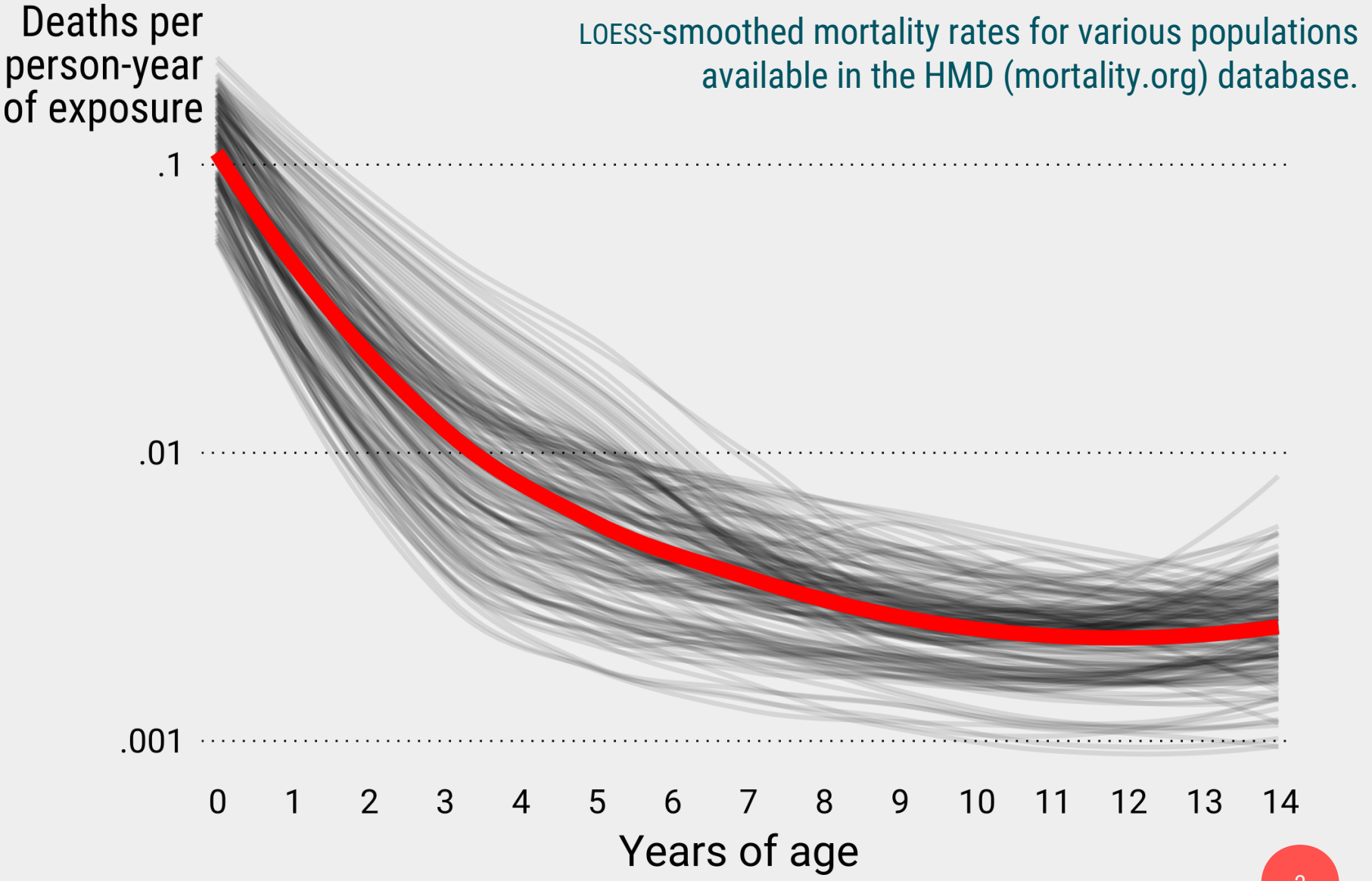
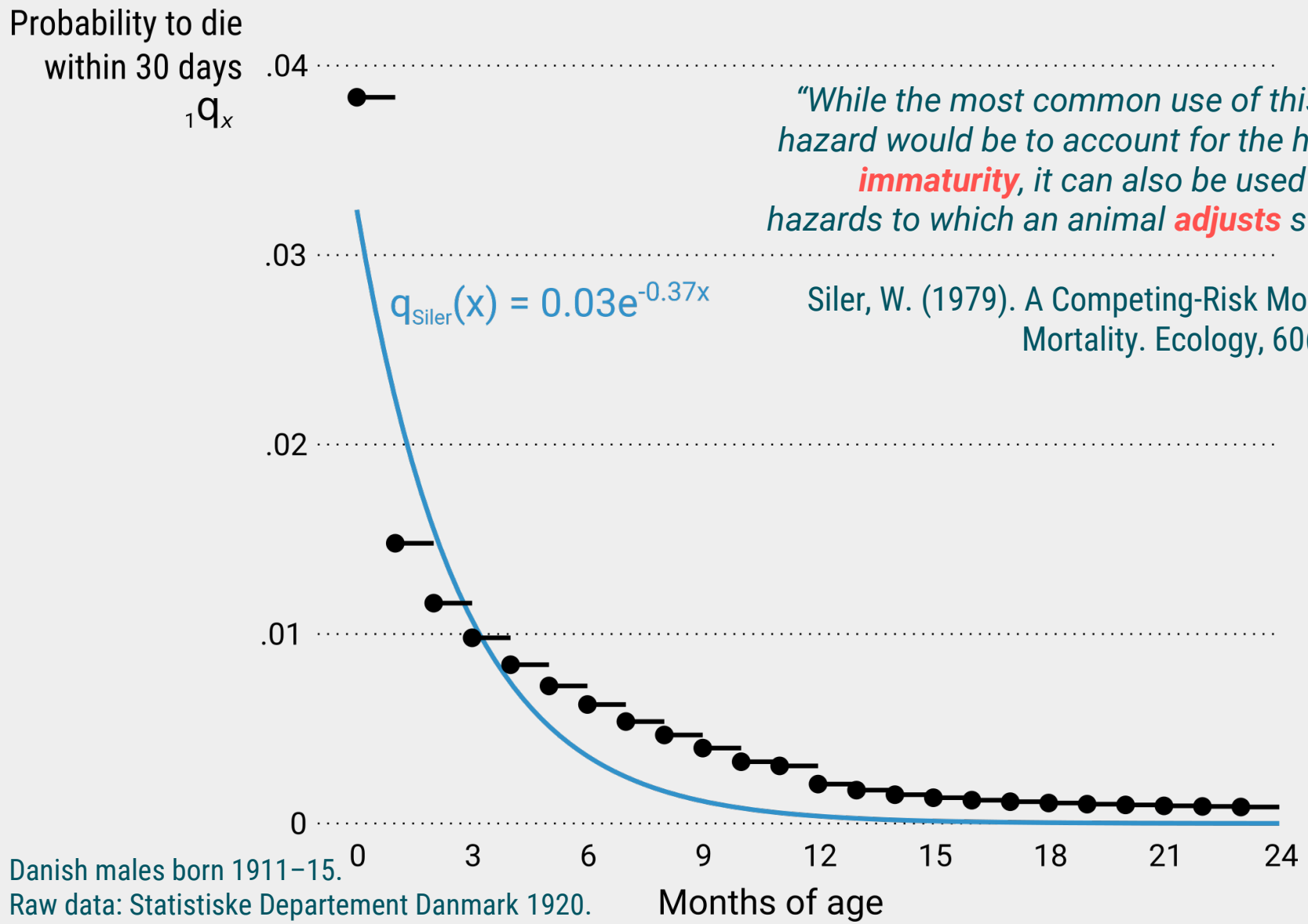
The age pattern of early life mortality



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

Mortality decline as growth and adaptation

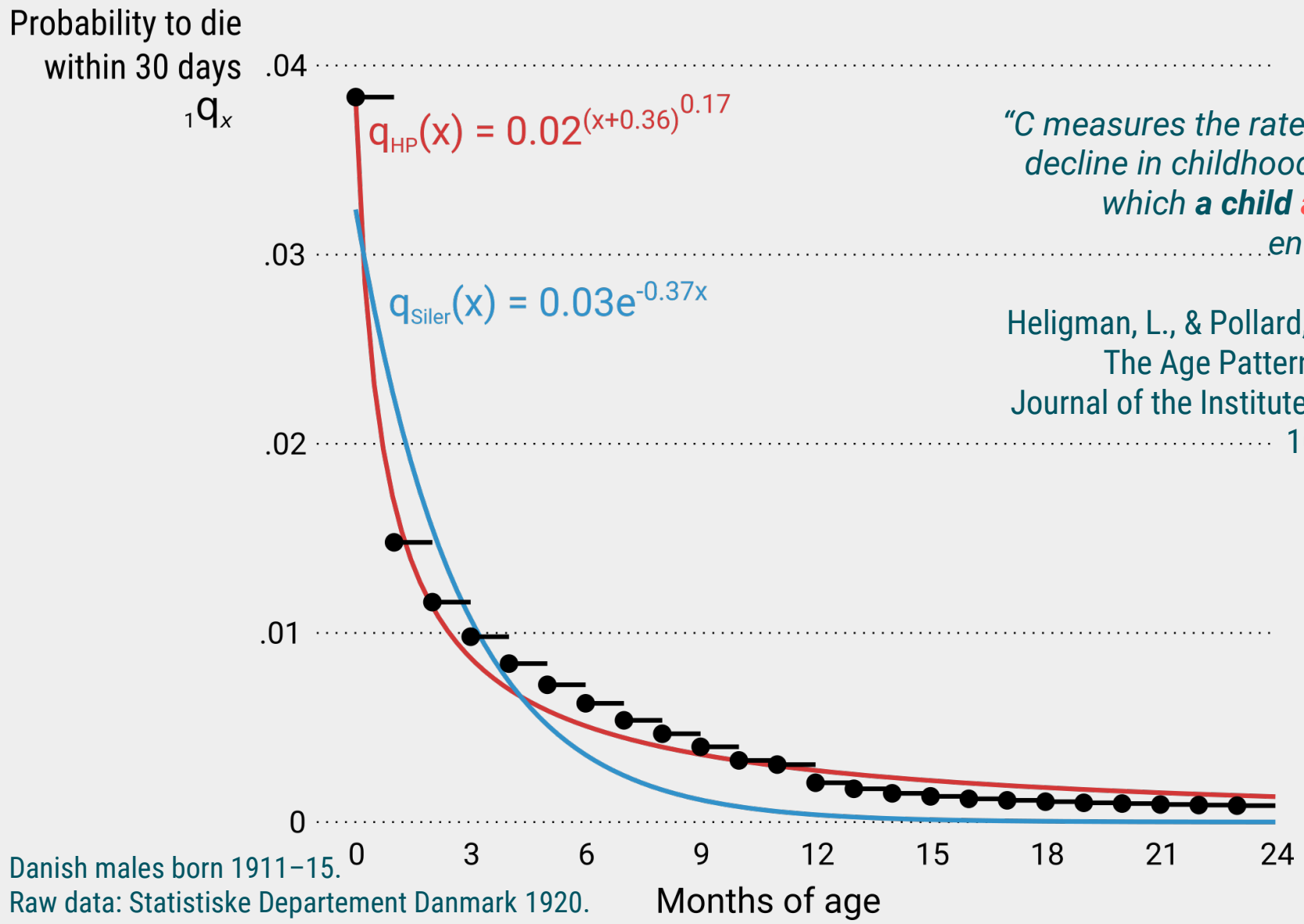


*"While the most common use of this decreasing hazard would be to account for the hazard due to **immaturity**, it can also be used [...] for other hazards to which an animal **adjusts** successfully."*

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

Danish males born 1911–15.
Raw data: Statistiske Departement Danmark 1920.

Mortality decline as growth and adaptation

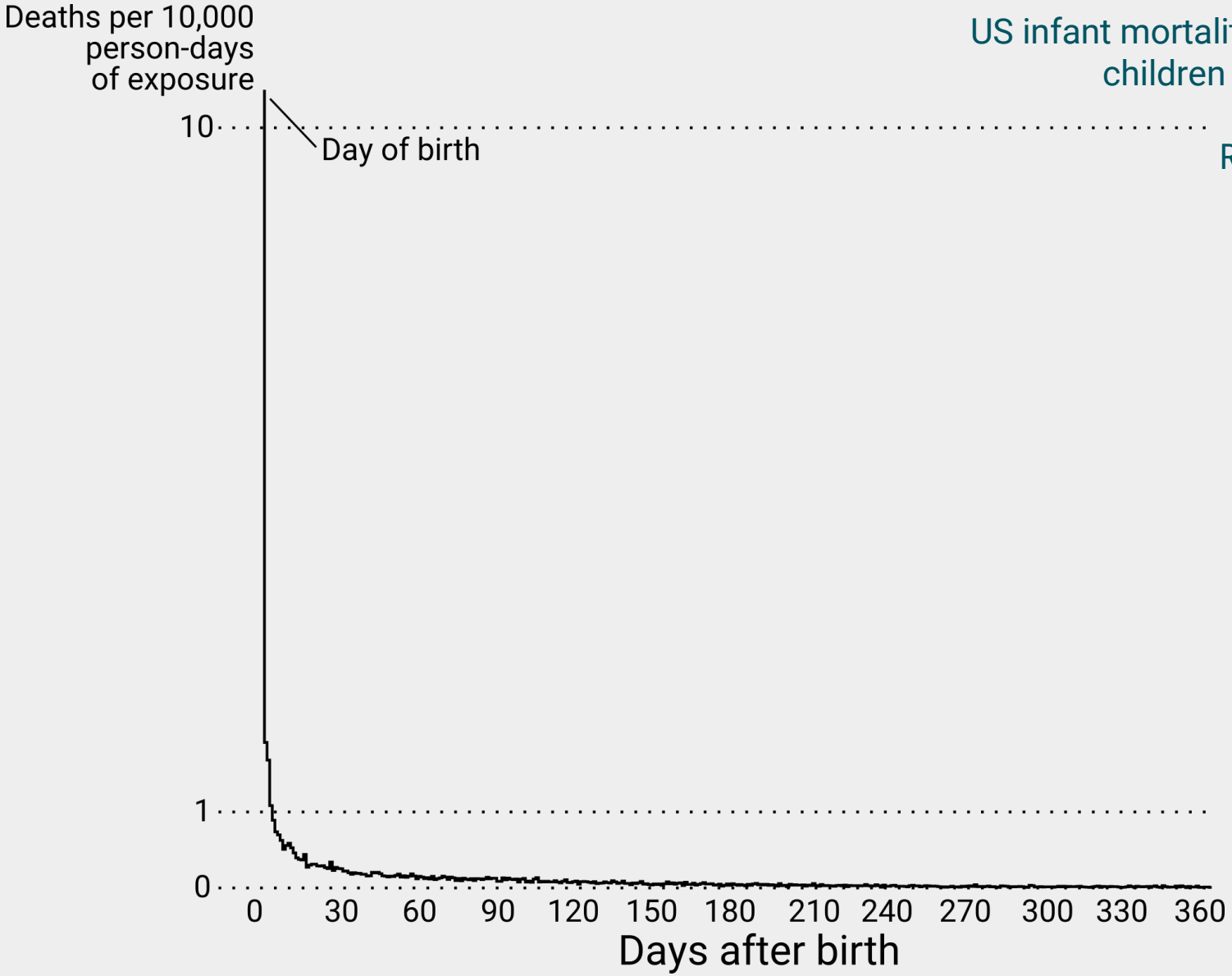


*"C measures the rate of mortality decline in childhood (the rate at which **a child** **adapts** to its environment)."*

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.

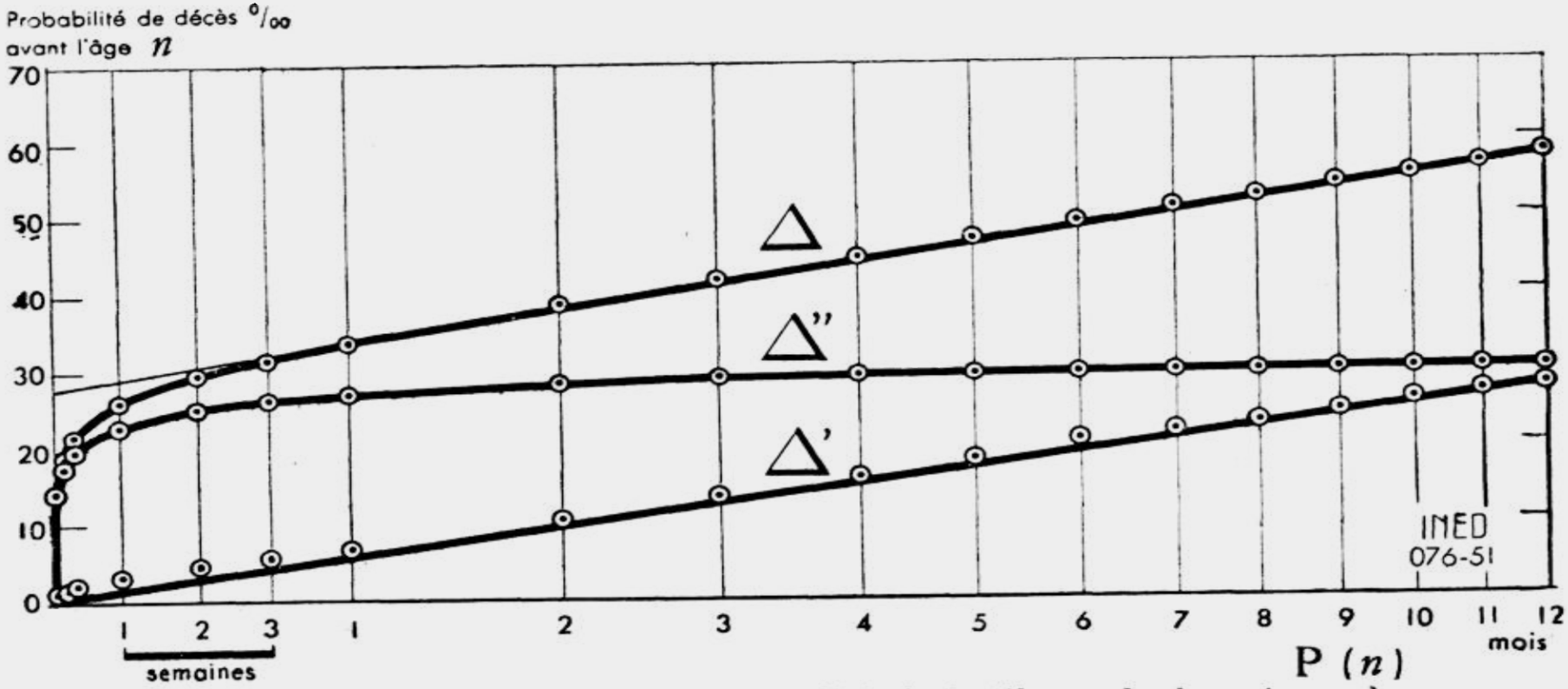
Mortality decline as mortality selection



US infant mortality by day of age for children conceived in 2009.

Raw data: CDC/NCHS.

Mortality decline as mortality selection

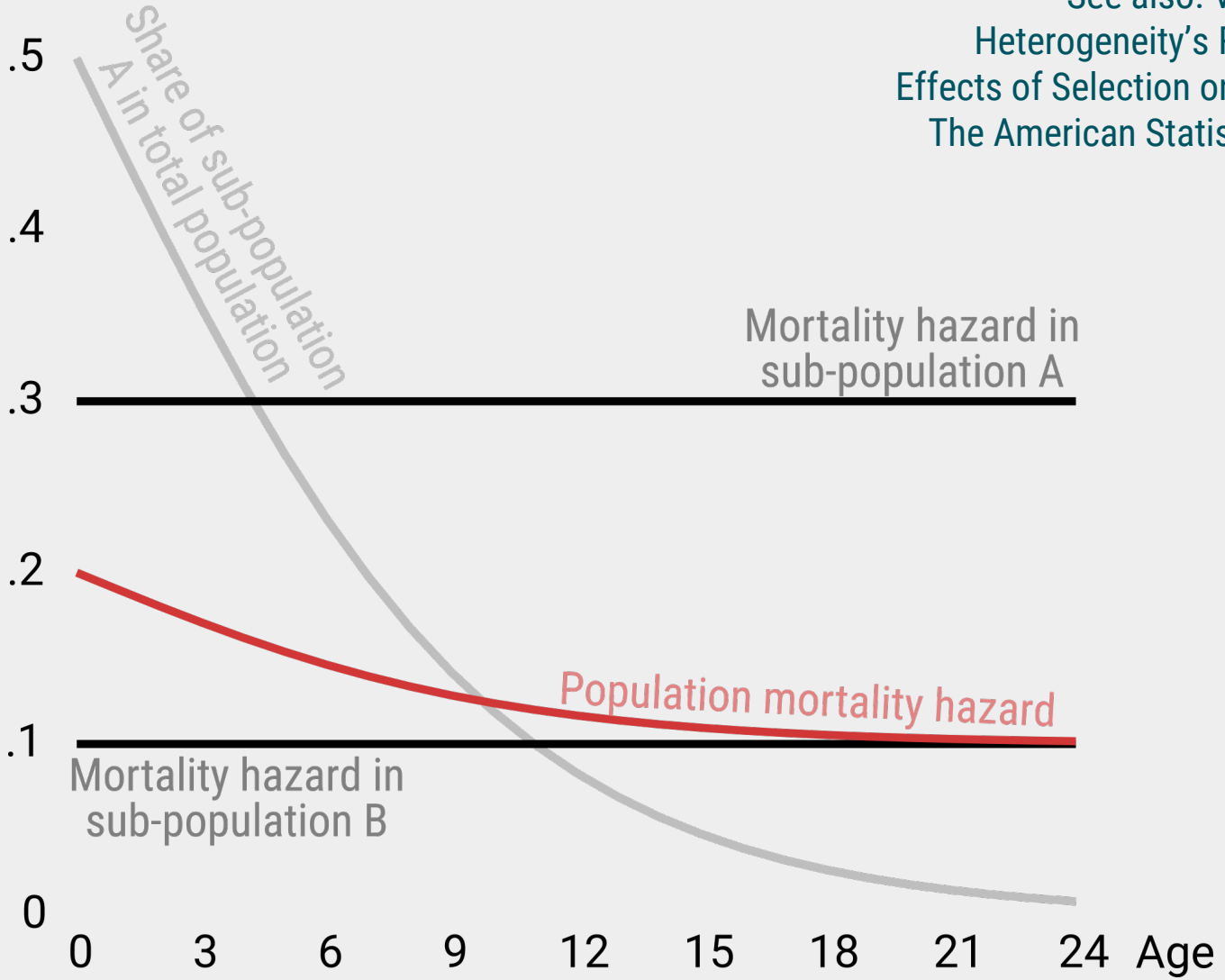


Graphique nº 8. — Séparation des mortalités infantiles endogène et exogène. (schéma observé aux Etats-Unis en 1932).

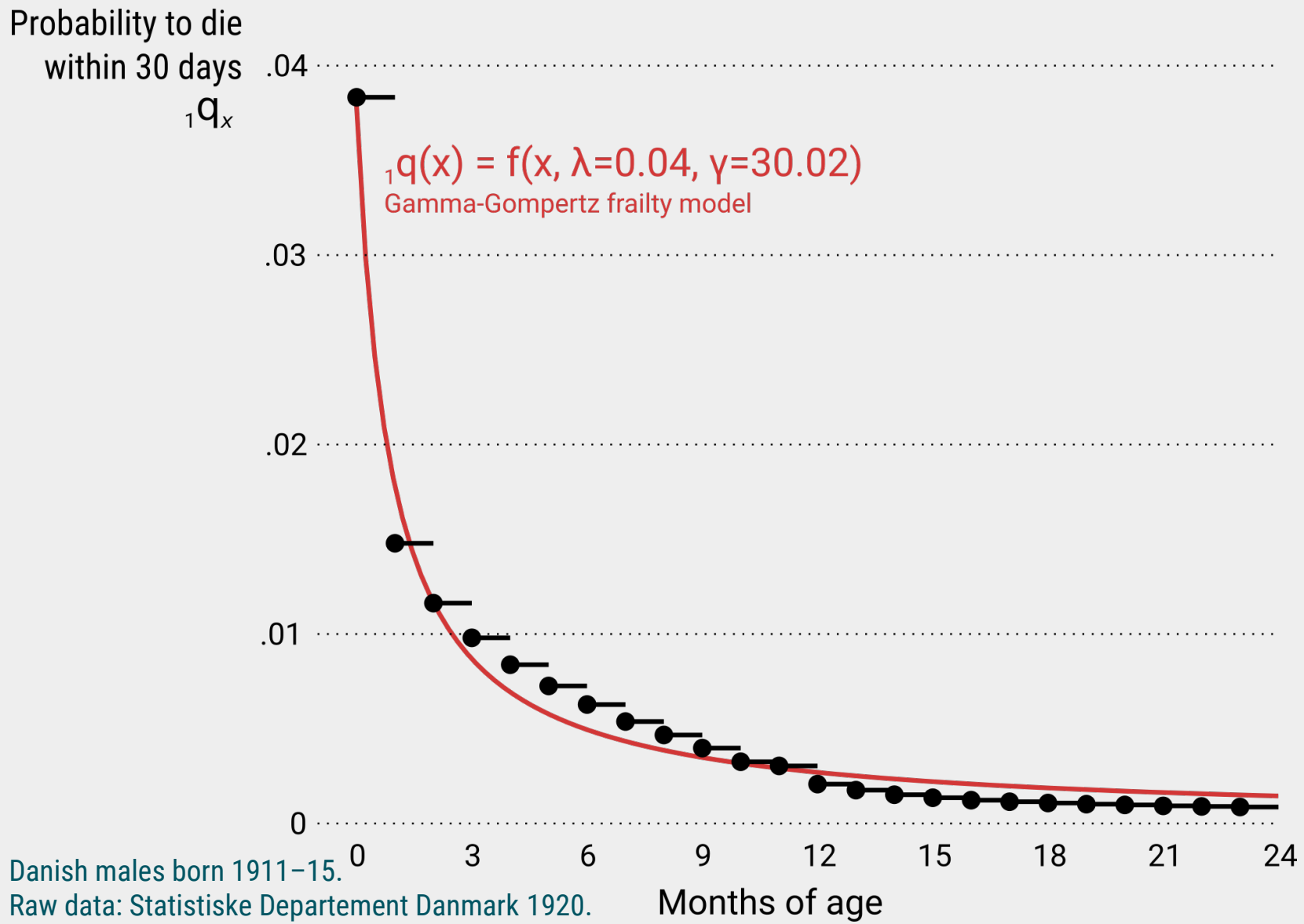
Bourgeois-Pichat, J. (1951). La mesure de la mortalité infantile. II. Les causes de décès. Population, 6(3), 459–480.

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.

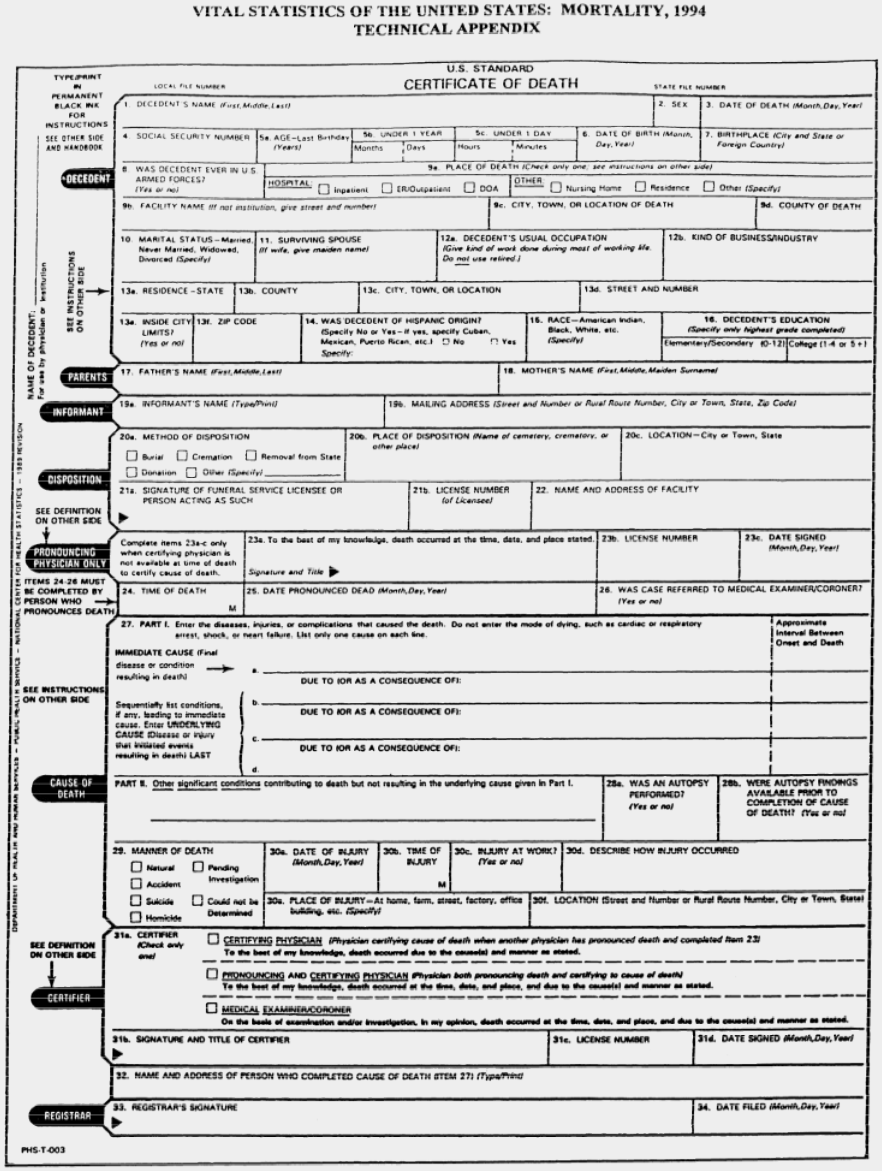


Mortality decline as mortality selection



Danish males born 1911–15.
Raw data: Statistiske Departement Danmark 1920.

Overcoming guesswork by using individual level data

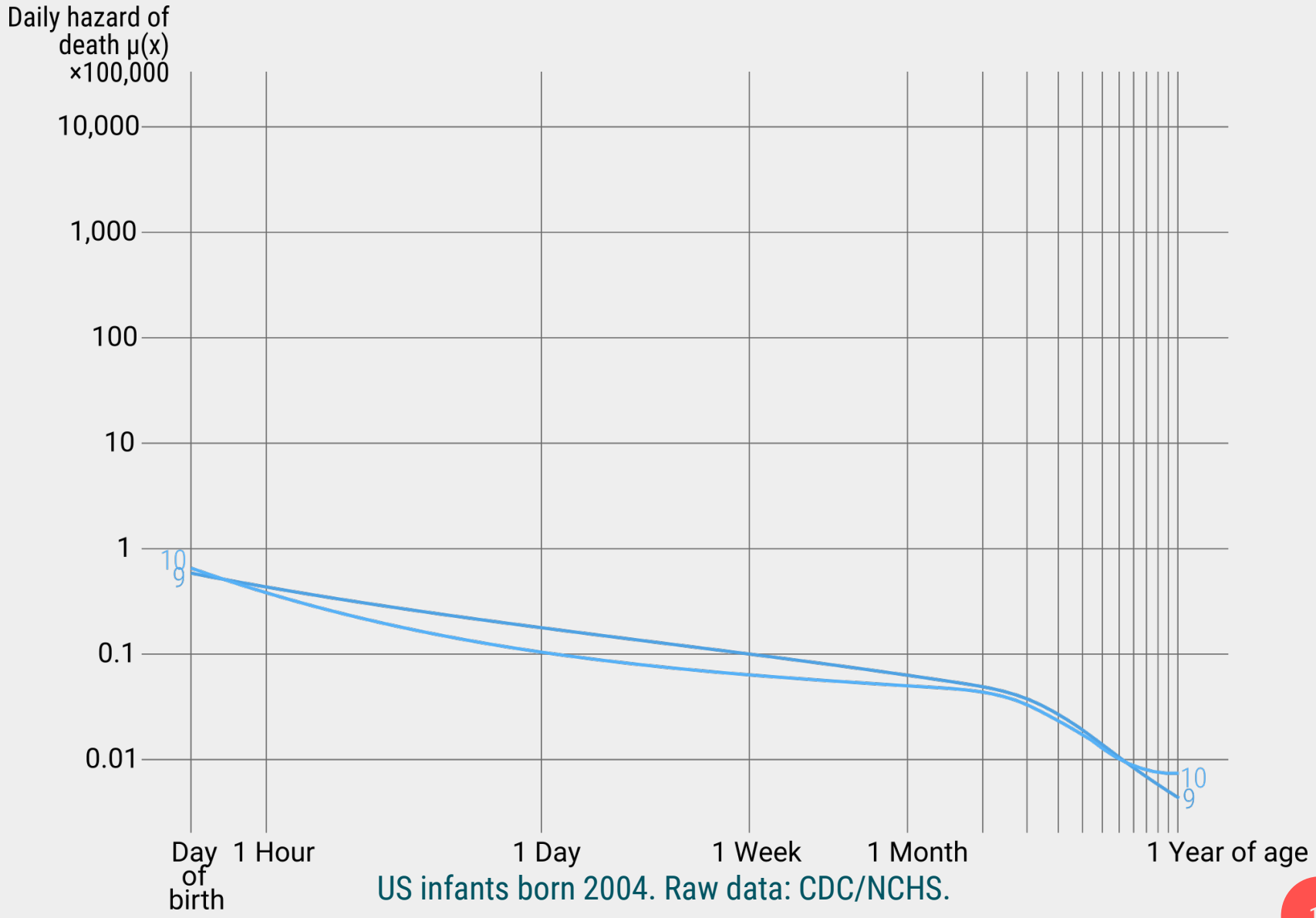


VITAL STATISTICS OF THE UNITED STATES: MORTALITY, 1994
TECHNICAL APPENDIX

U.S. STANDARD
CERTIFICATE OF DEATH

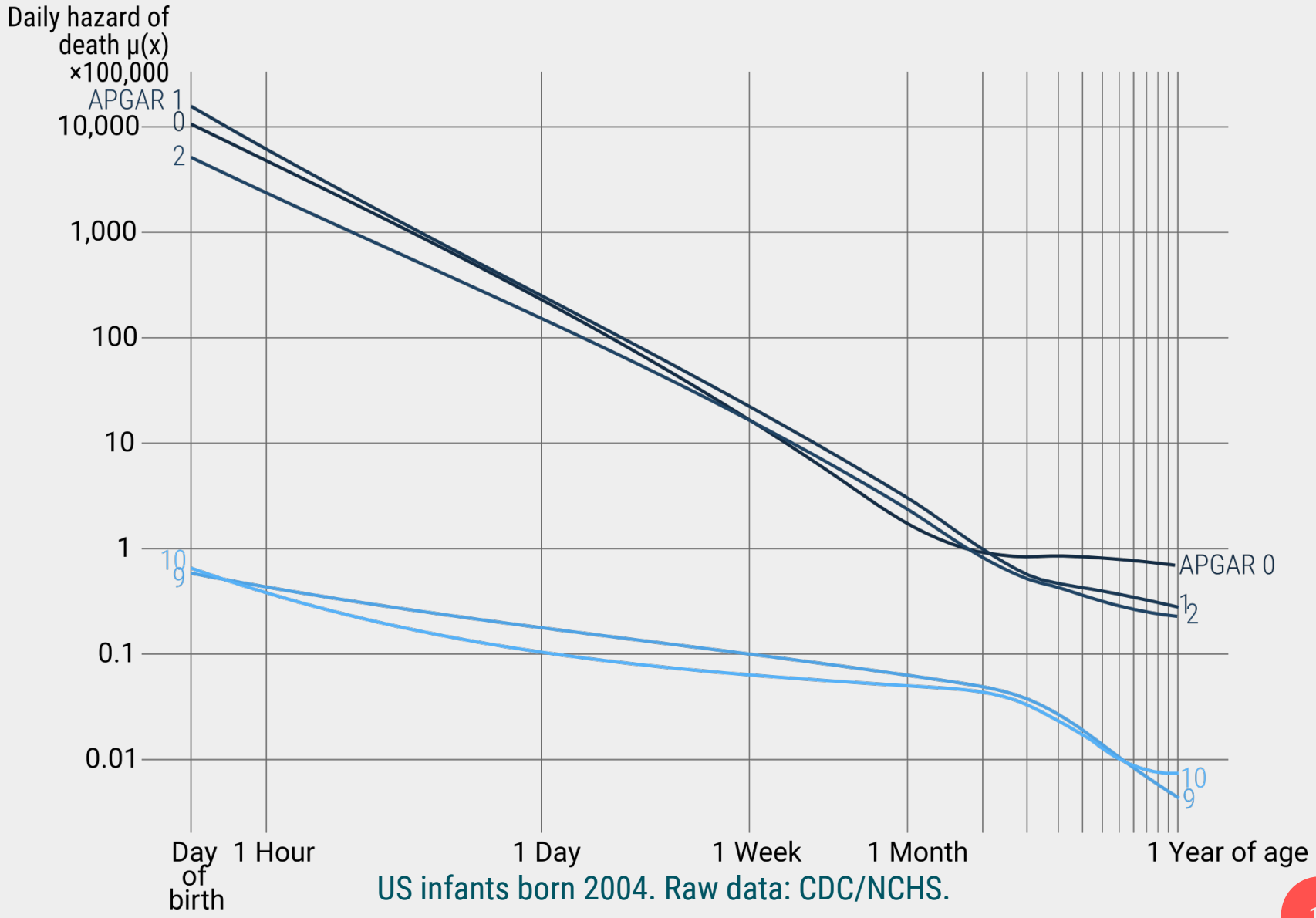
- The NCHS provides:
- birth certificates on **~70 million US births** over period 1995–2010
- death certificates on the 439,215 infant deaths during that time

A demonstration of mortality selection



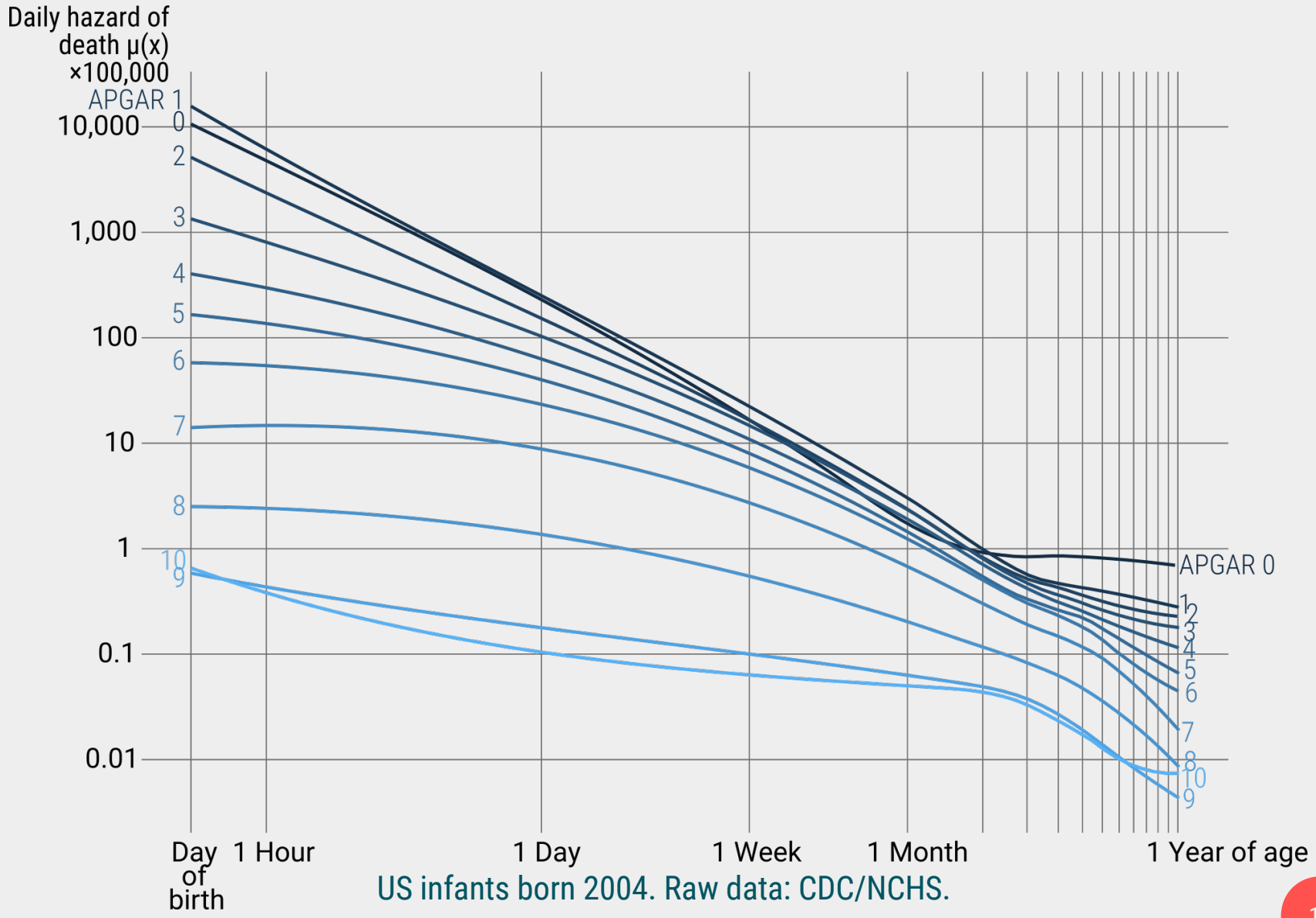
US infants born 2004. Raw data: CDC/NCHS.

A demonstration of mortality selection



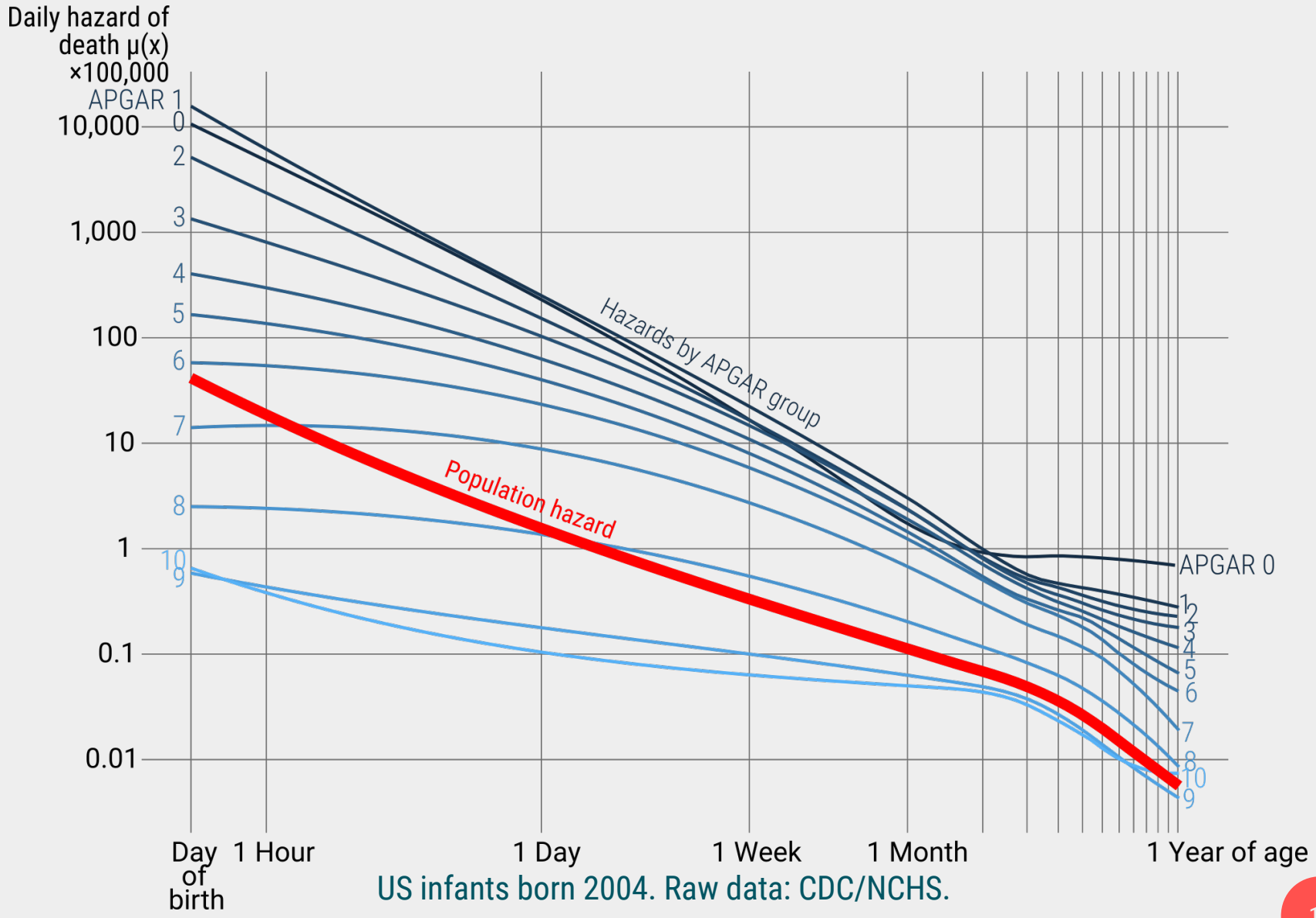
US infants born 2004. Raw data: CDC/NCHS.

A demonstration of mortality selection



US infants born 2004. Raw data: CDC/NCHS.

A demonstration of mortality selection



US infants born 2004. Raw data: CDC/NCHS.

Decomposition methods

Total difference in outcome between groups A and B = **Difference due to group effect** + **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.

Total difference in outcome between groups A and B = **Difference due to group effect** + **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.

Regression based decomposition

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

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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.

$$\overline{\dot{Y}} = \overline{\dot{Y}_z} + \mathrm{Cov}(Y_z, r_z)$$

Change in average Y = Average change of Y across strata z + Co-variance between 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.

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

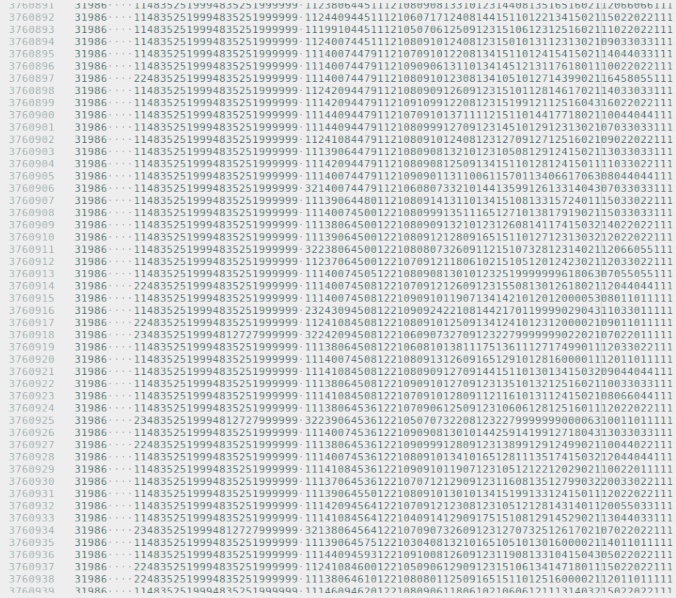
$$\overline{\dot{\mu}} = \overline{\dot{\mu}_z} + \sigma^2_{\mu z}$$

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

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



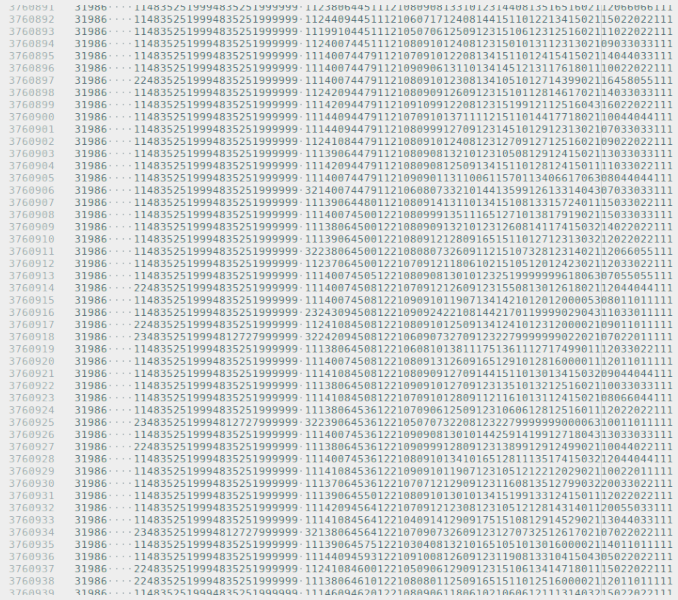
1. Raw data

US births 2005-10

N = 25,143,288

1 row = 1 birth

Analysis pipeline



1. Raw data

US births 2005-10

N = 25,143,288

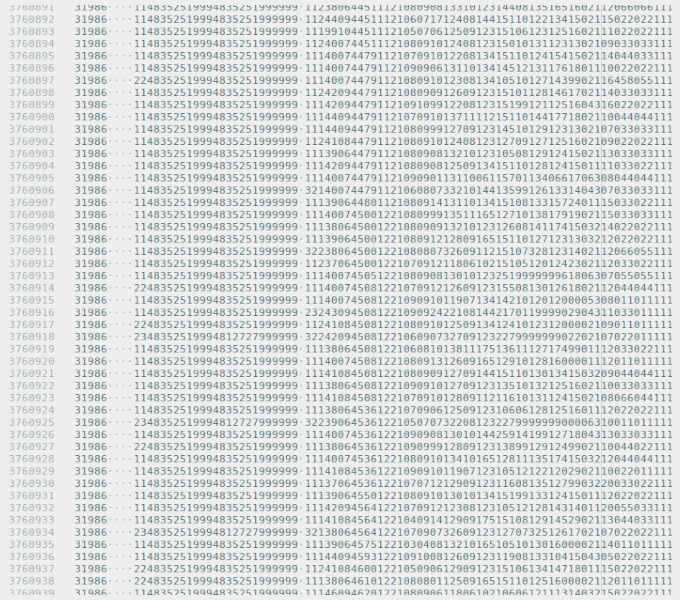
1 row = 1 birth

```
# 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*

Analysis pipeline



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      <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

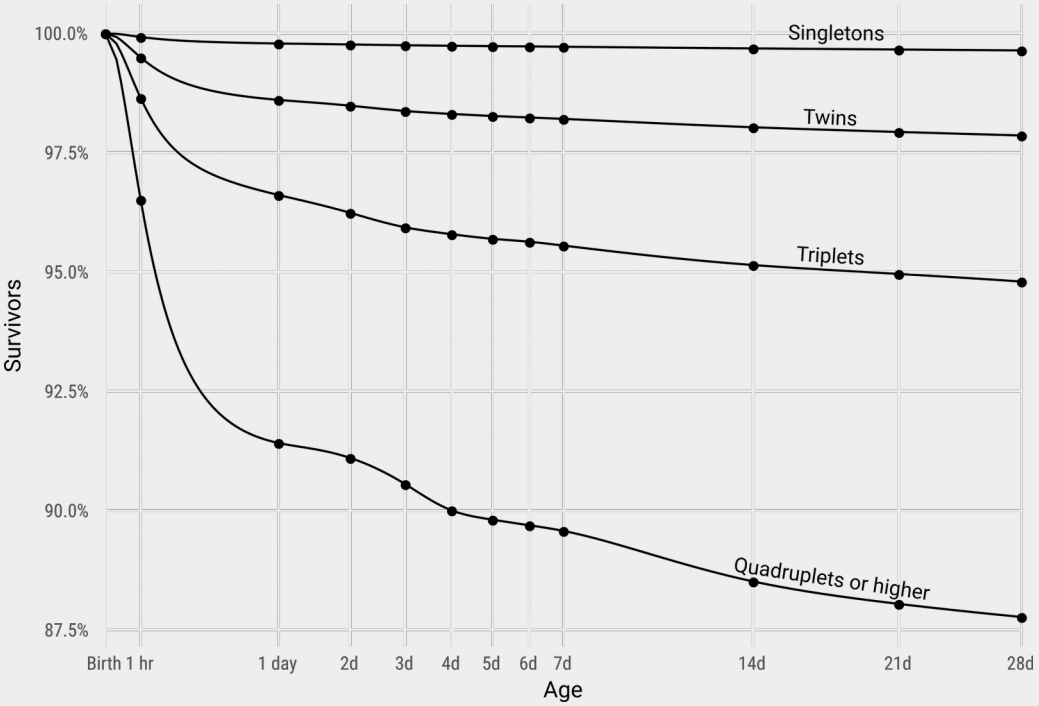
interval censored, *stratified*

```
# 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 1.0000000
 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*

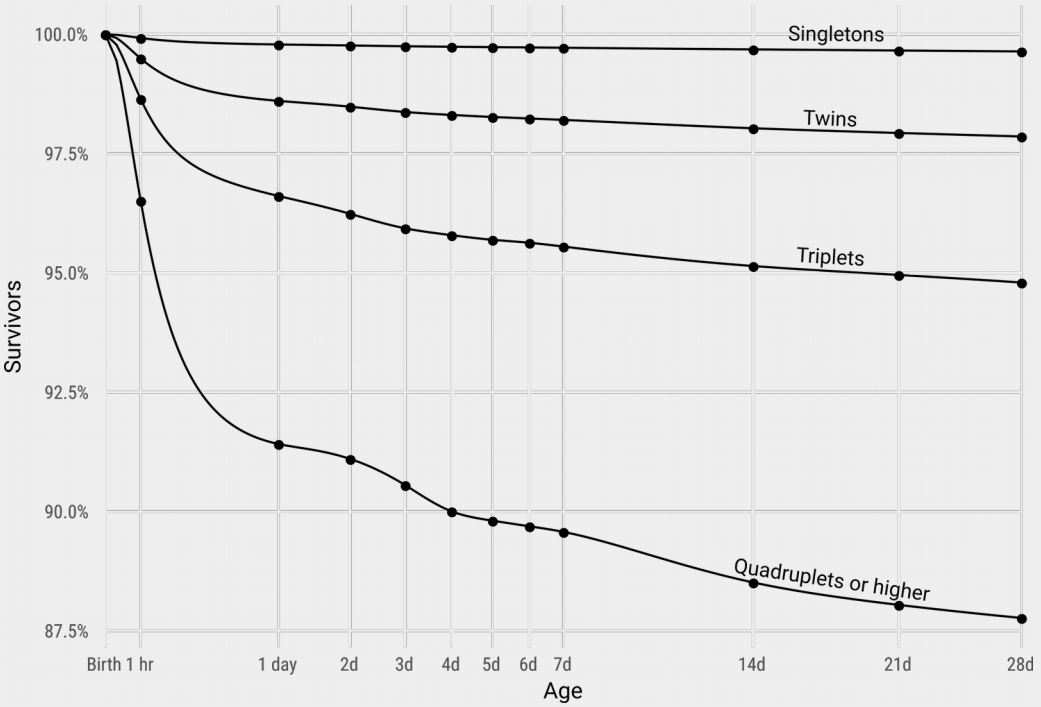
Analysis pipeline



4. Spline interpolation of life-tables

Hyman filtered cubic splines, *stratified*

Analysis pipeline

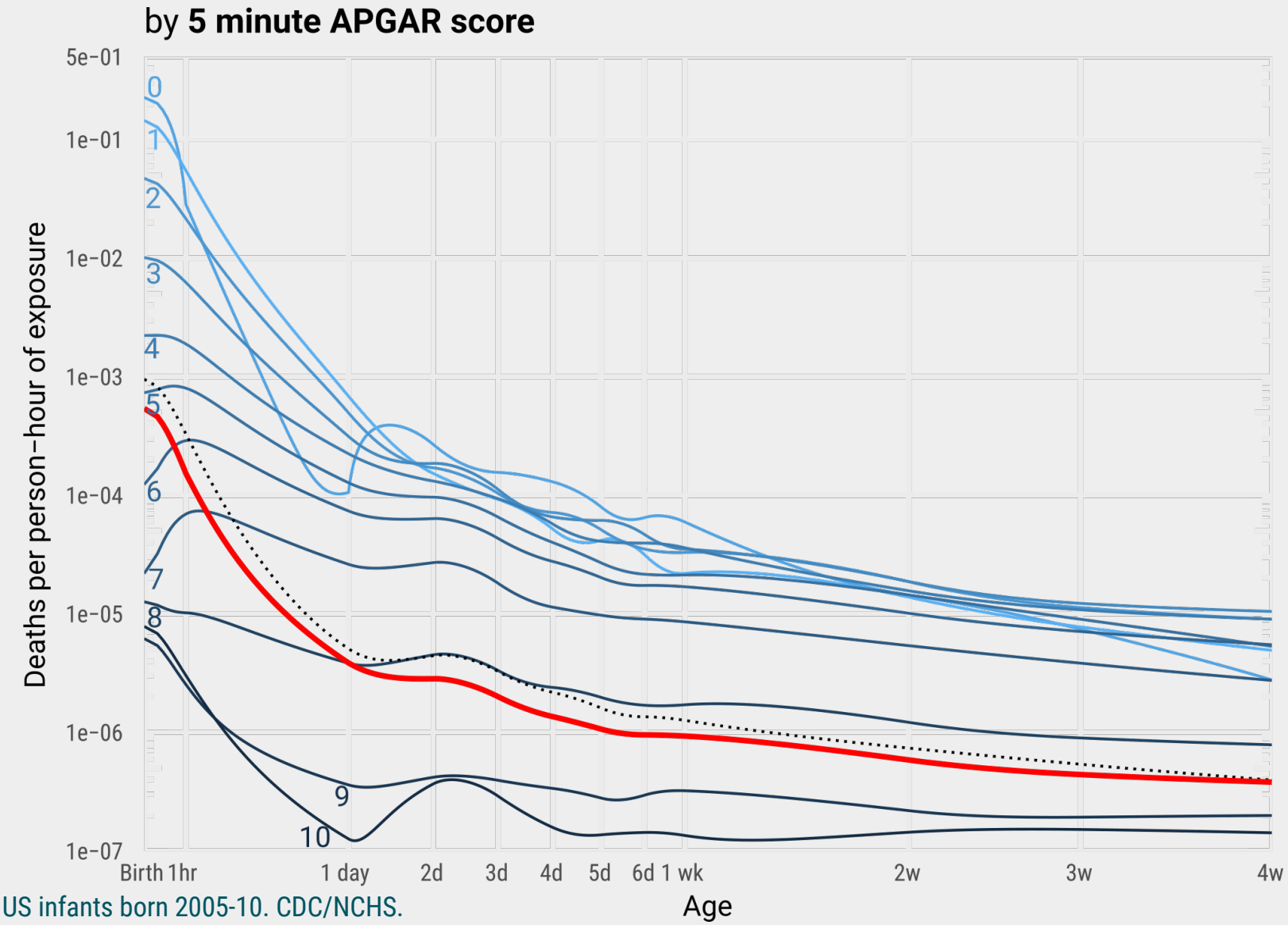


4. Spline interpolation of life-tables
Hyman filtered cubic splines, *stratified*

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
```

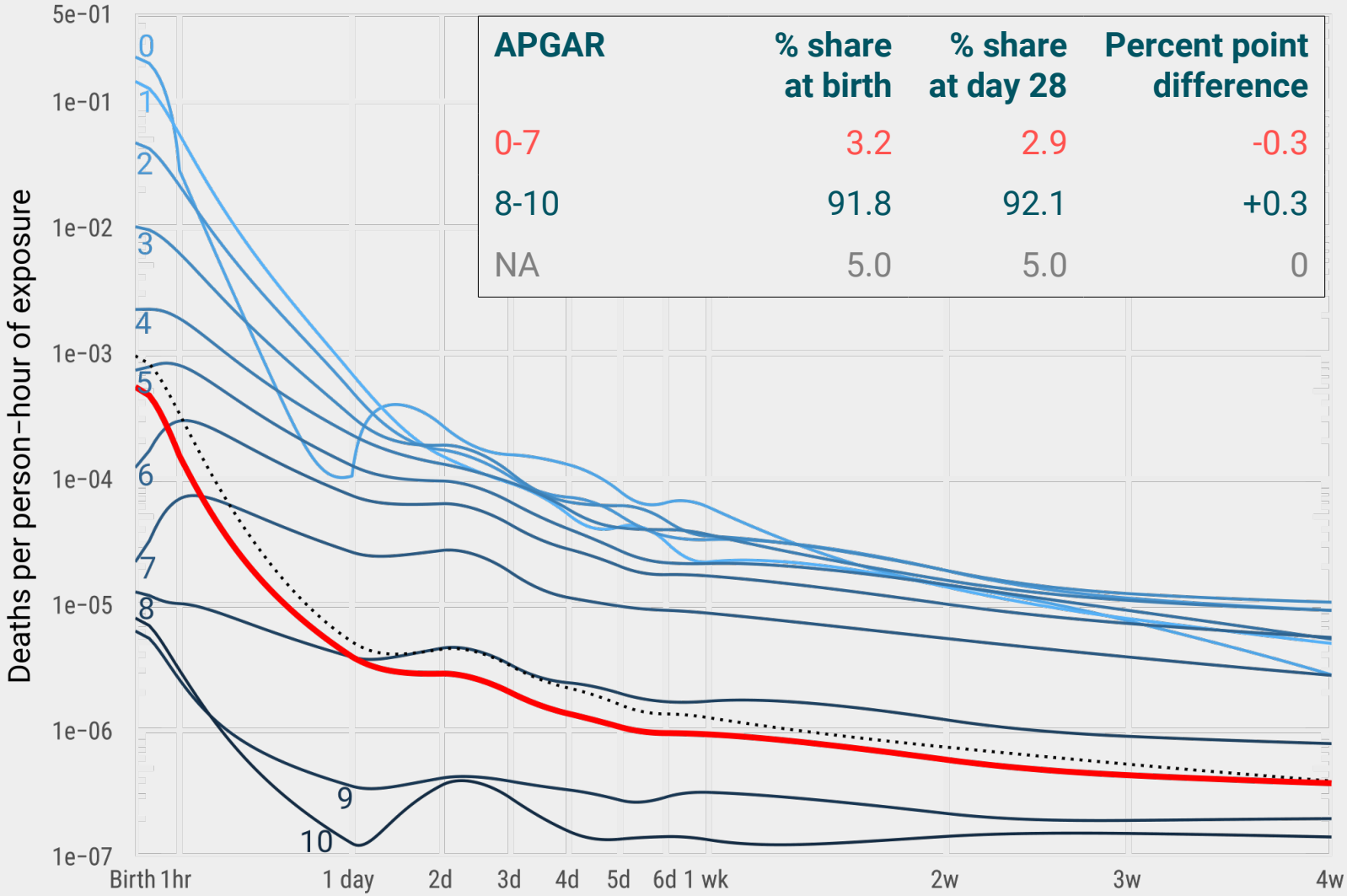
Decomposing the neonatal mortality age decline



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

Decomposing the neonatal mortality age decline

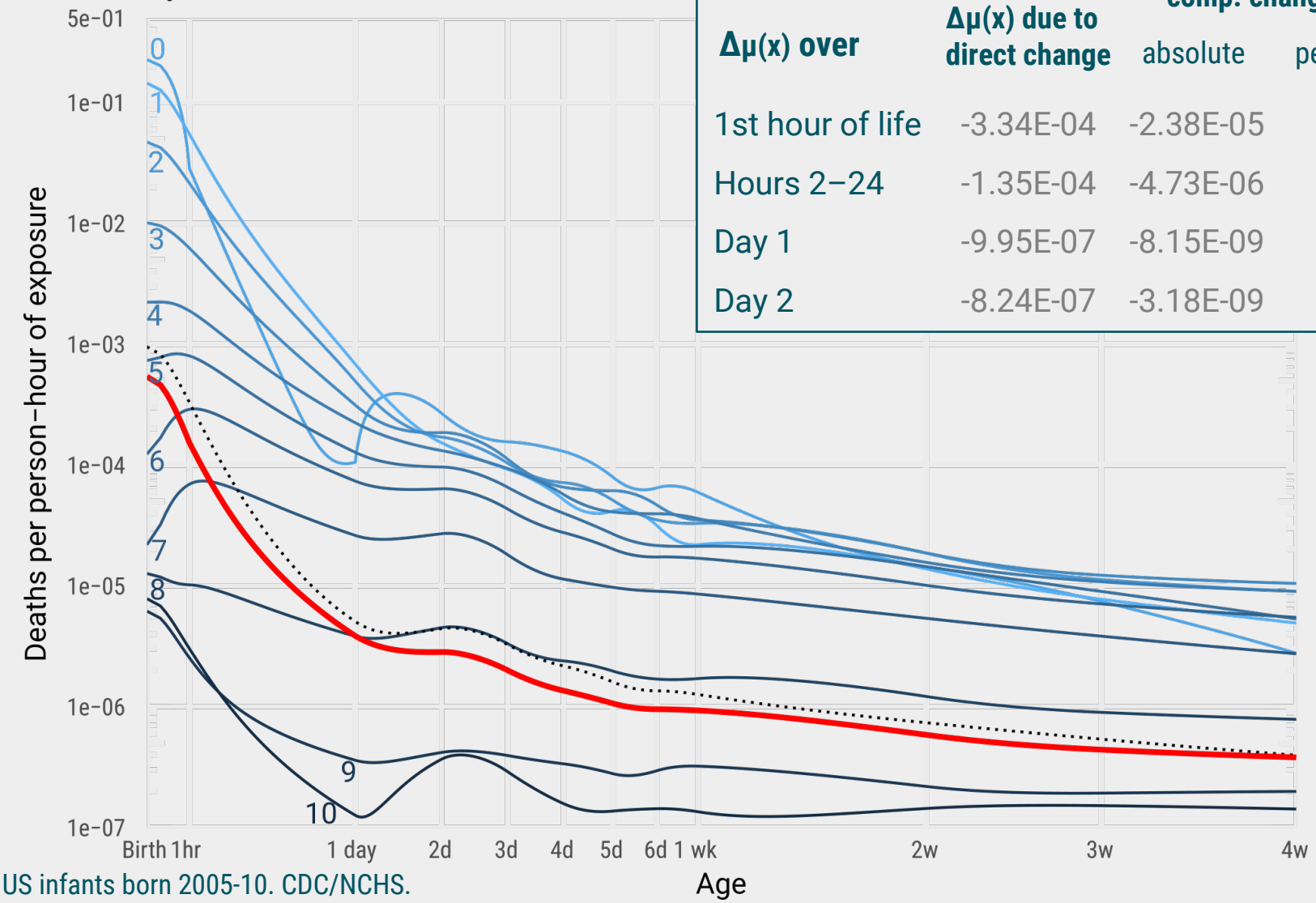
by **5 minute APGAR score**



APGAR	% share at birth	% share at day 28	Percent point difference
0-7	3.2	2.9	-0.3
8-10	91.8	92.1	+0.3
NA	5.0	5.0	0

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

Decomposing the neonatal mortality age decline

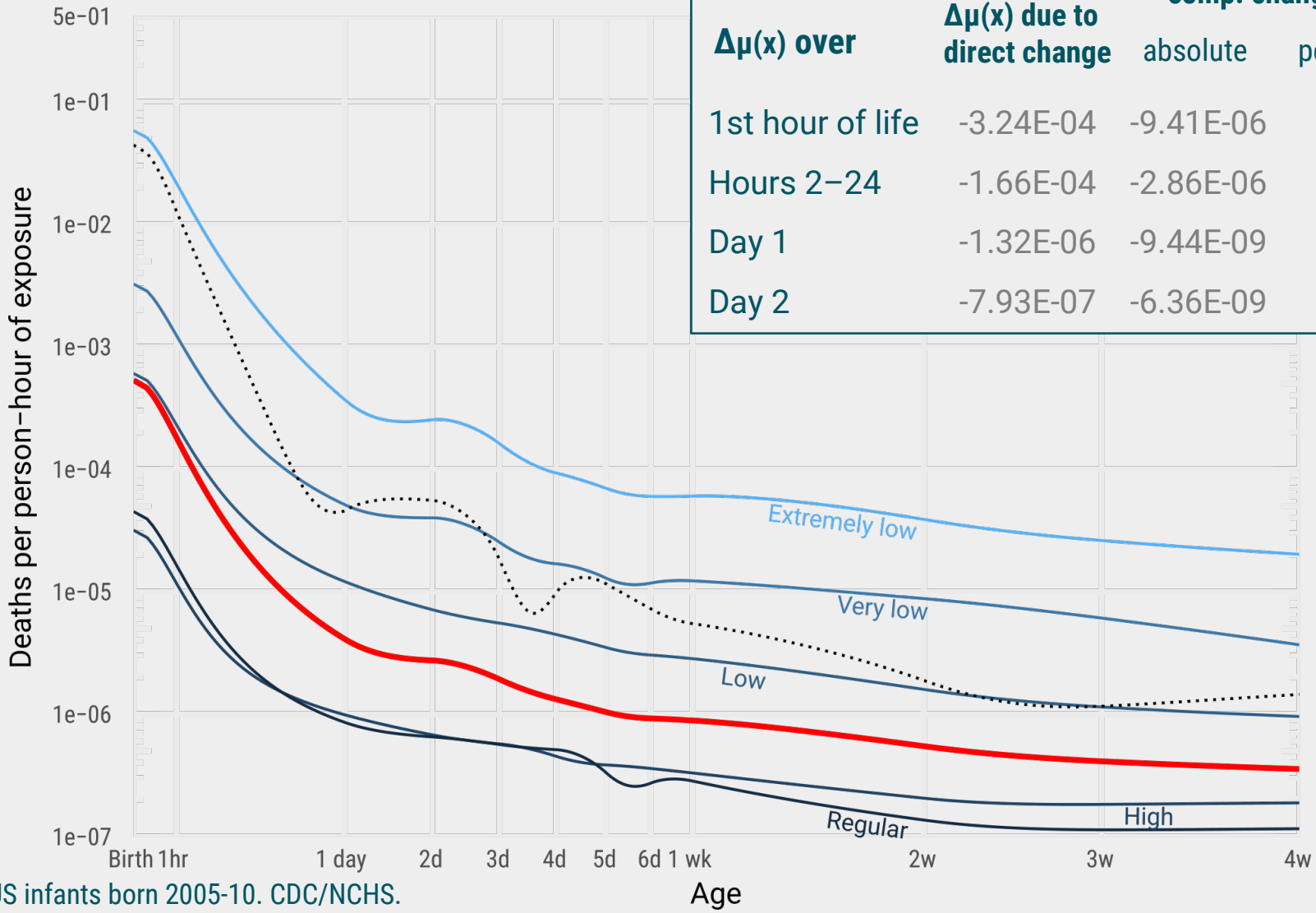


Δμ(x) over	Δμ(x) due to direct change	Δμ(x) due to comp. change	
		absolute	percent
1st hour of life	-3.34E-04	-2.38E-05	**7.1**
Hours 2–24	-1.35E-04	-4.73E-06	3.5
Day 1	-9.95E-07	-8.15E-09	0.1
Day 2	-8.24E-07	-3.18E-09	0

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

Decomposing the neonatal mortality age decline

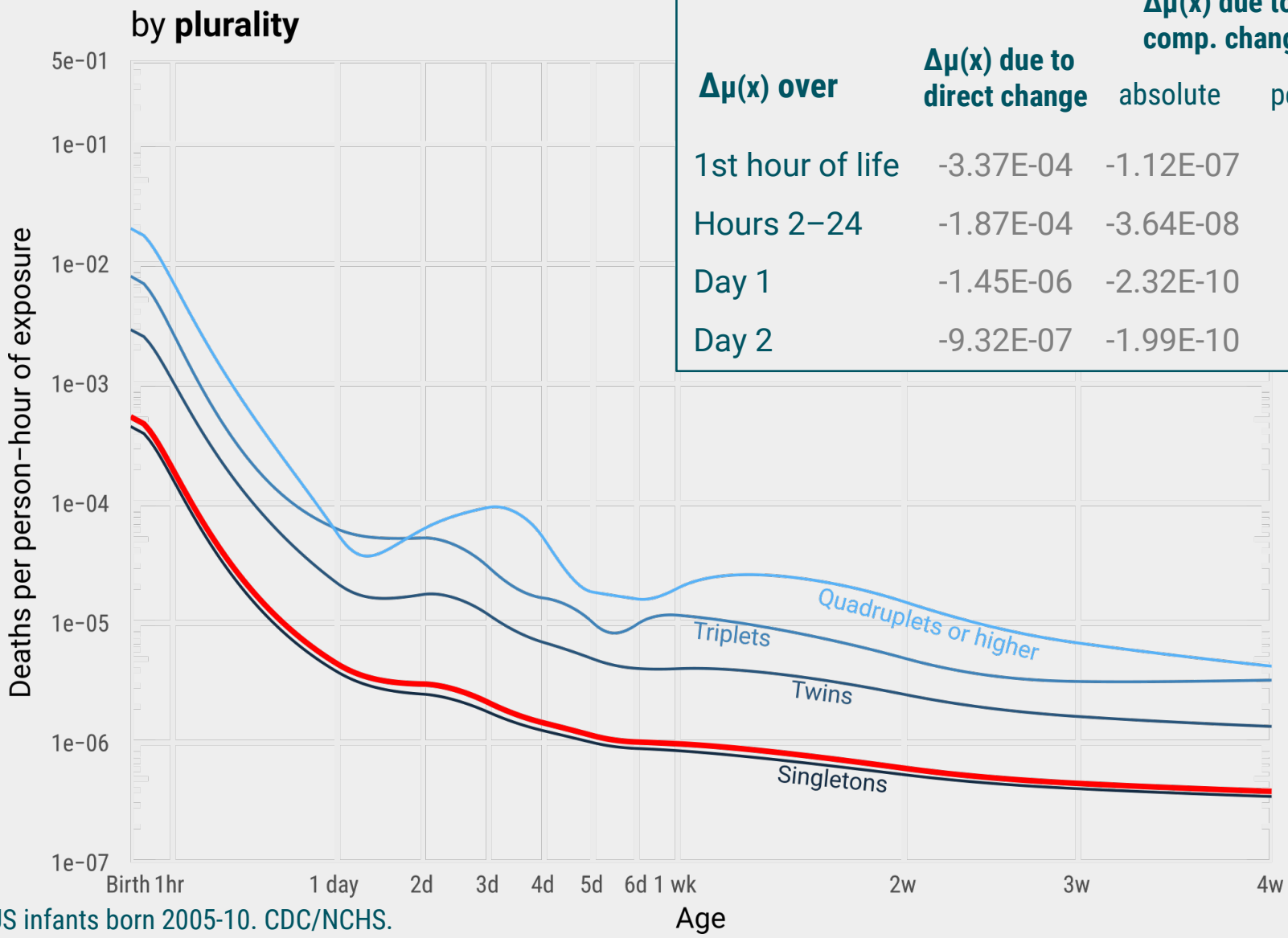
by **birthweight**



Δμ(x) over	Δμ(x) due to direct change	Δμ(x) due to comp. change	
		absolute	percent
1st hour of life	-3.24E-04	-9.41E-06	**2.8**
Hours 2–24	-1.66E-04	-2.86E-06	1.6
Day 1	-1.32E-06	-9.44E-09	0.7
Day 2	-7.93E-07	-6.36E-09	0.7

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

Decomposing the neonatal mortality age decline

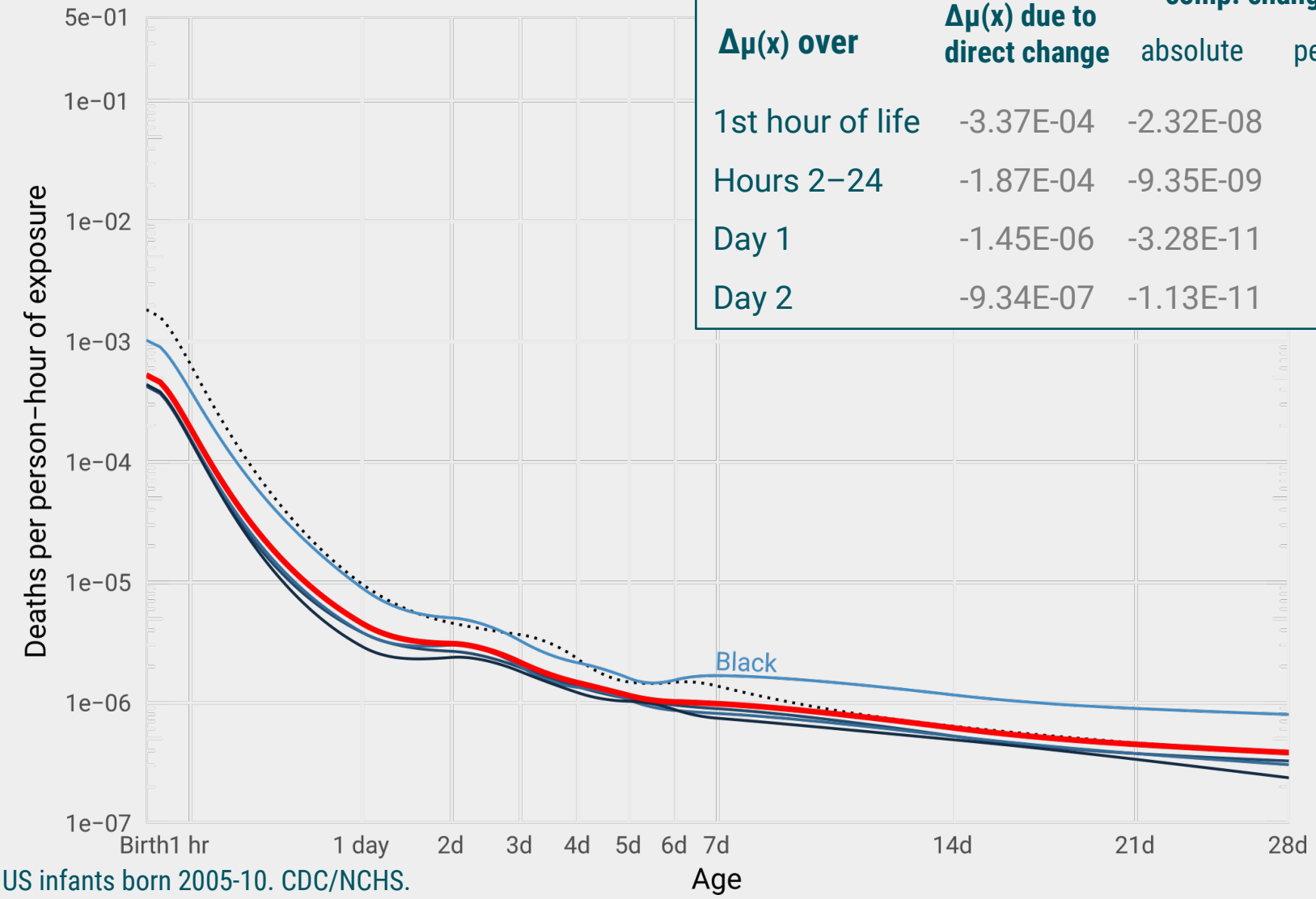


Δμ(x) over	Δμ(x) due to direct change	Δμ(x) due to comp. change	
		absolute	percent
1st hour of life	-3.37E-04	-1.12E-07	**0**
Hours 2–24	-1.87E-04	-3.64E-08	0
Day 1	-1.45E-06	-2.32E-10	0
Day 2	-9.32E-07	-1.99E-10	0

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

Decomposing the neonatal mortality age decline

by **origin of mother**



Δμ(x) over	Δμ(x) due to direct change	Δμ(x) due to comp. change	
		absolute	percent
1st hour of life	-3.37E-04	-2.32E-08	**0**
Hours 2–24	-1.87E-04	-9.35E-09	0
Day 1	-1.45E-06	-3.28E-11	0
Day 2	-9.34E-07	-1.13E-11	0

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

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

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

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

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

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

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/imort_select

Jonas Schöley

jschoeley@health.sdu.dk

Twitter: @jschoeley