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# ADVERSE SELECTION IN INSURANCE MARKETS: POLICYHOLDER EVIDENCE FROM THE U.K. ANNUITY MARKET

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ABSTRACT

In this paper, we present new evidence on the importance of adverse selection in insurance markets. We use a unique data set on all annuity policies sold by a large U.K. insurance company to analyze mortality and pricing differences across different annuity policies purchased by observationally identical individuals. We find systematic relationships between ex-post mortality and annuity policy characteristics such as whether the annuity will make payments to the estate in the event of an untimely death, and whether the payments from the annuity rise over time. These mortality patterns are consistent with models of asymmetric information in insurance markets but would not be predicted under symmetric information. We find no evidence of mortality differences, however, across annuities of different size, as measured by the initial annual payment from the annuity. The pricing of these different annuity features is consistent with the self-selection patterns. Our results therefore suggest the importance of taking account of specific features of insurance contracts that can potentially serve as screening mechanisms. They also indicate that insurance markets may be characterized by adverse selection, even when testing for the presence of such selection by stratifying policyholders only on the basis of the amount of payment in case of claim does not suggest selection effects.

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Theoretical research on insurance markets has long emphasized the potential importance of asymmetric information in such markets. The welfare implications of adverse selection, one of the consequences of asymmetric information, have been well documented. Yet several recent empirical papers have failed to find evidence of asymmetric information in both property-casualty and life and health insurance markets. Cawley and Philipson (1999), who study the U.S. life insurance market, Cordon and Hendel (1999), who study the U.S. health insurance market, and Chiappori and Salanie (2000), who study the French automobile insurance market, all find it difficult to reject the symmetric information null hypothesis about the functioning of insurance markets.

This paper tests two simple predictions of asymmetric information models using data from the U.K. annuity market. Models of insurance market equilibrium in the presence of asymmetric information make two robust predictions. The first is that higher risk individuals will self-select into insurance contracts that offer features that, at a given price, are more valuable to higher risk individuals. The second is that the equilibrium pricing of insurance policies will reflect the fact that the risk pool varies across different policies. Such self-selection across policies by risk type would not occur if the insurer and the insured had symmetric information. Our empirical work finds support for both of these predictions.

Annuity markets are an interesting setting in which to study asymmetric information problems. These markets are of substantial interest in their own right. Annuities – which provide insurance against outliving one's resources – have a potentially important welfare-improving role to play for retirees. But in spite of the potential value of annuity products for households that face uncertain mortality and have fixed resources, voluntary annuity markets in both the United States and the United Kingdom are small. Asymmetric information, in particular adverse selection, has often been raised as a potential explanation for the limited size of these markets (see Mitchell, Poterba, Warshawsky, and Brown (1999) for a recent discussion of these issues). Besides the intrinsic interest of annuity markets, there is another reason for studying asymmetric information issues in this context.

Most tests for asymmetric information cannot distinguish between adverse selection and moral hazard, even though the welfare implications of the two, and their potential policy implications, are often quite different. Moral hazard seems relatively unlikely to operate in the annuity context, however. If the impact of an annuity income flow on behavior that extends life is small, so that moral hazard problems are limited, testing for asymmetric information in the annuity market provides a particularly valuable test for adverse selection.

This paper is divided into six sections. The first outlines a simple theoretical model of screening and adverse selection. It presents a generalized version of the classic Rothschild-Stiglitz (1976) model that illustrates that, when insurance contracts are multi-dimensional, many features of the insurance contract can serve as screening mechanisms. Two empirical predictions of this model form the basis for our empirical tests. This section also summarizes the previous literature that has tested for asymmetric information in insurance markets.

Section two describes annuities markets in general, and notes several specific features of the U.K. market that are relevant for our analysis. It also presents a specialized version of the model from the first section that applies directly to the annuity market setting. The third section describes the data set that we have obtained from a large U.K. insurance company, and compares the annuitants at this firm with those in the market at large.

Section four presents the first part of our empirical framework. It describes the specification of hazard models that relate the probability of annuitants dying after purchasing annuities to detailed characteristics of the annuity policy, as well as other information the insurance company has about the annuitant. We present estimates both with and without accounting for unobserved individual heterogeneity. The empirical findings suggest that ex-post annuitant mortality varies systematically with characteristics of the annuity policy. This variation is consistent with theoretical models of asymmetric information.

The fifth section describes our second empirical test, which focuses on estimating hedonic pricing models of different features of annuity policies. Annuity pricing is consistent with the presence of adverse selection in the annuity market. Features of the annuity that our hazard models indicate are selected by low mortality individuals, who are "high risk" annuity buyers from the perspective of the insurance company, are priced higher than features that are selected by high-mortality individuals. We do not find any evidence in either the mortality or the pricing estimates of self-selection along the initial annual annuity payment, a crude measure of the "size" of the annuity policy, even though this variable is closest to the "amount of insurance" variable in most theoretical discussions of adverse selection.

The final section summarizes our findings and considers possible explanations for our results that might not involve adverse selection in the annuity market.

## 1. Adverse Selection and Screening in Insurance Markets: Theory and Evidence

This section describes the basic structure of adverse selection equilibrium and the associated structure of insurance market prices. The discussion is general; application to the annuity market context is reserved until the next section. This section also summarizes existing empirical research on asymmetric information in insurance markets.

### 1.1 Theoretical Background

Consider the standard model, developed for example in Rothschild and Stiglitz (1976), in which there are two types of individuals who differ only in their risk type $p$, where $p$ denotes the probability the individual will incur a claim against the insurance company. We denote these two types of individuals by $p_H$ and $p_L$, with $p_H > p_L$. The risk type is known by the individual but not by the insurance company. The insurance market is competitive and therefore a zero profit condition applies.

The insurance company offers a menu of insurance contracts with different features, and designs this menu to screen customers according to their risk type. The key to this screening mechanism is that if the value of a feature of the contract differs across individuals of different risk types, the insurance company can, through appropriate pricing, induce individuals to self-select into different contracts on the basis of their (privately known) risk type. Under symmetric information, in contrast, each individual would purchase the same, efficient, insurance contract and prices would reflect individual-specific risk.

In the Rothschild-Stiglitz (1976) framework, insurance contracts differ only in the quantity of insurance sold and the marginal price charged. The screening equilibrium involves the high risk type buying full insurance (as in the symmetric information case). The low risk type buy the maximum amount of insurance that he can have while leaving the high risk type indifferent between paying the marginal price $p_H$ for full insurance and paying the marginal price $p_L$ to buy the amount of insurance purchased by the low risk type. The key to this equilibrium is that the marginal utility that the high risk type gets from an extra unit of insurance at a given price is higher than the marginal utility that the low risk type gets from an extra unity of insurance at this same price. This Spence-Mirlees (or single crossing) property ensures that there exists some quantity of insurance that the low risk type can purchase at marginal price $p_L$ that leaves the high risk type indifferent between purchasing this quantity of insurance at price $p_L$ and buying full insurance at the higher price $p_H$.

It is straightforward to generalize this model to allow for a multi-dimensional vector of insurance product characteristics. Any feature that satisfies the Spence-Mirrlees condition can potentially be used to separate different risk types into different types of insurance contracts. The negative efficiency implications of asymmetric information are the same irrespective of what feature is used to screen customers.

Two key empirical predictions of this model form the centerpiece of our empirical tests for asymmetric information in the annuity market.[1] First, there is a positive correlation between (privately known) risk type and features of insurance whose marginal value is greater for high risk types. Second, features of insurance contracts that are purchased by higher risk types will be priced higher than features that are purchased by lower risk types. In practice, the insurance company may observe some risk features of the individual. The stylized model therefore applies to individuals who are observationally equivalent to the insurance company, and the foregoing predictions apply conditional on the characteristics of the insured that are observable by the insurance company.

1.2. Previous Empirical Literature on Asymmetric Information in Insurance Markets

Several recent empirical papers have tested for adverse selection in several different insurance markets. These papers share a common approach: They examine the relationship between ex-post risk type and insurance coverage, conditional on observable characteristics of individuals. Pueltz and Snow (1994) tested this relationship in the U.S. automobile insurance market. They found that higher risk individuals (measured by ex-post accident probabilities) choose, ex-ante, policies with lower deductibles. This finding is consistent with asymmetric information in the automobile insurance market.

Chiappori and Salanie (2000) have recently re-examined the question of asymmetric information in automobile insurance markets. They estimate a bivariate system of equations in which quantity of insurance and ex-post risk type are regressed on exogenous variables. Asymmetric information models predict a positive correlation between the errors of these two equations. Chiappori and Salanie (2000) find no evidence of such a correlation in French auto insurance data. Using a similar test, Cordon and Hendel (1999) find no evidence of asymmetric information in health insurance. In a related study, Cawley and Philipson (1999) examine the relationship between insurance coverage and risk in the U.S. life insurance market. They too find no systematic relationship on either the extensive or intensive margin between risk type and insurance coverage.

Three of these four recent studies thus fail to find a positive correlation between risk type and quantity of insurance coverage. One common limitation of these studies is their focus on a one-dimensional screening variable: the amount of payment in the event of an accident. In practice, many other aspects of insurance contracts may also satisfy the Spence-Mirlees condition and therefore have

[1]Chiappori and Salanie (2000) note that these predictions are robust to many modifications in the Rothschild-Stiglitz model.

the potential to serve as screening mechanisms. Such features need to be recognized in empirical tests; we attempt to do this below. Chiappori and Salanie (2000) acknowledge that there are "many different comprehensive coverage contracts on offer," but they focus on a binary measure of whether the individual has anything more than the legal minimum level of coverage. Cawley and Philipson (1999) examine the relationship between risk type and the amount the term insurance policy would pay out in the event of death, while ignoring other potential screening variables such as renewability. Our empirical work, like that in the earlier studies, finds no evidence of screening on the amount of payment that the insurance policy prescribes. We do, however, find evidence in support of asymmetric information using other screening devices.

Several of the foregoing studies also implement empirical strategies that are similar to our second test. This involves, at a general level, testing the prediction that contracts with more comprehensive coverage are sold at higher (unitary) premiums. Pueltz and Snow (1994) find evidence of a concave premium-deductible schedule, which suggests that low risk individuals – whom they find choose large deductibles – receive lower prices for their choice. Cawley and Philipson (2000), however, find no evidence of rising marginal prices with the amount of payment of the life insurance policy in the event of death. We will also investigate the pricing of different features of the annuity contract, in part using direct information that we have on the pricing formula used by the insurance company that we are studying.

## 2. Background on Annuities and Annuity Markets

This section presents an overview of annuity markets in the United Kingdom, and then applies the framework developed in the last section to the specific context of the annuity market. We formalize the model-based predictions that form the basis for our empirical work.

### 2.1 Annuity Market Overview

An annuity is a contract to pay a fixed payment stream for each period that the annuitant survives. It thus provides insurance for the annuitant against outliving his accumulated resources in retirement. As such, annuities function as reverse life insurance, insuring against the risk of living too long. From the standpoint of an annuity insurance company, a high-risk individual is an individual who is likely to live longer than his observable attributes, such as age, would otherwise suggest.

The welfare-improving role of annuity insurance for individuals facing uncertain mortality has been well-documented since Yaari (1965). Given this potential welfare-improving role for annuities, the small size of the voluntary annuity market in the United States and the United Kingdom has been something of a puzzle. One possible explanation for the small market size is adverse selection. Several previous studies suggest that there may be selection effects in annuity markets. The pricing of voluntary annuities in both the U.S. and the U.K. suggests that, for a typical individual from the population, the expected present discounted value of the payments from an annuity are only 80 to 85 percent of the original premium paid for that annuity. Although part of the difference in premiums from "actuarially fair" rates is likely to be due to administrative loads, part is also apparently due to adverse selection. If the typical annuitant is longer lived than the typical individual drawn at random from the population, then annuities priced to reflect the longevity of the annuitant population will not be actuarially fair for the typical individual in the population. Indeed, market-wide mortality tables published in the U.S. and the U.K. based on the mortality experience of voluntary annuitants suggest that the typical voluntary annuitant 65-year-old male is expected to live twenty percent longer than the typical 65-year-old male in the population.[2]

While these mortality patterns are consistent with adverse selection in the annuity market, they do not provide direct evidence on a relationship between mortality rates and the type of insurance

[2] Finkelstein and Poterba (1999) and Murthi, Orszag, and Orszag (1999) present summary information, and mortality comparisons, for the U.K. annuity market. Brown, Mitchell, and Poterba (2000), and Poterba and Warshawsky (2000), present related information for the U.S. market.

purchased by annuitants.[3] Yet this relationship is the central prediction of asymmetric information models of insurance markets. The data in this paper allow a direct investigation of this relationship.

The U.K. annuity market, which is described in more detail in Finkelstein and Poterba (1999), provides a particularly rich setting for studying adverse selection in annuity markets. There are effectively two annuity markets in the United Kingdom. There is a compulsory annuity market in which individuals who have accumulated savings in tax-preferred retirement vehicles similar to 401(k)'s or IRA's in the U.S. are required to annuitize a large portion of their accumulated balance. There is also a voluntary annuity market in which individuals with accumulated savings may use these accumulated assets to purchase an annuity. Finkelstein and Poterba (1999) suggest that mandatory annuitization halves the cost of adverse selection in the U.K. annuity market.

A wide variety of annuity products are sold in both the compulsory and voluntary annuity markets. Annuitants in the compulsory market face virtually no restrictions on the type of annuity they can purchase. Therefore, there is scope for selection among annuity products in both markets.

We concentrate in this paper on annuities that pay a pre-determined payment stream. We also limit our analysis to annuities that insure a single life, as opposed to annuities purchased by a couple that continue to pay out as long as one of the members of the couple remains alive.

We pay particular attention to three features of an annuity that may serve as screening devices. One is the initial annual annuity payment. This is the analog of the payment in the event of accident in the auto insurance market. A second is the tilt, or degree of backloading, of the annuity. A more backloaded annuity is one whose payment profile is such that a greater share of its payments is made in later years. The most common form of annuity is a nominal annuity, which pays out a constant nominal amount each period. In a world with positive expected inflation, the expected real payment stream from such an annuity is declining over time. A real annuity, in contrast, pays out an annuity that is constant in real terms. Annuities are also present in escalating amounts; such annuities escalate at a nominal rate of anywhere from 3% to 8.5% and may be rising in real terms depending on the

[3] There are no separate mortality tables calculated for different annuity products.

expected rate of inflation. Real annuities and escalating annuities are therefore more backloaded than nominal annuities. A third feature that we focus on is whether the annuity may make payments to the estate. Some annuities offer guarantee periods. The insurance company continues to make payments to the annuitant's estate for the duration of the guarantee period if the annuitant dies before the guarantee period expires.[4] Annuities with guarantee periods of 1 to 15 years are present in our data. "Capital protection" is another form of potential payments to the estate. If at the date of the annuitant's death the sum of nominal annuity payments to date is less than the premium paid for the annuity, a capital-protected annuity pays the difference to the estate as a lump sum. All three of these features -- initial payment amount, backloading, and payments to the estate -- are potential screening devices for insurance companies with less information than their customers

## 2.2 Market Equilibrium in the Annuity Market

To apply the equilibrium framework developed in the last section to the annuity market, we represent an annuity contract by a vector $x = (a, \tau, g)$. The initial annuity payment is $a$, $\tau$ denotes the tilt or backloading of the annuity payout stream, and $g$ denotes the guaranteed payout amount. We consider a two-period setting, in which an individual of risk type i has a probability of surviving in each period of $p_i$. We do not allow saving between the first and second period. The expected utility of individual of risk type i who purchases policy $x$ is therefore:

(1) $V_i(p_i, g_t, \tau, a) = (1 - p_i)U(g_1) + p_i U(a) + p_i^2 U(a(1+\tau)) + (1 - p_i) p_i U(g_2)$.

Screening on a given annuity characteristic requires that the Spence-Mirrlees property be satisfied for that characteristic. It is easy to see from (1) that the marginal value of the initial annual annuity payment (a) is increasing in risk type $p$ as is the marginal value of an increase in tilt ($\tau$). Finally, the marginal value of a guarantee period (g) is decreasing in $p$.

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[4] One restriction faced by compulsory annuitants is that they may not purchase an annuity with more than a 10 year guarantee period.

The intuition for these results is simple. An annuity with an upward tilt has more of its payments in later periods than an annuity with a flat payment profile. A longer lived annuitant, who is more likely to be alive in these later periods when the tilted annuity pays out more than the flat annuity, therefore gains more, at a given price, from a tilted annuity than a shorter lived annuitant does. Similarly, an annuity that pays in the event of soon death (either through a guarantee period as modeled above or through capital protection as discussed above), is of greater value to an individual who is shorter lived, than to an individual who is longer lived. Thus all three of these features satisfy the Spence-Mirrlees property and are potential screening devices.

The first empirical prediction discussed in the previous section suggests that, under asymmetric information, people who buy more backloaded annuities should be longer lived, conditional on observables, than those who buy less backloaded policies. It also suggests that those who buy annuities that make payments to the estate should be shorter-lived, and that those who buy annuities with larger initial annual payments should be longer lived, conditional on observables. The second empirical prediction suggests that more backloaded annuities and annuities with larger initial annuity payments will be priced higher to reflect the fact that in equilibrium they are purchased by riskier (i.e. longer lived) individuals. Similarly, annuities that make payments to the estate will be priced lower to reflect the fact that in equilibrium they are purchased by less risky individuals.

These predictions would not obtain in a setting with symmetric information. Consider the case of the degree of backloading of the annuity. With symmetric information, a longer-lived annuitant has no incentive to buy an annuity whose payments are more backloaded. Whatever annuity he buys, the annuity company will adjust the price charged to reflect the annuitant's mortality prospects. And given that the price adjusts, any preference for an annuity of a given tilt will be influenced only by discount rates, not by mortality prospects. However, if the annuitant has private information that he is likely to be long-lived, then when he chooses to buy a particular annuity the price is not fully adjusted to take account of his mortality prospects. An insurance company, knowing that backloaded annuities are more appealing than nominal annuities to longer lived individuals, will price backloaded annuities accordingly.

The key difference between the symmetric and asymmetric information scenarios is that under asymmetric information, the annuitant acts as a price taker, while under symmetric information, he does not. With asymmetric information, the price of a backloaded annuity will reflect average mortality prospects in equilibrium of backloaded annuitants, but will not adjust further to reflect an individual annuitant's mortality prospects. A longer-lived annuitant, taking prices as given, has an incentive to choose an annuity who payments are more backloaded. A longer-lived annuitant whose annuity options are all priced to reflect his individual-specific mortality faces no such incentives.

The fact that in practice, unlike in the stylized model, individuals differ on dimensions other than simply their risk type does not pose a problem for the interpretation of our empirical analysis. If product choice is driven not by private information about mortality but rather by (privately known) preferences such as discount rates or risk aversion which are correlated with mortality, the effect of such private information is similar to the effect of private mortality information. Anything that is correlated with mortality (such as wealth) and is known by the individual (even if he is not aware of its effect on mortality) but not to the insurance company operates just like traditional asymmetric mortality information.

**3. Data and Descriptive Statistics**

We have data on the complete set of immediate annuities sold by a large U.K. annuity company over a seventeen-year period ending on December 31, 1998. Our sample consists of both voluntary and compulsory annuities. While the company sold annuities prior to 1981, the first year in our sample, this was the first year in which both voluntary and compulsory annuities were sold. At the end of the sample period, our firm was among the ten largest in the U.K. in terms of new compulsory annuity sales.[5] The company's sales in the compulsory market have been growing over time, driven in part by the expansion in the late 1980s of the set of retirement savings plans that face compulsory annuitization requirements. In recent years, voluntary sales have been a small fraction of total revenue.

Our data consist of all of the information – except address and day of month of birth – that the insurance company has on its annuitants.[6] This includes information on the annuitant and on the policy purchased by the annuitant. It also includes information on the annuitant's date of death, if the annuitant died within the sample period. Death records are current through December 31, 1998. The insurance company collects very little information – only age and gender – about the personal characteristics of annuitants. In particular, it does not collect any information on the annuitants' wealth, income, education, occupation, or another other indicators of socioeconomic status. This is typical for insurance companies selling annuities in the U.K.

We restrict our attention to single life annuities, annuities whose payments are based on the mortality of one individual, because the mortality patterns of the single insured lives on each policy provide a straightforward measure of ex-post risk type, our key variable of interest. As Brown and Poterba (2000) note, it is considerably more complicated to analyze the joint mortality patterns of couples with joint life annuities to determine the risk type of a couple. Our final sample size is 42,054.

Table 1 provides an overview of the characteristics of the compulsory and voluntary annuity sales by our sample company. The voluntary market consists of about one tenth of total policies in our sample, and a somewhat higher fraction of premium volume; the relative size of the voluntary and compulsory market in our sample company is similar to that for the aggregate U.K. market as reported by the Association of British Insurers (various years). Differences between voluntary and compulsory annuitants in our data also appear typical of the U.K. market as a whole. Table 1 indicates that annuitants in the voluntary market are substantially older at purchase and more likely to be female

[5] Information on the market share of various U.K. insurance companies in the annuity market may be found at *http://insider.econ.bbk.ac.uk/pensions/annuities/experiences/uk/q97s.htm*

than are those in the compulsory market. Banks and Emmerson (1999), using data from the Family Resources Survey, also report that voluntary annuitants are more likely to be female than compulsory annuitants. The characteristics of annuities purchased through our company also match what little aggregate data exist on characteristics of U.K. annuities sold. Index-linked and escalating products together make up less than 10% of the voluntary or the compulsory market, with index-linked policies less than 5% in each market. This prevalence of nominal policies mirrors the U.K-wide breakdown reported in Murthi, Orzsag, Orszag (1999).

The modal policy in the compulsory market for 1997 and 1998, when sales were at their peak, is a male, 65 year old, nominal annuity with a five year guarantee. In the voluntary market, the modal policy in 1984 and 1985, which together account for more than one quarter of the voluntary annuity sales in the sample, is a female, 74 year old, nominal annuity with no guarantee.

**4. Annuitant Mortality and Product Choice**

Our empirical analysis involves two distinct projects. In the first, we test for systematic relationships between the type of annuity that an annuitant purchased, and that annuitant's subsequent mortality experience. We do this by estimating hazard models for annuitant mortality. In the second project, we investigate the relationship between the price charged for an annuity and the features of the annuity. This section describes our methods for the mortality comparison project, and presents our main results. The next section presents our findings on annuity pricing.

4.1 Annuitant Mortality Comparisons: A Hazard Model Framework

We estimate mortality differences among different groups of annuitants using the discrete-time, semi-parametric, proportional hazard model of Meyer (1990) and Han and Hausman (1990). Our duration measure is the length of time lived by the annuitant after purchasing an annuity. We let $\lambda(t, x_i, \beta, \lambda_0)$ denote the hazard function; it represents the probability of an annuitant with

[6] Those two pieces of information were suppressed to protect the identity of the annuitants.

characteristics $x_i$ dying $t$ periods after purchasing the annuity, conditional on living until $t$. The proportional hazard model assumes that $\lambda(t, x_i, \beta, \lambda_0)$ can be decomposed into a baseline hazard $\lambda_0(t)$, and a "shift factor" $\phi(x_i, \beta)$ as follows:

(2) $$\lambda(t, x_i, \beta, \lambda_0) = \phi(x_i, \beta)\lambda_0(t)$$

The baseline hazard, $\lambda_0(t)$, is the hazard when $\phi(\cdot)$ =1. $\phi(\cdot)$ represents the proportional shift in the hazard caused by the vector of explanatory variables $x_i$ with unknown coefficients $\beta$. The major assumption of the proportional hazard model is that the effects of the explanatory variables ($x_i$) are independent of duration $t$.

A common functional form for $\phi(\cdot)$, and the one adopted here, is $\phi(x_i; \beta) = \exp(x_i'\beta)$. The proportional hazard model is then written as:

(3) $$\lambda(t, x_i, \beta, \lambda_0) = \exp(x_i'\beta)\lambda_0(t)$$

A key issue in estimating proportional hazard models is the specification of the baseline hazard $\lambda_0(t)$. We model the baseline hazard non-parametrically as a piece-wise constant (step) function. This allows us to avoid imposing any restrictive functional form assumptions on the baseline hazard. We have 17 years of data and therefore allow for 17, annual, discrete time periods. Letting $\delta_t = \int_0^t \lambda_0(s)ds$ denote the integrated baseline hazard, the general proportional hazard model in (3) becomes for this specific case:

(4) $$\lambda(t_i; x_i, \beta, \delta) = 1 - \exp\{\exp(x_i'\beta)(\delta_t - \delta_{t+1})\}$$

The model is then estimated by maximum likelihood with the log likelihood function given by

(5) $$\ln(L) = \sum_{i=1}^{n} (1 - c_i)\ln(\lambda(t_i; x_i, \beta, \alpha)) - \int_0^t \lambda(s_i; x_i, \beta, \alpha)ds$$

where c is an indicator variable that equals 1 if the individual is right censored (i.e., has not died by the end of our sample period) and 0 otherwise. Eighty-four percent of the voluntary annuitants, and 47 percent of the compulsory annuitants, are right-censored. The likelihood function in (5) corresponds to that of an ordered categorical model. We assume that $\varepsilon = \ln \delta_t + x_i'\beta$ has an extreme value distribution, and therefore the likelihood function in (5) is the same as that for an ordered logit model.

We also estimate hazard models that try to account for unobserved heterogeneity across individuals. Unobserved heterogeneity in hazard model applications is typically handled by modeling the unobserved regressor as a proportional shifter of the baseline hazard, just like the observed $x_i$ regressors. We therefore rewrite the proportional hazard function given in (3) as

(6) $$\lambda(t; x_i, \beta, \alpha, v_i) = v_i \exp(x_i'\beta)\lambda_0(t;\alpha)$$

where $v_i$ summarizes the effect of omitted regressors for individual i. We handle unobserved heterogeneity by assuming a density for $v_i$ and then integrating it out of the conditional density function above to get the marginal density function. We assume that $v_i$ is distributed as a Gamma variate with unit mean and variance $\sigma^2$, independently of $x_i$ and $t$, implying that the density of $v_i$ is proportional to $v^{\sigma^{-2}-1}\exp(-v\sigma^{-2})$. This density is chosen mainly for its convenient mathematical form, for it admits an analytical expression for the marginal hazard function:

(7) $$\lambda(t; x_i, \beta, \alpha) = \frac{\exp(x_i'\beta)\lambda_0(t;\alpha)}{1 + \sigma^2 \exp(x_i'\beta)\int_0^t \lambda_0(s)ds}$$

We can therefore maximize the likelihood function in (5) using (7), with the addition of $\sigma^2$ as another parameter to be estimated.

We estimate hazard models of annuitants' death as a function of all of the known characteristics of the annuitant and all of the features of the annuity policy. We estimate these models separately for annuitants in the voluntary market and for annuitants in the compulsory market so as not to constrain the effect of policy features to be the same across markets.  In all regressions we include dummies for the age at purchase of the annuity (in five-year categories), the year of purchase of the annuity, and the gender of the annuitant. We also include dummies for the frequency of annuity payments (monthly, termly, quarterly, semi-annually or annually).

We include two dummies to capture the degree of backloading of the annuity payment: INDEX-LINKED is a dummy for whether the annuity payments are indexed to inflation and ESCALATING is a dummy for whether the annuity payments are escalating in nominal terms. The omitted category is a nominal annuity. The theory described above suggests that individuals who buy index-linked or escalating annuities should be longer lived than those who buy nominal annuities. They should therefore have a lower hazard and so the expected sign on both covariates in the hazard model is negative.[7]

We also include two dummies intended to capture payments to the estate.  These are a dummy for whether the annuity is guaranteed (GUARANTEED) and a dummy for whether the annuity is capital protected (CAPITAL PROTECTED). The omitted category is an annuity that does not make any payments to the estate (i.e. is neither guaranteed or capital protected).  An annuity cannot be both guaranteed and capital protected.  The theory described above predicts that individuals who buy annuities with more payments to the estate will be shorter-lived (i.e. have a higher hazard rate) than individuals who buy annuities that do not make any payments to the estate. The predicted coefficient on the GUARANTEED and CAPITAL PROTECTED covariates in the hazard model is therefore positive.  There is no prior prediction concerning the relative longevity of guaranteed and capital protected annuitants, as there is no clear measure of which is relatively more attractive to someone with mortality that diverges from the population average.

Finally, we include one other feature of the annuity product that satisfies the single crossing property and is therefore a potential screening device: the initial annual annuity payment

(PAYMENT). This is perhaps the most traditional screening device, corresponding to the amount that would be paid out in life insurance in the event of death or the amount that would be paid out from an automobile insurance policy in the event of an accident.

We do not include any measure of "marginal price" in the regression because with all of the known characteristics of the annuity and annuitant controlled for, the premium and marginal price should be completely determined. We estimate the relationship between mortality and product characteristics separately for the voluntary and the compulsory market.

Table 2 summarizes the theoretical predictions for each of the potential screening devices with respect to both mortality rates and product pricing (The latter are developed in the next section). Our empirical tests are designed to provide evidence on these two sets of predictions.

4.2 Basic Results: Annuity Choice and Mortality Patterns

Table 3 presents estimates of the hazard model in equation (4). The first column presents estimates from the compulsory annuity market, while the second channel corresponds to the voluntary market. The results in Table 3 closely match our theoretical predictions of self-selection under asymmetric information. In both the compulsory and voluntary market, there is strong evidence that individuals who buy more backloaded annuities are longer-lived. The coefficients on INDEX-LINKED and on ESCALATING are negative and statistically significant in both markets, indicating that individuals who buy index-linked or escalating annuities have a lower mortality hazard rate (and hence longer life) all else equal than individuals who buy nominal annuities.

There is also evidence strong evidence that voluntary annuitants who buy annuities that make payments to the estate in the event of an early death are shorter lived than individuals whose annuities do not make such payments. The coefficient on GUARANTEED is positive, indicating that individuals who buy guaranteed annuities have higher hazards (and hence are shorter-lived) than observationally similar individuals who buy non-guaranteed, non-capital protected annuities. The

[7] There is no prior prediction for the relative longevity of escalating annuitants and index-linked annuitants since this would depend on the level of escalation and level of indexation, as well as on expected inflation at the time

coefficient on GUARANTEED is significant at the 1% level in the voluntary market. Additionally, the coefficient on CAPITAL PROTECTED is positive in the voluntary market, indicating that individuals who buy capital protected annuities are shorter lived than observationally similar individuals who buy non-guaranteed, non-capital protected annuities. Although the coefficient on CAPITAL PROTECTED is not significantly different from zero in our basic specifications, once we allow for unobserved heterogeneity, it does become statistically significant.

In the compulsory market, Table 3 indicates that although individual who buy guaranteed annuities are shorter lived than individuals who buy non-guaranteed annuities, the difference in hazard rates is not statistically significant. However, in results not reported here we enriched the basic model to consider whether there was selection by the length of the guarantee period or the degree of backloading. We grouped annuities by length of guarantee period into those that were guaranteed for 1-4 years, those that were guaranteed for 5 years and those that were guaranteed for 10 years.[8] We also grouped annuities by degree of escalation into those that escalated at 3% per annum, those that escalated at 5% per annum, and those that escalated at 8-8.5% per annum. In the compulsory market, we find that although guaranteed annuitants as a group are not significantly shorter lived than non-guaranteed annuitants, annuitants with 10 year guarantee periods (the longest in the compulsory market) are significantly (at the 5% level) shorter lived than annuitants with non-guaranteed annuities. We also find that the hazard increases monotonically with the length of the guarantee period and decreases monotonically with the degree of escalation. Moreover, the difference between the hazard for 5 versus 10 year guaranteed annuities and for 3% vs. 5% escalation is significant at the 5% level.

These results suggest not only that longer lived individuals self select escalating annuities and that shorter lived individuals self select guaranteed annuities, but also that in the compulsory market individuals base their choice of the degree of guarantee period or degree of escalation on private mortality information. We do not find evidence of this finer level of selection in the voluntary market.

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of purchase.

Finally, Table 3 indicates that, on the third potential screening device, there is evidence in the compulsory market that annuitants with a higher initial annual payment are longer lived than annuitants with a lower initial annual payment. This is the relationship predicted by the Rothschild and Stiglitz model if insurance companies use PAYMENT as a screening variable. In the voluntary market, however, the coefficient on PAYMENT is positive, which is something of a puzzle. However, in both the compulsory and voluntary market, the effect of PAYMENT is extremely small compared to the magnitude of the other screening devices.

To evaluate the estimates from hazard models, we translate these coefficients into survival probabilities for individuals with different types of annuities. Table 4 presents probabilities of survival until age 75 for several different hypothetical individuals who purchase different types of annuities. All of the estimates are conditional on the individual reaching the youngest age category in our sample (55-60), which we treat as age 58. The table shows the estimated effect of all of the potential screening variables as well as the estimated effect of gender. The "baseline" (first row) is the survival probability for a 58 year old female annuitant with a nominal, non-guaranteed, annual payment, single life annuity purchased in 1981 and paying the mean annual initial annuity payment for that market (voluntary or compulsory). Subsequent rows indicate the change in survival probability associated with various changes in the features of the annuity policy

Table 4 indicates the large mortality differences among certain classes of annuitants. For example, in the compulsory market, the baseline annuitant has a 64% chance of surviving to age 75. The switch to an index-linked but otherwise-identical annuity is associated with a survival probability of 83%, or a 30% increase in the survival probability compared to the baseline (nominal) annuity. In contrast, an increase in the initial annual annuity payment of one standard deviation is only associated with a conditional survival probability of 66%, or in other words, only a 3% increase in the 64% baseline survival probability (which has the mean annual annuity initial payment).

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[8] In the voluntary market we also had a category for annuities that were guaranteed for 15 years; as discussed above, there were no such annuities in the compulsory market.

In the voluntary market, we note that the mortality difference associated with guaranteed payments is somewhat smaller than that associated with backloading. For example, the probability for the baseline annuitant of surviving to 75 is 92% in the voluntary market; it rises to 97% for index-linked annuitant and 98% for escalating annuitants but falls only to 90% for guaranteed annuitants. This suggests that more selection occurs on the backloading than on the guarantee dimension.

To make the comparisons of mortality differences between individuals with more or less backloading in their annuity, or with and without payments to their estate, more concrete, we can compare these mortality differences to those between men and women. The mortality table for compulsory annuitants suggests that a 58 year old male annuitant has a 42% chance of surviving until 75 compared to a 64% chance for an otherwise identical female annuitant. A female annuitant who purchases an escalating annuity has an 86% survival probability. Therefore the increase in survival probability associated with purchasing an escalating annuity (34%) in the compulsory market is the same as the decrease in survival probability associated with being male in the compulsory market (also 34%). In the voluntary market, the increase in survival probability associated with purchasing an escalating annuity (7%) is even larger than the decrease associated with being male (2%).

The results in Tables 3 and 4 thus suggest substantial mortality selection based on the backloading of the annuity, some mortality selection based on payments to the estate, and very little – if any – screening of annuitants based on the initial annual payment of their annuity. The lack of selection on initial annual annuity payment is comparable to the results obtained by Cawley and Philipson (1999) for life insurance and by Chiappori and Salonie (2000) for auto insurance. These papers examine only one potential screening device: it is the amount paid in the event of death for term life insurance and whether the individual has coverage above the legal minimum for auto insurance. This screening device most closely matches our PAYMENT measure of the quantity of insurance. Like we do, they find little evidence of screening on this variable. They do not examine other characteristics of the insurance contract that might provide screening. Our evidence of screening largely emerges from analysis of these other dimensions.

There is a priori reason to have expected that annuity companies would not use the initial annual payment as a screening device. Recall that the screening device must be priced to reflect self-selection. Offering marginal prices that increase with the payment in the event of an accident requires that insurers be able to monitor and to verify the total amount of such state-contingent payments that each buyer has purchased. It also requires that insurers are able to condition the price the buyer faces on the total amount of insurance, not just the amount purchased from a single firm making a sale. If such conditioning were not possible, then if the marginal price rises with the payment in the event of an accident, individuals who desire a large payment will be better off buying several smaller policies from different insurance companies.

Such monitoring may be particularly difficult in annuity markets. Unlike many insurance markets (such as automobile insurance) in which payments occur only infrequently, if ever, annuities are almost certain to make some payments and may make many payments. For most other insurance products, the insurance company can stipulate that the contract is valid only if the insured has not purchased other insurance, and investigate compliance upon submission of a claim. Doing this with an annuity would require continuous monitoring and therefore is substantially more costly to achieve. As a result, many economists have conjectured that it would be difficult to offer a rising marginal price with the payment of an annuity.[9]

Such a problem is not present in making the price of backloading higher to reflect the higher average risk pool, or making the price of annuities with payments to the estate lower to reflect the lower average risk pool. Individuals who desire a backloaded annuity cannot replicate such an annuity buy buying several (cheaper) immediate nominal annuities. Although at the same date, the potential annuitant might consider buying several annuities with different starting dates to create his own

[9] See for example Abel (1986) or Brugiavini (1993), who make this argument for annuities. Chiappori (2000), in surveying different insurance markets, specifically mentions annuities and life insurance as insurance markets where the non-exclusivity of the contract makes a rising marginal price not possible. And in looking at the life insurance market, Cawley and Philipson (1999) find no evidence of a rising marginal price.

backloaded annuity out of a series of nominal annuity products; our data include only immediate, and not deferred, annuities.

### 4.3 Sensitivity Analysis

We subjected these results to a battery of robustness checks. We tried estimating the hazard models separately for men and women. We estimated the hazard models on subsamples of our years of sales data, to see if our results might possibly be contaminated by time trends in the annuity market that could be correlated with product characteristics and mortality. We also re-estimated the hazard model using as our duration measure total age rather than years since purchase of the annuity. Almost all of the results discussed above for both the voluntary and compulsory market were robust in sign and significance to these various robustness checks. One notable finding, however, concerns the PAYMENT variable. When we estimated separate hazard models for male and female annuitants, the PAYMENT variable was only statistically significant for men in the compulsory market and for women in the voluntary market. The sign on the coefficient remained the same in each market as reported in Table 3.

We also explored the robustness of our findings to accounting for unobserved heterogeneity. The results for the estimated coefficients on the covariates are shown in Table 5. The first and third columns reproduce the results in Table 3, while the second and fourth columns show the effects on the coefficients on the covariates of accounting for unobserved heterogeneity in the compulsory and voluntary market respectively. In both markets, the sign and significance of our substantive results are robust to the inclusion of gamma heterogeneity.

The estimated coefficient $\sigma^2$ is the estimate of the variance from the gamma distribution; a significant coefficient here is evidence of unobserved heterogeneity. There is evidence that there is unobserved heterogeneity, conditioning on all observables, in the voluntary market but not in the compulsory market. This suggests that in the voluntary market, there is still heterogeneity in risk type within a product-annuitant type. This is an indication that, perhaps because of fixed costs associated with offering each product class, insurance companies do not find it optimal, in practice, to screen individuals into perfectly homogeneous product-risk categories. In the substantially larger compulsory market, it appears that individuals have been screened based on observables and product characteristics into homogeneous risk classes.

Accounting for gamma heterogeneity in the voluntary market appears to increase the absolute value of the estimated coefficients on the covariates. There is no such effect in the compulsory market. In particular, in the voluntary market, the coefficient on CAPITAL PROTECTED is now significant, whereas it was not when unobserved heterogeneity was not accounted for.

Since unobserved heterogeneity is significant in the voluntary market, we consider how the magnitude of estimated selection effects in the voluntary market changes once unobserved heterogeneity is accounted for. A simple comparison of the coefficients in columns (3) and (4) of Table 5 is potentially misleading as these coefficients represent proportional shifts in the baseline hazard and Table 6 indicates that the estimated baseline hazard in the voluntary market changes once unobserved heterogeneity is taken into account. To estimate the difference in magnitude of estimated selection effects in the voluntary market with and without accounting for unobserved heterogeneity, Table 7 reports the effect of covariates on the probability of the baseline, 58 year old, annuitant surviving until age 75. This measure incorporates both the effect of the estimated coefficients and the estimated baseline hazard. The first column of Table 7 replicates the results in column 2 of Table 4 for the voluntary market when unobserved heterogeneity is not accounted for. The second column produces the same estimates once unobserved heterogeneity is accounted for.

Table 7 indicates that the magnitude of all of the selection effects in the voluntary market increases once unobserved heterogeneity is taken into account. For example, when unobserved heterogeneity is not taken into account, an index-linked annuity is associated with an increase in probability of survival until age 75 from a baseline of 92% to 97%, a 5% increase. Once unobserved heterogeneity is accounted for, an index-linked annuity is associated with an increase in survival probability from a baseline of 91% to 98%, an 8% increase. Similarly, the decrease from the baseline survival probability associated with a guaranteed annuity is 2% when unobserved heterogeneity is not taken into account and 5% when it is. In both specifications, the mortality differences associated with backloading are larger than those associated with gender, while those associated with payments to the estate are of the same or smaller size than those associated with gender.

## 5. Pricing Differences Across Annuity Products

Our second empirical exercise explores the relationship between the price of an annuity and its characteristics. If annuitants self-select among insurance products on the basis of private information about their mortality, in equilibrium, prices on different annuity features should adjust to reflect the feature-specific average mortality.

### 5.1 "Money's Worth" of Annuity Products

To calculate the price of an annuity, the concept of the “money’s worth” of the annuity is useful. We define the “money’s worth” of the annuity as the ratio of the expected discounted present value of annuity payments to the premium. This expected present discounted value is calculated based on the mortality curve of a typical individual in the population. An annuity that is actuarially fair for the typical individual in the population will have a money’s worth of unity. Money’s worths may be less than one due to administrative loads. They may also be less than unity if the mortality of the individuals buying an annuity is lighter than that in the population at large. We therefore define the price of the annuity as the deviation of the money’s worth from its actuarially fair value. The price of the annuity is therefore one minus the money’s worth.

If individuals who buy product j are longer-lived than individuals who buy product k the firm must respond to this mortality difference in its pricing. A given premium should therefore purchase a lower payment stream for product j than for product k since the owners of product j will be around to collect the payment for longer than the owners of product k . If we evaluate the money’s worth of products j and k using a common mortality table, then, product j should have a lower expected present discounted value of payments and hence a lower money's worth. Since we measure the price of the annuity by 1 minus the money's worth, product j would therefore have a higher price than product k.[10]

The formula for the money's worth of a nominal, non-guaranteed annuity is:

(8) $$MW_{NOM} = \frac{\sum_{t=1}^{T} \frac{A * S_t}{\Pi_{j=1}^{t}(1+i_j)}}{Premium}.$$

In this expression, A denotes the per-period payment from the nominal product, $S_t$ denotes the probability that the annuitant survives until payment period t, and $i_j$ denotes the expected nominal interest rate at time period j. The above formula is easily adjusted, as in Finkelstein and Poterba (1999), for the case of index-linked or escalating annuities, and for the cases in which payments are made to the estate.

We calculate a money's worth value for each annuity in our data set. The annuity payments and premium are taken directly from the data. We use a common mortality table, the U.K. population mortality table provided by the Government Actuaries' Department, in all of our calculations. These tables are specific to the age and gender of each individual in our data set. The tables are cohort tables: they reflect the projected mortality curve for an individual of a given age as he ages. We use mortality tables from the year in which the annuity is sold. For example, for a 65 year old male who purchased an annuity in 1988, we use the 1988 population projections of his survival probability in each successive year. For the term structure of nominal interest rates, we use the zero-coupon yield curve of nominal Treasury securities. We use the yield curve from the day of purchase of the annuity. Finally, for inflation-indexed annuities, we use data on the expected rate of inflation over time from the Bank of England, matching our profile of expected inflation to purchase date.

To explore how annuity prices are related to product characteristics, we regress the price of the annuity (defined as 1 minus the money's worth of the annuity computed with the above data and

[10] This comparison of different products assumes that insurance companies are charging the same markup on annuities of different types, and that there are no systematic differences in the costs of producing different

formulae) on characteristics of the annuity and annuitant. The hedonic pricing equation, which we estimate by ordinary least squares, is:

$$\text{(9)}\quad \begin{aligned} &\text{PRICE}_i = \alpha + \beta_1 \text{INDEX}_i + \beta_2 \text{ESCALATING}_i + \beta_3 \text{GUARANTEED}_i + \beta_4 \text{CAPITAL}_i \\ &+ \beta_5 \text{PAYMENT}_i + \beta_6 \text{PAYMENT}^2{}_i + \beta_7 X_i + \varepsilon_i \end{aligned}$$

X consists of all other known features of the annuitant and the annuity product not labeled separately above. These are the age of the annuitant at purchase (in five year groupings), the gender of the annuitant, the year of purchase, and a series of dummies for the frequency of the annuity payments.

Equilibrium requires that the price of various features of annuity products is affected by the selection of different mortality types into a particular feature. We therefore expect a positive coefficient on INDEX (a dummy for whether the annuity is index-linked) and on ESCALATING (a dummy for whether the annuity is escalating). Because we found the mortality of these annuitants to be lighter than that of nominal annuitants, we expect that the annual payments offered will be lower than those for nominal annuitants in anticipation of the fact that escalating and indexed annuitants are likely to live longer. As a result of the lower annual payments, the money's worth calculated using a common mortality table will be lower (the price of the annuity will be higher) for escalating or indexed products than for nominal ones. Similarly, we expect a negative coefficient on GUARANTEED (a dummy for whether the annuity is guaranteed) and on CAPITAL (a dummy for whether the annuity is capital protected). These predictions are summarized in the right hand side of Table 2.

Pricing differentials such as those described in the previous paragraph are not only to be expected; their existence is critical to the screening equilibrium described above. If features that are purchased by higher risk (lower risk) individuals are not priced higher (lower), then the incentive compatibility constraint of the low risk type would be violated. Since the low risk type gets less than his optimal insurance, he would want to switch to the full-insurance, high risk type package if prices did not vary across the package.

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annuity products.

5.2 Empirical Findings

Table 8 reports the results of the regression of price on product characteristics. The results indicate that the pricing response is as predicted. The estimated coefficients on GUARANTEED and on CAPITAL indicate that annuities that make payments to the estate have significantly lower prices in both the compulsory and voluntary market than annuities that do not make payments to the estate. This is consistent with the results of the hazard models that indicate that annuitants who purchase annuities that make payments to the estate are shorter lived (lower risk) than annuitants who purchase annuities that do not make payments to the estate. The results for backloading are similarly supportive. Index-linked annuities are priced significantly higher than nominal annuities in both the compulsory and voluntary market, reflecting the fact that the hazard models revealed that the typical annuitant who purchases an index-linked annuity is longer lived (higher risk) than the typical annuitant who purchases a nominal annuity. In the compulsory market, there is also evidence that, as predicted, escalating annuities have higher prices than nominal annuities. The negative sign on ESCALATING in the voluntary market, however, is puzzling.

In results not reported here, we also examined the pricing of increments of escalating and guarantee periods. This is analogous to the hazard model estimates of selection by length of guarantee period or degree of backloading. In the compulsory market, consistent with theory and with the selection results reported in the previous section, the price rises monotonically in the amount of escalation and falls monotonically with the length of guarantee period. These differences are statistically significant between annuities of different guarantee lengths but not between annuities of different escalation rates. In the voluntary market, there is no clear pricing pattern for different degrees of escalation but the price does fall monotonically with the length of guarantee period; the difference in price between a 5 year and 10 year guaranteed annuity is statistically significant although differences in price between other lengths of guarantees are not.

Finally, the negative coefficient on PAYMENT is indicative of bulk discounts in both markets, similar to those found by Cawley and Philipson (1999) in the US life insurance market. The positive coefficient on PAYMENT SQUARED is consistent with the Rothschild and Stiglitz (1976) prediction of a higher marginal price for larger quantities of insurance. However the magnitude of the coefficient is tiny. As with the effects of PAYMENT in the hazard models, the small magnitudes suggest little mortality screening on PAYMENT and correspondingly little pricing response.

Chiappori and Salanie (2000) and Chiappori (2000) note that estimation of a firm's pricing policy is notoriously difficult. Fixed costs and economies of scale and scope can introduce non-linearities in a firm's pricing policy which are difficult to distinguish from the predictions of models of asymmetric information. We are fortunate in this regard to have direct information on our firm's pricing policies in addition to the hedonic pricing relationship estimated above. The firm's pricing formula, which was described to us, is as follows. Within a given class (guarantee period, tilt, frequency of payment, gender and age), if a £10,000 purchase price buys an annual payment of A, then a purchase price of P buys an annual annuity payment of (P*A)/10,000+((P*f-10,000f)/10,000) where f is the fixed policy fee. This formula applies both in the voluntary market and the compulsory market. It indicates the presence of bulk discounts for policies of less than £10,000 and a constant marginal price. Thus for example, a purchase price of £10,000 in 1999 could buy an annual annuity payment of £539.64 for an index-linked voluntary annuity for a 65 year old male single life monthly payment non-guaranteed annuity. The fixed policy fee (f) was £18. Our estimation of a very small bulk discount and an even smaller rising marginal price of increased annual payments is consistent with the pricing policy. More importantly, this linear pricing scheme is consistent with our findings that the insurance company does not use the initial annual payment to screen individuals into risk categories.

## 6. Conclusion and Discussion

This paper has used a unique data set of the annuitants in a large U.K. insurance company to provide new evidence of the presence of asymmetric information in insurance markets. We find evidence consistent with the view that individuals self-select across annuity products based on private information about their mortality. We also find that, as would be expected in equilibrium, the pricing of different annuity products reflects the product-specific average mortality of annuitants in that product class. This evidence is robust to alternative specifications of the model and to various changes in the sample on which we estimate hazard models for mortality. It is also robust to the extension of the basic hazard model to allow for unobserved heterogeneity across individuals.

We find the clearest evidence of self selection on two attributes of annuity policies that are potential screening devices: the time profile (backloading) of the annuity, and whether it promises any payments to the estate of the annuitant. All else equal, annuitants who are longer lived self-select annuities with payment streams that are backloaded and that therefore provide relatively more in later years. Similarly, annuitants who are shorter lived self-select annuities that make payments to the annuitant's estate in the event of an early death. The magnitude of this self-selection is large. For example, in the compulsory market, the mortality difference between otherwise identical individuals who purchase backloaded and non-backloaded annuities is similar in magnitude to the mortality difference between men and women. In the voluntary market, the mortality differences between backloaded and non-backloaded annuitants is several times larger than that between men and women. We also find evidence that relatively backloaded annuities are priced higher than less backloaded annuities and annuities with payments to the estate are priced lower than annuities that do not make payments to the estate, which is what we expect if insurance companies take account of selection effects in setting their prices. Our results broadly confirm the prediction of models of asymmetric information in insurance markets that emphasize a positive correlation between risk type and characteristics of the insurance policy that are of greater value to high risk individuals.

Our findings on the differential mortality experience of annuitants who purchase different types of policies are consistent with individual having private information about their mortality experience, and acting on this information in their insurance purchases. These findings are complementary to survey-based studies, such as Hamermesh (1985) and Hurd and McGarry (1997) that have explored the extent to which individuals have informed, and plausible, views about their potential life expectancy.

While our results are consistent with the presence of adverse selection in the annuity market, there are two other potential explanations of our findings that warrant some discussion. The first is the possibility that our results are somehow an artifact of the particular firm whose annuity sales we have analyzed. This small sample concern is difficult to address without other data from other insurance firms, and we do not have such data. Our comparison of data from the insurance company whose policies we study, and the aggregate market, does not suggest obvious differences in the pool of policy-holders. Moreover, although we only have detailed pricing and mortality data from one insurance company, we have elsewhere reported on market-wide pricing of annuities with different guarantee periods and different degrees of backloading; the aggregate patterns match those found for our particular company (Finkelstein and Poterba 1999).

A second concern is that our findings are not the result of adverse selection, but rather are due to moral hazard. If individuals who purchase more insurance change their behavior in a way that results in higher claims against their insurance company, then we would observe the patterns we have documented in the relative mortality of different groups of annuitants. It is notoriously difficult to distinguish empirically between adverse selection and moral hazard. Even if we cannot distinguish between these two alternative explanations for our results, we have still presented convincing evidence of asymmetric information. As such, this is counter to the recent claims of symmetric information in insurance markets, such as those by Cawley and Philipson (1999) and Chiappori and Salanie (2000). Moreover, the case for interpreting findings like ours as due to moral hazard is particularly weak for annuity markets.

To apply the moral hazard analysis to annuities, the conversion of income to an annuity stream must affect the individual's mortality. It is difficult to think of a convincing mechanism for this. For example, since individuals with an insured income stream can consume more each period because they do not have to save for the possibility of living longer and not having enough resources, it could be argued that this increased consumption possibilities frontier improves their mortality. Philipson and Becker (1998) note that in principle the presence of annuity income may have effects on individual efforts to extend length of life, although they suspect that such effects are more likely to be important in developing than in currently developed nations. Even recognizing this potential effect, the importance of moral hazard in annuity market sis likely to be much smaller than that in many other insurance markets. Banks and Emmerson (1999) report that among both voluntary and compulsory annuitants in the U.K., annuity income represents less than 1/5 of annual income. This makes it less likely that the form of the income stream is affecting mortality.

One important feature of our results is that on the most traditional screening mechanism, the payment in the event of an accident, we find no evidence of self-selection: There is no evidence of a positive correlation between risk type and payment in the event of an accident. This is consistent with the evidence found in other papers such as Cawley and Philipson (1999) and Chiappori and Salanie (2000). Consistent with the lack of selection on initial annuity payments, the price of additional increments of initial annuity payment is linear; Cawley and Philipson (1999) report similar findings for the life insurance market. Our research therefore highlights the importance of paying careful attention to the detailed policy features of real-world insurance contracts when testing theoretical models of asymmetric information in insurance markets.

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## TABLE 1: OVERVIEW OF THE COMPULSORY AND VOLUNTARY MARKET

| | COMPULSORY MARKET | VOLUNTARY MARKET |
|---|---|---|
| Number of policies | 38,362 | 3,692 |
| Number (%) of first lives that are deceased. | 6,311 (16.5%) | 1,944 (52.7%) |
| Number (%) of lives that are male | 29,681 (77.4%) | 1,272 (34.5) |
| Average age of first life at commencement | 63.2 | 76.4 |
| | **Backloaded Annuities** | |
| Number (%) of policies that are index-linked | 428 (1.3%) | 66 (3.5%) |
| Number (%) of policies that are escalating in nominal terms | 1,492 (3.9%) | 175 (4.7%) |
| | **Payments to Estate** | |
| Number (%) of policies that are guaranteed | 28,424 (74.1%) | 872 (23.6%) |
| Number (%) of policies that are capital protected | 0 | 843 (22.8%) |
| | **Initial Annual Annuity Payments** | |
| Average Initial Payment (£) | 1,151 | 4,773 |
| Median Initial Payment (£) | 627 | 3,136 |
| Standard Deviation of Initial Payment (£) | 1,929 | 5,229 |
| Average Premium (£) | 10,523 | 25,603 |

Notes: All monetary figures in the paper are in December 1998 pounds. The first index-linked policy was sold in February 1985; therefore percentage of policies index-linked refers to percentage of policies sold since that date.

**TABLE 2:**
**PREDICTIONS OF ASYMMETRIC INFORMATION MODELS FOR ANNUITY MARKETS**

| ANNUITY FEATURE / POTENTIAL SCREENING DEVICE | MORTALITY PATTERN | | PRICING RESPONSE | |
|---|---|---|---|---|
| | Mortality difference | Coefficient in Hazard Model | Pricing Difference | Coefficient in Hedonic Price Equation |
| BACKLOADED ANNUITIES | Backloaded annuity buyers will be longer lived than nominal annuity buyers | Negative | Backloaded annuities will have higher relative prices | Positive |
| PAYMENTS TO THE ESTATE | Annuitants with annuities that make payments to the estate will be shorter lived | Positive | Annuities with guarantees will have lower relative prices | Negative |
| INITIAL ANNUAL ANNUITY PAYMENT | Annuitants with larger initial annual payments will be longer lived | Negative | Rising Marginal Price | Positive coefficient on square of variable |

**TABLE 3: SELECTION EFFECTS AMONG PRODUCT CHARACTERISTICS**

| | COMPULSORY MARKET | VOLUNTARY MARKET |
|---|---|---|
| **Backloaded Annuities** | | |
| INDEX-LINKED | -0.839***<br>(0.217) | -0.894**<br>(0.358) |
| ESCALATING | -1.085***<br>(0.113) | -1.497***<br>(0.253) |
| **Payments to Estate** | | |
| GUARANTEED | 0.019<br>(0.029) | 0.216***<br>(0.060) |
| CAPITAL-PROTECTED | ------------- | 0.056<br>(0.051) |
| **Initial Annuity Payment** | | |
| PAYMENT (in £100s) | -0.003***<br>(0.0006) | 0.001**<br>(0.0004) |
| N | 38,362 | 3,692 |
| Number of failures (i.e. deaths) | 6,311 | 1,944 |

Note: All estimates are from Han-Hausman discrete-time, semi-parametric proportional hazard models. These are estimated using 17 annual discrete time intervals; baseline hazard parameters are not reported here. Dummies for age at purchase (in five year blocks) and year of purchase dummies are included in all regressions. Also included as controls are dummies for gender, and for the frequency of payments. Standard errors are in parentheses. The omitted category for the "tilt" dummies (index-linked and escalating) is nominal annuities. The omitted category for the guarantee feature dummies (guaranteed and capital protected) is not guaranteed and not capital protected. The omitted category for the frequency of payments dummies is annual payments. * Denotes significance at the 10% level. ** Denotes significance at the 5% level. *** denotes significance at the 1% level.

**TABLE 4: IMPACT OF COVARIATES ON PROBABILITY OF SURVIVING UNTIL AGE 75**

| | COMPULSORY MARKET | VOLUNTARY MARKET |
|---|---|---|
| Baseline | 0.641 | 0.916 |
| Index-linked annuity | 0.827 | 0.965 |
| Escalating Annuity | 0.862 | 0.981 |
| Guaranteed Annuity | 0.635 | 0.897 |
| Capital Protected Annuity | --------- | 0.912 |
| Initial annual annuity payment one standard deviation above the mean | 0.657 | 0.912 |
| Male Annuitant | 0.423 | 0.893 |

Note: Baseline mortality curve is for a 58 year old female annuitant with a nominal, non-guaranteed, annual payment, single life annuity purchased in 1981 and paying the mean initial annual annuity payment for the compulsory or voluntary market. Other rows reflect the survival probability of an annuitant who has the baseline characteristics and the baseline annuity except for the change notes in the left-most column. All of the potential screening variables are included in this table. The mortality differences associated with men versus women are also given as a source of comparison.

**TABLE 5:**
**COMPARISON OF RESULTS WITH AND WITHOUT GAMMA HETEROGENEITY**

| | COMPULSORY | | VOLUNTARY | |
|---|---|---|---|---|
| | No Heterogeneity Factor | Allowing For Heterogeneity | No Heterogeneity Factor | Allowing For Heterogeneity |
| | (1) | (2) | (3) | (4) |
| IINDEX-LINKED | -0.839*** | -0.874*** | -0.894** | -1.671*** |
| | (0.217) | (0.222) | (0.358) | (0.582) |
| ESCALATING | -1.085*** | -1.114*** | -1.497*** | -2.442*** |
| | (0.113) | (0.122) | (0.253) | (0.352) |
| MALE ANNUITANT | 0.640*** | 0.663*** | 0.252*** | 0.463*** |
| | (0.039) | (0.045) | (0.051) | (0.094) |
| GUARANTEED | 0.019 | 0.024 | 0.216*** | 0.423*** |
| | (0.029) | (0.031) | (0.060) | (0.105) |
| CAPITAL PROTECTED | | | 0.056 | 0.389*** |
| | ----------- | ------------- | (0.051) | (.105) |
| SEMI-ANNUAL PAYMENTS | -0.020 | -0.025 | 0.121 | 0.296 |
| | (0.048) | (0.051) | (0.111) | (0.184) |
| TERMLY PAYMENTS | -0.424 | -0.257 | | |
| | (0.428) | (0.436) | --------------- | |
| QUARTERLY PAYMENTS | 0.004 | 0.0009 | 0.165 | 0.406** |
| | (0.038) | (0.040) | (0.108) | (0.180) |
| MONTHLY PAYMENTS | -0.006 | -0.008 | 0.256*** | 0.544*** |
| | (0.034) | (0.036) | (0.099) | (0.162) |
| PAYMENT (in £100s) | -0.003*** | -0.003*** | 0.001** | 0.001 |
| | (0.0006) | (0.0006) | (0.0004) | (0.0009) |
| Sigma Squared | | 0.253 | | 2.021*** |
| | -------------- | (0.241) | ------------ | (0.216) |

Notes: All estimates are from Han-Hausman discrete-time, semi-parametric proportional hazard models. These are estimated using 17 annual discrete time intervals; baseline hazard parameters are not reported here. Age at purchase (in five year blocks) and year of purchase dummies included in all regressions. Standard errors in parentheses. The omitted category for the "tilt" dummies (index-linked and escalating) is nominal annuities, for the guarantee feature dummies (guaranteed and capital protected) is not guaranteed and not capital protected, for the frequency of payment dummies is annual payments. Sigma squared is the estimated variance of the gamma heterogeneity. *** Indicates Significance at the 1% level; ** Indicates Significance at the 5% level; * Indicates Significance at the 10% level. Sample size for first two (last two) columns is 38,362 (3,692), with 6,311 (1,944) failures.

**TABLE 6:**
**HAN HAUSMAN BASELINE HAZARD FUNCTION WITH AND WITHOUT GAMMA HETEROGENEITY**

| | COMPULSORY MARKET | | VOLUNTARY MARKET | |
|---|---|---|---|---|
| Years | No Heterogeneity Factor (1) | Allowing for Heterogeneity (2) | No Heterogeneity Factor (3) | Allowing for Heterogeneity (4) |
| 1 | 0.0091 | 0.0090 | 0.0011 | 0.0001 |
| | (0.0008) | (0.0008) | (0.0003) | (0.0001) |
| 2 | 0.0104 | 0.0103 | 0.0018 | 0.0002 |
| | (0.0009) | (0.0009) | (0.0005) | (0.0001) |
| 3 | 0.0110 | 0.0110 | 0.0022 | 0.0003 |
| | (0.0010) | (0.0010) | (0.0006) | (0.0002) |
| 4 | 0.0144 | 0.0144 | 0.0024 | 0.0004 |
| | (0.0012) | (0.0013) | (0.0006) | (0.0002) |
| 5 | 0.0146 | 0.0148 | 0.0030 | 0.0007 |
| | (0.0012) | (0.0013) | (0.0008) | (0.0004) |
| 6 | 0.0166 | 0.0169 | 0.0027 | 0.0008 |
| | (0.0014) | (0.0015) | (0.0007) | (0.0004) |
| 7 | 0.0182 | 0.0187 | 0.0032 | 0.0011 |
| | (0.0015) | (0.0016) | (0.0008) | (0.0006) |
| 8 | 0.0195 | 0.0202 | 0.0036 | 0.0015 |
| | (0.0016) | (0.0018) | (0.0009) | (0.0008) |
| 9 | 0.0213 | 0.0224 | 0.0032 | 0.0016 |
| | (0.0018) | (0.0021) | (0.0008) | (0.0008) |
| 10 | 0.0224 | 0.0237 | 0.0038 | 0.0022 |
| | (0.0019) | (0.0023) | (0.0009) | (0.0011) |
| 11 | 0.0256 | 0.0275 | 0.0042 | 0.0030 |
| | (0.0022) | (0.0028) | (0.0010) | (0.0014) |
| 12 | 0.0305 | 0.0331 | 0.0039 | 0.0032 |
| | (0.0027) | (0.0037) | (0.0009) | (0.0015) |
| 13 | 0.0334 | 0.0368 | 0.0039 | 0.0037 |
| | (0.0029) | (0.0044) | (0.0009) | (0.0017) |
| 14 | 0.0345 | 0.0387 | 0.0063 | 0.0068 |
| | (0.0033) | (0.0051) | (0.0016) | (0.0032) |
| 15 | 0.0391 | 0.0446 | 0.0056 | 0.0069 |
| | (0.0040) | (0.0069) | (0.0014) | (0.0033) |
| 16 | 0.0519 | 0.0603 | 0.0060 | 0.0086 |
| | (0.0061) | (0.0105) | (0.0016) | (0.0041) |
| 17 | 0.0800 | 0.0956 | 0.0260 | 0.0452 |
| | (0.0125) | (0.0215) | (0.0089) | (0.0249) |

Note: These are the estimates for the baseline hazard parameters from the Han-Hausman hazard model of the voluntary market and in the compulsory market; coefficients on the covariates for this model are reported in columns 1-4 of Table 6. The model is estimated using 17 annual discrete time intervals. Standard errors (computed using the delta method) are in parentheses. The baseline hazard represents the hazard of a 55-60 year old female annuitant who purchased a nominal, non-guaranteed, annual payments, single life annuity in 1981.

**TABLE 7:**
**EFFECT OF HETEROGENEITY ON MAGNITUDE OF ESTIMATED SELECTION EFFECTS IN THE VOLUNTARY MARKET**

| | NO HETEROGENEITY FACTOR | ALOWING FOR HETEROGENEITY |
|---|---|---|
| Baseline | 0.916 | 0.912 |
| Index-linked annuity | 0.965 | 0.983 |
| Escalating Annuity | 0.981 | 0.992 |
| Guaranteed Annuity | 0.897 | 0.868 |
| Capital Protected | 0.912 | 0.873 |
| Initial annual annuity payment one standard deviation above the mean | 0.912 | 0.908 |
| Male Annuitant | 0.893 | 0.863 |

Note: Baseline mortality curve is for a 58 year old female annuitant with a nominal, non-guaranteed, annual payment, single life annuity purchased in 1981 and paying the mean initial annual annuity payment for the voluntary market. Other rows reflect the mortality of an annuitant who has the baseline characteristics and the baseline annuity except for the change notes in the left-most column.

**TABLE 8: PRICING OF ANNUITY PRODUCT CHARACTERISTICS**

| | COMPULSORY MARKET | VOLUNTARY MARKET |
|---|---|---|
| INDEX-LINKED | 0.096*** | 0.046*** |
| | (0.004) | (0.007) |
| ESCALATING | 0.004* | -0.032*** |
| | (0.002) | (0.005) |
| GUARANTEED | -0.014*** | -0.037*** |
| | (0.0009) | (0.002) |
| CAPITAL PROTECTED | | -0.081*** |
| | ---------------- | (0.002) |
| PAYMENT (in £100s) | -0.002*** | -0.0003*** |
| | (0.00003) | (0.00003) |
| PAYMENT Squared (in £100s) | 2.56e-06*** | 5.31e-07*** |
| | (9.24e-08) | (8.78e-08) |
| N | 38,362 | 3,692 |

Note:. Estimates are coefficients from linear regression of price, which is defined as (1-Money's Worth) on product characteristics. Regression includes dummy for age at purchase (in five year groups) as well as year of purchase, gender of annuitant, and frequency of annuity payments. Standard errors are in parentheses. The omitted category for the "tilt" dummies (index-linked and escalating) is nominal annuities. The omitted category for the guarantee feature dummies (guaranteed and capital protected) is not guaranteed and not capital protected. The omitted category for the frequency of payments dummies is annual payments. *** denotes significance at the 1% level. ** denotes significance at the 5% level. * denotes significance at the 10% level.