Adverse Selection in Annuity Markets: Evidence from the British Life Annuity Act of 1808

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Abstract

We look for evidence of adverse selection using data from an 1808 Act of British Parliament which effectively opened up a market for life annuities. Our analysis indicates significant selection effects. The evidence for adverse selection is particularly strong among a sub-sample of annuitants whose annuities were purchased by profit-seeking speculators. We find evidence of additional selection among self-nominated annuitants after the annuities were re-priced to reflect the observed longevity of the early annuitants. The pattern of selection effects is reminiscent of the early stages of an Akerlovian “death spiral,” suggesting that adverse selection may be an important factor underlying the paucity of annuity sales in contemporary annuity markets. The magnitudes indicate that it is unlikely to be a complete explanation.

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1 Introduction

In 1808, Britain’s Parliament passed the Life Annuity Act, effectively opening a market for government-provided life annuities. The unique features of the Act provide an unusual opportunity to explore the empirical importance and consequences of adverse selection.

Adverse selection has played an important role in economic theory since the seminal works of Akerlof (1970), Spence (1973), and others. Studying its empirical importance has proved challenging in several respects. First, as emphasized by Chiappori and Salanié (2000), it is difficult to empirically distinguish between moral hazard and adverse selection.

Second, informational asymmetries are likely to extend to researchers, who are unlikely to observe information hidden from the insurance provider. This has motivated the development of tests relying only on ex-ante observable information and ex-post outcomes. As described in Dionne et al. (2001), these test for a correlation between insurance choices and ex-post risk, conditioning on information observable by the insurance provider. Even these tests can pose empirical challenges, since econometricians may not even have access to all information symmetrically known by the market participants.

Third, the existing empirical evidence for even the most robust consequences of informational asymmetries is less than definitive. For example, Cawley and Phillipson (1999) find no evidence of selection in life insurance markets, Cardon and Hendel (2001) find no evidence in health insurance markets, and Chiappori and Salanié (2000) and Dionne et al. (2001) find no evidence of adverse selection in auto insurance markets (overturning Peltz and Snow’s (1994) suggestive evidence). Some economists have recently argued that this absence of evidence may be due to countervailing informational advantages of the insurance provider (Villeneuve, 2003) or else to a fourth empirical challenge: the confounding effects of “advantageous” selection via heterogeneity in risk aversion (DeMeza and Webb, 2001, Cohen and Einav, 2007, and Finkelstein and McGarry, 2006).

Annuity markets provide a particularly interesting setting to study informational asymmetries, not least because many of these empirical challenges are less acute than in other insurance settings. In annuity markets, “adverse” selection is expected to lead to a particularly healthy and long-lived annuitant pool, relative to the population as a whole. This means both that moral hazard is plausibly negligible and that heterogeneity in risk aversion is likely to be adverse-selection enhancing in annuity markets. Furthermore, annuity
providers do minimal risk-classification in practice, so researchers can more easily identify characteristics “selected on” by annuitants.

In part for these reasons, annuity markets are one of the few settings in which direct evidence of adverse selection has been documented (Finkelstein and Poterba, 2002, 2004, 2006). Unfortunately, the applicability and generality of this evidence is limited for at least two reasons. First, the evidence comes from a “compulsory” market, wherein annuitization is mandatory. Second, a substantial literature documents a puzzling dearth of voluntary annuitization, and understanding this puzzle is crucial for interpreting any evidence of informational asymmetries in annuity markets.

This paper uses the 1808 Act to provide a novel empirical look at adverse selection in the purely voluntary annuity market effectively opened thereby. We provide evidence of adverse selection by comparing the age- and gender-specific population and annuitant longevities. Since annuity pricing under this Act varied only by age and gender, our evidence is indicative of selection relative to the risk-classification scheme employed by U.K. government. Insofar as we do not have data on the entire set of information available to the U.K. government, however, we cannot distinguish perfectly between “selection on observables” (as in Finkelstein and Poterba, 2006) and “pure” adverse selection (as in Dionne et al., 2001).

Beyond documenting adverse selection in a voluntary annuity market, this paper makes two main contributions. First, an odd feature of the 1808 Act permitted “speculators” to purchase annuities on the lives of others. In Section 4, we show that the active selection of lives by these speculators was significantly stronger than the passive selection by self-nominees.

Second, the Act’s history also provides a unique opportunity to study the first stages of the type of “death spiral” dynamics found by Cutler and Reber (1998) (but not by Buchmueller and DiNardo, 2002) in health insurance markets. In Section 5, we show that the pattern of selection effects are suggestive of the early stages of such a death spiral, but that the magnitudes indicate these dynamics would not have been sufficient to completely unravel the market. This is important in light of the extensive literature on the under-annuitization “puzzle,” since it provides suggestive evidence that, while adverse selection is likely a contributing factor, a “death spiral” is unlikely to fully explain the dearth of annuity sales in contemporary markets.

Before we turn to our main results, Section 2 describes the 1808 Life Annuity Act and its subsequent evolution. Section 3 describes the available data. Since these data are in an awkwardly condensed form that renders
standard survival-curve analysis impossible, Section 3 also develops a simple
Z-test method for analyzing them; details are contained in a brief technical
appendix. Section 6 concludes.

2 The 1808 Act

Prior to the Life Annuity Act of 1808, British government debt consisted
almost exclusively of Consols – coupon bonds with infinite maturity. The
explicit goal of the Act was to replace Consols with finite-lived debt by allow-
ing the exchange of Consols for life annuities.\(^1\) Since Consols were tradable
assets, the act effectively opened a life-annuity market.

Annuities sold under this act made twice-annual tax-exempt payments.
The size of these payments depended on the interest rate (the market Consol
prices) and the age of the annuitant (henceforth: the nominee). Prices were
designed to be actuarially fair; to that end, they were priced to be 2% more
expensive than the actuarially fair price implied by the Northampton life
table. This table, first published by Richard Price in 1771,\(^2\) was based on
the mortality experience of all residents of the town of Northampton and was
used widely by life assurance companies (Francis, 1853).

Nominees had to be at least 35 years of age, and annuity yields were
capped at age 75, strongly discouraging purchases by older annuitants. A
minister- or magistrate-certified register of birth or baptism was required
for age verification. Verification of non-decease was required for receipt of
each payment. Finally, the act allowed individuals to purchase and own
the income stream from annuities on the lives of others (in which case the
nominee was required to be from Britain or Ireland).

Shortly after passage of the Act, there appears to have been a recognition
that the use of the Northampton tables was leading to large government

\(^1\) There may well have been more subtle motivations leading to its passage. Spencer
Perseval, addressing Parliament in 1808 (\textit{viz} Hendricks, 1856), argued that the Act would
allow the government to retire debt at favorable interest rates without causing interest
rates to rise – an argument Murphy ridicules as indicating Perseval’s desire to “have his
cake and eat it too” (Murphy, 1939, page 6) but which is plausible if the government
believed it could extract surplus by filling a missing market. Alternatively, there could
have been a political desire to align the interests of the retired monied classes with the
government by providing for them a valued service – as argued by Weir (1989) for the
French government-issued Tontines of the 18th century.

\(^2\) We transcribed the tables from a republished version in Baily (1813).
losses. Murphy (1939) writes that it “was wholly unsuitable as a measure of
the lower rates of mortality experienced by a self-selected group of annuitants.
It was not long before this shortcoming was brought to the attention of
the Exchequer.” In contrast to Murphy, Francis (1853) suggests that self-
selection may have been minor concern relative to active speculation. He
writes: “The speculators soon found out that the Government charge for
a life annuity afforded a very remunerative investment, and the insurance
offices made considerable profits by purchasing and re-selling them ... The
mistake made by Government in its calculations was no secret.”

In 1823, the Parliament finally took active steps to address this per-
ceived mispricing and commissioned John Finlaison to study the mortality
experience of the early nominees.\(^3\) His 1829 report developed a new set of
gender-specific life tables, known as the Finlaison tables, based on the ob-
served mortality experience of the nominees. After some debate and a brief
suspension of the life annuity program, Parliament determined to resume it
with gender-specific pricing based on these new tables.

This re-pricing made annuities significantly more expensive – especially
for females. For example, periodic payments fell by 4.4% and 17% for sixty
year old males and females, respectively (author’s calculations, based on
pricing in Hendriks, 1856). It ironically appears to have coincided with a
boom in “speculation,” however, as a result of a contemporaneous decision
to increase the maximum yield to age 90. The old-age mortality experience
underlying Finlaison’s tables (hence new annuity prices) was primarily that
of young nominees who subsequently grew old. John Francis (1853) relates
a number of amusing anecdotes about speculators realizing that this likely
overstated the mortality of actively selected older lives and making profits
by combing the countryside for healthy old men to nominate for annuities.\(^4\)

To address this speculation, an 1834 law reduced the maximum yield
to age 80, and, in practice, eliminated speculative purchases above age 65
(Murphy, 1939); speculation was banned outright in 1852 (Cohen, 1953). The
market for self-nominees continued, with periodic revisions to the life tables,
until its dissolution under Parliament’s 1962 Finance Act. Murphy (1939)
suggests that these revisions prevented the government from experiencing
significant losses after 1852 – perhaps in part because private companies

\(^3\)He also studied nominees of several earlier (and smaller) life-contingent debt issues.

\(^4\)Among these are tales of speculators paying surgeons and clergymen to maintain the
health of the nominees – a rare case of moral hazard in annuity markets.
entered the market offering better pricing.\footnote{See Hendriks (1856), Murphy (1939), and The Insurance Institute of London (1969) for additional historical details.}

We exploit three features of this unique history in our study. First, Section 3 provides evidence of “selection on observables” by documenting a shift in the gender composition of nominees in favor of men following the adoption of gender-specific pricing in 1829. Second, Section 4 provides evidence of stronger adverse selection effects among speculator-nominated annuitants \textit{vis a vis} self-nominees. Third, we use the re-pricing dynamics to test for the early stages of a “death spiral” in Section 5.

3 Data and Empirical Approach

The only available data are in the highly aggregated form described below. Lacking the individual-level data required for standard survival analysis, we also briefly discuss our techniques for using them to test for selection effects.

3.1 The Data

Data are available from two reports commissioned by Parliament to examine the profitability of the annuities sold under the 1808 Act. The first is John Finlaison’s 1829 report, which contains data on annuities sold between 1808 and 1826. The second is Alexander Glen Finlaison’s 1860 report examining annuities sold between 1808 and 1850.

John Finlaison’s 1829 report contains one data set for each gender. Each set consists of three columns of data. The first column is a list of the number of annuities sold between 1808 and 1826 at each nominee age.\footnote{The data refer to the ages of the \textit{nominee} of a given contract, not the contract’s owner.} The second column gives the number of nominee deaths (between 1808 and January, 1826) at each age. The final column reports the distribution of ages, in January 1826, of all “censored” nominees – i.e., those still living in January 1826. We do not have individual level observations. Rather, \textit{all} we observe are three distributions: an aggregate entry age distribution, an aggregate death age distribution, and an aggregate age-at-censoring distribution for the non-censored and censored individuals, respectively.

The 1860 report is in a similar format, but it contains five distinct three-column data classes. The first three describe three distinct classes of “the
Table 1: Complete Age 59-64 Speculative Nominee Data Set

<table>
<thead>
<tr>
<th>Age</th>
<th>Number Nominated*</th>
<th>Number Dead†</th>
<th>Number Living‡</th>
<th>Age</th>
<th>Number Nominated*</th>
<th>Number Dead†</th>
<th>Number Living‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>68</td>
<td>0</td>
<td>9</td>
<td>36</td>
</tr>
<tr>
<td>60</td>
<td>50</td>
<td>0</td>
<td>4</td>
<td>69</td>
<td>0</td>
<td>5</td>
<td>43</td>
</tr>
<tr>
<td>61</td>
<td>61</td>
<td>1</td>
<td>13</td>
<td>70</td>
<td>0</td>
<td>3</td>
<td>42</td>
</tr>
<tr>
<td>62</td>
<td>91</td>
<td>3</td>
<td>25</td>
<td>71</td>
<td>0</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>63</td>
<td>81</td>
<td>3</td>
<td>17</td>
<td>72</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>64</td>
<td>63</td>
<td>7</td>
<td>17</td>
<td>73</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>65</td>
<td>0</td>
<td>8</td>
<td>2</td>
<td>74</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>66</td>
<td>0</td>
<td>6</td>
<td>16</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>67</td>
<td>0</td>
<td>8</td>
<td>34</td>
<td>76</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

*Between 1828 and 1850. †By May 8, 1854. ‡Nominees still living on May 8, 1854, by age on Dec 31, 1850. Source: A. G. Finlaison (1860).

nominees of those parties who speculated in life annuities” (A. G. Finlaison, 1860, p. 14), henceforth speculative nominees, all of whom were males nominated after 1828. Each of the three sets appears to represent one or more distinct investment portfolios put together by a group of speculators. The first contains 353 nominees aged 59 to 64. The second contains 288 nominees aged 73-84, and the third contains 34 nominees aged 85-92.

The final two data classes in A. G. Finlaison’s report contain information on all male and female nominees from 1808 to the end of 1850, excluding the aforementioned speculative nominees, but including all nominees in J. Finlaison’s data. We refer to these nominee classes as “non-speculative,” but it is important to note that they may include speculative nominees from the 1808 and 1828 period as well as any post-1828 speculator-nominated annuitants that the government failed to identify as such.

The first data column in each of the five data classes in the 1860 report contains the distribution of the nomination ages in that class. For the non-speculative males and females and the youngest speculative class, the second column records the death-age distribution for nominees who died between 1808 and May 8, 1854. For the two older speculative classes, it instead reports the deaths until June 10, 1856. The third column reports the distribution of ages, on December 31, 1850, of all nominees still alive on May 8, 1854 (June 10, 1856 for the two older speculative classes).

For illustrative purposes, Table 1 presents the entire data set for the youngest class of speculative nominees. The rest of the data are in a similar form; we omit them to save space.
Table 2: Data Summary

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Gender or Nominees</th>
<th>Nominees (#)</th>
<th>(%)</th>
<th>Dead (% of Row)</th>
<th>Living (% of Row)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1829 Report</td>
<td>Male</td>
<td>2077</td>
<td>30.1%</td>
<td>28.6%</td>
<td>71.4%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>4815</td>
<td>69.9%</td>
<td>19.8%</td>
<td>80.2%</td>
</tr>
<tr>
<td>1860 Report, Non-Speculative</td>
<td>Male</td>
<td>5542</td>
<td>34.3%</td>
<td>59.3%</td>
<td>40.7%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10595</td>
<td>65.7%</td>
<td>58.9%</td>
<td>41.1%</td>
</tr>
<tr>
<td>1860 Report, Speculative</td>
<td>Age 59-64</td>
<td>353</td>
<td>52.3%</td>
<td>56.4%</td>
<td>84.4%</td>
</tr>
<tr>
<td></td>
<td>Age 73-84</td>
<td>288</td>
<td>42.7%</td>
<td>99.6%</td>
<td>0.3%</td>
</tr>
<tr>
<td></td>
<td>Age 85-92</td>
<td>34</td>
<td>5.0%</td>
<td>100%</td>
<td>0%</td>
</tr>
</tbody>
</table>

The third (fourth) column reports the number of nominees (percent of data set). The fifth and sixth data columns report the percentage of nominees with in each class who were, respectively, dead and still-living at the time of observation (January 1, 1826 for the 1829 report; June 10, 1856 for the age 73-84 and 85-92 classes; May 8, 1854 for remainder of the 1860 report). Source: J. Finlaison (1829) and A.G. Finlaison (1860).

Table 2 summarizes the data from the two reports. Of the 6892 annuities purchased between 1808 and Jan 1, 1826, we see that approximately 30% were male, and most (71% of male and 80% of female) nominees were still alive on Jan 1, 1826. Of the 16137 non-speculative annuities purchased between 1808 and Dec 31, 1850, 34% were male, and 41% of nominees of both genders were still living on May 8, 1854. All but one of the older speculative nominees had died by June 10, 1856, while nearly 85% of the nominees in the younger class were still living on May 8, 1854.

Since the 1860 non-speculative data set subsumes the 1829 data set, the increase in the (non-selected) male nominee proportion shown in Table 2 understates the true shift (to 37.5%) which occurred with the 1829 implementation of gender-specific pricing. Relatively more favorable pricing for men thus significantly shifted purchases in their direction, providing clear evidence of “selection on observables” – though, as the government observed gender, not of “true” adverse selection.

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7He died at the age of 102 in March, 1857 (A.G. Finlaison, 1860, page 88).
8This class was clearly nominated shortly before 1850. We speculate that this wave of speculation prodded Parliament into its 1852 ban on speculator-purchased annuities.
3.2 Empirical Methodology

To highlight the empirical challenge posed by our data, note that each nominee in a given data set implicitly appears twice: his age at nomination is recorded, and either his death age or his “censored” age is recorded. However, the data do not provide any way for us to connect these two appearances.

Testing for selection involves answering the question: Did the nominees live longer than we would have expected? To answer this question with our data, we first develop a simple test which applies when we know the death ages of all nominees. We then extend the test to account for censoring.

Take as given a population mortality table \( \overrightarrow{q} = (q_0, q_1, q_2, \cdots, q_{109}, q_{110}) \), where \( q_t \) denotes the age- \( t \) mortality hazard (i.e., the probability of dying before turning \( t + 1 \), conditional on having reached age \( t \)), and where we assume that nobody survives beyond age 110. View the first column of data from each nominee class as a known vector \( \overrightarrow{e} = (e_0, e_1, \cdots, e_{109}, e_{110}) \), where \( e_t \) is the number of age- \( t \) nominees. Let \( \overrightarrow{d} \) denote the realized value of the (random) average death age of the nominees. We then test whether \( \overrightarrow{d} \) is significantly greater than we would have expected given \( \overrightarrow{e} \) and \( \overrightarrow{q} \).

Specifically, the test statistic:

\[
Z = \frac{\overrightarrow{d} - E[\overrightarrow{d} | \overrightarrow{e}, \overrightarrow{q}]}{\sqrt{V[\overrightarrow{d} | \overrightarrow{e}, \overrightarrow{q}]}}
\]

has an asymptotic standard normal distribution, where \( E[\overrightarrow{d} | \overrightarrow{e}, \overrightarrow{q}] \) and \( V[\overrightarrow{d} | \overrightarrow{e}, \overrightarrow{q}] \) are, respectively, the expected value and the variance of \( \overrightarrow{d} \) (given \( \overrightarrow{q} \) and \( \overrightarrow{e} \)). High \( Z \) scores are then evidence of a nominee pool which is adversely selected relative to \( \overrightarrow{q} \).

Equation 1 is based on the difference between the expected and actual death ages of the nominees. Unfortunately, most of our data sets have “censoring,” we do not know actual death ages, and we cannot use Equation 1. Instead, we develop an analogous test based on comparing the unconditionally expected death ages of the nominees with the expected death age conditional on the observed mortality experience up to the time of censoring. To compute the latter we combine two pieces: the known death ages \( \overrightarrow{d}_{\text{early}} \) of those who died before censoring (i.e., the second data column), and the expected average death ages of the still-living nominees, computed using their age distribution \( \overrightarrow{l} \) (i.e., the third data column)\(^9\) and the mortality table \( \overrightarrow{q} \).

\(^9\)For the 1860 data sets, there is a discrepancy between the third column of data and
Equation 2 describes a formal test statistic $Z'$ based on this intuition. The appendix establishes that $Z'$ has an asymptotic standard normal distribution.

$$Z' = \frac{E[d| \overrightarrow{l}, d^{early}, \overrightarrow{q}] - E[d| \overrightarrow{e}, \overrightarrow{q}]}{\sqrt{V[d| \overrightarrow{e}, \overrightarrow{q}] - V[d| \overrightarrow{l}, d^{early}, \overrightarrow{q}]}}$$

(2)

The terms in the numerator of Equation 2 are the conditional and unconditional expected mean death ages described above. The denominator’s terms are conditional variances of the average death age: the first is conditional only on $\overrightarrow{e}$; the second is conditional on the realized values of $\overrightarrow{l}$ and $d^{early}$.

Note that the conditionally expected average death age is computed under the assumption that the “censored” individuals will age according to $\overrightarrow{q}$. This reduces the power of the $Z'$-test vis-à-vis the simple $Z$-test: when the actual mortality of the annuitant class being tested differs from $\overrightarrow{q}$, the conditionally expected average death age $E[d| \overrightarrow{l}, d^{early}, \overrightarrow{q}]$ is biased towards $E[d| \overrightarrow{e}, \overrightarrow{q}]$, particularly in the presence of extensive censoring.

Each term in Equation 2 can be directly computed to arbitrary precision by simulation. We compute $E[d| \overrightarrow{e}, \overrightarrow{q}]$ and $\hat{V}[d| \overrightarrow{e}, \overrightarrow{q}]$ for a given mortality table $\overrightarrow{q}$ by simulating 8000 final death profiles for the nominee population $\overrightarrow{e}$. Similarly, we compute $E[d| \overrightarrow{l}, d^{early}, \overrightarrow{q}]$ and $\hat{V}[d| \overrightarrow{l}, d^{early}, \overrightarrow{q}]$ by simulating 8000 final death profiles $d^{late}$ for the still-living population $\overrightarrow{l}$.

### 3.3 Basic Z-Test Results

We now present raw results based on the $Z$-tests described in Equations 1 and 2. Sections 4 and 5 below detail their implications.

Table 3 uses Equation 2 to test the appropriateness of the Northampton tables for the male and female nominees in the 1829 data set. It indicates that the early nominees of both genders are conditionally predicted to live significantly longer than unconditionally predicted by the population average mortality tables, with males and females living an estimated average of .63 (i.e., $72.97 - 72.34$) and 1.53 years longer, respectively. Note again that this conditional prediction likely understates the degree of adverse selection, as the conditional prediction is made under the assumption that the survivors will age according to the Northampton tables.

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$\overrightarrow{l}$, since the data report the “censored” age as of December 31, 1850, but the “censoring” actually occurs later (e.g., May 8, 1854).
### Table 3: Testing for Adverse Selection, Northampton Tables

<table>
<thead>
<tr>
<th></th>
<th>Unconditional</th>
<th>Conditional</th>
<th>( \hat{\sigma} )</th>
<th>( Z' )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males, 1826</td>
<td>72.34</td>
<td>72.97</td>
<td>0.126</td>
<td>5.02</td>
</tr>
<tr>
<td>Females, 1826</td>
<td>71.31</td>
<td>72.84</td>
<td>0.082</td>
<td>18.72</td>
</tr>
</tbody>
</table>

Testing for adverse selection of the early nominees relative to the Northampton table. \( E(d) \) refers to the expected average nominee death age of all nominees. Column “Unconditional” (“Conditional”) reports the unconditional expected average death age (the expected average death age \( \text{conditional} \) on the observed mortality history through 1826). Column \( \hat{\sigma} \) is the estimated standard error of the difference between these two columns. \( Z' \) is the \( Z \)-score of the difference (\( \text{viz} \) Equation 2).

Table 4 uses Equations 1 and 2 to test the appropriateness of Finlaison’s tables for each of seven classes of nominees.

The final two rows of Table 4 suggest that Finlaison’s life tables were appropriate for describing the mortality of the 1808-1826 nominee population: males and females are conditionally and unconditionally predicted to have a statistically (and economically) identical average death ages.

The first two rows of Table 4 indicate that non-speculative 1808-1850 male and female nominees are conditionally predicted to live an average of 0.84 and 0.22 years longer than would be unconditionally predicted. Both are statistically significant at standard levels.\(^{10}\)

The middle 3 rows of Table 4 indicate that all three classes of speculative nominees lived significantly longer than predicted by the Finlaison tables.\(^{11}\) This is evidence of selection among speculator-selected nominees. Note, however, that we cannot distinguish whether this was true \textit{adverse} selection or selection on observables: there may have been other symmetrically known

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\(^{10}\)The pre-1828 nominees are a subset of these nominees. Hence, this is a pure test for \textit{additional} selection amongst post-1828 nominees only insofar as the Finlaison tables accurately describe the mortality of early nominees. Similarly, these results \textit{understate} the degree of adverse selection among the post re-pricing nominees insofar as they involve pooling the un-selected early nominees with the selected later nominee.

\(^{11}\)Francis (1853) indicates why speculators selected \textit{older} nominees. The post 1829 pricing was based on the mortality experience of the early nominees, and, since payouts from early annuities were capped at age 75, there were few nominees above this age prior to 1828. Hence, the old-age mortality experience underlying Finlaison’s tables was mostly from individuals who were nominated at a young age and subsequently grew old, and likely exceeded that of \textit{selected} older lives. Francis relays anecdotes suggesting that speculators understood this well (\textit{viz} Footnote 4).
Table 4: Testing for Adverse Selection, Finlaison Tables

<table>
<thead>
<tr>
<th></th>
<th>$E(d)$</th>
<th>$\hat{\sigma}$</th>
<th>$Z, Z'$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unconditional</td>
<td>Conditional</td>
<td></td>
</tr>
<tr>
<td>NS Males, 1850</td>
<td>73.79</td>
<td>74.63</td>
<td>0.126</td>
</tr>
<tr>
<td>NS Females, 1850</td>
<td>76.23</td>
<td>76.45</td>
<td>0.087</td>
</tr>
<tr>
<td>S Males, 59-64</td>
<td>84.84</td>
<td>84.72</td>
<td>0.230</td>
</tr>
<tr>
<td>S Males, 73-84</td>
<td>83.40</td>
<td>91.62</td>
<td>0.329</td>
</tr>
<tr>
<td>S Males, 85+</td>
<td>73.87</td>
<td>73.87</td>
<td>0.123</td>
</tr>
<tr>
<td>Males, 1826</td>
<td>76.12</td>
<td>76.11</td>
<td>0.086</td>
</tr>
<tr>
<td>Females, 1826</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Testing with Finlaison’s tables. “NS” and “S” refer to non-speculative and speculative classes, respectively. $E(d)$ refers to the expected average death age of all nominees. Column “Unconditional” (“Conditional”) reports the unconditional expected average death age (expected average death age conditional on the observed mortality history through 1854, 1856, or 1826 for the first four rows, the fifth row, and the final two rows, respectively). Column $\hat{\sigma}$ is the estimated standard error of the difference between the two death age estimates. $Z, Z'$ is the $Z$-score of the difference between the conditional and unconditional averages death ages (viz Equations 1 and 2).

information (e.g., township of birth) that we do not observe.

4 Selection Effects

4.1 Selection Among Early Annuities

Under the 1808 act, Parliament priced annuities under the assumption that the Northampton tables correctly captured the mortality of the British population. The results in Table 3 thus indicate at least one of two things: that there was significant selection amongst the early nominees, or that Parliament’s assumption about the Northampton table was incorrect.

The Northampton table was based on the mortality history of residents in a single town, and it was developed from observations in the middle and late 1700s. So there is clearly reason to view with some skepticism its appropriateness as a measure of population average mortality in the early 1800s. Unfortunately, reliable data on mortality rates prior to 1838 – when the British Government began systematically recording all births and deaths – are lacking (McKeown and Record, 1962). The earliest reliable population mortality table – known as the English Life Table 3 (ELT3) – was developed by William Farr on data collected between 1838 and 1853 (Farr, 1864). Table
Table 5: Comparing Selection Effects Across Life Tables

<table>
<thead>
<tr>
<th>Class</th>
<th>Northampton</th>
<th>Finlaison</th>
<th>ELT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males, 1826</td>
<td>0.63 (5.0)</td>
<td>0.00 (0.0)</td>
<td>0.35 (2.9)</td>
</tr>
<tr>
<td>Females, 1826</td>
<td>1.53 (18.7)</td>
<td>-0.01 (-0.2)</td>
<td>0.91 (11.6)</td>
</tr>
<tr>
<td>NS Males, 1850</td>
<td>2.24 (20.9)</td>
<td>0.84 (7.8)</td>
<td>2.00 (14.4)</td>
</tr>
<tr>
<td>NS Females, 1850</td>
<td>3.90 (46.9)</td>
<td>0.22 (2.6)</td>
<td>2.51 (30.2)</td>
</tr>
</tbody>
</table>

This table reports the difference between the conditional and unconditional expected number of years lived for three life tables (the Northampton, Finlaison, and English Life Table 3 described in the text) and four nominee classes. Parentheses denote Z-scores (viz Equation 2).

5 compares the magnitudes of the selection effects relative to the Northampton, Finlaison, and ELT3 tables. It indicates that there were significant selection effects among early nominees relative to ELT3, though the effects are slightly more modest than those indicated by the Northampton table. The Northampton tables may have been inappropriate, but the selection effects appear to have been important nevertheless.\textsuperscript{12}

### 4.2 Selection Among Later Annuitants

Regardless of why the early nominees look selected relative to the Northampton tables, the Finlaison tables appear to have done a good job capturing their mortality. Table 4 therefore indicates that later nominees were longer lived than Finlaison’s tables predicted. We take this as evidence that they were more selected than early nominees.

In principle, this apparent additional selection may instead reflect a time trend in mortality rates. As mentioned above, the lack of reliable data prior to 1838 prevents a definitive resolution of the practical importance of time trends. Wrigley and Schofield (1981, pages 230 ff), using a sophisticated back-estimating technique, infer that life expectancy at birth exhibited a mild upward trend in the first half of the 19th century. But Greenwood (1936), examining post-1841 data, indicates that this trend was driven by early-life mortality, stating:

> When the historical sequence is examined... [O]ne could hardly say that the rate at 35-45 had hardly moved decisively before the

\textsuperscript{12}As we discuss below, time trends in mortality could in principle confound this interpretation, but seem unlikely to be a problem in practice.
early eighties, or that at ages 45-55 until the turn of the century. In old age, improvement is now barely perceptible. (page 678)

The age specific mortality trends presented in McKeown and Record (1962) confirm this. This suggests that the increased longevity of the later nominees relative to the earlier nominees was largely due to additional selection effects rather than time trends.

4.3 Comparing the Degrees of Selection

Table 4 indicates that both the speculative and non-speculative nominees from A. G. Finlaison’s data set display higher longevity than the Finlaison (or ELT3) tables predict. We take two approaches to understanding the extent to which the various nominee classes were selected. First, for a visual sense of the degree of selection, Figure 1 plots the conditional and unconditional expected age-at-death distributions according to Finlaison’s tables for the females and non-speculative males. We see a notable rightward shift of the conditional distribution relative to the unconditional distribution, particularly for the males classes.

To quantitatively address the degree of selection, our second approach involves computing a “longevity enhancement factor” (LEF) for each nominee class. LEF is defined as:

\[
LEF = \frac{Actual \ average \ death \ age - Expected \ average \ death \ age}{Expected \ average \ death \ age - Average \ nomination \ age}\quad (3)
\]
Table 6: Estimated Longevity Enhancements

<table>
<thead>
<tr>
<th>Class</th>
<th>Lower Bound LEF</th>
<th>Upper Bound LEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Speculative Males, 1850</td>
<td>5.65%</td>
<td>9.06%</td>
</tr>
<tr>
<td>Non-Speculative Females, 1850</td>
<td>1.17%</td>
<td>1.80%</td>
</tr>
<tr>
<td>Speculative Males, 59-64</td>
<td>22.56%</td>
<td>121.91%</td>
</tr>
<tr>
<td>Speculative Males, 73-84</td>
<td></td>
<td>25.37%</td>
</tr>
<tr>
<td>Speculative Males, 85+</td>
<td></td>
<td>94.02%</td>
</tr>
</tbody>
</table>

Estimated “longevity enhancement factors” (LEF): the percentage by which the longevity of a given group of nominees exceeded the longevity predicted by Finlaison’s mortality tables.

Intuitively, it measures the percent by which average longevity exceeds predicted longevity.

The structure of the data prevents a direct computation of a LEF when there is “censoring,” so we instead compute upper and lower bounds on the LEF. Our lower bound assumes that the still-living nominees subsequently age according to the Finlaison tables. Our upper bound assumes instead that the still-living nominees have equal proportional enhancements prior and subsequent to censoring.\(^{13}\)

Table 6 reports our calculations. We see that the longevity of the speculative classes was substantially more enhanced – relative to expectations – than the longevity of the non-speculative classes. The non-selected males are estimated to have lived between 5.65% and 9.06% longer than the Finlaison tables predicted. In contrast, the selected groups are estimated to live more than 20% and as much as 122.91% longer than the Finlaison tables predicted. The longevity of the non-selected female nominee class appears even less selected than the males, with a LEF estimated to be between 1.17% and 1.80%.\(^ {14}\)

\(^{13}\)Formally, the upper bound LEF solves:

\[
N_T \cdot (A_N + (E[A_F] - A_N)(1 + LEF)) = N_D \cdot A_D + N_L \cdot (A_L + (E[A_{LD}|i] - A_L)(1 + LEF)),
\]

where: \(N_T, N_D,\) and \(N_L\) are the number of nominees, the number of nominees who had died by the time of observation, and the number of living nominees, respectively; \(A_N, A_D,\) and \(A_L\) are the average ages of the nominees, the dead nominees, and the living nominees, respectively; and \(E[A_F]\) and \(E[A_{LD}|i]\) are the expected average death age of the nominees at nomination and the expected (using Finlaison’s tables) average death age of the censored nominees.

\(^{14}\)Note that all the “enhancement” is attributable to the post-1826 nominees; this does
The relative enhancement of the non-selected males and the non-selected females may stem from the combination of gender-blind early pricing and the fact that the pre-1828 data on which the Finlaison tables were based did not distinguish between “speculative” and “non-speculative” nominees. The most profitable nominees in the gender neutral pre-1829 pricing regime were the longer lived females, and Table 4 indicates that speculators were quite good at selecting long-lived nominees. So Finlaison’s female life tables may reflect the mortality experience of a particularly selected nominee pool.

5 Annuity Markets and Death Spirals

There is a substantial and growing literature on the so-called “annuity puzzle,” the observation very few individuals voluntarily choose to annuitize their retirement assets in spite of the benefits economic theory suggests annuities provide. On the theoretical side, Yaari (1965) showed that full annuitization should be optimal under specialized circumstances, and Davidoff et al. (2005) have recently shown that the theoretical prediction of significant annuitization by optimizing individuals is quite general. But on the empirical side Poterba et al. (2003), Johnson et al. (2004) and others have documented a marked paucity of life annuity purchases by households in the Health and Retirement Survey. This paucity is corroborated by industry sales data indicating a paltry $5.9 billion in immediate annuity sales in in the U.S. in 2006 (LIMRA, 2007) and by international evidence (James and Vittas, 2004).

A number of papers have attempted to explain the annuity puzzle. Potential explanations include pre-existing (public or company pension) annuities, unfavorable pricing resulting from adverse selection or administrative loading (Mitchell et al., 1999), within-household risk pooling for married couples (Brown and Poterba, 2000), bequest motives (Friedman and Warshawsky, 1990), higher returns from alternative assets (Milevsky, 1998), the need for liquidity to cover health shock expenditures (Sinclair and Smetters, 2004), the option value of delaying annuitization (Dushi and Webb, 2004), and behavioral “framing” effects (Brown et al., 2008). Whether some combination of these explanations can fully resolve the puzzle remains an open question.

The typical approach in this literature is to posit that households are life-cycle utility maximizers – typically with constant relative risk aversion,
additively separable utility functions – and to compute the value such individuals would place on having access to private annuity markets. Brown (2000) provides some empirical support for this approach by showing that individuals’ stated intentions to annuitize are indeed correlated with the predictions of such models. Nevertheless, a distinct weakness of this approach is that quantitative conclusions about “optimal” annuitization rely heavily on functional-form utility assumptions. Our empirical methodology helps speak to the importance of adverse selection as a possible resolution to the puzzle without making any functional form assumptions.

5.1 The 1808 Act and the Annuity Puzzle

The historical evolution of the 1808 Life Annuity Act closely mimics the first stages of an Akerlofian death spiral. The government initially sold annuities at prices consistent with what it believed to be population-average longevity. Table 3 indicates that the resulting annuitant pool had significantly higher longevity. In 1829, it repriced the annuities based on the mortality of the early annuitants. Table 4 indicates that the new annuitant pool had significantly higher longevity than even this new table indicated.

This evidence indicates that the adverse selection spiral was not complete: additional rounds of re-pricing and market thinning were clearly needed. Nevertheless, we are inclined to tentatively interpret the results as at least moderately suggestive of the absence of a complete death spiral – at least for females. Several factors contribute to this interpretation. First, while the non-selected females from A. G. Finlaison’s data set were statistically significantly longer-lived than the Finlaison mortality tables indicated, the absolute magnitude of the longevity enhancement is modest. This suggests that additional re-pricing “rounds” were unlikely to raise prices so dramatically as to significantly reduce the population of female annuitants.

Second, the market for annuities did not get markedly thinner in response to the 1829 re-pricing: Table 2 can be used to show that the annual number of annuities sold fell by only about 10% after re-pricing.

Third, a back-of-the-envelope calculation suggests that the absolute size of the market was substantial. Wrigley and Schofield (1981, page 529) provide British population data by broad age category. Of a total 1816 population of approximately 10 million, we infer that not more than about 25% were old enough to reasonably consider purchasing an annuity. Only a fraction of the resulting 2.5 million potential annuitants would have had the resources
to actually buy one: the 1808 act required a minimum of £100 to purchase an annuity (Parliamentary Papers, 1808), and data from Marshall (1833, pages 212 and 214) indicates that the average annuity size between 1817 and 1832 was over £1100. Soltow (1968) presents data on the income of various classes of the British population between 1801 and 1803. We infer from Soltow’s data that only 4.3% of the population had annual family incomes in excess of £200. Even if we take this low bound on the income required to reasonably consider purchasing annuities, only about 100,000 individuals were plausible candidates for annuities. The 16,000 annuities sold under the 1808 act between 1808 and 1850 thus represents a substantial fraction of a plausible upper bound on the total number sold. (Taking the annual income cutoff to equal the average annuity size makes the results even starker, reducing the plausible candidates to about 7500 individuals.)

These considerations together suggest that there was scope for a well-functioning “thick” market for non-speculative life annuities – at least for females. Though one must be cautious about extrapolating to contemporary markets, this at least provides some suggestive evidence that a “death spiral” driven by standard self-selection is unlikely to explain the annuity puzzle.

6 Discussion and Conclusions

The United Kingdom’s 1808 Life Annuity Act effectively opened up a market for government-provided life annuities. Analysis of data on purchases and subsequent mortality rates suggests that the market was characterized by two types of adverse selection: classic “self-selection” whereby individuals purchasing annuities for themselves were healthier than the average individual in the population, and “speculative” selection, whereby pecuniary-minded individuals or institutions took advantage of an odd feature of the act which allowed them to purchase annuities contingent on the lives of others.

Our results indicate that self-selection of annuitants was substantial: the annuitant pool between 1808 and 1826 appears to have been dramatically

\[15\] Additionally, though we have had not had luck finding data from after 1850, Murphy (1936) indicates that the market continued to exist and stabilize after speculation was banned in 1852. One must interpret this cautiously, however: by the late 1800s, the confounding effects of improving mortality trends begin to bite. Furthermore, Murphy reports that the market was fairly modest in size by the early 1900s, in part because there were better-priced private-sector annuity options by this time.
longer lived than the population as a whole, even when we account for the age and gender of the annuitants. Furthermore, a 1829 attempt by the government to re-price annuities to reflect the higher longevity of the early annuitants resulted in an annuitant pool that was longer lived still. This is reminiscent of the early stages of a death spiral, though the degree to which the later annuitants were selected and the robustness of the market size suggests that, while adverse selection was clearly an important concern, it is unlikely to have eviscerated the market. This finding reinforces the view that an adverse selection death spiral is unlikely to explain the puzzling dearth of annuity sales in contemporary markets.

Our analysis also indicates that speculators effectively selected particularly long-lived individuals to nominate for annuities and profited considerably at the expense of the government from the Act. This recommends care to modern policy makers when contemplating expanding choice in government provided services: when choices can be made by pecuniary-minded individuals or institutions, selection effects may be significantly exacerbated and may impose particularly large costs on the government.

References


[37] Parliamentary Papers. Life annuities: Abstract and explanation of the act for enabling the commissioners for the reduction of the national debt to grant life annuities by the transfer of funded property. Hansard and Sons, 1808.


## 7 Appendix

This appendix shows that the test statistic $Z'$, defined in Equation (2), is asymptotically distributed as a standard normal random variable.

Fixing a class of nominees (e.g., pre 1829 males), view the random process underlying the data as a three-step compound process: (i) process $\alpha$ draws an independent random age and nomination year for each nominees $j = 1, \cdots, N$ from some fixed distribution; (ii) process $\beta$ draws an independent random lifetime up to the censoring date for $j$ (using mortality table $q_\tau$); and (iii) random process $\gamma$ draws an independent random lifetime beyond the censoring time for censored individuals.

Let $m_j$ denote the (random) death age of $j$, and let $b_j = E_\gamma[m_j|\alpha_j, \beta_j]$, which is a random function of $\alpha_j$ and $\beta_j$. Then:

$$E[d_{\text{early}}, l] = \frac{1}{N} \sum_{j=1}^{N} b_j.$$  

(5)
Since \( \{b_j\}_{j=1}^N \) is a set of i.i.d. random variables, the Central Limit Theorem establishes that

\[
Z' \equiv E(d|d_{early}, \bar{r}) / \sqrt{V[b_j]/N}
\]

has an asymptotic standard normal distribution.

Towards deriving the variance of \( b_j \), we use the law of iterated expectations:

\[
V[m|\alpha] = E_{\beta,\gamma}[m^2|\alpha] - (E_{\beta,\gamma}[m|\alpha])^2
= E_{\beta}[V[m|\alpha, \beta] + (E_{\gamma}[m|\alpha, \beta])^2] - (E_{\beta}[E_{\gamma}[m|\alpha, \beta]])^2
= E_{\beta}[V[m|\alpha, \beta]] + E_{\beta}[b^2] - (E_{\beta}[b])^2
= E_{\beta}[V[m|\alpha, \beta]] + V[b],
\]

where we have dropped \( j \) subscripts for notational convenience. The \( \alpha \)-conditional variance is thus the sum of two components: the expectation of the \( \beta \)-conditional variance of the mean death age plus the variance of the \( \beta \)-conditional expected mean death age.

Re-arranging Equation 7 gives

\[
V[b]/N = V[m|\alpha]/N - E_{\beta}[V[m|\alpha, \beta]]/N.
\]

To complete our derivation, observe that since the distribution of entrants across ages \( \bar{c}/N \) converges in probability, \( V[m|\alpha]/N \) is consistently estimated by the variance of \( \bar{d} \) conditional on the observed entrant distribution, i.e., by \( \bar{V}[d|\bar{c}, \bar{q}] \). Similarly, \( E_{\beta}[V[m|\alpha, \beta]]/N \) is consistently estimated by \( \bar{V}[d|\bar{r}, \bar{d}_{early}, \bar{q}] \). Equation 2 follows directly from these observations and Equations 6 and 8.