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Adverse Selection in the Irish Tontines of 1773, 1775 and 1777

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Abstract

A "tontine" is a special kind of annuity in which all participants contribute equally to a subscription pool, and a fixed percent of the total capital raised is distributed equally among surviving nominees every year. In this paper, we examine the adverse selection in the Irish tontines of 1773, 1775 and 1777 because of the presence of a group of speculative investors, namely a group of Genevan bankers. These Genevan investors purportedly cherry-picked nominees with greater expected longevity. Their existence allows us to study a rather unconventional aspect of adverse selection, which arises from the informational asymmetry among different types of buyers. Using a newly compiled data set on the nominees and their subsequent mortality, we estimate that these Genevan investors earned on average 8.5% more per share than the other subscribers of the Irish tontines. The result suggests that speculative investors with access to superior information may earn higher returns at the expense of average investors, a phenomenon implicit but difficult to quantify in other insurance markets.

Acknowledgment

I am highly indebted to Prof. Rothschild for his constant support and boundless patience throughout my thesising. It is Prof. Rothschild who inspired me to study this thesis topic and provided me with countless helpful advice that made the completion of this thesis possible.

I thank Wellesley, for transforming me from a single-minded student who never knew the beauty of learning to a liberal person who constantly wants to know more about this world. Growing up in Chinese education system where standardized exams dictate college admission, I learned because I had to. Wellesley updated my understanding of learning; here, I learned because I wanted to. Classes at Wellesley taught me the art of learning, and inspired me to ask more questions and savor the moments of pondering over hard problems. I realized that learning can be so fun for its own sake and internalizing the beautiful theories discussed in class makes me feel connected to those masterminds behind them. I guess that's the starting point of this thesis: I want to join the group, joining their adventurous journeys in discovering the unknown.

Had it not been the encouragements from Prof. Rothschild and Lizi Chen '13, I would have never embarked on this thesis project and carried it off. Prof. Rothschild's mind-opening class Strategy and Information deepened my understanding of economics, and ignited my passion in knowing more. Lizi is the lighthouse beaming through the darkness when I am lost. Her encouraging words and heartfelt life advice bring me through difficult times. Her comments and insights greatly helped me improve this thesis. They made me realize that passion accompanied with perseverance is the best fuel of producing a good research.

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I thank the Schiff Fellowship for providing me the financial support which enables the trip to the National Archives, London, where I collected all my data.

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Contents

1 Introduction

A "tontine" is a special kind of annuity in which all participants contribute equally to a subscription pool, and a fixed percent of the total capital raised is distributed equally among surviving nominees every year. It terminates when the entire nominee group has deceased. A tontine may also allow subscribers to nominate lives other than their own. Thus, in a tontine scheme, a subscriber's returns depend on not only his nominee's years of living, but also the ranking of his longevity among all nominees. Since the value of the shares devolves to the other participants on the death of a nominee, subscribers with nominees who outlive all others earn the highest returns. The tontine was popularized in 1689 by King Louis XIV who used it to raise fund for France [Weir, 1989]. They then became a popular form of purported insurance against retirement and elderly age. The French and British authorities issued a total of 15 tontines throughout the 18th century.

Jennings and Trout [1982], Clark [1999], and Weir [1989] provide historical background for tontines. Jennings and Trout [1982] document the history of tontines in the 18th century Europe. Clark [1999] provides historical context of the culture of life insurance in England from 1695 to 1775. Weir [1989] describes the implementation of tontine schemes in the 18th century Britain and France, and claims that the French authority allied with its middle class citizens through subsidizing their tontine payments.

The unique design of tontines has long attracted scholarly attention. Many researchers have presented qualitative evidence of adverse selection in the scheme. Clark [1999] points out anecdotal evidence of adverse selection and moral hazard in the tontine section of his book. Gautier [1951] notes the large presence of Genevan bankers in the 1777 Irish tontine and argues that they adversely selected young and healthy women into the scheme. Jennings and Trout [1983] claim that the nominees selected by the Genevan bankers lived on average well beyond the expected longevity suggested by the contemporary life tables. Rothschild (2003) presents statistical evidence of adverse selection in the tontines issued in Europe in the 18th century. However, to our knowledge, no paper to date has systematically studied adverse selection in historical tontines quantitatively. This paper fills the void by examining this historical insurance product through the lens of modern economics.

We focus on the 1773, 1775 and 1777 Irish tontines because of the presence of a group of speculative investors, namely the Genevan bankers as discussed in Gautier [1951] and Jennings and Trout [1983]. These Genevan bankers reportedly cherry-picked longer-lived nominees into the tontine and earned higher average returns. The existence of tontines allows us to study a rather unconventional aspect of adverse selection, which arises from the informational asymmetry among different types of buyers.[1] We quantitatively demonstrate the existence of adverse selection, and estimate that the sophisticated Genevan

[1]The term "adverse selection" typically refers to market inefficiency introduced by informational asymmetry between buyers and sellers

bankers earned on average 8.5% more than the rest of the tontine subscribers. The excess returns were essentially at the expense of other tontine buyers, not the Irish government.

Studying market inefficiencies in annuity market caused by asymmetric information is empirically challenging. First, classifying the insured people into different risk types requires granular data on private information. Second, even if potential high-risk participants could be identified, their adverse impacts on the low-risk participants are elusive. We do not directly observe how one type of participants may have affected the returns of the others because individual payment each year in a standard annuity is predetermined. But in theory - at least in some market contexts - the low-risk type subsidizes the high-risk type because the issuer uses profits earned from the former to make up for the losses incurred by the latter. In contrast, in tontines due to its group dynamic where a subscriber's risk level directly affects another's income, we can easily measure the damages that the high-risk type incur on the low-risk ones.

The rest of the paper proceeds as follows. Section 2 provides a brief introduction to the elements of the tontine schemes relevant to our analysis. Section 3 describes the data. Section 4 provides suggestive graphical evidence of adverse selection and outlines the empirical analysis. Section 5 presents the main findings. The final section concludes.

2 Background on Tontines

2.1 Tontines in the 18th century Europe

Tontines are life contingent group annuities with benefits determined by survivorship. The financial scheme was first proposed by Lorenzo Tonti, an expatriate Neopolitan who secured a position in the court of the French King in the 1650s. Tonti's original proposal was first carried out by King Louis XIV in 1689, when France was surrounded by a European coalition and was in dire financial straits.[2] The scheme was introduced as an attempt to raise funds to ameliorate the situation.

One distinct feature of many life-contingent investments in the 18th century Europe was their separation of subscribers and nominees.[3] Tontines are one of these life-contingent investment plans. The tontine issuers allowed subscribers to nominate other peoples' lives to participate in the scheme. Prior to the enrollment, the tontine issuers first established nominee classes by age. In the case of the Irish tontines for example, Class 1 consisted of nominees of age 40 and above; class 2 consisted of noinees of age between 20 and 39; class 3 consisted of nominees under age 20. Subscribers then selected nominees

[2] See McClure's [1906]

[3] For example, the British annuity discussed in Rothschild [2009] has the same feature.

on whose lives they would bet, and enrolled the nominees in the corresponding nominee classes. For every nominee in the same class, subscribers purchased tontine shares at an equal price and paid the issuing government a one-time, lump-sum payment.[4] The government in turn would pay out a fixed percent of the total capital raised each year, and divide the payment equally among surviving nominees.

Table 1: A summary of tontines in France and Britain, 1689-1789

#	Year	Number of age classes	Number of nominees	Capital raised
		French Tontines		
1	1689	14	5,912	3611
2	1696	15	4,105	2928
3	1709	16	2,642	2996
4	1733	7	14,270	11126
5	1734	15	12,653	15365
6	1743	15	4,275	
7	1743	15	3,822	
8	1744	15	7,131	9000
9	1745	15	10,397	8820
10	1759	8	49,463	46870
		British Tontines		
1	1693	1	1,002	£108.1
2	1757	5	[cancelled]	
3	1765		900	18.0
4	1773-77(Irish)	3	3,384	928.0
5	1789	6	3,495	421.9

Notes: French capital is given in thousands of livres tournois; British in thousands of pounds sterling. Source: Weir [1989].

The French and the British government consistently raised large fund from tontine schemes throughout the seventeenth and eighteenth century (Table 3). In France, tontines had a subscription rate near 100% except for the year 1689 when it was first issued. Adopting the French scheme, the British government issued a total of five tontines in the 18th century. The British authority never managed to collect as much fund as they intended to seek, with the exception of the Irish tontines. Issued by the Irish Parliament in 1773, 1775 and 1777, the Irish tontines raised a total of £928,000, the greatest sum ever raised from tontines in Britain.

2.2 Genevan bankers in the Irish Tontines

The presence of the Genevan bankers distinguished the Irish tontines from the other tontine schemes issued in the 18th century Britain. Prior to the Irish tontines, these bankers had already developed the "thirty demoiselles" strategy for investing in French annuities. "Thirty demoiselles" refers to the investment strategy of selecting young women aged 7 to 14 from wealthy families as nominal beneficiaries of the annuity, pooling the subscriptions on thirty young demoiselles, and selling a claim on the group

[4]The unit price of the Irish tontines was £100. Suppose a subscriber purchased two shares for a nominee he chose, the total payment would be £200.

as in a mutual fund [Kindleberger, 2005]. The Genevan bankers outwitted the French annuity issuer and other subscribers by artificially selecting the healthiest pool among Genevans and diversifying the risk over a multitude of claim purchasers [Jennings and Trout, 1983].

The Irish tontines, similar to the French annuities, afforded the Genevan bankers an opportunity to speculate. It is unclear whether the Genevan bankers practiced the same "thirty demoiselles" strategy, but we have evidence that many names of these young Genevan women that appeared on the French life annuity lists were also enrolled in the Irish tontines. Our results in Section 5 accord well with Jennings and Trout [1983]'s claim that the selected Genevans survived, on average, beyond the population average, procuring greater profits from the tontines than the rest of the group.

It should be noted that for practical reasons, subscribers in the Irish tontines only selected nominees residing in the same city or parish as themselves. To keep subscriptions in force, subscribers needed to deliver to the tontine officials certificates of existence for all their nominees every half year signed by the clergyman of the parish in which the nominees resided. Traveling was still a toil in the 18th century. To avoid frequent travels to their nominees' residences, subscribers limited their nominee choices to people living nearby. Sometimes the subscribers may have also wanted to check on their nominees' health status, sending local doctors to the nominees if necessary to prolong their lives, hence extending the years that they could receive tontine incomes. Therefore, the Genevan bankers only nominated Genevans, and the non-Genevan investors only nominated non-Genevans. The distinction helps us identify the speculative nominees, indicated by their residences in Geneva, and the remaining non-speculative nominees, indicated by their residences outside of Switzerland. Potentially confounding our analysis is the possibility that the Genevans were inherently healthier and tended to live longer. We address and attempt to rule out this possibility in our subsequent analysis.

2.3 Policy implications of tontines

It is worth noting that the Irish tontines set a fixed price for all nominees in the same class regardless of their age and gender. In fact, actuarially unfair flat rate pricing was common among historical tontines, despite the fact that efficient annuity pricing technique had become available in the early 18th century. Abraham de Moivre, a French mathematician, published his work *Annuities on Lives* in 1724 and reduced the valuation of a life annuity to a simple formula for any interest rate, making annuity pricing a task that anyone well-trained in mathematics could undertake [Rothschild, 2003]. A superficial reason for this negligence was that unlike in other insurance markets, the tontine issuer did not suffer from flawed pricing; they paid a fixed amount each year regardless of the demand. But a more fundamental reason was because of the government's apathy towards the interest of its people. Although the original tontine

was packaged as an insurance instrument against retirement and elderly age to appeal to the public[5], in reality, it was no more than a convenient fundraising tool for the French government. As Tonti revealed in one of his letters, "[the tontine] is an easy way whereby the King may get several millions from his people which would never be subject to redemption" and "transforms France into a gold mine for the monarchy."[6]

Weir [1989] conjectured that the tontine scheme was part of the French authority's political agenda of allying the urban middle class at the eve of the French Revolution in 1789. Comparing the returns from the tontines and annuities to alternative investments, Weir [1989] noted that the government paid returns well above average on the former. The uneven returns were intentional, argued by Weir, to subsidize subscribers of urban middle class, with the hope of including "numerous and economically powerful urban bourgeoisie in their stable political coalition [Weir, 1989]". Unsuccessful in achieving its original goal, the plan had the unintentional effect of providing arbitrage opportunities for the savvy speculators.

2.4 Special features of tontines

We begin by describing a few special features of tontines, which distinguished them from standard annuities.

Unlike classic adverse selection models in which the producer's endogenous pricing strategy tends to complicate the analysis of the demand side, the tontines we examine in this paper adopted a flat-rate payment structure. Specifically, the Irish government paid a fixed percent of the total capital raised each year as long as some nominees were alive. Since the total payments to the Irish government only depended on the expected longevity of the last surviving nominee, the predetermined dividend rate and the total capital raised, the group mortality was almost irrelevant in calculating the tontine costs to the government. By design, the Irish government shielded itself from potential losses due to adverse selection.[7]

Another notable feature of the tontine schemes is that the price of a tontine was the same regardless of a nominee's age and gender. In addition, tontines may allow investors to bet on multiple nominees. Given these, the optimal investment strategy was to select the young and healthy pool and diversify risks

[5]See Jennings and Trout [1982] p.34: "John Houghton - journalist, apothecary, and Fellow of the Royal Society - promoted the London tontine in language as extravagant as Tonti's. ... Houghton echoed Tonti's cynical suggestion that the elderly nominee would receive excellent care, since a longer life meant more wealth and a larger inheritance for relatives. Merchants and even gamblers might invest in tontines to offset extraordinary losses."

[6]Source: *Journal of the Institute of Actuaries*, List of members issued with v. 35-46 with separate paging. Alden Press, 1863

[7]For example, in the case of the 1777 Irish tontine in which a total of £228,200 capital is raised and the last nominee died in 1871, the cost of an extra 10 years of tontine payments is only £220 discounted at 7.1% interest rate, a rate equivalent to the pre-determined tontine dividend rate.

within each pool of nominees. A sophisticated investor would adopt this strategy and procure greater profits at the expense of the naive investors.

These distinct features of the tontine markets open up new possibilities to study adverse selection arising from the heterogeneous risk types among consumers. Importantly, in this specific setting, financial savviness is synonymous with risk types. We can effectively distinguish between the low-risk type and the high-risk type and study the pecuniary externalities one group imposes on the other by obtaining information on the degree of sophistication of an investor, even though risk types are, by definition, unobservable. As we will illustrate in our subsequent analysis, in the case of the Irish tontines, the Genevan bankers played the role of speculators (or the sophisticated investors) who selected the nominees with the highest survival rates and earned the highest monetary returns.

3 Data

Our study is made possible by compiling various extant records of the Irish tontines in the National Archives, London.

3.1 Data sources

Data are available from three nominee books documenting the details of the nominees of the 1773, 1775 and 1777 Irish Tontines, and two tontine report appendices surveying existing nominees in 1810 and 1830, all of which can be found in the National Archives in London.

The nominee books provide a detailed profile for each individual nominee, including the nominee's name, country of residence, enrollment age, death date and subscription amount, with missing death dates for some nominees.[8] The 1773, 1775 and 1777 nominee books were completed in 1775, 1775 and 1779 respectively. Hand-written notes of death dates were added to the records over time. If no claim had been made for a nominee for three years, the shares subscribed under this nominee's name were forfeited by law.[9] Forfeited debentures were notated in red ink with the date of forfeiture. Nominees were divided into three classes by age in all issuances. Classes 1-3 refer to the 3 age groups (40 and above, 20 to 39, and under 20) introduced previously. Class 3 was the youngest age class among these classes.

Each nominee book contains one dataset for every class. Each set has four columns of data: name, age, abode and other descriptions, and sums subscribed. The age column reports the nominee's age

[8]The nominee books are published "for the information and satisfaction of the subscribers, by order of the Right Hon. Nathaniel Clement, Deputy Vice-Treasurer of Ireland."

[9]See The Committee on Irish Tontine Annuities [1812],p.2

Table 2: An example data set of five Class 3 nominees in the 1777 Irish tontine

Genevan	Death year	Age enrolled	Number of shares	Alive in 1810	Alive in 1830
0	1830	17	3	1	1
0	1827	16	4	1	0
0	1851	8	5	1	1
0	0	14	1	1	0
1	1830	3	6	1	1

Notes: The variables in the 1st, 5th and 6th columns are dummies. A "1" in the last two columns indicates that the nominee was alive as of that year. The nominee in the fourth row does not have a recorded death date. Source: The Committee on Irish Tontine Annuities [1779]

Table 3: Data Summary

Tontine	Nominees	#	%	Shares	#	%
1773 Class 3	G	21	3%	G	22	1.3%
	NG	684	97%	NG	1675	98.7%
Total		**705**		**1697**		
1775 Class 3	G	37	5.6%	G	45	4%
	NG	627	94.4%	NG	1105	96%
Total		**664**		**1150**		
1777 Class 3	G	174	16%	G	857	37.6%
	NG	917	84%	NG	1425	62.4%
Total		**1091**		**2282**		

Notes: "G" stands for the Genevan nominees and "NG" stands for the non-Genevan nominees. The third (fourth) column reports the number (%) of Genevan and non-Genevan nominees. The fifth (sixth) column reports the number (%) of Genevan and non-Genevan shares subscribed. Source: The Committee on Irish Tontine Annuities [1775],The Committee on Irish Tontine Annuities [1777],The Committee on Irish Tontine Annuities [1779]

at enrollment. The abode and other descriptions indicate the nominee's country of residence, gender and family lineage. Nominees of the Genevan bankers are identified by their residences in Geneva. The last column records the number of shares subscribed for each nominee at a price of £100 per share. Exact death dates are supplied by the hand-written notes for some but not all nominees. The subset of nominees with known death dates does not appear to be chosen systematically, though on average this group lived longer than nominees with missing death dates. For simplicity, we will call nominees with recorded death dates the "known group" and the remainder the "missing group".

In general, records for the Class 3 nominees were most comprehensive. Hand-written notes of death dates were sparse for Class 1 and Class 2 nominees. Given the same payout rate for all classes, Class 3 is also the natural age class to look for speculator-driven adverse selection because the pecuniary returns to investment in that class were higher, all else equal. We therefore focus our study on the Class 3 nominees of the 1773, 1775 and 1777 Irish tontines. The 1777 nominee book contains more mortality information than the 1773 and 1775 nominee books. About 80% of the 1777 nominees were labeled with death dates compared with 50% of those in 1773 and 1775.

Although exact death dates are missing for some nominees, the two tontine reports ordered by the Committee of Irish Tontine to "examine the state and management of the several tontine annuities" provide snapshots of the mortality status for *all* Class 3 nominees in the three waves of the Irish tontines. We therefore use them to impute the missing data in our empirical analysis. The first tontine report, published in 1811, contains a list of the nominees who were alive as of December 25th, 1810. The second report published in 1830 contains a list of the nominees who were alive as of April 26th, 1830. Both lists contain the same type of information for each nominee as recorded in the nominee books. By cross-referencing, we were able to obtain additional data which indicate whether the mortality status for all nominees in 1810 and 1830.

For illustrative purposes, Table 2 presents the entire data set we construct for a small subset of Class 3 nominees in the 1777 Irish tontine. The rest of the data are in a similar format.

Table 3 summarizes our data. The Genevan presence among the Class 3 nominees increased from 3% in 1773 to 16% in 1777. The rising trend was more prominent if we account for the Genevan presence in number of shares subscribed: approximately 40% of the entire subscription pool in 1777.

4 Empirical Analysis

4.1 Graphical evidence: longer lived nominees

The main goal of our empirical analysis is to test for the existence of adverse selection among the Genevan-selected nominees by comparing the average returns received by the Genevan investors with those of the rest of the group. We start with statistical evidence indicating higher survival rates among the Genevan nominees *after* enrollment. To rule out the possibility that the Genevans outlived other nominees due to inherently better health or better medical care in Switzerland, we plot the age selection of the Genevan and non-Genevan investors to show that the greater expected longevity among the Genevan nominees was at least partly a result of their intelligent age choice, thus assuaging these concerns. We then simulate the average returns earned by the Genevan and non-Genevan investors, using two alternative approaches. Finally, we present a strategy for decomposing the differences in returns.

To formally test for the existence of adverse selection, we apply a non-parametric Wilcoxon test [Wilcoxon, 1945] to compare the unconditional longevities of the Genevan nominees with those of the non-Genevan ones. For a given class, we generate *all* possible pairs of Genevan and non-Genevan nominees and count the number of pairs for which the non-Genevan outlives, the Genevan outlives, or otherwise (either they both live to the same age or information is unavailable). With the 1810 and 1830 survey data, we are able to compare the mortality among nominees who either have recorded death dates or differ in mortality status in 1810 or 1830, whenever that information is available. For each wave of the Irish tontines, we reject the null hypothesis that the Genevan and non-Genevan nominees have the same expected longevity if we derive a p-value close to zero.

Figure 1 indicates that with the exception of the year 1773, the number of pairs in which the Genevan nominee outlived the non-Genevan nominee dominates. Indeed, both the 1775 and 1777 Wilcoxon tests obtain a p-value of 0, confirming the disparities in longevity between the Genevan and non-Genevan nominees in the 1775 and 1777 Irish tontines. The p-value for the 1773 Wilcoxon test is 0.02619, which implies that we can reject the null hypothesis at the 95% confidence interval, but fail to reject it at the 98% confidence interval. If a Genevan and non-Genevan was randomly selected in the 1773 Irish tontine, it is unclear whether the Genevan always had the longer life span after enrollment.

One may wonder why the mortality comparison is not conditional on ages of the nominees. We argue that controlling for age is unnecessary for this exercise since our goal is to test whether the Genevans earn better returns, and the ultimate criterion for picking the best nominees is whether the nominees tend to live longer after enrollment. On the other hand, even if the Genevans indeed had lower mortality rates after controlling for age, it does not necessarily follow that they earned higher returns because they

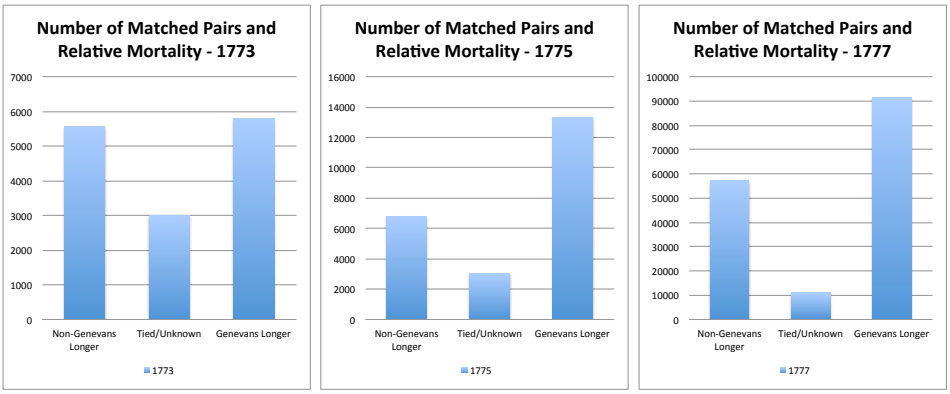

Figure 1: Number of Matched Pairs and Relative Mortality

may have had made an unwise age choice that offset their advantages in mortality. Furthermore, an unconditional comparison allows us to pool data across all age groups and achieve the maximum statistical power. This is an important advantage because the death date data is missing for a nontrivial subsample.

Adverse selection in the sense of the Genevans being better at picking lives is not the only possible explanation for the mortality differences exhibited in Figure 1. They could also have arisen from population wide mortality differences between Swiss and non-Swiss. This hypothesis is unlikely to be true because if the mortality differences we identified in the Wilcoxon tests were due to population-wide differences between Swiss and non-Swiss, we should have observed the differences in the 1773 Irish tontine equally as strong as those in 1775 and 1777, which is not true in reality. Furthermore, we argue that the mortality differences exhibited in the last two Irish tontines were partially a result of Genevans' intelligent age choices. The three panels in Figure 2 plot the percentage of nominees the Genevan and non-Genevan investors selected at each age from 0 to 19 in the three waves of the Irish tontines. Since subscribers paid an equal price for all nominees in the same class, the optimal strategy was to select younger and healthier lives. Neither the Genevans nor the non-Genevans learned this strategy in the 1773 Irish tontine. Beginning with the second Irish tontine, however, the Genevans shifted their strategy to include more younger nominees, in particular, nominees of age 2-6 who had survived the high infant mortality period. To the contrary, the age choice curve for the non-Genevans remains surprisingly flat in all three waves of the Irish tontines, suggesting that they did not recognize the tontine pricing flaws or had other reasons to invest than pure speculation. The phenomenon strongly suggests that the Genevan investors were actively betting on younger nominees with greater expected life spans after enrollment starting the 1775 Irish tontine.

4.2 Simulations

To estimate the differences in returns received by the Genevan and non-Genevan investors, we simulate the actual tontine scheme. We first address the missing data issue by imputing the missing data in

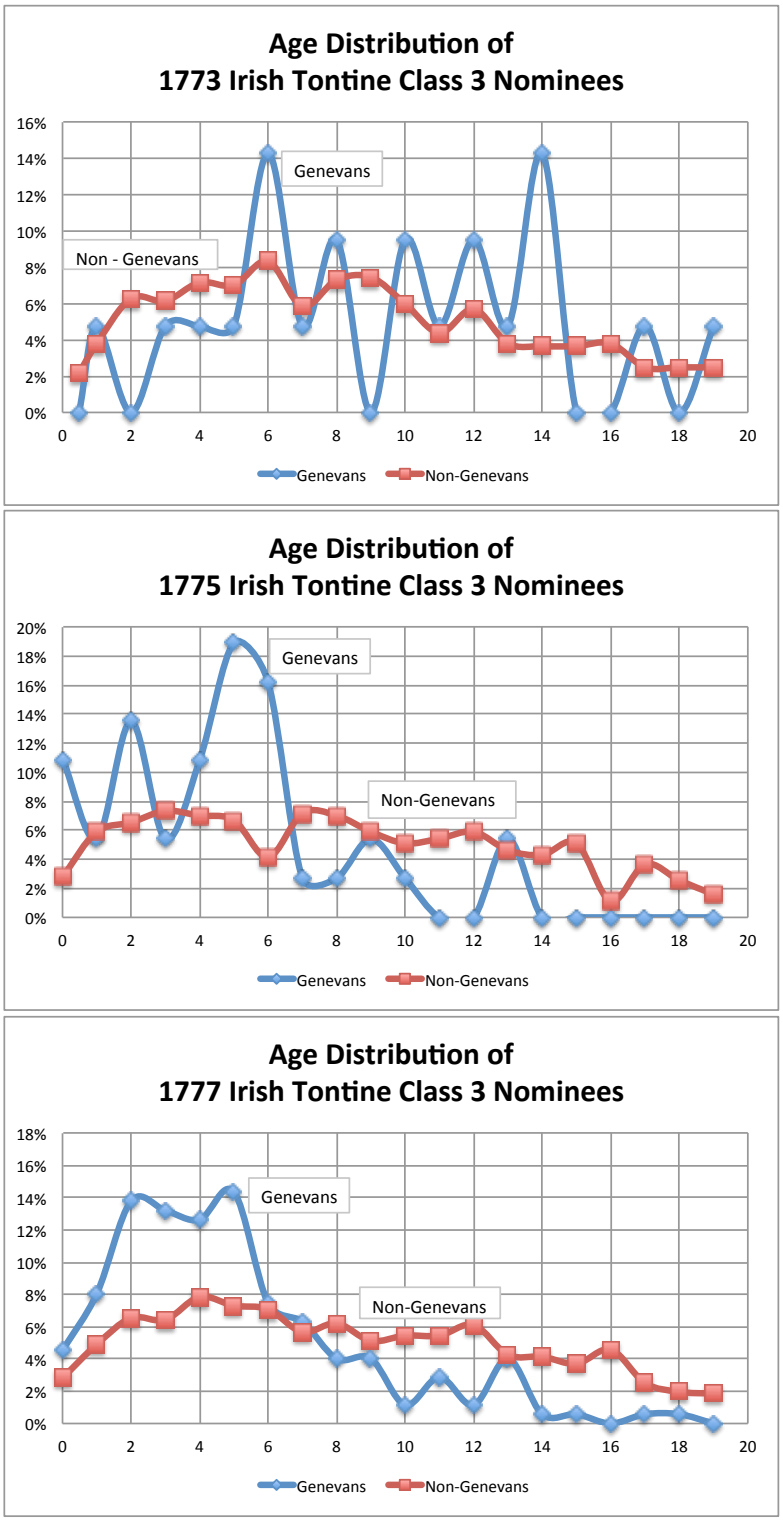

Figure 2: Age Distribution for the Class 3 Nominees in the 1773, 1775 and 1777 Irish Tontines. The horizontal axis represents the age range: 0 to 19. Source: The Committee on Irish Tontine Annuities [1775], The Committee on Irish Tontine Annuities [1777],The Committee on Irish Tontine Annuities [1779]

Table 4: Best Enhancement Factors for the Class 3 Nominees in the **Missing Group** of the 1773, 1775 and 1777 Irish tontines

Tontine	Missing	Std. Error
1773	4.3378	0.2855
1775	2.1511	0.1419
1777	2.5007	0.1791

Note: if the enhanced mortality hazard ($m_j(1+x)$ in the model) exceeds one which is impossible, we reset the value to 0.99. We use the .99 normalization rather than 1 to avoid the program working abnormally at infinity.

Table 5: Number of nominees who died before or in 1810, between 1810 and 1830, and after 1830 in the missing and known group of the 1773, 1775 and 1777 Irish tontines.

Tontine	Group	before or in 1810		1810 to 1830		after or in 1830		TOTAL
		#	%	#	%	#	%	
1773	missing	307	87%	45	13%	0	0%	**352**
	known	0	0%	37	10%	316	90%	**353**
1775	missing	195	61%	117	36%	10	3%	**322**
	known	0	0%	32	9%	310	91%	**342**
1777	missing	136	55%	106	42%	8	3%	**250**
	known	141	17%	153	18%	547	65%	**841**

Source: The Committee on Irish Tontine Annuities [1811],The Committee on Irish Tontine Annuities [1830]

two ways. In method 1, we portray the mortality profile of the missing group with an adapted life table derived from applying a parametric maximum likelihood estimator (MLE) adjustment to a known contemporary life table. In method 2, we model the unknown death dates based on the mortality distribution of the known group assuming that the missing are quasi-random with time-dependent "recording failure" probability. We assume that the missing are random within each time period (prior to year 1810, 1810-1830, and after 1830), but that probability differs across different time periods. The two approaches arrive at similar results.

In general, the fact that these missing data are not random makes the simulations more difficult. If the missing were random, we could model the unknown death dates based on the mortality distribution of the known group, that is, use the mortality distribution of the known group to draw a random death age for the nominees with missing data. However, the missing nominees in general tended to die early, precluding us from applying this strategy. Table 5 shows that in all three Irish tontines, over 90% of the missing group died before 1830 (100%, 97% and 97% in the 1773, 1775 and 1777 Irish tontines, respectively), whereas more than 60% of the known group survived 1830 (90%, 91% and 65% in the 1773, 1775 and 1777 Irish tontines, respectively).

In method 1, we generate a life table for the missing group in each Irish tontine based on the Carlisle

- a contemporary life table - to simulate their death ages. The table is generated by computing a "best enhancement factor" (BEF) which captures the percent by which the average mortality hazards of the missing group exceeds those predicted by the Carlisle table. The "best-fitting enhancement factor"(BEF) is defined as the maximum likelihood parameter (MLE) that adjusts the Carlisle table to fit the intended group. Suppose in the Carlisle table, the mortality hazard at any age j is m_j, then an adapted Carlisle table inherits an "enhanced" mortality hazard $m_j(1+x)$ where x is the enhancement factor. Recall that we do not know the death dates for all nominees, but we do know their death windows (prior to 1810, 1810-1830, and after 1830) given by the two survey data from the 1810 and 1830 Irish tontine reports. Hence we use the number of existing nominees remaining in 1810 and 1830 to find the best enhancement factor - the enhancement factor that maximizes the likelihood function. For each enhancement factor x, the likelihood of x being the observed outcome given the parameter values:

$$P(x) = \coprod_{j \in J} P_j(x) \text{ where } J = \{1, 2, 3, \ldots, 19\}$$

$$P_j(x) = q_{1810_{jx}}^{n_{1810}} \times q_{1830_{jx}}^{n_{1830}} \times q_{post1830_{jx}}^{n_{post1830}} \text{ for each j}$$

The parameters q_{1810}, q_{1830} and $q_{post1830}$ denote the possibility that a nominee died before 1810, in between 1810 and 1830, and after 1830 respectively. The parameters are calculated from the life table enhanced by x and vary with the age j and the enhancement factor x. The constants n_{1810}, n_{1830} and $n_{post1830}$ denote the number of nominees who died before 1810, in between 1810 and 1830 and after 1830, which are obtained from the survey data. Table 4 shows the BEFs computed for the three missing groups. To impute the death data, we draw a random death date for each nominee in the missing group based on the enhanced life table.

Our second imputing approach assumes that the missing death dates are random, but with a time-dependent "recording-failure" probability. In other words, we assume that in any given year, the administrator randomly forgot to record the death dates for some nominees in the group, but the likelihood for the administrator to "forget" decreased overtime. Due to the large portion of missing data in 1773 and 1775, we only apply this assumption to the 1777 Irish tontine simulation.

One justification of this assumption is that the tontine administrator might have worked more diligently when he foresaw an imminent dissolution of the scheme. Naturally, the issuers were most eager to know when they could be released from the tontine's financial responsibility. During the early period of the Irish tontines, when dissolution was unlikely, the administrator recorded death information carelessly, sometimes crossing out a nominee's name without noting the date. But towards the later period in which the chance of dissolution became non-trivial, he may have began to notate a larger percent of the death records. An alternative conjecture is that the nominee books we find were notated by different

	before or in 1810	1810 to 1830	after or in 1830
percentage of missing data	49.10%	40.93%	1.44%

Table 6: Percentage of nominees with missing death dates over time - 1777 Irish tontine. Source: The Committee on Irish Tontine Annuities [1779], The Committee on Irish Tontine Annuities [1811], The Committee on Irish Tontine Annuities [1830]

administrators for each period. The one who supervised the book in the later period took better care of the records.

To implement this strategy, we assume that the decrease in the "recording-failure" probability is discrete. For all nominees, we know that the person died in one of the three time windows: before or in 1810, between 1810 and 1830, and after or in 1830. We assume that the likelihood for an administrator to miss a record in each particular period is constant, but such likelihood decreases overtime (see Table 6). Therefore, for the missing Genevan nominees who died before or in 1810, we randomly draw a death year for each of them using the mortality distribution of the known Genevan nominees who died in the same period. We simulate the death years in the same fashion for all nominees in the missing group and generate a full dataset.

Once the death dates are imputed by either method 1 or method 2, it is easy to compute the tontine income for each individual subscriber. Suppose that the Irish government raised A amount of capital. Then for any interest rate r, the Irish government paid $\frac{A}{(1+r)^n}$ in total in year Y_n, n years after the tontine issuance. Note again that in a tontine scheme, the total payment is fixed while individual incomes vary each year. To obtain individual income per share in year Y_n in present value, we divide the sum $\frac{A}{(1+r)^n}$ by the number of existing shares in that year. For each individual subscriber in year Y_n, if his nominee had survived, he would accumulate a tontine income that equaled the income per share times the number of shares he purchased. His total income per share from the tontine scheme would be the sum of the tontine incomes accumulated each year divided by the number of shares he purchased. To derive the mean total returns per share for the Genevan and non-Genevan investors, we average the sum of returns received by that particular group with respect to their total shares subscribed.

For both imputation methods, we use a bootstrapping procedure to compute the expected mean returns per share and their standard errors. We first generate 1000 equal-size resamples of the original dataset described in Secion 3, each of which is obtained by random sampling with replacements from the dataset. In each resample, we impute the death years for the missing group and derive an average return per share for the Genevan nominees, the non-Genevan nominees, and the entire class. We average over the average returns per share computed from each resample to obtain the overall expected mean returns. Section 5 below presents the results.

4.3 Counterfactual simulations

To further examine the difference in returns between the Genevan and non-Genevan investors, we conduct two counterfactual simulation exercises. The first exercise asks the question: what would the Genevans have earned if they did not select the longest-lived age group? In this exercise, we impose on the Genevan nominees the age distribution of the non-Genevan ones. The resulting difference in returns can be interpreted as hence the percentage of the Genevans' higher returns attributed to their nominees' low mortality. The second simulation imposes an identical mortality profile on both the Genevan and non-Genevan nominees, thus capturing the extra returns attributed to the Genevan bankers' intelligent age choices.

To control for the mortality profile of the Genevan and non-Genevan nominees, we randomly assign death years for both the Genevan and non-Genevan nominees according to the mortality profile of the entire nominee group disregarding their residences. So both groups' mortality profiles become random samples of the original data. Hence by construction, the remaining difference in returns must result from the Genevan bankers' distinctive age selection.

5 Results

We first present the basic results of the simulations using the maximum likelihood method. These simulations show that the Genevans indeed earn higher returns than the non-Genevan investors since the second wave of the Irish tontine in 1775. We then compare this result with the results computed from the quasi-random imputation method. The comparison suggests that the former tends to underestimate the excess tontine incomes received by the Genevan investors. Lastly, we decompose the source of the Genevan's additional incomes into intelligent age choice and mortality advantage.

5.1 Quantify the difference in returns

Figure 3 presents the Genevan and non-Genevan investors' mean returns per share. The left panel shows the present discounted values at 0% interest rate, which is the actual amount paid out by the Irish government at that time. The right panel shows the present discounted values at 6% for the 1773 and 1775 tontine, and 7.1% for the 1777 tontine. These interest rates are set at the dividend rates established by the Irish government for each tontine, which makes the returns in the three waves of the tontines comparable. In effect this treats the relevant interest rates as the Irish governments borrowing rates.[10]

The results in Figure 3 accord with our suggestive graphical evidence (Figure 2 and Figure 1). The

[10] At the interest rate of 6-7%, tontines in class 3 are basically perpetuities. See footnote 6 for detail.

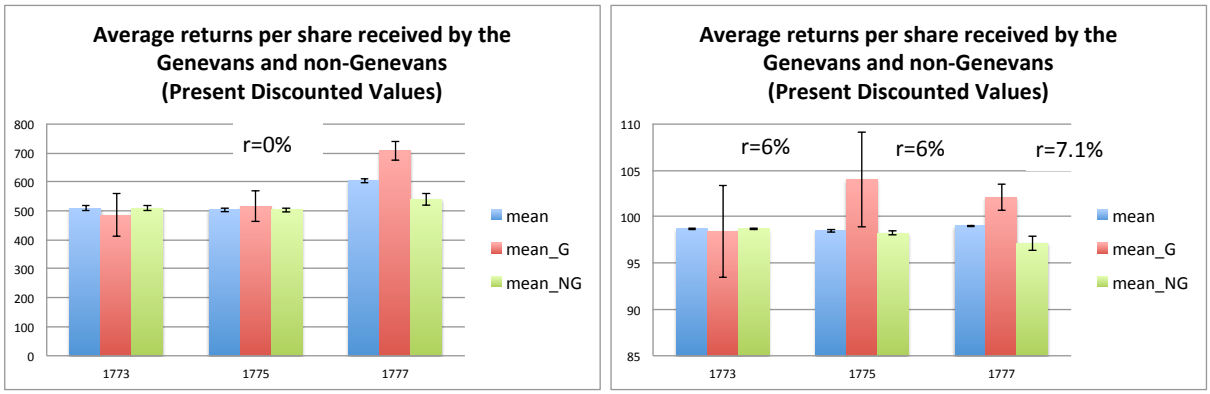

Figure 3: Mean returns per share received by the Genevan and non-Genevan Class 3 investors in the 1773, 1775 and 1777 Irish Tontines. The returns are in units of the Irish pound.

Genevans outperform the non-Genevan group in 1775 and 1777, but fail to do so in 1773. Hence, 1773 serves as an interesting base year to study. The fact that the Genevans do not earn significantly higher returns than the non-Genevans in 1773 provides evidence that Genevans are not inherently longer-lived than the rest of the Europeans. We therefore conclude that the uneven returns between the Genevan and non-Genevan in 1775 and 1777 indeed arise from adverse selection.

5.2 Comparing the maximum likelihood method with the quasi-random simulation

Figure 4 compares the returns per share calculated using the maximum likelihood method and the quasi-random method. The panel shows that the latter method produces a greater tontine income gap between the Genevan and non-Genevan investors. One reason for the income gap is that the maximum likelihood method ignores the difference between Genevans and non-Genevans when simulating the missing group's death dates. Because we generate a single lifetable for both Genevan and non-Genevan missing nominees in the maximum likelihood approach, the lifetable takes the average mortality hazards of the two groups. Therefore, the approach underestimates the non-Genevan's mortality hazard and overestimates the Genevan's mortality hazard.

5.3 Decomposing the difference in returns

Figure 5 shows the results from the two counterfactual simulations. After controlling for mortality, the Genevans earn £2.64 per share more than the non-Genevan investors. After controlling for age choice, the Genevans earn £5.87 per share more than the non-Genevan investors. Note that the sum of the two £8.51 is approximately the total income gap per share between the two group as computed in previous sections - £8.72 per share. In particular, their intelligent age choice appears to account for 31% (2.64£/£8.51 = 31.04%) of their excess income, and their meticulous selection of healthy nominees

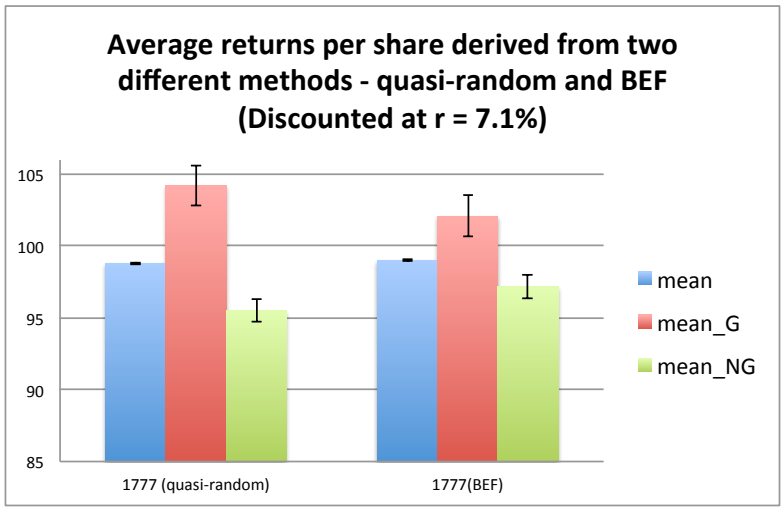

Figure 4: Mean returns per share received by the Genevan and non-Genevan Class 3 investors in the 1777 Irish Tontines. The returns are in units of the Irish pound.

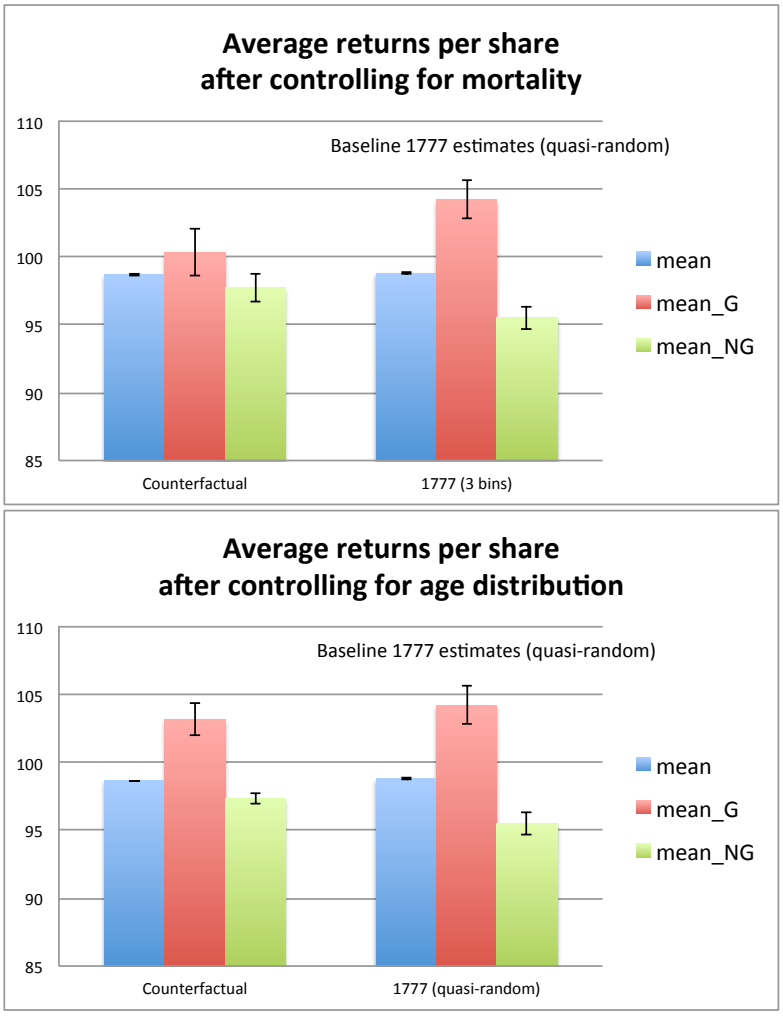

Figure 5: The top panel presents the average returns per share in present value that would have been received by the Genevan and non-Genevan investors if the Genevan nominees had aged according to the non-Genevans' life table. The bottom panel presents the average returns per share in present value that would have been received by the Genevan and non-Genevan investors if the Genevans had picked ages like the non-Genevan did. The discount rate is set at the 1777 Irish tontine dividend rate - 7.1%. The returns are in units of the Irish pound.

accounts for the remaining excess income.

5.4 Moral hazard v.s. adverse selection

Both adverse selection and moral hazard are market failures caused by asymmetric information among market participants. The difference between the two is the timing of the event. Adverse selection happens ex-ante whereas moral hazard happens after the contract is purchased. Though we have established that the Genevan bankers earned higher returns than the non-Genevan investors, we cannot isolate moral hazard from adverse selection. Jennings and Trout [1983] confirm that adverse selection occurred. When selecting a nominee, the Genevan bankers consulted a doctor who recorded the person's family history of longevity.[11]

A request from the Irish Tontine Committee issued in 1811 suggested the possibility of moral hazard or even fraud among the Genevan investors. The Committee suspected that the Genevan bankers may have had forged certificates of existence for their nominees after they passed away and ordered a new form of certificate that demanded more detailed information of the nominees.[12] All subscribers of the Irish tontines were required to submit certificates of existence for their nominees every half year to qualify for receiving the tontine incomes. These certificates needed to be certified by the clergymen of the parish. Domestic subscribers were required to present one certificate for each nominee he selected. However, for the convenience of foreign investors, mainly the Genevans, the Irish Tontine office allowed the Genevans to submit one joint certificate for all nominees they nominated. Strained by the large amount of verification work, the Genevan clergyman may have relied on the subscribers' words instead of hard evidence. Incentivized by pecuniary interest, the subscriber could have had easily cheated on the mortality status of his nominees. Indeed, the committee noticed a large amount of ongoing Genevan subscriptions - £90,000 - that should have been forfeited by 1811.[13] We have no way of distinguishing this possibility in our data.

6 Discussion and Conclusions

Our analysis indicates that the Genevan investors on average earned 8.5% more per share than the non-Genevan investors in the 1773, 1775 and 1777 Irish tontines. The result qualitatively aligns with Rothschild [2009], which detects a much stronger degree of adverse selection among speculative nominees in a 19th century British annuity. This paper studies not only differences in mortality prospect, but also differences in monetary returns. We show that the non-speculative investors receive lower incomes due to the existence of speculative nominees. This result has important implications for policy researches on the privatization of the insurance market: aggressive speculators with access to superior information

[11] See Jennings and Trout [1983]
[12] See [The Committee on Irish Tontine Annuities, 1812]
[13] See [The Committee on Irish Tontine Annuities] Appendix

can take advantage of the arbitrage opportunities to procure profits, at the expense of the interests of investors with less information.

The gaming of the system is widely documented in modern public finance literature. Chetty et al. [2013] finds that individuals with better knowledge of the Earned Income Tax Credit (EITC) obtain larger EITC refunds by manipulating their reported incomes. Einav et al. [2013] documents that individuals approaching age 65 strategically delay their drug purchases to have them covered by Medicare Part D, a public insurance that covers drug purchases for elderly Americans above the age of 65.

Our results highlight the importance of asymmetric information across non-government players in government-created "markets". Individual investors may make suboptimal investment choices due to their lack of knowledge about relevant policies. Kling et al. [2008] notes that a nontrivial portion of seniors are not well-informed about Medicare Part D drug plans and do not seek personalized comparative information, despite its potential value. On the other hand, sophisticated investors such as the insurance companies may take advantage of the scheme. Our results provide an early and particularly clean window in testing the information asymmetries because the competition among different types of subscribers in the Irish tontines were free from any government intervention.

The study also sheds lights on the importance of the government keeping the public's interests in mind when designing public policies. The Irish tontines example was a stark illustration of what could go wrong when the government payoff is arbitrarily determined and severed from the welfare of the public.

Our study also illustrates a way to study historical data through the lens of modern economics. By utilizing archived data in novel ways, this paper provides a vignette on how various fields - history, economics, statistics - can be integrated to provide rigorous analysis on societal issues.

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7 Appendix

The Irish Act formulated the 1773 Irish tontine as follows:

> The entire interest of the entire sum so to be advanced by person subscribing in any of the said Classes, computing such interest at the rate of six pounds by the hundred by the year, shall go to and be divided among the persons so subscribing, in proportion to the sums by them respectively subscribed and paid.[14]

[14]Source: The language appears in the later report "Returns of Sums subscribed by Nominees of Tontines in Ireland"