

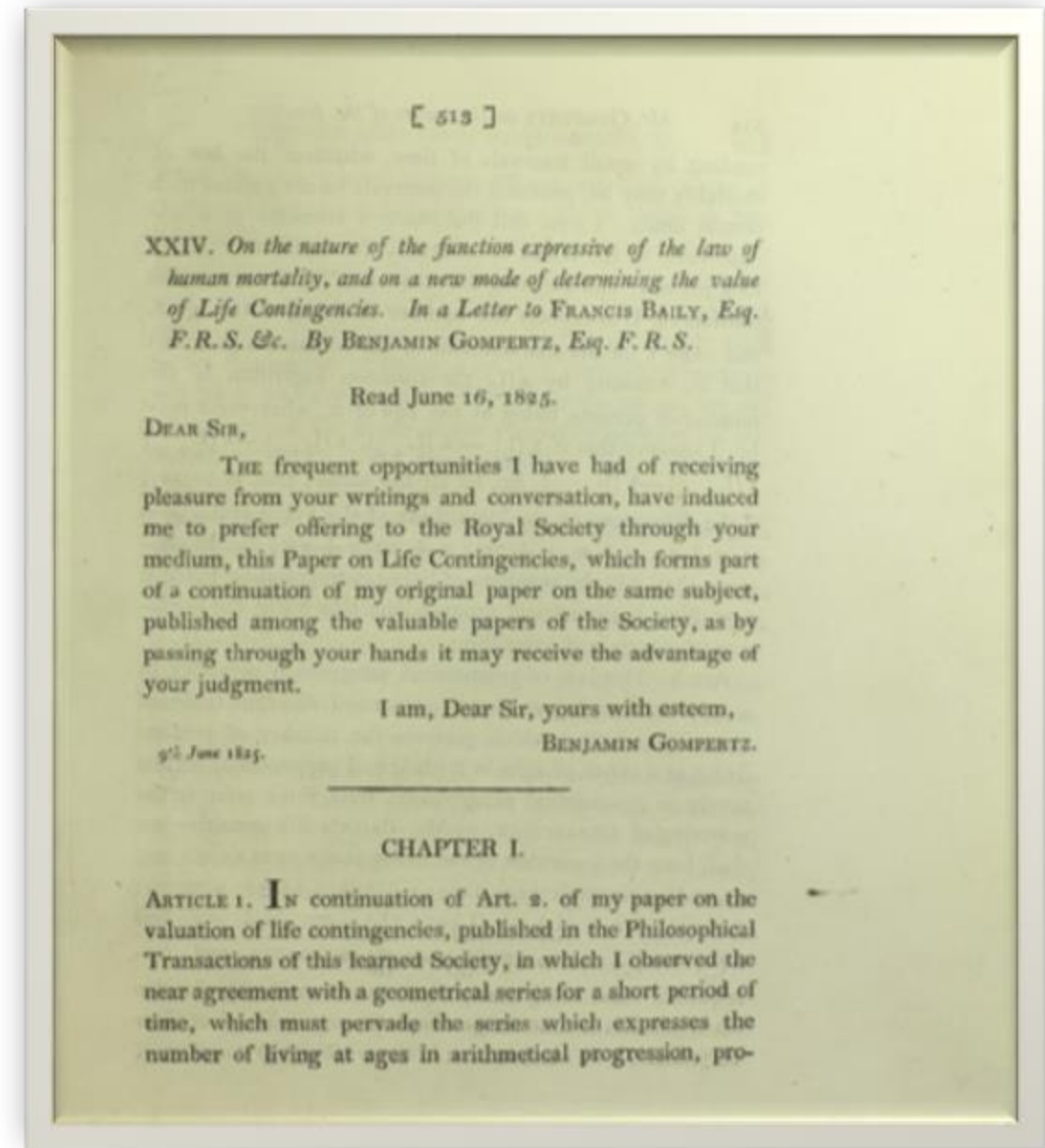
# Benjamin Gompertz: Financial Economist

September 9, 2025, Singapore

Longevity 20

Moshe A. Milevsky  
CIT Chair in Finance Services  
Professor, Schulich School of Business  
York University, Toronto

Two hundred years ago,  
nearly to today's date,  
Benjamin Gompertz  
published an article, and  
presented a model, that  
would become (very)  
famous...





Institute  
and Faculty  
of Actuaries

## Associateship Qualification

### Risk Modelling and Survival Analysis (CS2) Core Principles

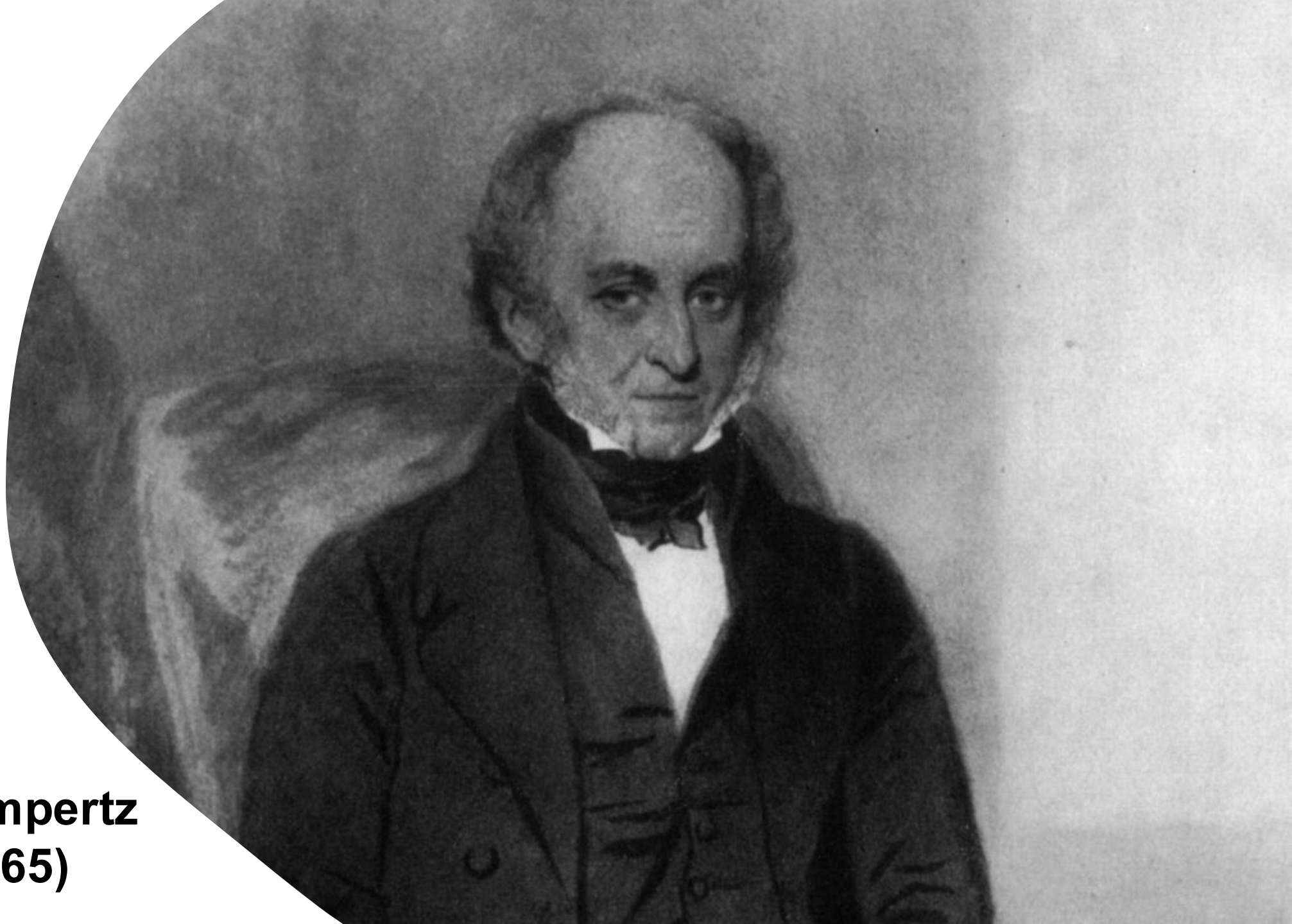
Syllabus for the 2025 Examinations

#### 4 Survival models [25%]

Description, estimation and use of statistical models for the time until an event occurs.

##### 4.1 Concepts of survival models

- 4.1.1 Model of lifetime or failure time from age  $x$  as a random variable
- 4.1.2 Consistency condition between the random variable representing lifetimes from different ages
- 4.1.3 Distribution and density functions of the random future lifetime, the survival function, the force of mortality or hazard rate, and derive relationships between them
- 4.1.4 Understand the actuarial symbols  $t_p x$  and  $t_q x$  and derive integral formulae for them
- 4.1.5 Gompertz and Makeham laws of mortality
- 4.1.6 Curtate future lifetime from age  $x$  and state its probability function
- 4.1.7 Understand the symbols  $e_x$  and  ${}^o e_x$  and derive an approximate relation between them. Define the expected value and variance of the complete and curtate future lifetimes and derive expressions for them
- 4.1.8 Two-state model of a single decrement and compare its assumptions with those of the random lifetime model



**Benjamin Gompertz**  
**(b. 1779, d. 1865)**

# My (three part) Objective for Today

1. What exactly is the Gompertz Mortality Model? (**Refresher.**)
2. Why is a (simple) model still so popular in the **21<sup>st</sup> century?**
3. Who was Benjamin Gompertz in the **19<sup>th</sup> century?**

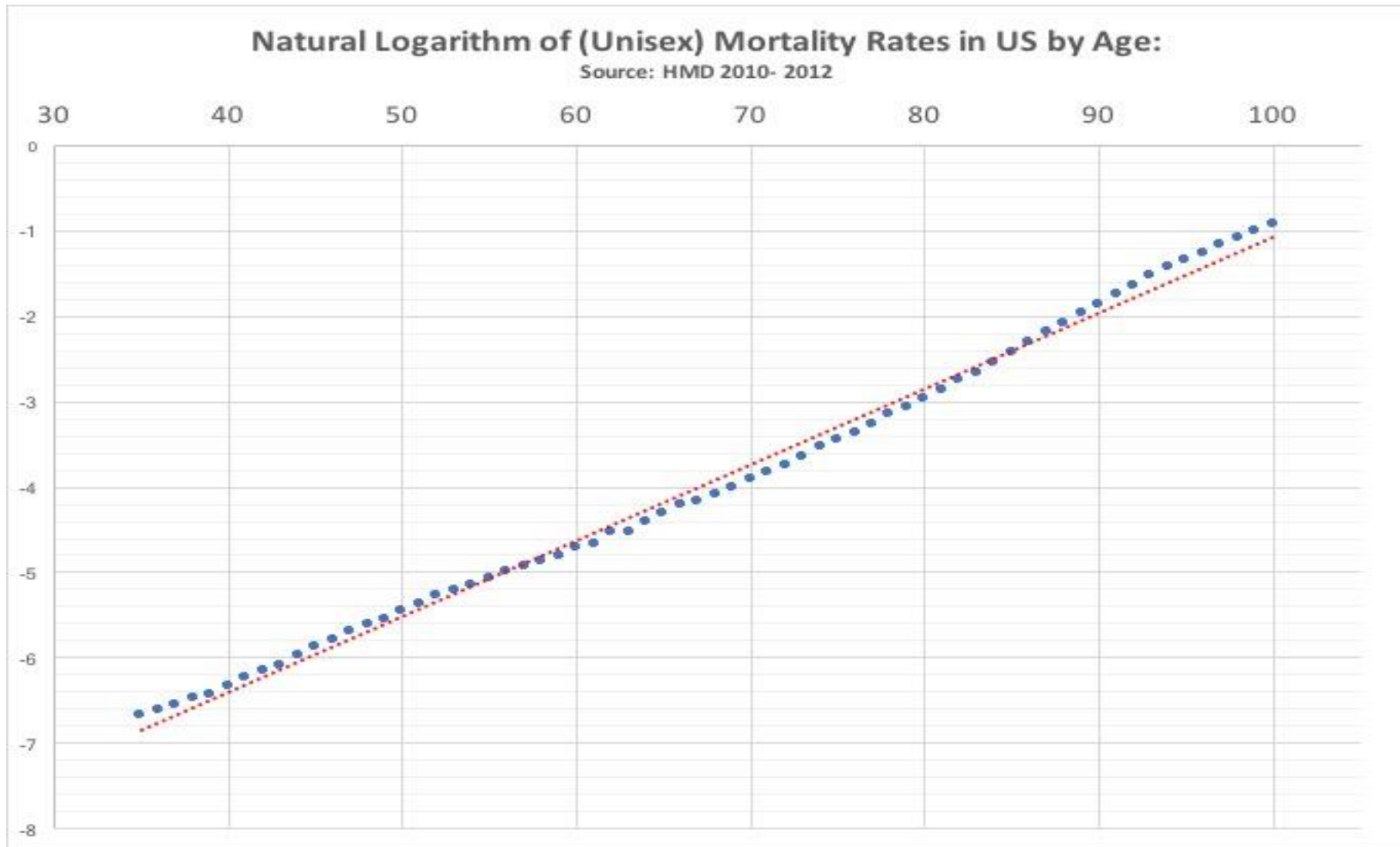
**Part I:**

**What is the Gompertz Model?**

# The original equation ....

Pg.518 Art. 5. If the average exhaustions of a man's power to avoid death were such that at the end of equal infinitely small intervals of time, he lost equal portions of his remaining power to oppose destruction which he had at the commencement of those intervals, then at the age  $x$  his power to avoid death, or the intensity of his mortality might be denoted by  $aq^x$ ,  $a$  and  $q$  being constant quantities; and if  $L_x$  be the number of living at the age  $x$ , we shall have  $aL_x \times q^x \dot{x}$  for the fluxion of the number of deaths  $= -(\dot{L}_x)$ ;  $\therefore abq^x = -\frac{\dot{L}_x}{L_x}$ ,  
 $\therefore abq^x = -\text{hyp. log. of } b \times \text{hyp. log. of } L_x$ , and putting the common logarithm of  $\frac{1}{b} \times$  square of the hyperbolic logarithm of 10  $= c$ , we have  $c.q^x = \text{common logarithm of } \frac{L_x}{d}$ ;  $d$  being a constant quantity, and therefore  $L_x$  or the number of persons living at the age of  $x = d.g^x$ ;  $g$  being

# Log-Mortality Rate: Linear in Age

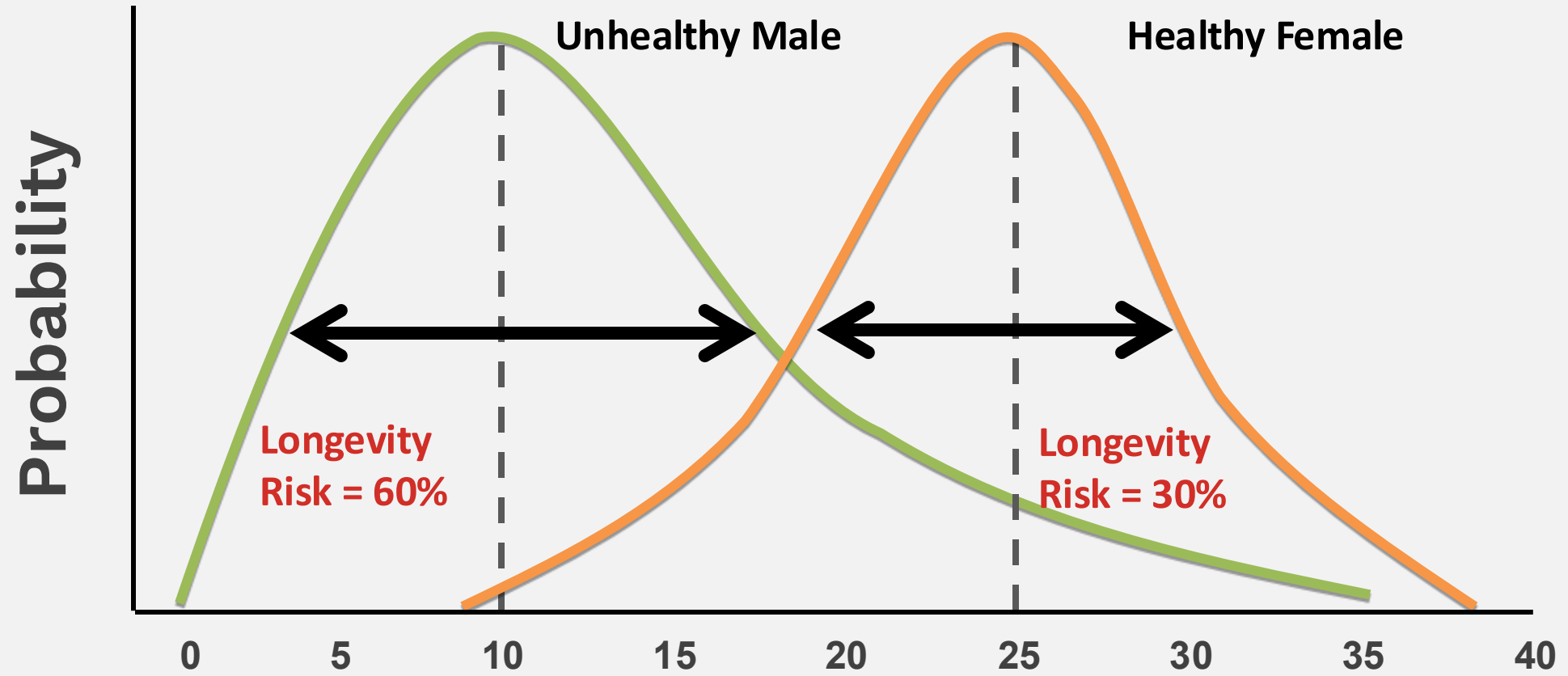


## Gompertz Survival Probability (m,b)

$$\ln[p] = (1 - e^{t/b})e^{\left(\frac{x-m}{b}\right)}$$

What is the (log) probability I'll survive?

# How to think about longevity in retirement



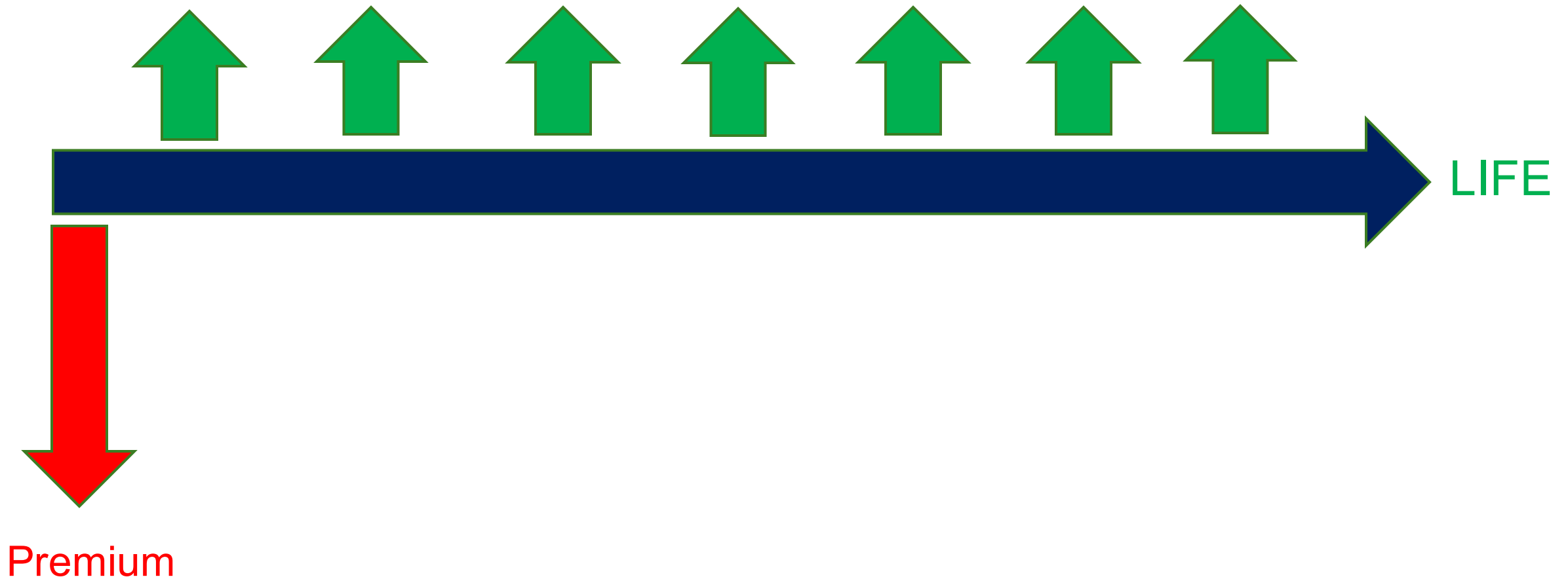
The Gompertz expression makes it **very easy** to price & obtain actuarial present values for all life annuities, analytically!

# **Annuities:**

Immediate, Deferred, Contingent and Reversionary

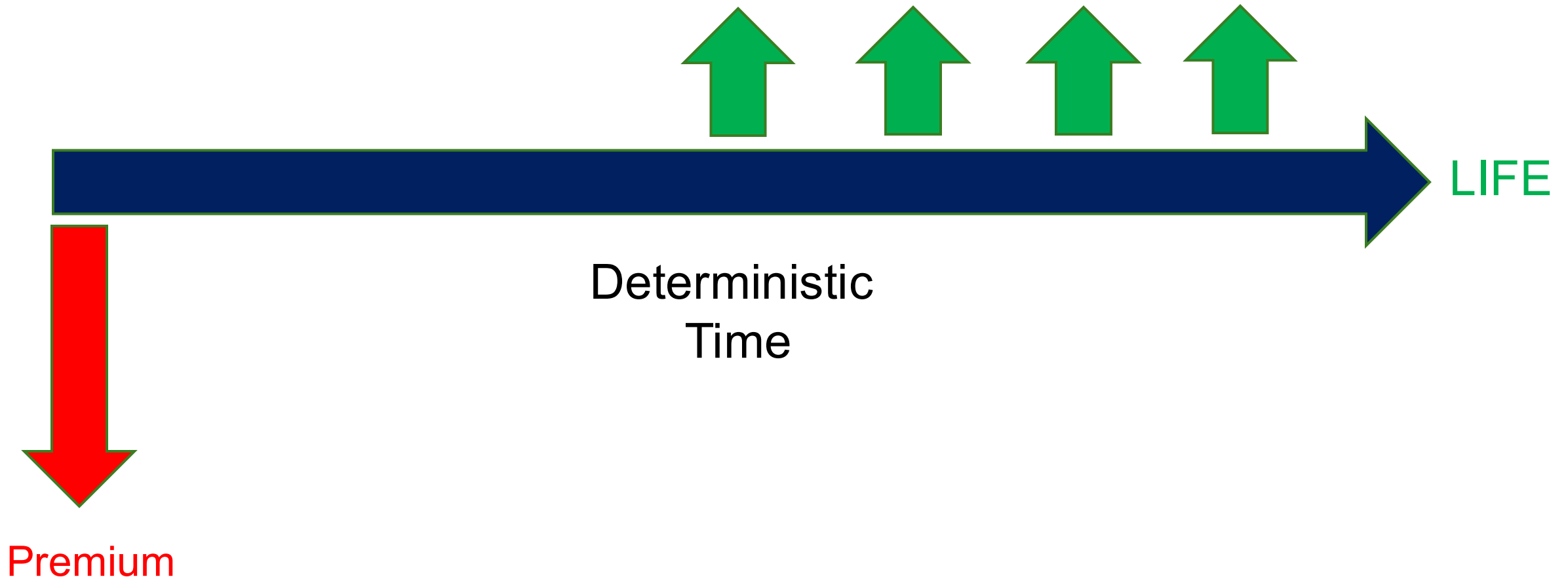
# Annuities:

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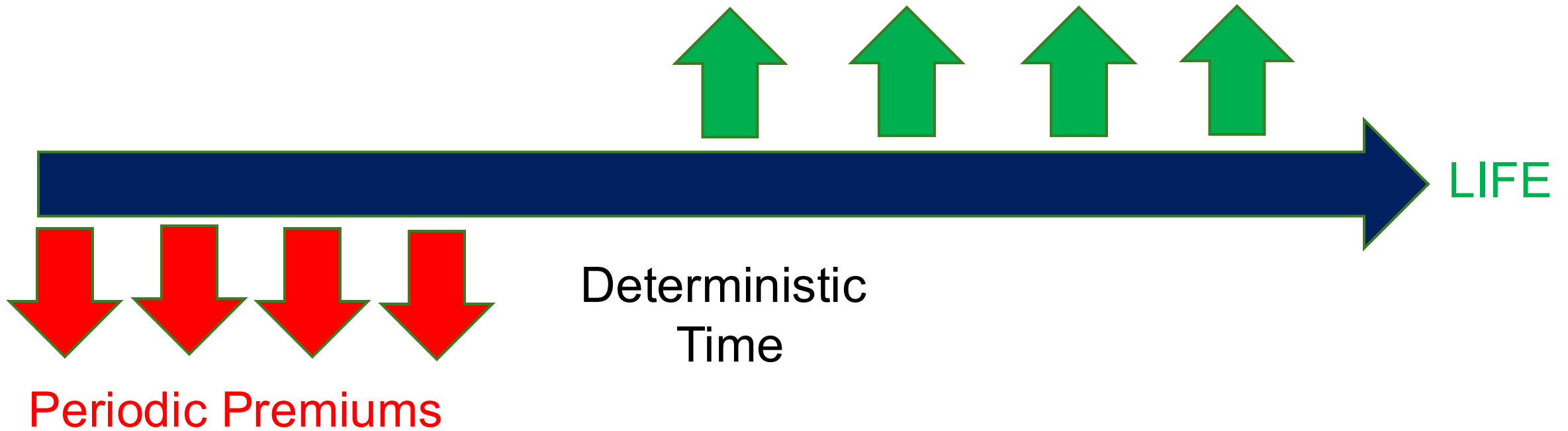
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# Annuities:

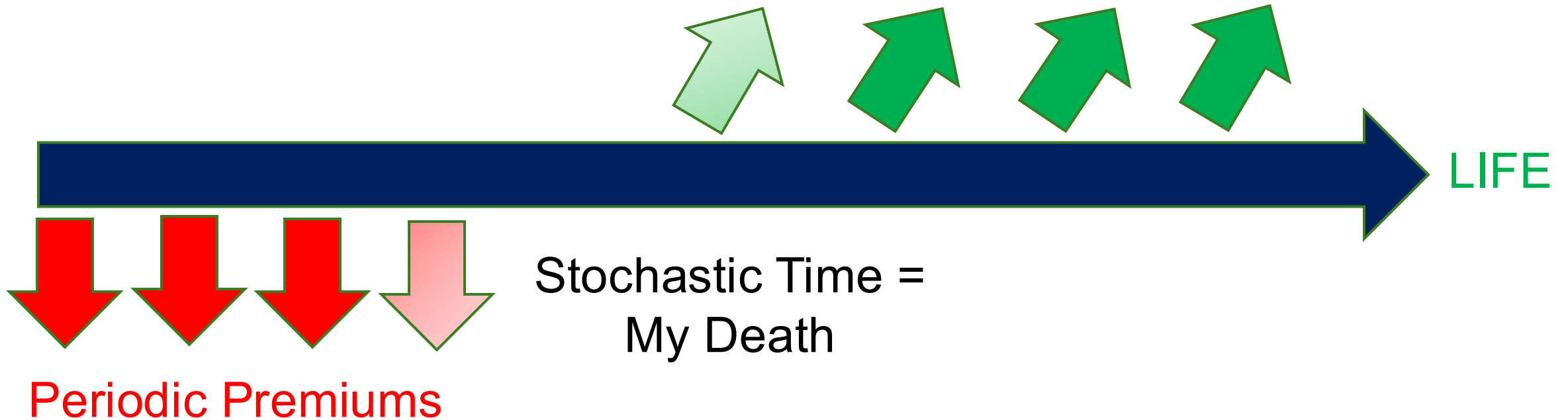
Immediate, Deferred, **Contingent** and Reversionary



# Annuities:

Immediate, Deferred, Contingent and Reversionary

Income Continues for Life of Spouse



# Gompertz Annuity Pricing Model (GAPM)

$$\bar{a}_x = \frac{b\Gamma(-rb, e^{(x-m)/b})}{\exp\{r(m-x) - e^{(x-m)/b}\}}$$

$$\Gamma(a, c) := \int_c^\infty e^{-t} t^{a-1} dt$$

**Source:** Milevsky (2006), pg. 117

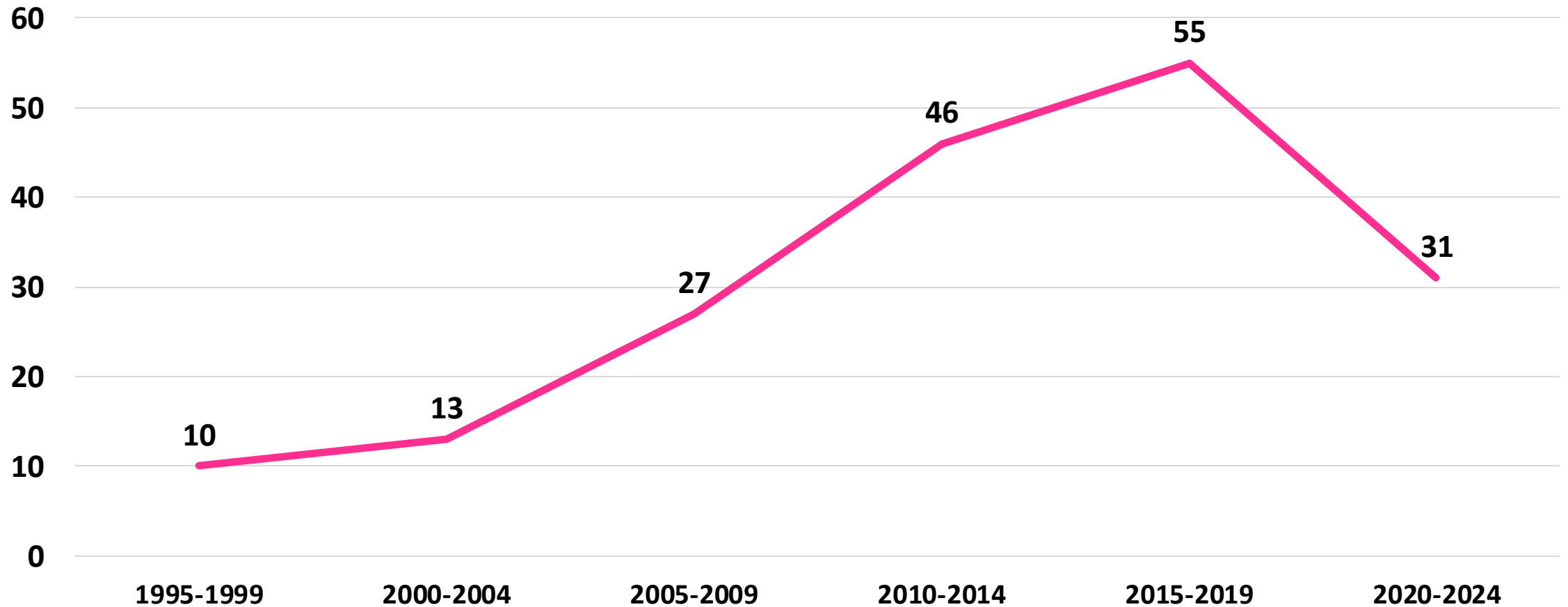
## **Part II:**

**The Gompertz mortality model is (today) especially popular with financial economists.**

# Who still uses it? Start with academic journals.

<b>Field of Demography</b>
<b>Demography</b>
<b>International Migration Review</b>
<b>Population Studies</b>
<b>European Journal of Population</b>
<b>Population and Environment</b>
<b>Demographic Research</b>

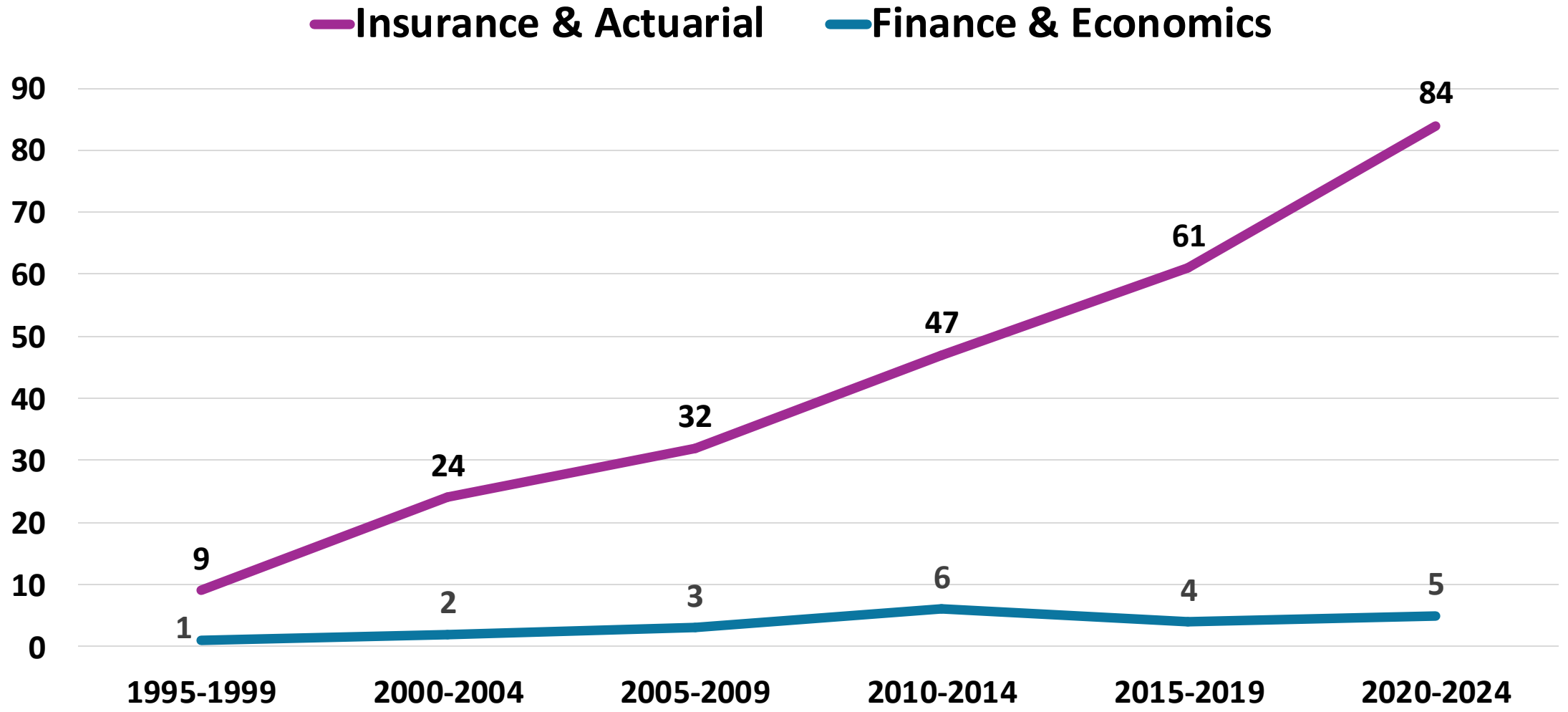
# Published papers in Field of Demography (mentioning the Gompertz Model)



# Moving on ... to other fields

<b>Insurance and Actuarial</b>	<b>Finance and Economics</b>
<b>Scandinavian Actuarial Journal</b>	<b>American Economic Review</b>
<b>Journal of Risk and Insurance</b>	<b>Journal of Political Economy</b>
<b>European Actuarial Journal</b>	<b>Quarterly Journal of Business and Economics</b>
<b>ASTIN Bulletin</b>	<b>Econometrica</b>
<b>Insurance: Mathematics and Economics</b>	<b>Review of Economics and Statistics</b>
<b>Annals of Actuarial Science</b>	<b>Journal of Public Economics</b>
	<b>Journal of Development Economics</b>
	<b>European Economic Review</b>
	<b>American Economic Journal: Applied Economics</b>

# Published papers referencing “Gompertz” (since 1995)

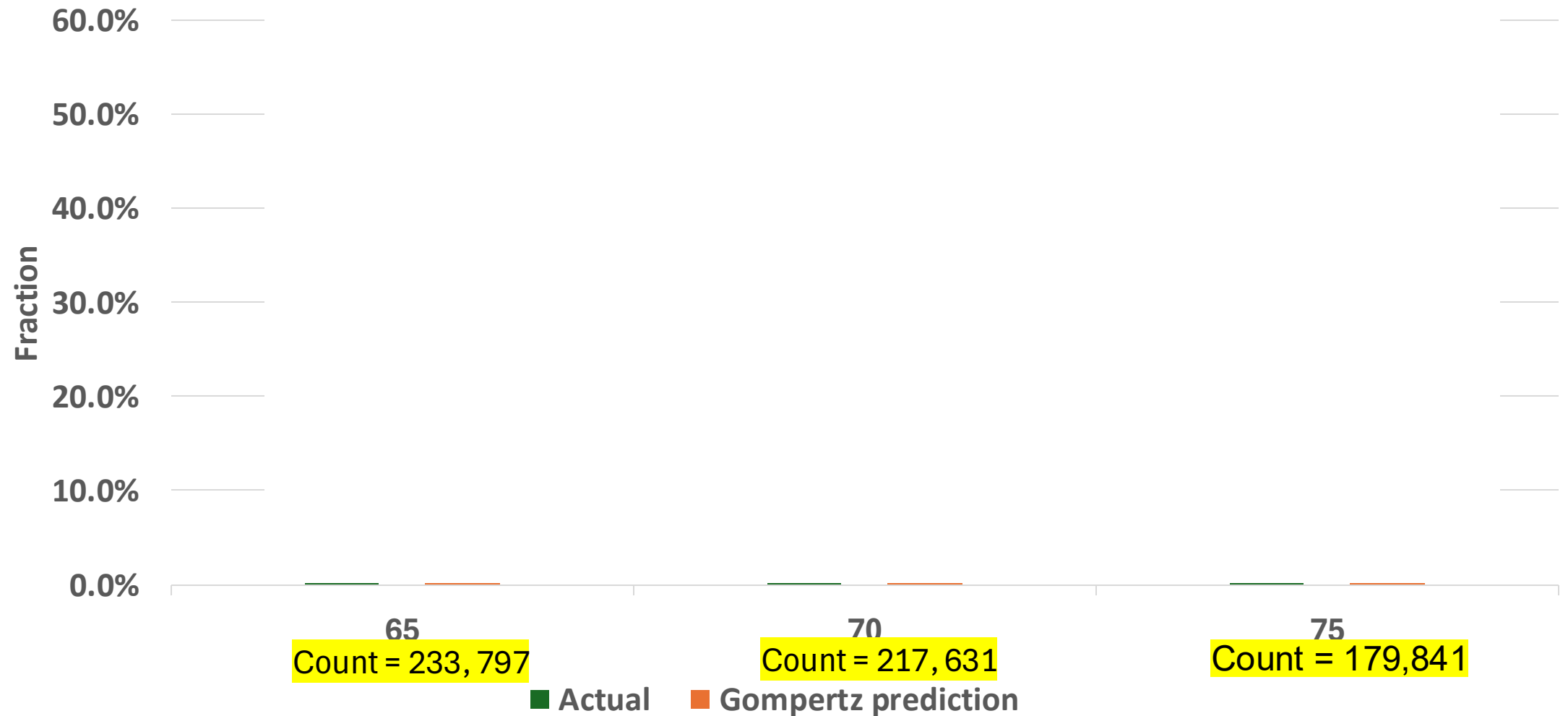


# Published papers mentioning Gompertz

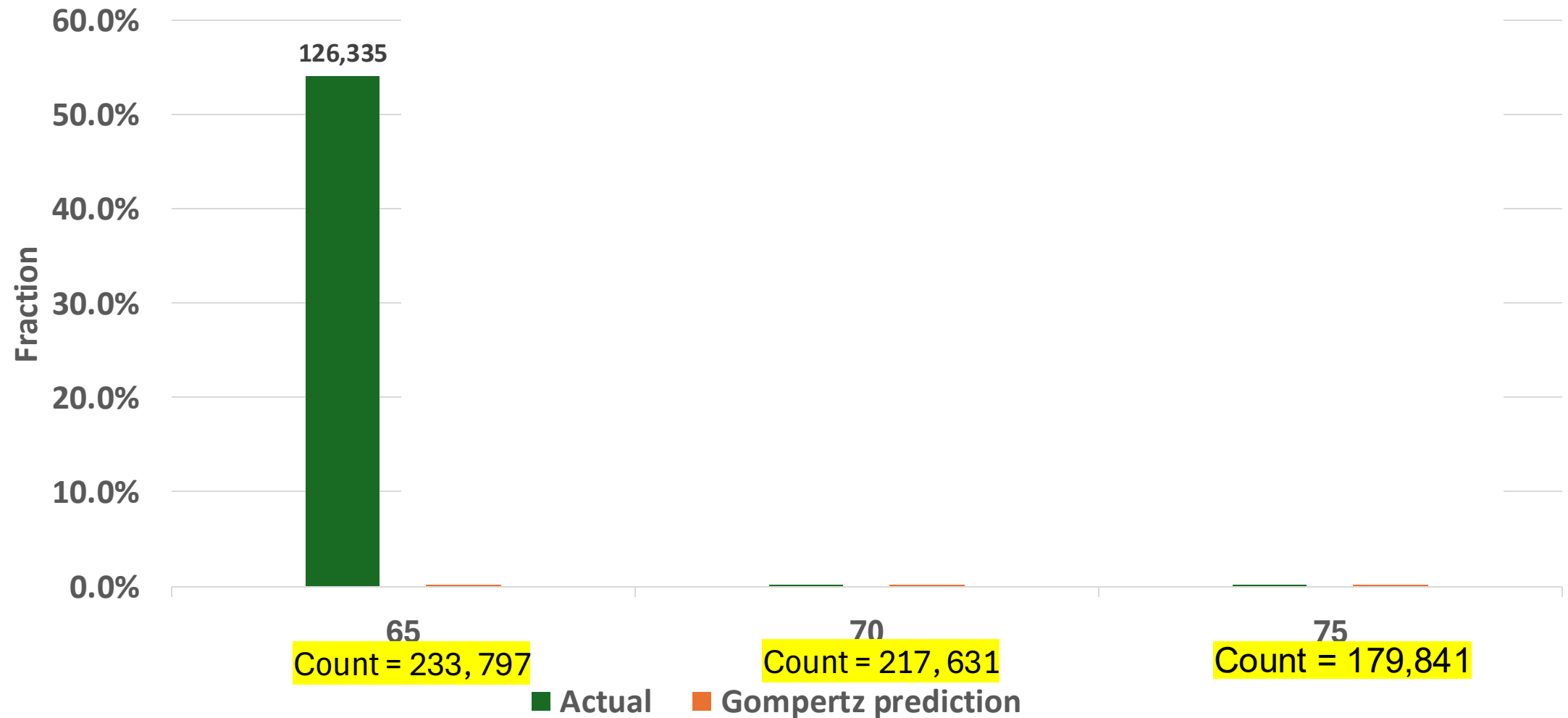
	<b>Insurance &amp; Actuarial</b>	<b>Finance &amp; Economics</b>
<b>1995-1999</b>	<b>9</b>	<b>1</b>
<b>2000-2004</b>	<b>24</b>	<b>2</b>
<b>2005-2009</b>	<b>32</b>	<b>3</b>
<b>2010-2014</b>	<b>47</b>	<b>6</b>
<b>2015-2019</b>	<b>61</b>	<b>4</b>
<b>2020-2024</b>	<b>84</b>	<b>5</b>
<b>Total</b>	<b>257</b>	<b>21</b>

**Further (empirical) “proof” that  
Gompertz is a rather good model**

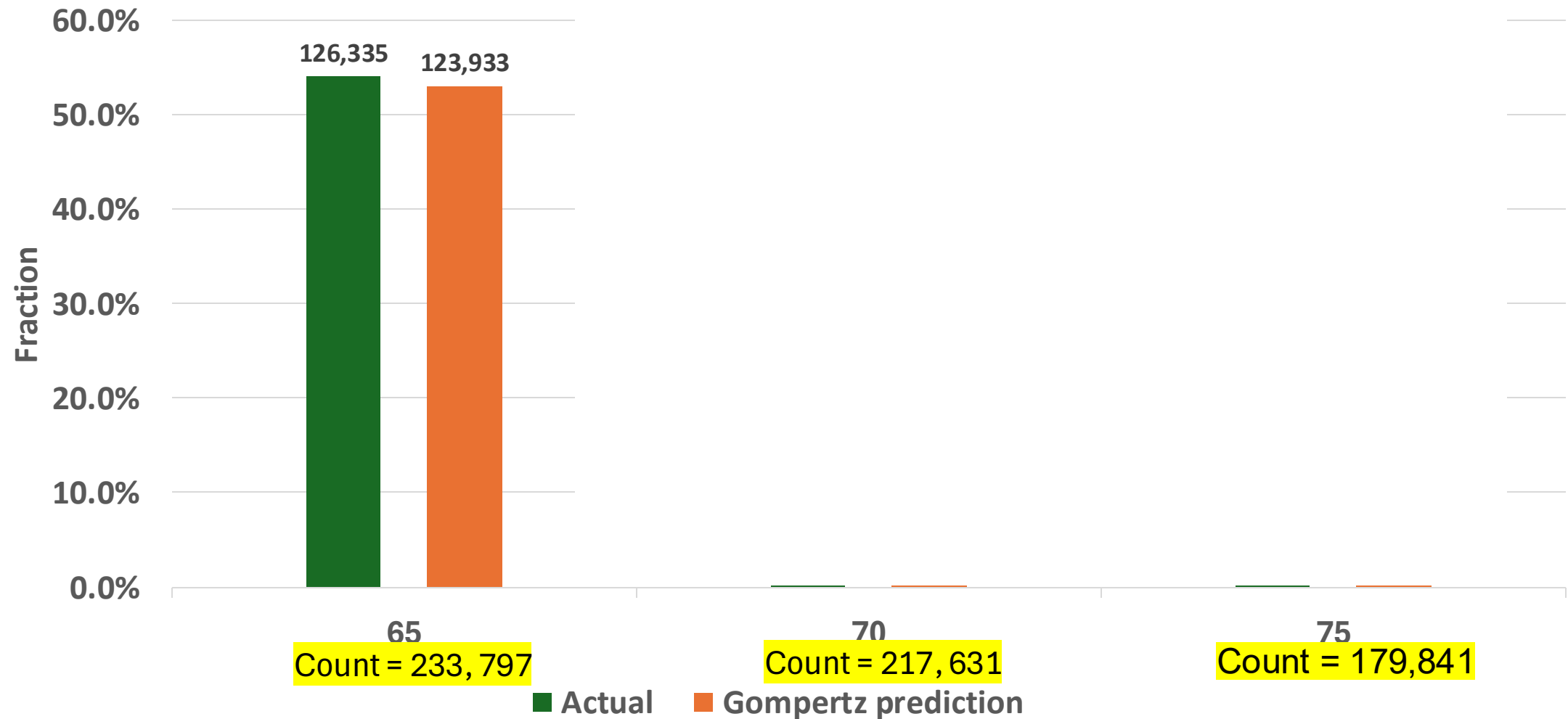
**We are Currently in the Year 2000 (Canada).  
How many will survive for 20 more years to 2020?  
Assume Gompertz ( $m = 88.05$ ,  $b = 8.88$ )**



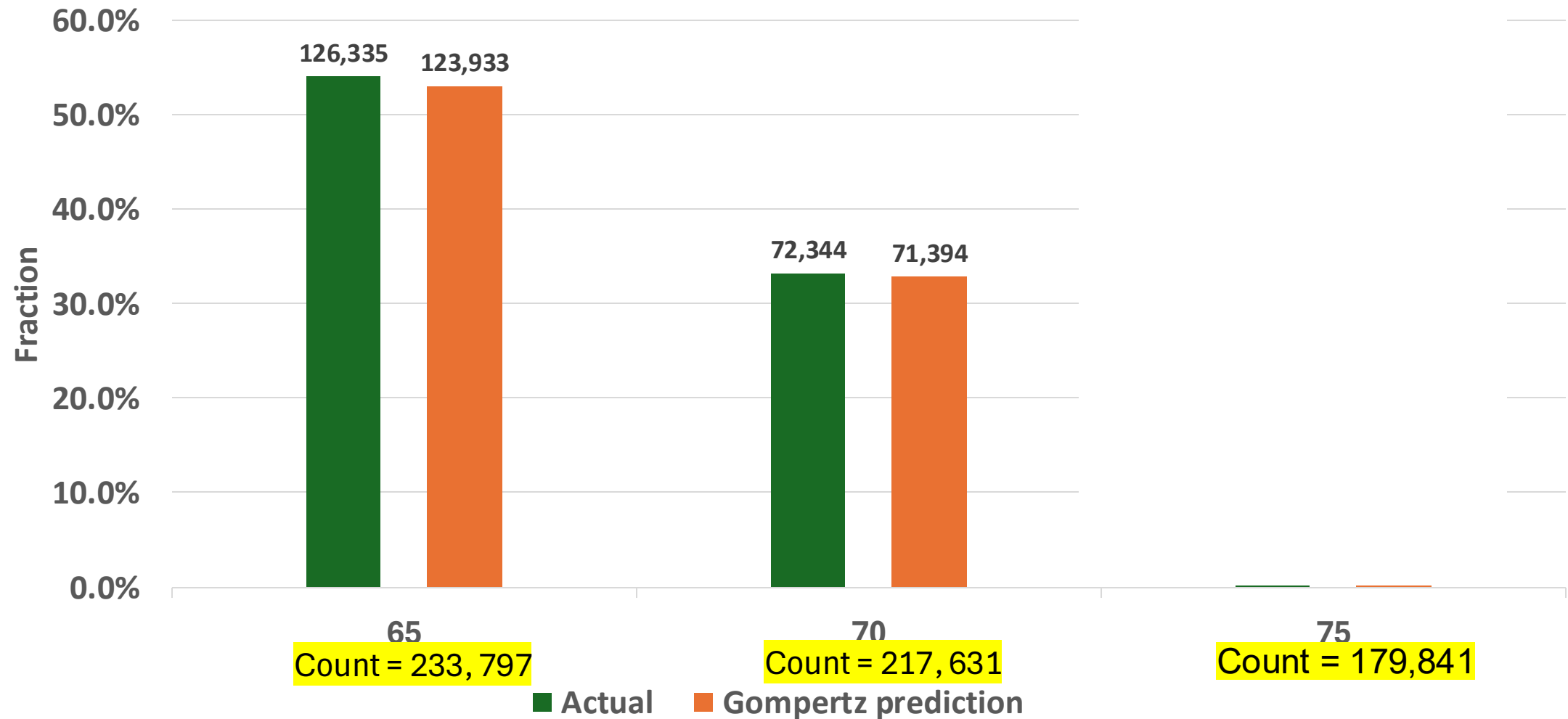
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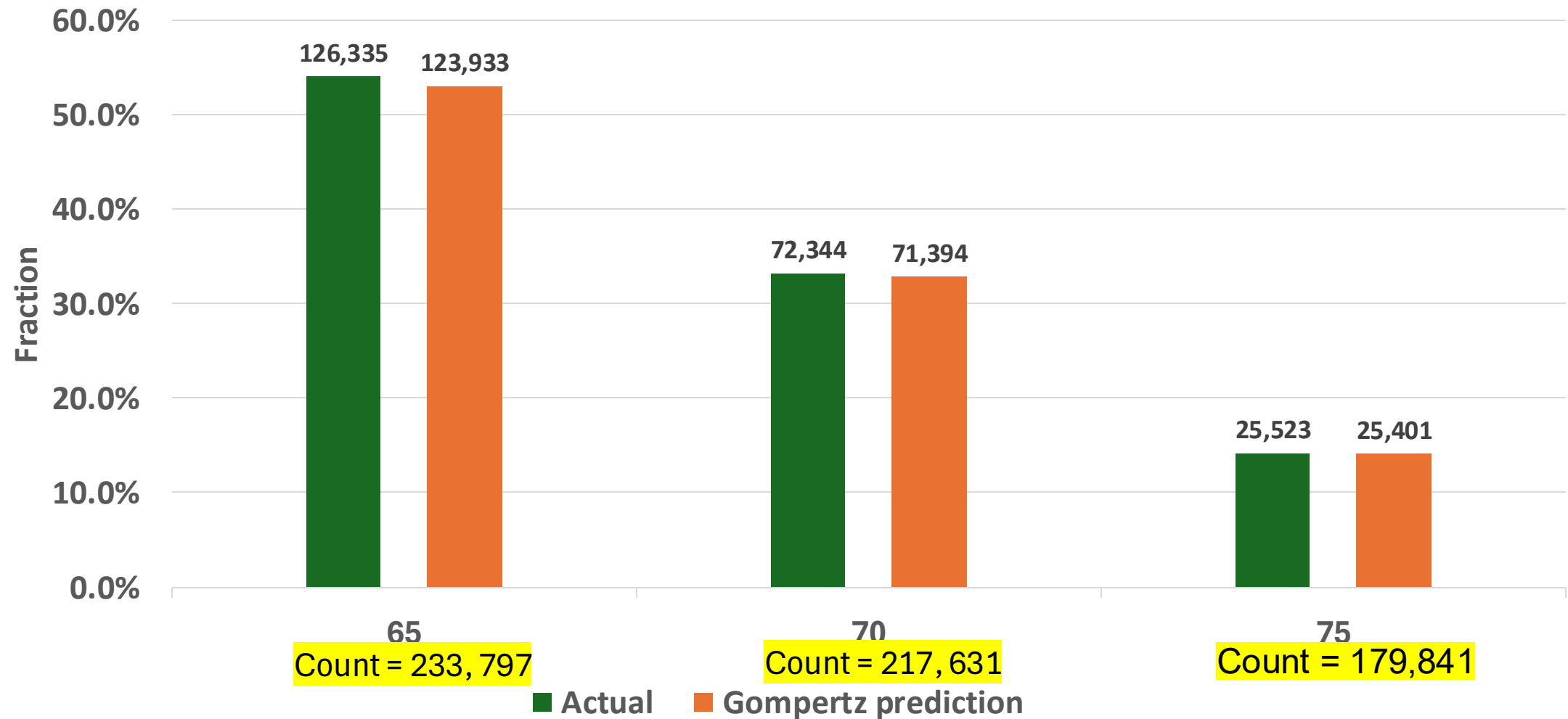
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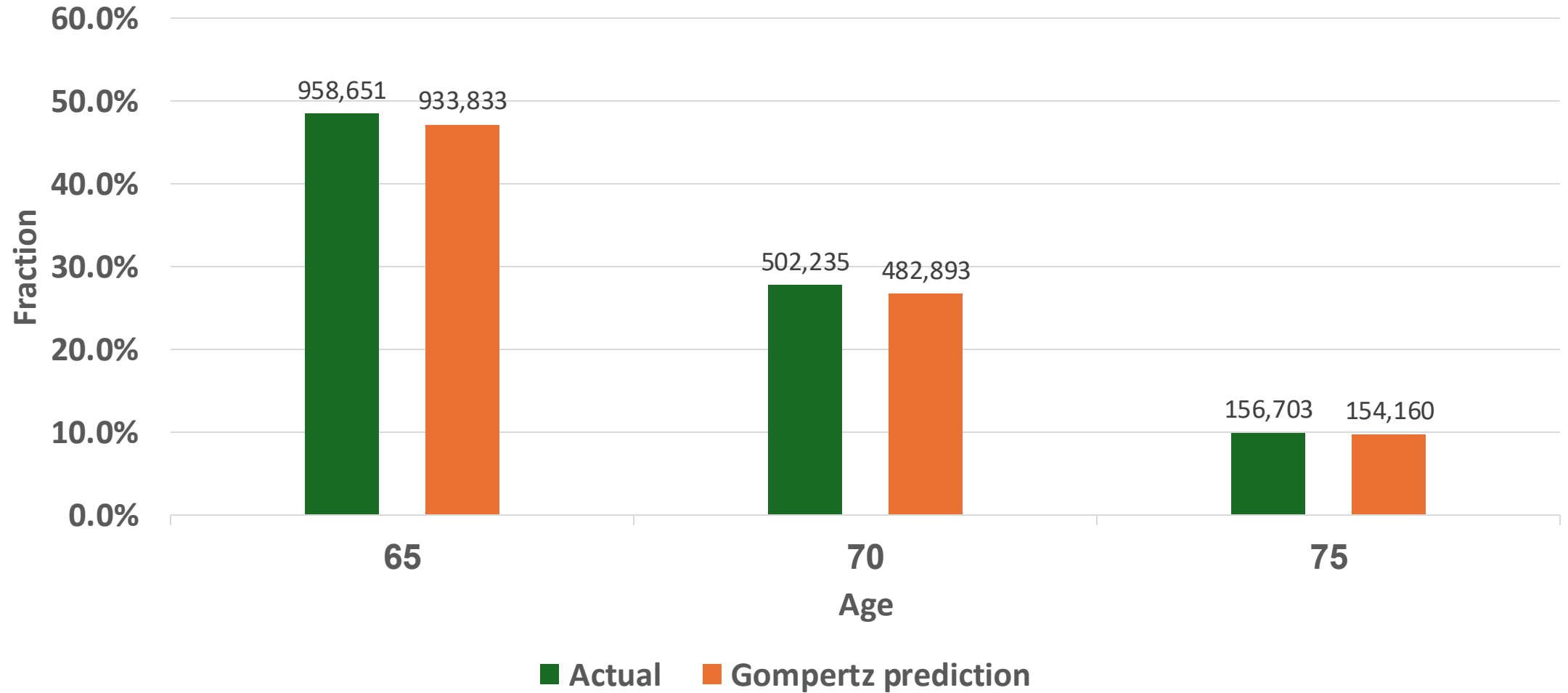
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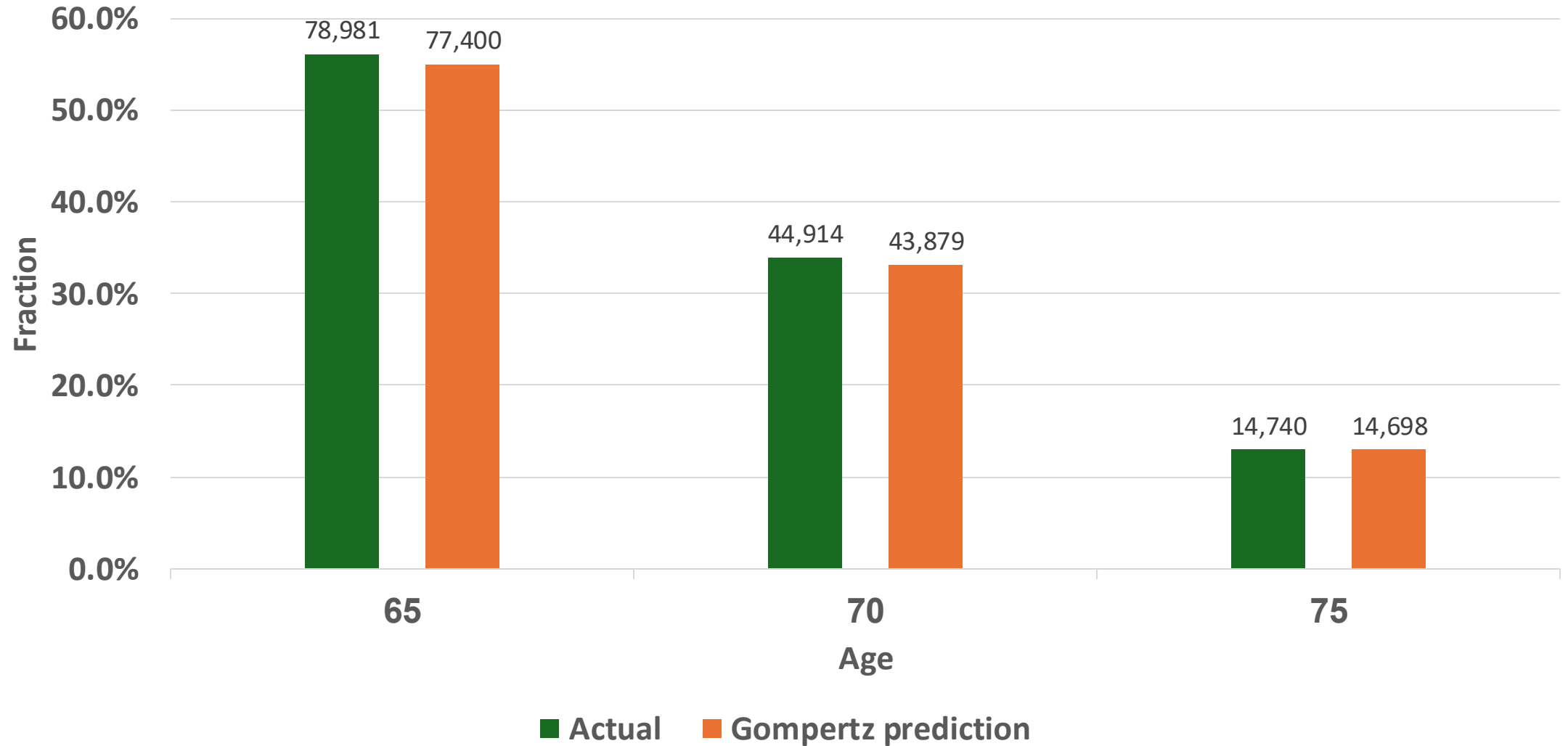
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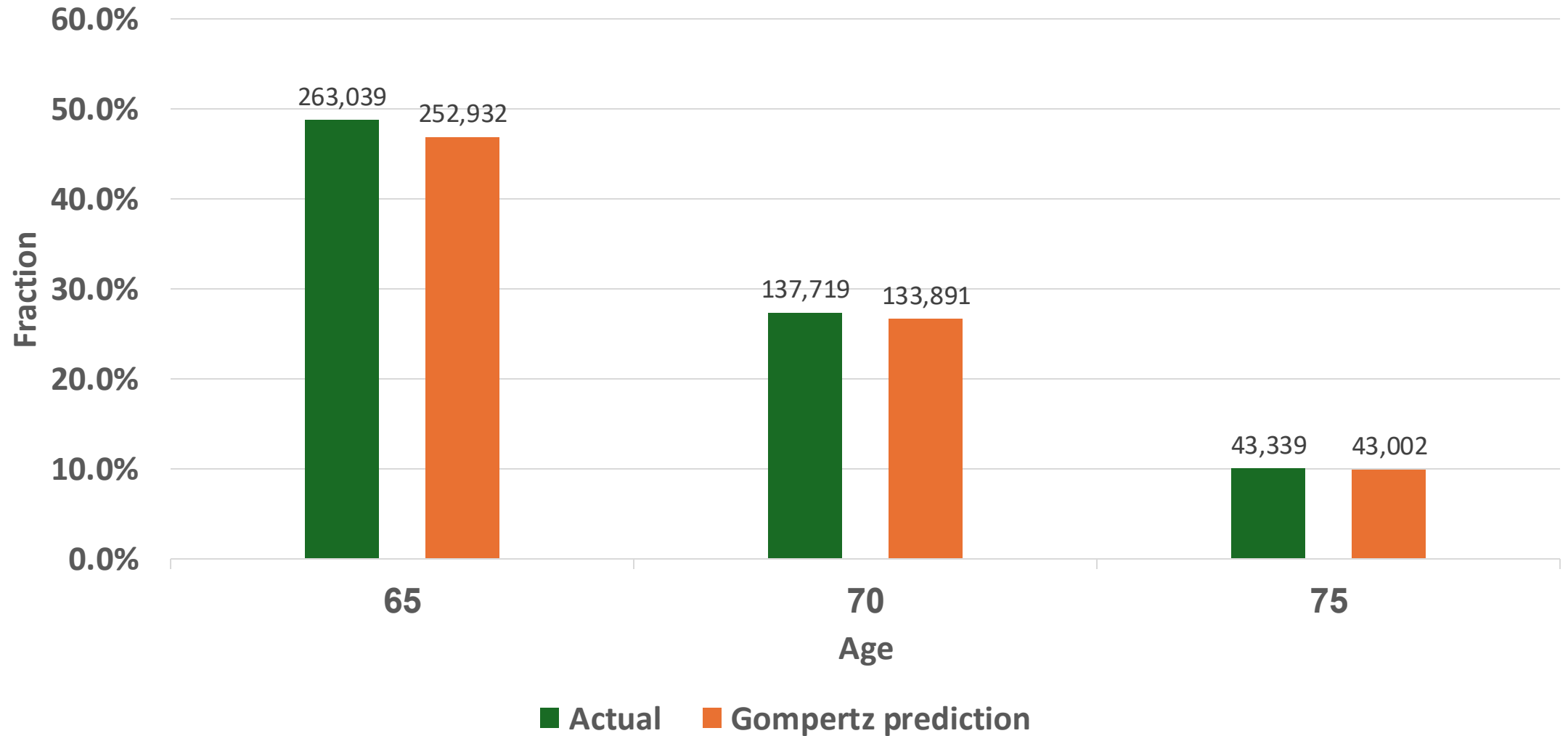
## Year 2000 Survival rate to 2020 in the U.S. ( $m = 86.56$ , $b = 8.84$ )



## Year 2000 Survival rate to 2020 in Australia (m = 88.46, b = 8.14)



## Year 2000 Survival rate to 2020 in U.K. ( $m = 86.48$ , $b = 8.96$ )



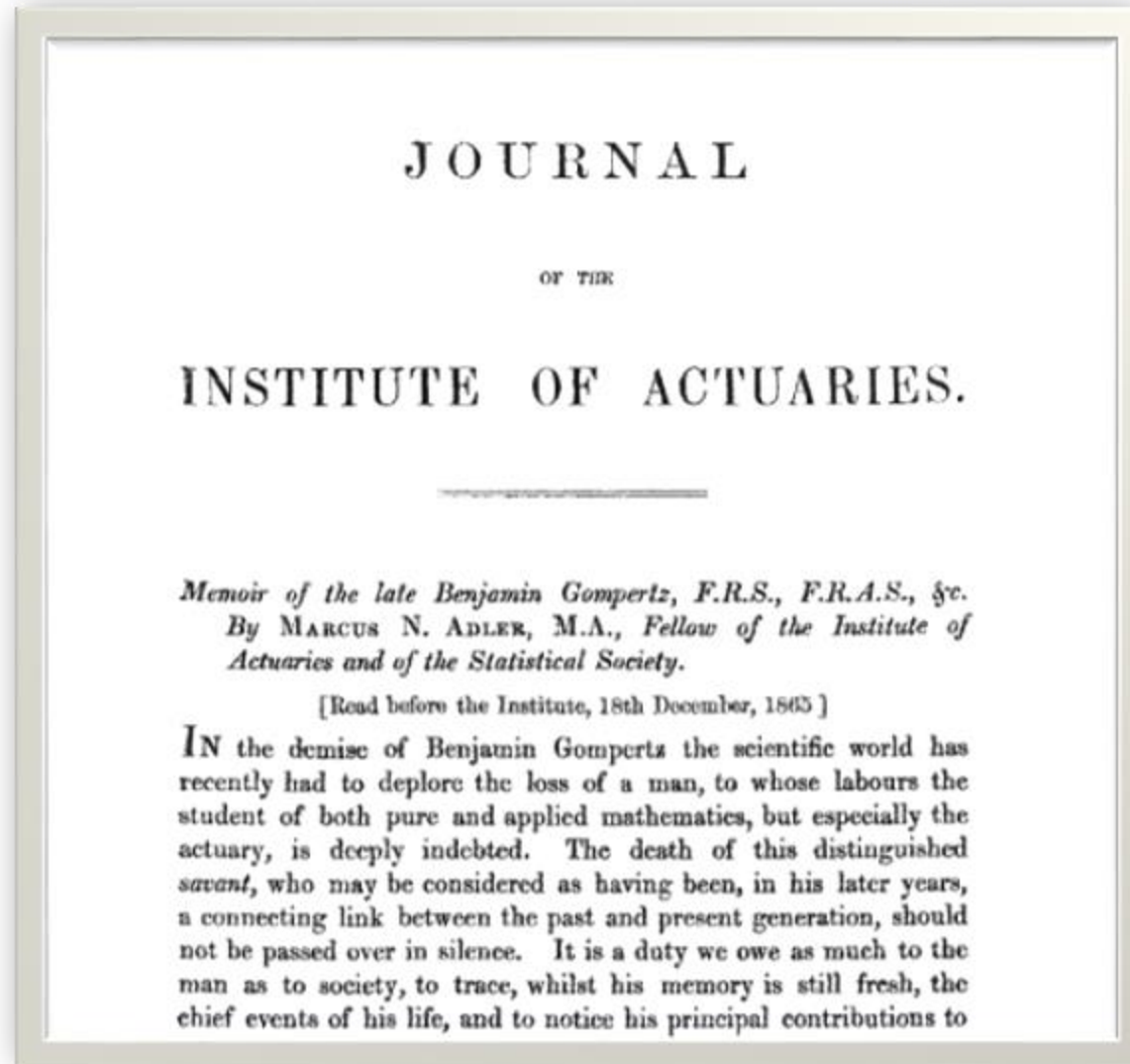
**My point?**

**It's a great pedagogical tool.**

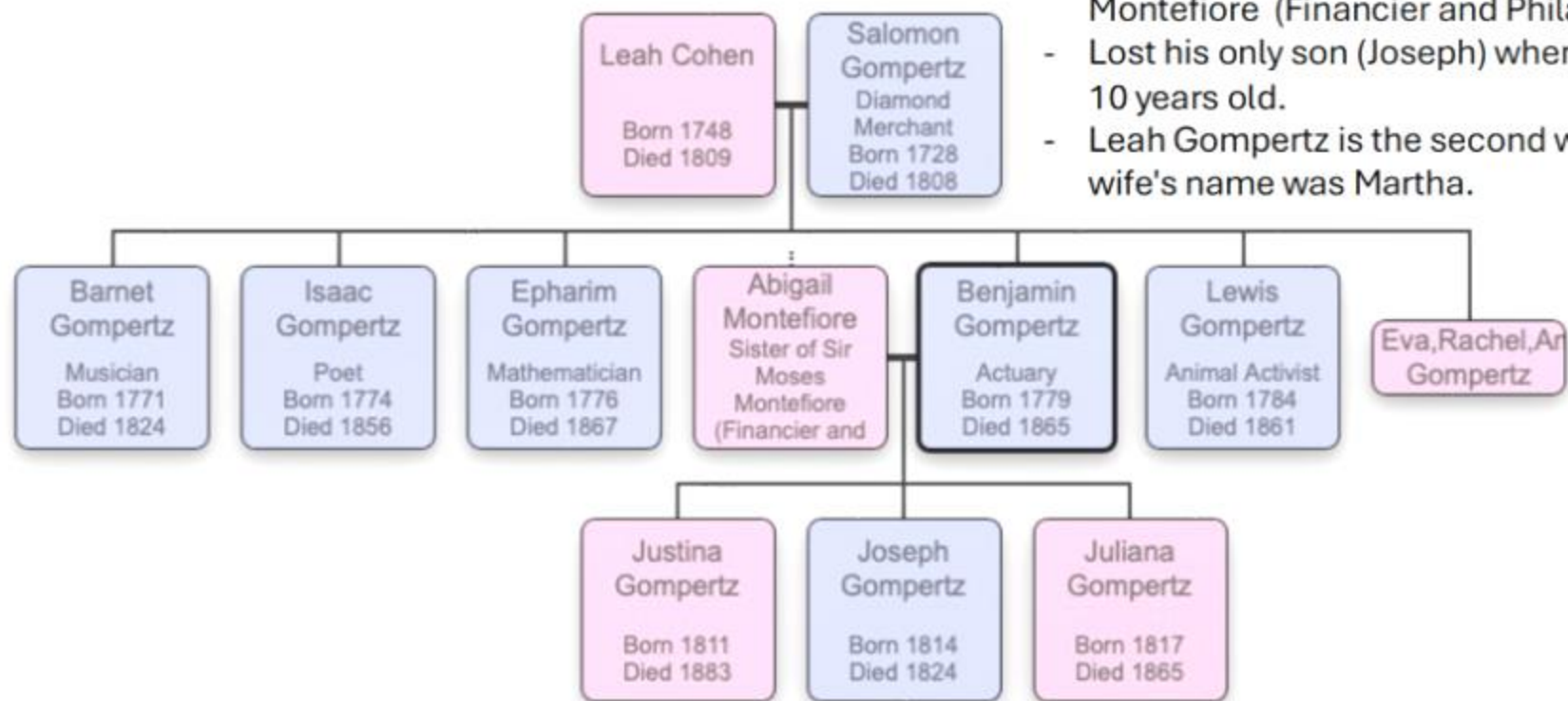
## Part III:

**Benjamin Gompertz engaged with  
issues that were of interest to  
financial economists...**

Adler, M. N. (1866). Memoir of the late Benjamin Gompertz.  
*Journal of the Institute of Actuaries*, Vol. 13(1), pg. 1-20.



# Gompertz Family Tree



## Items to Note about the Gompertz Family:

- Born into a family of wealthy Jewish Diamond Merchants.
- Brothers all lead successful lives (pursuing one's passions).
- Married (1810) the sister of Sir Moses Montefiore (Financier and Philanthropist).
- Lost his only son (Joseph) when he was just 10 years old.
- Leah Gompertz is the second wife. First wife's name was Martha.



Staple Inn, High Holborn



Me at the Institute and Faculty of Actuaries



Staple Inn, High Holborn

# Second Marriage: Pricing when "No Data Given"

Directors entitled to action without losing every benefit, he should on their opinion receive from the fund, the ~~share~~ <sup>share</sup> to be ~~submitted~~ to allow a similar beneficial valuation or even ~~agreed~~ <sup>any</sup> ~~more~~ <sup>advantageous</sup> one according to the state of his health ~~prove~~ <sup>be</sup> the benefit ~~did not exceed~~ was less than the value ~~agreed~~

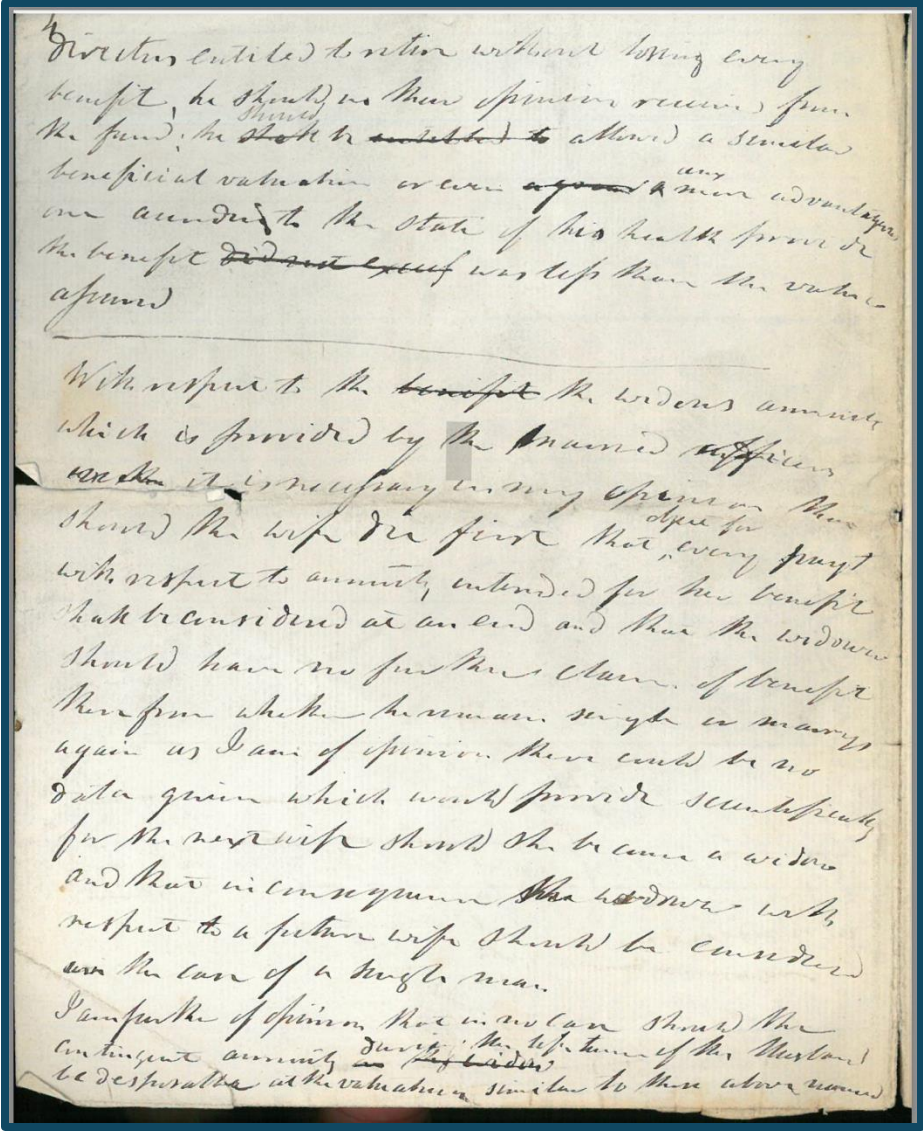
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With respect to the ~~benefit~~ the widows annuity which is provided by the ~~named~~ <sup>named</sup> ~~officers~~ <sup>officers</sup> ~~and~~ <sup>it is necessary</sup> ~~to~~ <sup>to</sup> ~~express~~ <sup>my</sup> ~~opinion~~ <sup>on</sup> ~~that~~ <sup>the</sup> ~~the~~ <sup>wife</sup> ~~die~~ <sup>first</sup> that <sup>due</sup> ~~every~~ <sup>part</sup> with respect to annuity intended for her benefit shall be considered at an end and that the widower should have no further claim of benefit therefrom whether he remain single or marry again as I am of opinion there could be no data given which would provide ~~clearly~~ <sup>clearly</sup> for the next wife should she become a widow and that in consequence ~~the~~ <sup>the</sup> ~~widow~~ <sup>widow</sup> with respect to a future wife should be considered as the case of a single man.

Furthermore of opinion that in no case should the contingent annuity <sup>due</sup> ~~be~~ <sup>to</sup> ~~the~~ <sup>the</sup> ~~widow~~ <sup>widow</sup> be ~~desirable~~ <sup>at</sup> ~~the~~ <sup>the</sup> ~~valuation~~ <sup>valuation</sup> similar to those above ~~mentioned~~

Gompertz, Benjamin and Marcus N Adler. Manuscript notebooks and papers of Benjamin Gompertz bequeathed in July 1865 to Marcus Adler, ca. 1836-1864.

# Second Marriage: Pricing when "No Data Given"



"...With respect to the benefit the widows' annuity that should the wife die first that object which is provided by the married officers it is necessary in my opinion for every payment with respect to annuity intended for her benefit shall be considered at an end and that the widower should have **no further claim of benefit** therefore **whether he remain single or marries again** as I am of opinion there could be **no data given** which **would provide scientifically** for the next wife should she become a widow."

Gompertz, Benjamin and Marcus N Adler. Manuscript notebooks and papers of Benjamin Gompertz bequeathed in July 1865 to Marcus Adler, ca. 1836-1864.

# Insurance is "Not to Gamble"

was not to be confined to continue at the rates commenced with  
 of the experience of the association subsequently, showed that  
 they were neither sufficient in amount nor were charges nor  
 in equitably regulated with respect to different ages,  
 therefore the law which bound the association to adopt  
 plans, adopted before experience taught how the  
 rules should be regulated - was a law which might  
 have destroyed the association, at its commencement -  
 And many of the associations were destroyed, at their  
 commencement, - at the time the equitable association  
 was in a flourishing condition; and distributing bonuses of  
 large amounts - What had their rates been properly  
 regulated, as the charge ought not have surpassed the  
 risk incurred, there would have been no business to  
 distribute - The spirit of assurance is not to gamble,  
 but to pay the proper rate against the risk assured  
 for - But the immense bonuses which some of the  
 old assurances obtained, on what I consider a false principle  
 to the prejudice of the Body at large, have misled  
 assurance in all establishments to expect advantages which  
 they cannot obtain, and have completely reversed the  
 advantages which capitalists ought to obtain from a large  
 security capital and unlimited risk. By creating a competition  
 among the offices which many ultimately find a hazard  
 to which my paper is endeavoring to <sup>think or</sup> draw men from, and not  
 then were satisfied by the enormous premiums of the assured  
 and as I feel confident that the valuable and faithful  
 reports of the two Messrs <sup>Adler</sup> ~~Adler~~, should <sup>be</sup> ~~be~~ my countrymen  
 lead to the conclusions I have come to in my paper,  
 might not to be felt offensive to the association or to the talented  
 actuary, Mr Arthur Morgan, but should by them, and by all  
 assurance establishments, be hailed as a benefit, I am then  
 more inclined to believe that, if my pen, for duty, considered  
 might lead to a means of <sup>improving</sup> ~~improving~~ the future state of the  
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"...the spirit of Assurance is **not to gamble** but to pay the proper rate against the risk assured for - but the bonuses, which some of the old assurers obtained, on what I consider a **false principle** to the prejudice of the Body at large; have misled assurers in all establishments to **expect advantages which they cannot obtain** and have completely ruined the advantages which capitalists ought to obtain from a large security capital and unlimited risk by **creating a competition** among the offices."

Gompertz, Benjamin, and Marcus N Adler. Manuscript notebooks and papers of Benjamin Gompertz bequeathed in July 1865 to Marcus Adler, ca. 1836-1864.

# Your Paper is "Unnecessarily Bulky"

of very useful tables and formulas after the same plan in different varieties of single and two joint lives and a few of three joint lives together with useful additions but still without supplying the desiderata attended. But in my paper on the Law of mortality I gave tables by which many joint lives might with small difficulty be obtained but still there remained the difficulty of the computation of problems being solved by those tables by reducing all of them into joint lives which I felt ought to be remedied. The receipt of which will appear by the following problem to find the value of  $\mathcal{L}$  to be received at the death of the longest of five persons of the respective ages of  $a, b, c, d, e$  at the rate per cent  $i$  which would be

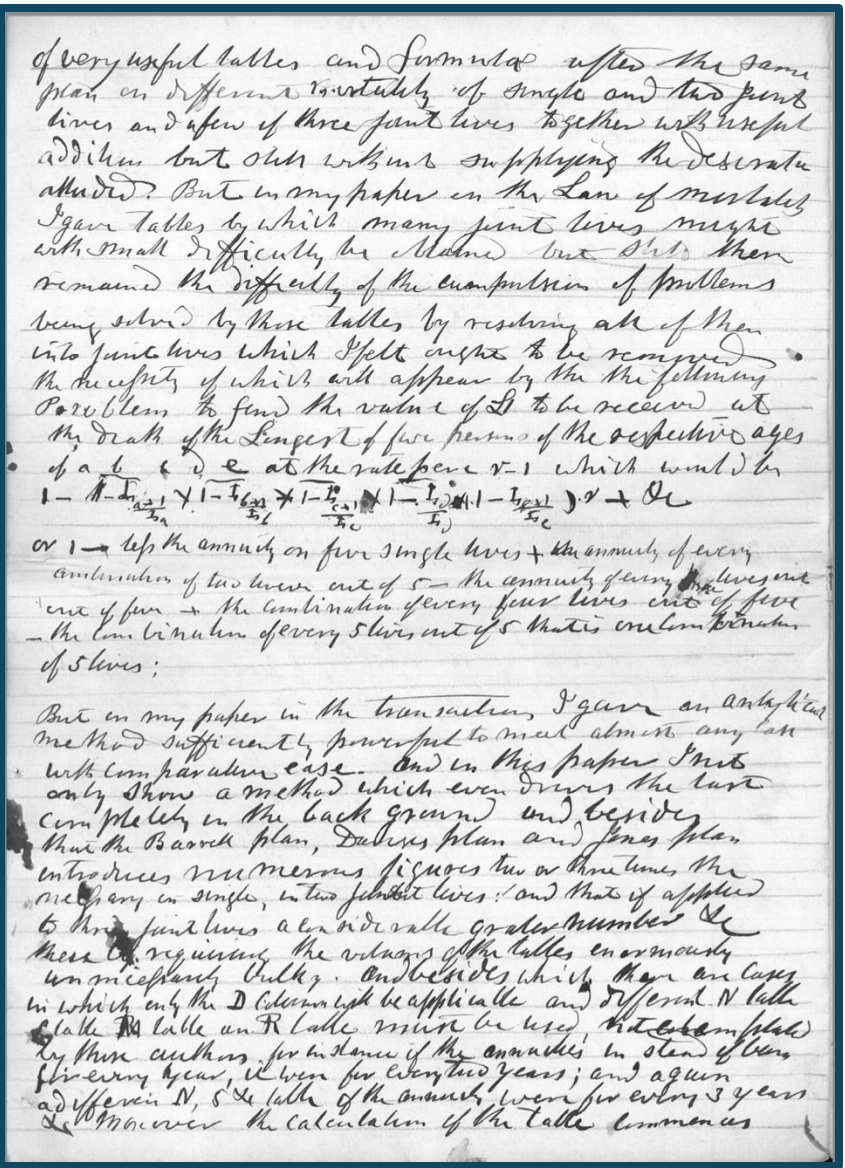
$$1 - \frac{1 - \frac{1}{x_a}}{i} \times (1 - \frac{1}{x_b}) \times (1 - \frac{1}{x_c}) \times (1 - \frac{1}{x_d}) \times (1 - \frac{1}{x_e}) \times i \rightarrow \mathcal{L}$$

or  $1 \rightarrow$  the annuity on five single lives + the annuity of every combination of two lives out of 5 - the annuity of every three lives out of five + the combination of every four lives out of five - the combination of every 5 lives out of 5 that is one combination of 5 lives;

But in my paper in the transactions I gave an analytical method sufficiently powerful to meet almost any case with comparative ease. And in this paper I not only show a method which even drives the last completely in the back ground and besides that the Bachel plan, Davies plan and Jones plan introduces numerous figures two or sometimes three in single, in two joint lives and that if applied to three joint lives a considerable greater number of these  $\mathcal{L}$  requiring the values of the tables enormously unacceptably bulky. And besides which there are cases in which only the D column will be applicable and different  $N$  table shall be used and R table must be used. It is contemplated by these authors for instance if the annuities in stead of being for every year, it were for every two years; and again if different  $N, S$  table of the annuity were for every 3 years &c. Moreover the calculation of the table becomes

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# Your Paper is "Unnecessarily Bulky"



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# Break "In Case of Pregnancy" ... and Let's Collude

Insurance Office  
July 12<sup>th</sup> 1856

Dear Sir

In answer to your enquiry I beg to state that the practice of our Office in case of Pregnancy is to make no extra charge if the Insurance be effected for the whole duration of life, but if the Insurance be made for 1 or 7 years we charge an extra Premium of 20/- per cent on the sum insured. In some cases such as first Pregnancy at an advanced age or some apprehension on the part of the medical adviser of the Company that danger may attend the delivery we have deviated from the above Rule. I think the Insured some other Offices act in a similar manner

I am  
Dear Sir  
Yours faithfully  
Giffith Davis

B Gompertz Esqr

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I am  
Dear Sir  
Yours faithfully  
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B Somersby Esq

"...Dear Sir, In answer to your enquiry I beg to state that the practice of our office **in case of Pregnancy** is to make no extra charge if the Insurance be effected for the whole duration of Life but if the Insurance be made for 1 or 7 years we charge an **extra Premium of 20/- per Cent** on the sum Insured. In some cases such as first Pregnancy at an advanced age or some apprehension on the part of the medical adviser of the Company that danger may attend the delivery we have deviated from the above Rate. I think the **Sun and some other Offices act in a similar manner.**"

# Background - The Great Recoinage Act of 1816

384

C. 68.

56<sup>o</sup> GEO. III.

A.D. 1816.

## C A P. LXVIII.

An Act to provide for a New Silver Coinage, and to regulate the Currency of the Gold and Silver Coin of this Realm.

[22d June 1816.]

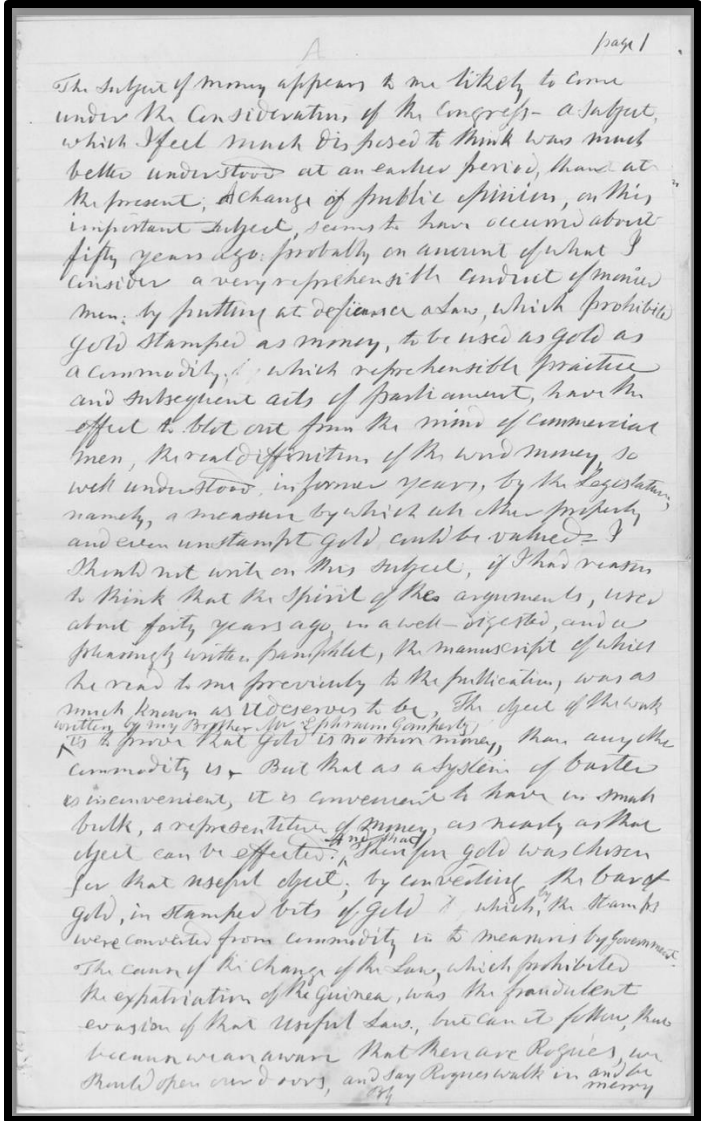
‘ WHEREAS the Silver Coins of the Realm have, by long Use and other Circumstances, become greatly diminished in Number and deteriorated in Value, so as not to be sufficient for the Payments required in Dealings under the Value of the Current Gold Coins, by Reason whereof a great Quantity of Light and Counterfeit Silver Coin and Foreign Coin has been introduced into Circulation within this Realm; and the Evils resulting therefrom can only be remedied by a new Coinage of Silver Money, to be made and issued under proper Regulations for maintaining its Value and preserving the same in Circulation;’ Be it therefore enacted by The King’s Most Excellent Majesty, by and with the Advice and Consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the Authority of the same, That from and after the passing of this Act, so much of an Act made in the Eighteenth Year of the Reign of His late Majesty King *Charles the Second*, intituled *An Act for encouraging of Coinage*, and also so much of all and every other Act and Acts as provide and enact that whatsoever Person or Persons, Native or Foreigner, Alien or Stranger, should bring any Foreign Coin, Plate or Bullion of Silver, in mass, molten or alloyed, or any Sort or Manufacture of Silver, into His Majesty’s Mint or Mints within the Kingdom of *England*, to be there melted down and coined into the Current Coins of this Kingdom, should have the same there assayed, melted down and coined with all convenient Speed, without any Defalcation, Diminution or Charge for the Assaying, Coinage or Waste in Coinage, so as that for every Pound Troy of Sterling or Standard Silver that should be brought in and delivered by him or them to be assayed, melted down and coined as aforesaid, there should be delivered out to him or them respectively a Pound Troy of the Current Coins of this Kingdom, of Sterling or Standard Silver, and so proportionably for a greater or lesser Weight, or more or less, in Proportion to the Excess or Deficiency in Fineness of any such Bullion, shall be and the same is and are hereby repealed.

18 Car. 2. c. 5.  
§ 1. in part  
repealed.

“...Be it therefore enacted, That from and after the passing of this Act, **the Gold Coin of this Realm shall be and shall be considered and is hereby declared to be the only legal Tender for Payments** (except as hereinafter provided) within the United Kingdom of Great Britain and Ireland; being the Weight and Fineness of the Mint Indenture...”

The Statutes of the United Kingdom of Great Britain and Ireland, 56 George III. 1816. *His Majesty's Statute and Law Printers.*

# Using Gold as "Barter is Inconvenient"



”...The **real definition** of the word **money**, so well understood in former years by the legislation, namely, **a measure** by which all other property and even unstamped gold could be **valued**.

...written by my brother **Mr. Ephraim Gompertz** is to prove that **gold is no more money than any other commodity** is -but that **as a system of barter is inconvenient**, it is convenient to have in small bulk a representation of money.”

Gompertz, Benjamin, and Marcus N Adler. *Manuscript notebooks and papers of Benjamin Gompertz bequeathed in July 1865 to Marcus Adler, ca. 1836-1864.*

# Gold Standard?! What if We Find a “Mountain of Gold”

I wish then for papers for the consideration  
 of the Congress the following questions for solution.  
 How would the Land holder be affected, if he had  
 let his Land for a term of years for a certain annual  
 amount of Sovereigns, in case of a discovery of a mountain  
 of gold of various sizes and portions if the payment he  
 had to receive were in pieces of gold equivalents  
 of which in value, any one might procure by a  
 pleasant walk to the mountain. How would the  
 National creditor be affected by such a discovery,  
 who would give him bond for his Sovereigns  
 what laborer would work for him. For Sovereigns  
 would the farmer be satisfied with Sovereigns for  
 his corn, who would become of the advantage  
 of all contracts for the future stipulating for  
 payment in Sovereigns, which had been thought  
 a measure of value for all commodities, if it  
 were found out that they were not so, and that  
 the contracts were not for a measure of a portion  
 of wealth which the thing contracted for was worth,  
 entitled to come to the good of a Country,  
 at large to have no easy and secure representation  
 of portions of the value of the wealth of the Country, And  
 should it not be understood that if a Government  
 contracts for a Loan, to assist to preserve the welfare  
 of the Nation, that though the Loan be nominally  
 stated for Sovereigns it is for so much of the wealth  
 of the Country, as the Sovereigns are at that time  
 considered to represent at a medium of exchange  
 from one species of property to another  
 should it not be considered that when Loans become  
 from the contractors, a loan from the individuals of  
 a paternal Government, by the division of it  
 from the contractors, who gain all

Bh

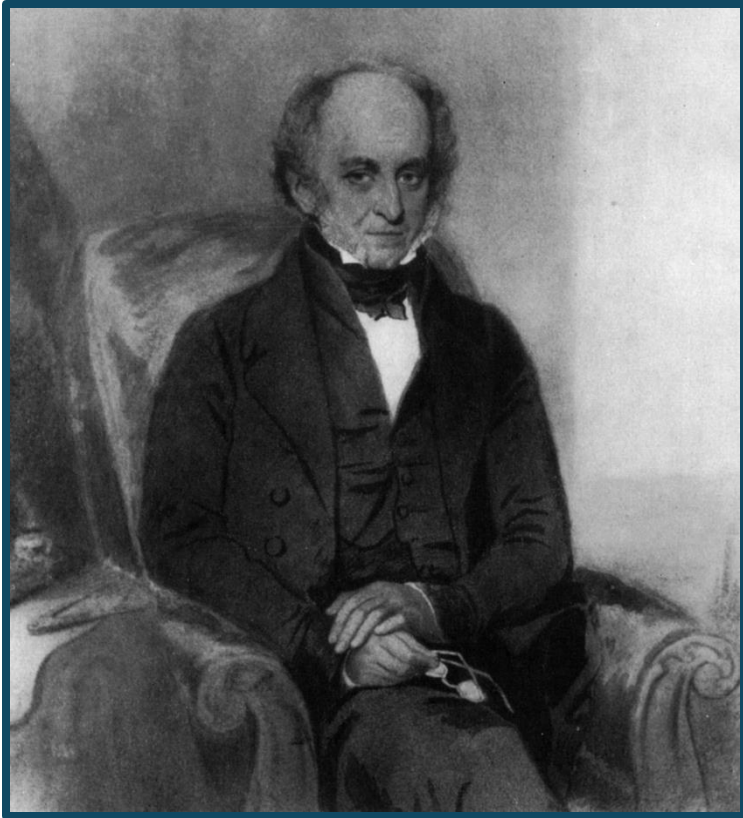
“...The cause of the change of the law, which prohibited the expatriation  
 of the Guinea, was the fraudulent evasion of that useful law, but can it  
 follow that because we are aware that there are rogues, we should  
**open our doors and say rogues walk in and be merry.**

...How would the land holder be affected if he had let his land for a  
 certain term of years for a certain annual amount of sovereigns in case  
 of a **discovery of a mountain of gold** of various sizes and portions if the  
 payment he had to receive were in pieces of gold equivalents of which  
 in value **any one might procure by a pleasant walk to the mountains.**”

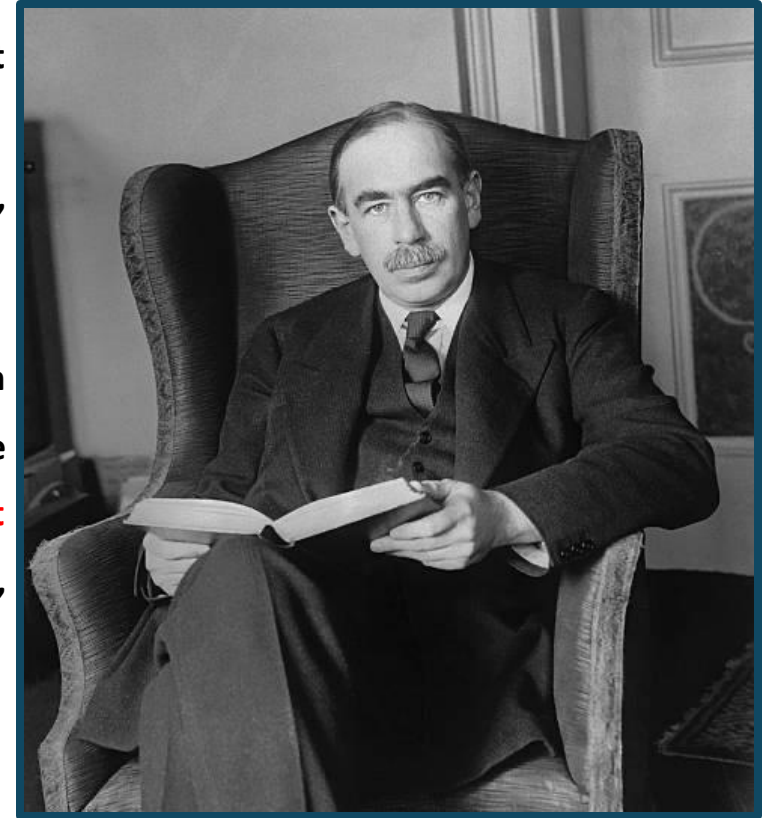
# Let's Compare Giants - Gompertz vs. Keynes

## Keynes Said

- “The gold standard is already a **barbarous relic**” (Tract on Monetary Reform, 1923).
- “The duty ... **cannot safely be left in private hands**” (General Theory, 1936).
- “The thing for Government is not to do things which individuals are doing already, and to do them a little better or a little worse; but to **do things at present which are not done at all**” (The End of Laissez Faire, 1927).



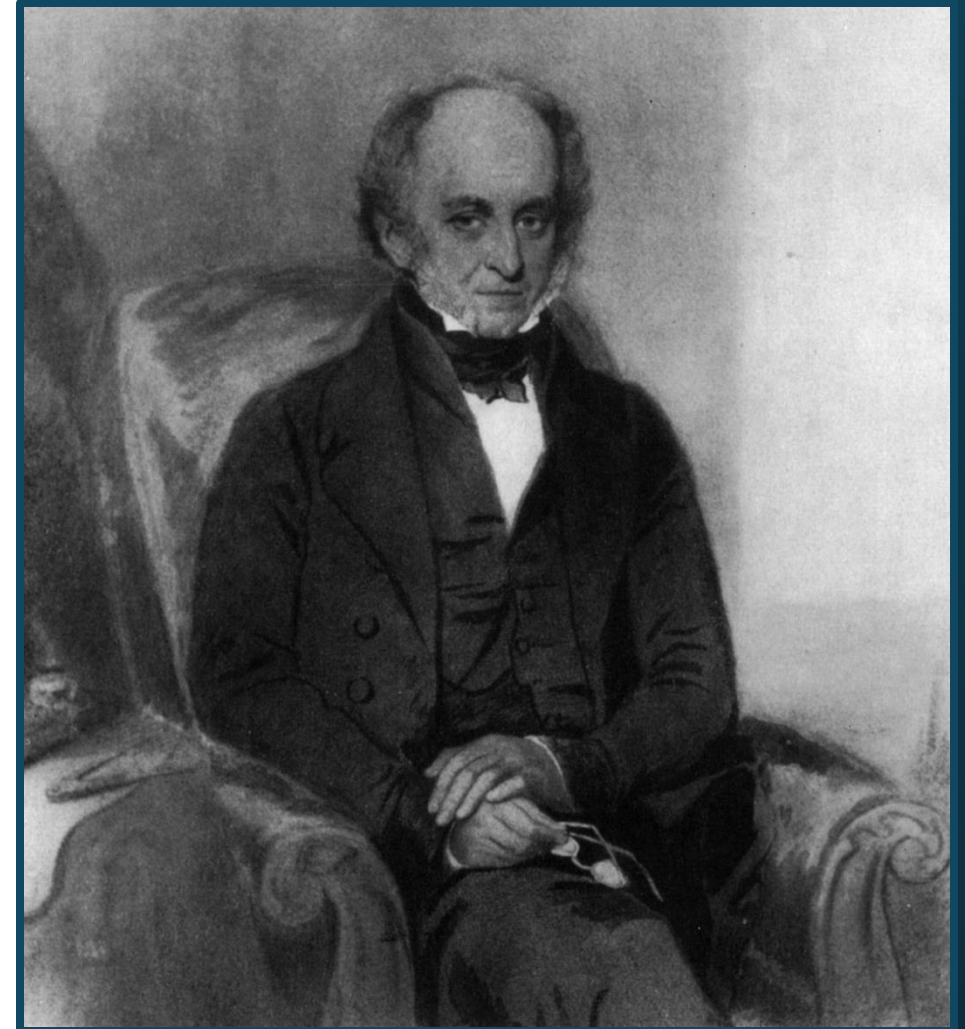
Benjamin Gompertz, b.1779 – d.1865



John Maynard Keynes, b.1883 – d.1946

## Ok, What Did I Learn Today?

- The Gompertz model is still used today because it's a good approximation and helps us 'think' about mortality.
- The historic Benjamin Gompertz was more than an actuary or demographer.
- His insights on financial economics were quite prescient ... for his time.



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- **Finaly, he granted his (lucky) pets a reversionary life annuity.**
- **Thank you!**

