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HEALTH SECTION LUNCHEON

Leader: ALICE ROSENBLATT

- Winning papers from the Health Section's research paper competition will be presented.

MS. ALICE ROSENBLATT: I want to start out by explaining something about the Health Section Council, because I'm sure there are a lot of people here that may not even know who is on the council and what we do. We basically focus on education and research, and meetings like this are a large part of both the education and the research effort. I'm the chair of the Health Section Council.

There are nine members on the Health Section Council. Three new members are elected each year and we all serve a three-year term. The other members of the council right now are Paul Fleischacker, who is the Vice Chair; Bill Bugg, who is our Treasurer; Greg Herrle, our Secretary; and other members are Larry Gorski, Joe Moran, Irwin Stricker, Henry Essert, and John Bertko.

You will get a ballot in the mail to elect the next three members to serve on the council. One of the things you should look for as you're voting is that we have proper representation. We like to have a mix of consulting actuaries and insurance company actuaries; people focused on individual versus group business; people focused on disability, as well as some medical experts; we need representation from commercial carriers, as well as Blues as well as HMOs; and representation from regulatory bodies. You will also see that the ballot is set up to make sure that we get representation from both the United States and Canada.

The Health Section also has a lot of committees, and I just want to make you aware of them and who the chairs of those committees are right now. We have the Education Committee headed up by Bill Bluhm; the Continuing Education Committee is headed up by Ted Dunn; the Communications Committee is led by Paul Fleischacker and he's also the editor of the Health Section newsletter that you all get; the Research Committee is chaired by Steve Meskin, who I'm going to be introducing shortly. The Program Committee has been headed up by Leonard Koloms, who was responsible for much of the planning for this meeting; and Bill Thompson will be taking over and planning the Toronto and future meetings.

The other thing that we have going on is that we're attempting to create something called a health database. John Bertko is heading up that effort. I'm sure if anybody wants to volunteer resources to work on the health database, John would love to hear from you. Make sure you go over to him and say, "Yes, my company wants to contribute to the health database." Our Board Advocate is Howard Bolnick. The Health Section Council also works closely with the Academy Health Practice Council and that's currently headed up by Bob Dobson.

I'm going to be introducing Steve Meskin to speak very briefly about what the "Call for Papers" was and to explain the topics. Then we're going to have the winners of the "Call for Papers" make a presentation on their papers.

SECTION MEETING

MR. STEPHEN A. MESKIN: Somewhere in my Research Committee file, I found the following quote; I don't know where it came from. "Research is what is important for actuaries to do, but what they don't have the time for." Well, in the spring of 1989, someone said, "Who'd like to be the Research Chairman in the Health Section Council?" and I said, "Gee, that sounds interesting. I'd like to see what the Health Section Council does." Well, I found out, after I was appointed Chairman of the Research Committee that, the Chairman of the Council and everybody else on the Council was really hot to do a lot of research. Now I compounded my mistake by missing a meeting. In January 1990, there was a meeting, and as result of that meeting, I received in the mail, at the same time that everybody else received it, a call for research papers, which Dave Axene, who was Chairman at the time, sent out. The call said, the section would give up to three prizes in three categories, prizes of $2,500 each for research papers. Category I was retiree health costs and liabilities; Category II was selection modeling, and Category III was miscellaneous. Well I did the best I could to try and figure out how to implement it. What happened after that is, we received, based on that call, eight abstracts. One of those abstracts was rejected as not being relevant to actuarial practice. Of the remaining seven, five papers were submitted. These five papers were sent to five judges. The judges were asked to review these papers and rank them. The judges did not know who the authors were, and they did not know who the other judges were. They were independent, although not random, judges. All the judges were actuaries. Three of the judges are practicing health actuaries; they included a Canadian, a government actuary and an academic and a nonacademic research actuary.

We suggested criteria for ranking the papers. The judges could choose their own criteria, if they wanted. The suggested criteria were: (1) How useful would the results contained in the papers be to the practicing health actuary? (2) Are the results contained in the paper original, at least as far as their application to health actuarial problems. (3) Are the results contained in the paper important? (4) Is the paper well written, i.e., would it be understood by practicing health actuaries?

The results of the five independent judges were fairly consistent, which made my job easier. Two papers were clear winners, although some of the other papers were contenders. We have decided to award prizes in Category I and Category II. Category I was Retiree Health Costs and Liabilities. The prize for that paper will go to Jeff Petertil for his paper "The Natural Limitations of Health Care Trend: A Paper Concerned with Methodologies of Determining Trend Assumptions for Retiree Health Costs." In the second category, Selection Modeling, the prize winner was a joint paper by Arnold Shapiro and Chuck Fuhrer. The title of their paper was "Modelling Flexible Benefit Selection."

Jeff Petertil is a practicing consultant actuary. He joined the firm of Petertil & Associates about six months ago. Let me read some of the comments that the judges made about his paper. They said that it "was useful," "well written," was "a thought provoking analysis of a very important subject," "interesting ideas and nice itemization of the components of trend," "a useful prospective and helpful analysis," "highlights the important distinctions between assumptions and methodologies," "much of the analysis appears original." The other comments, Jeff, I will send to you. I hope you take them in as constructive criticism.

The second paper is by Chuck Fuhrer and Arnold Shapiro. Chuck is an actuary with Washington National. Arnold Shapiro is a professor in the School of Business at Penn State and does a lot of work in the insurance area. Their paper is "Modeling Flexible Benefit Selection." It provides a mathematical framework for benefits and choices in a flexible benefit environment.

We're also planning to publish summaries of these papers in the next issue of the *Health Section News*, along with summaries of the other papers that were submitted, if those authors are so inclined. Chuck, one of the things you didn't do is invite people to read your paper. I try to read the statistical papers in the *Transactions* and I always get to about page 3, when my Part II, which is now Part 110, (there's inflation, that's trend for you 2 to 110) sort of fades out. I must say that you can read Chuck's paper all the way through, with just the material you've learned in Part II (or 110, whichever). I didn't mention some of the comments that the judges made about the paper. They said it was "potentially very useful," "original and interesting ideas," "a good blend of practical and mathematical," "comprehensive and can form the foundation of some very good practical work." So I do invite you to read both of these papers. I think you'll find them well worth it.

THE NATURAL LIMITATIONS OF HEALTH CARE TREND: A PAPER CONCERNED WITH METHODOLOGIES OF DETERMINING TREND ASSUMPTIONS FOR RETIREE HEALTH COSTS
by Jeffrey P. Petertil

The valuation of retiree health benefits has presented actuaries with one of their greatest challenges. While annual inflation at a double-digit pace is rare in other parts of the United States economy, it has become commonplace for the health care sector of the economy, particularly for health benefit plans sponsored by employers and unions.

The actuary who undertakes a valuation of health benefits for retirees must project health care costs far into the future, for at least 20 years in the case of participants already retired and for 50 years or more when active employees are included. If double-digit health care inflation rates are used for each of those future years, as past history might indicate, the figures quickly escalate beyond what most people today consider reasonable. Yet if the actuary selects some increase level below the historical rates, can it be justified on any basis other than hopeful "gut-level" reasoning?

This paper will examine how a health care benefits actuary confronted with a history of high health care cost increases can accommodate that experience in a future cost projection model. Guidance in this area is necessary because the assumption about future health care cost trends can have the dominant influence in a retiree health valuation.

HEALTH CARE COST TRENDS AND INCREASES
The first thing that an actuary must do is determine whether the cost increase witnessed in a particular time period is truly indicative of a trend in cost for that period. The general focus of this paper is to distinguish between those variables that have affected past costs and those that will accurately project future costs per capita.

It is important for the actuary analyzing past costs to identify factors and how they will and will not be used for the given projection model. (Projection models vary somewhat among practitioners. For a general review of projection models, see my paper, "An Actuarial Model of the Cost Projection of Retiree Health Benefits," a study note available from the Society of Actuaries.)

It is beyond the scope of this paper to discuss all the possible factors that might be separated from the trend assumption but a brief mention should include such factors as changes in plan population and provisions. For instance, if all other things were equal, an increase in the population covered under a plan would be expected to increase the aggregate cost for the plan. Likewise, a change in plan provisions to reduce covered expenses would be expected to reduce costs if nothing else changed. The changes in cost from these factors are irrelevant, however, to the cost trend assumption of a projection model which quantifies plan population and plan provisions in other assumptions.

The relevant costs are usually expressed in monthly or annual measures of cost per individual or family unit for a given plan of coverage. The measure may be premiums charged by an insurer or rates derived by an actuary or a claims administrator. The change in this measure for a given plan from year to year has come to be known as "trend." A rate or premium which increases to $120 per month from $100 per month is said to have an upward trend of 20%. (The past 30 years has left us with few periods when costs decreased, so mention of a "trend of 20%" can invariably be taken to mean the trend was upward.)

IMPLICATIONS OF CURRENT HEALTH CARE TREND LEVELS

An initial survey of 1990 medical indemnity plan increases indicates costs per employee went up 21.6% over the previous year, following a 20.4% increase between 1988 and 1989. [A. Foster Higgins & Co. Inc. quoted in *Business Insurance,* January 28, 1991.] If this 21% average annual increase is applied in a retiree health valuation under the simple assumption that in the future such increases will occur annually, the resulting future health care costs are astounding. Costs increase by a factor of 10 every 12 years. The 40-year-old employee who reaches age 80 will find costs 2,000 times higher at age 80 than they were at age 40. If an employee who was age 25 when retiree health costs per capita were $1,000 per year were to live to be 95, a 21% annual increase results in a retiree cost of $623,700,000 per year!

The enormity of numbers such as these led many actuaries in the mid-1980s to say that it simply could not come to pass. Some of the arguments put forth said it was impossible while others merely indicated it was inconceivable. This paper will discuss the validity of the arguments against the high future cost, pointing out that some of the arguments involve little more than wishful thinking while others have a more analytic base in reality.

The common sense argument that average health costs "simply could never be" $623 million per person has credibility up to the point that we recall how little we ever know about the future (in this case, cost levels 70 years from now), and how the value of a unit of money can change over time.

IMPLICATIONS OF TREND IN RELATION TO GNP

Actuaries involved in a retiree health valuation, however, have the responsibility of predicting the future, so analysis should turn to the question of what a unit of money spent on health care might mean in relation to total spending. The question can be generally phrased, "What health care cost trend is likely in relation to society's future willingness to spend money on health care to the exclusion of spending money on other things?" The implicit assumption in asking the question is that there are limits beyond which the society would balk at additional health care expenditures.

The measure of society's expenditure chosen by most actuaries answering the question is gross national product (GNP), specifically GNP of the United States. This paper will similarly use U.S. GNP as the main reference point, with certain misgivings discussed at the end of the paper. GNP is a well-known measure, regularly updated and with separable components for health care. The most recent U.S. GNP figures for 1989, show that health care accounts for 11.6% of total GNP, a percentage which has grown slowly but surely for a number of years.

Any approach which purports to show the limits on the costs for a specific employee benefit plan based on limits for the country as a whole must assume that constraints which affect the country also affect the plan. In practice this means finding the national equivalents for the plan's trend rates, applying them to national health care statistics, and examining the results in relation to national GNP. Where the results strain against the limits which have been chosen for the nation, adjustments to the trend are made to conform to the constraints, and it is assumed that the equivalent adjustments would be made to the plan trend.

In the simplest example, the 21% annual increase of recent years for employer-sponsored medical indemnity employee benefit plans would be applied to the current health care portion of the GNP (11.6% in 1989) to show what the resulting GNP portion would be for each of the years in the future. If it had been decided beforehand that the maximum the populace in aggregate would allow health care to become as a portion of national GNP was, say 25%, then the figures would be checked to see when 25% was obtained. The trend figures would be scaled back for years beyond that point. The adjusted trend figures would then be used for the actuary's valuation of the benefit plan.

This approach is easier said than done. It will be useful to show some of the ways it can go wrong. For instance, if we simply apply the 21% increase to 11.6%, we get the progression shown in Table 1: which implies that, beyond 1993, health care increases of any kind, even 1%, would be considered unreasonable.

TABLE 1

Year	Health Care % of GNP
1989	11.6
1990	14.0
1991	17.0
1992	20.6
1993	24.9
1994	30.1

Note, however, that using this method also implies that with increases in health care each year, which is certainly a possibility, the health care portion of GNP would ultimately exceed 100%, which is not a possibility.

The same fallacy which is present above in the straight application of cost increases to GNP portions is also present when the cost increases are applied to the health care sector and to the total GNP. Unfortunately, that was the method which was used in one of the early published studies of retiree health benefits. The study postulated that health care would increase at a certain percentage each year while the total economy increased at a lower rate. While this method recognizes that health care is not the only sector of the economy with cost increases, it also is constructed in such a way that it is possible for the health care percentage of GNP to be greater than the total GNP. Contrary to the study's conclusion, this does not prove that such cost increases are impossible; it just indicates the method was wrong.

THE BASIC METHOD OF RELATING TREND AND GNP

The basic method which must be used with the GNP portion approach is to make an assumption about the cost increases for the nonhealth sector of the GNP as well as for the health sector. The two projected results are then added together to see what the GNP total would be and each sector is measured against that total. Table 2 shows how this would work, using the 21% annual health care sector increase and an 8% annual increase for the rest of GNP.

TABLE 2

Year	Health Care Index	Index for Other GNP	Health Care Increase	Other GNP Increases	Health Care % of GNP
1989	$0.116	$0.884	20.4%	8.0%	11.6%
1990	0.141	0.955	21.6	8.0	12.9
1991	0.171	1.031	21.0	8.0	14.2
1992	0.207	1.114	21.0	8.0	15.6
1993	0.250	1.203	21.0	8.0	17.2
1994	0.302	1.299	21.0	8.0	18.9
1995	0.366	1.403	21.0	8.0	20.7
1996	0.443	1.515	21.0	8.0	22.6
1997	0.536	1.636	21.0	8.0	24.7
1998	0.648	1.767	21.0	8.0	26.8
1999	0.784	1.908	21.0	8.0	29.1

In Table 2 the health care portion of GNP exceeds 25% in 1998. To keep health care at 25% of GNP in 1998 and beyond, the health care increase would have to be adjusted downward for those years. One way to do this is shown in Table 3. After an increase of 10.2% in 1998 extends the health care GNP up to the 25% limit, the health care increase is kept at the same rate of growth as the rest of GNP, about 8%, for the years following 1998.

For the valuation of the retiree health plan itself, the new increase figures – 21% annually until 1997, 10.2% for 1998, and 8.0% thereafter – would then be used. (See Table 3.) But first, the validity of the figures needs to be examined. As with any process which claims to predict the future, a check of past history should be made to see if the process worked in the past. Here, before we can find if the process works, we are confronted with the fact that the 21% increase does not fit in with the national figures.

TABLE 3

Year	Health Care Index	Index for Other GNP	Health Care Increase	Other GNP Increases	Health Care % of GNP
1989	$0.116	$0.884	20.4%	8.0%	11.6%
1990	0.141	0.955	21.6	8.0	12.9
1991	0.171	1.031	21.0	8.0	14.2
1996	0.443	1.515	21.0	8.0	22.6
1997	0.536	1.636	21.0	8.0	24.7
1998	0.590	1.767	10.2	8.0	25.0
1999	0.638	1.908	8.0	8.0	25.0
2000	0.689	2.061	8.0	8.0	25.0

PAST TRENDS AT THE NATIONAL AND PLAN LEVEL

The survey of benefit plans indicated a 21.6% increase in costs from 1989 to 1990 and a 20.4% increase from 1988-89. Table 3 started from the last known GNP figures in 1989 and projected forward from there. Checking the method by projecting backwards indicates a conflict, however.

When the 1988 GNP figures are calculated using the known 1989 figure and the 20.4% increase, the result conflicts with what is actually known about 1988, as shown in Table 4.

TABLE 4

Year	Health Care Index	Index for Other GNP	Health Care Increase	Other GNP Increase	Health Care % of GNP
1988	$0.096	$0.819		8.0%	10.5%
1989	0.116	0.884	20.4%	8.0	11.6
1990	0.141	0.955	21.6	8.0	12.9
1991	0.171	1.031	21.0	8.0	14.2

The health care portion of GNP for 1988 was, according to the national statistics, 11.2%, not 10.5% as Table 4 would indicate. The national figures further show that the increase in national health expenditures between 1988 and 1989 was 11.0% and not the 20.4% shown by this survey. This difference presents a problem. The problem is not in the survey, because other surveys showed average benefit plan increases which, if not exactly 20.4%, were well above 11%.

The difference comes about because employee benefit health plans pay for less than a third of the national health expenditures. The rest is paid for by government, individual health insurance, individuals themselves, charity and other sources. The national figures have never carefully tracked expenditures for health benefit plans, much less retiree health benefit plans.

Furthermore, the portion of the national health expenditures paid for by employee benefit plans also includes dental and vision care as well as health care through health maintenance organizations (HMOs), none of which are included in the medical indemnity plans increasing at 20.4%. (The survey quoted showed total group health care benefit costs, which includes dental, vision and HMOs, rose 16.7% between 1988 and 1989.) This paper emphasizes medical indemnity coverage, however, because it is more typical of retiree health plans.

This comparison and the differences noted raise the question of whether national figures can be used for retiree health purposes. National health care figures are made up of many pieces, some of which have little relevance to the future of retiree health benefits. Some of the figures which do have relevance are based on estimates which do not have the accuracy needed for valuation work on a specific plan of benefits.

Nevertheless, national figures are valuable guidelines to relationships between system flows and should not be ignored unknowingly. Past growth of the health care portion of GNP should serve as a presumption of future national growth unless facts and informed speculation point in a different direction.

HEALTH CARE DATA AT THE NATIONAL LEVEL

The annual tally of gross national product released by the U.S. Department of Commerce includes as one of its major subcategories, national health expenditures (NHE). This allows charting of NHE growth rates as well as the portion of GNP devoted to NHE. The earliest available figures are for 1929. Table 5 shows the figures for GNP growth, NHE growth, the growth of GNP less NHE, and NHE as a portion of GNP for every five years. At the bottom of the table are the annual growth rates for selected longer periods.

TABLE 5

Year	Annual GNP Growth	Annual NHE Growth	Annual Growth of GNP less NHE	NH as % of GNP
1929				3.5%
1935	-5.8%	-3.5%	-5.8%	4.0
1940	6.6	6.6	6.6	4.0
1950	11.1	12.2	11.1	4.4
1955	7.1	6.9	7.1	4.4
1960	4.9	8.7	4.7	5.2
1965	6.5	9.3	6.3	5.9
1970	7.6	12.3	7.2	7.4
1975	9.5	12.1	9.3	8.3
1980	11.3	13.3	11.1	9.1
1985	7.9	11.0	7.6	10.5
1929-85	6.74	8.87	6.59	2.00
1950-85	7.80	10.51	7.60	2.51
1965-85	9.06	12.20	8.79	2.88

NHE growth has been consistently higher than GNP growth and that has led to the increasing portion of GNP which NHE consumes. These figures can be looked at in two other ways. One is to see what the types of NHE are and the other is to see what has been affecting the growth of NHE. The former figures are available only since 1950 while the latter are available just since 1965.

NHE two main categories are: health services and supplies, and research and construction. The first is the more substantial, rising from 92.4% of the total in 1950 to 96.5% in 1986. The 96.5% for health services and supplies can be further broken into three subcategories: personal health care with 88.2%, program administration and net cost of health insurance with 5.4%, and government public health activities with 2.9%. The first two subcategories are where employee benefit plan expenditures reside.

Arguably, it is this portion of GNP and not the entire NHE which should be tracked from the past into the future to estimate what society's limit on health benefit plan costs might be. Nevertheless, while they have risen slightly as a portion of the total NHE (from 89.6% in 1950 to 93.6% in 1986), the increase is so insignificant and the portion of NHE they represent is so substantial that conclusions drawn from the more accessible NHE total can be taken as a surrogate for the more appropriate personal health care and net cost of health insurance subcategories. For instance, when NHE was 10.9% of GNP in 1986, personal health care and net cost of insurance were 10.2% of GNP. The numerical growth restraints which will be discussed below can be expected to be similar for both national measures. The premise is that the restraints which would keep NHE at, say 20% of GNP, would also act to keep personal health care and net cost of health insurance at a similar figure, say 18.6% of GNP. So when talking about proportion of GNP we will consider only NHE.

Data on NHE can be used to project benefit plan costs within a national context, but at a minimum, a basic understanding of how the health care costs increase, both at a national and plan level, is essential. Costs increase for one or both of two reasons – price increases or quantity increases. This is true at all levels. The next sections of this paper will examine how in the past health care prices have related to total price changes and how health care quantity change has related to real growth in the GNP. (It should be noted that in the past all four of these items – prices and quantities in total and for health care – have increased almost continually. Any item might decrease in the future but the usual assumption in the analysis will be that increases are likely.)

NATIONAL PRICE CHANGES

The relationship between health care prices and other prices can be surmised from examining the medical care component of the Consumer Price Index (CPI) and comparing it with total CPI or CPI less medical care (Table 6).

Over this total period of recordkeeping, the medical CPI exceeded the total CPI by 1.56 percentage points annually. In recent years it has been considerably higher.

TABLE 6

Period Ending	Annual Change in CPI, All Items	Annual Change in CPI Less Medical Care	Annual Change in Medical Care CPI	Difference between CPI and Medical Care CPI
1960	2.1%	Not Available	4.0%	1.9%
1965	1.3	1.2%	2.5	1.2
1970	4.2	4.1	6.1	1.9
1975	6.7	6.7	6.9	0.2
1980	8.9	8.8	9.6	0.7
1985	5.5	5.3	8.7	3.2
1950-85	4.37		5.93	1.56
1960-85	5.30	5.20	6.73	1.44
1965-85	6.32	6.23	7.82	1.49

THE INTENSITY (OR UTILIZATION) FACTOR

The Health Care Financing Administration (HCFA) does not explicitly split factors affecting cost growth for total NHE, but it does split them for personal health care expenditure. The three variables, price inflation, intensity, and population growth, closely parallel those used by actuaries to analyze the growth of benefit plan costs. Price inflation has just been discussed and population growth will be. The intensity factor reflects changes in the kinds of supplies and services and changes in their level of use. (I would prefer to call this factor "utilization" but some define that term as a factor that does not take into account changes due to new medical techniques or demographic change. I will use "utilization" below as a factor which is intensity less demographic change.)

The analysis of the HCFA intensity growth factor could be conducted in much the same way as the price analysis above. The figures go back only to 1965, however, and successful analysis would still leave the task of reconciling the results to total growth in the health sector of the economy. A simpler method, suggested here, is to begin with the total growth in national health care, separate the growth due to prices, and consider the rest to be due to intensity and population growth. This avoids the reconciliation problem while allowing the analysis to be carried back to 1950. (Use of the CPI for medical care to adjust all health expenditures introduces the possibility of small errors but does use easily available data.) Using the data from Tables 5 and 6, the following Table 7 is derived.

Adjusting the resulting figure for changes in real GNP eliminates factors for both the population growth and general productivity. The goal is to derive an indicator of the health care intensity factor in excess of GNP growth.

TABLE 7

Years	Nominal NHE Growth	Change in CPI, Medical Care	Real NHE Growth Factor
1950-60	7.8%	4.0%	1.036
1960-65	9.3	2.5	1.066
1965-70	12.3	6.1	1.059
1970-75	12.1	6.9	1.049
1975-80	13.3	9.6	1.034
1980-85	11.0	8.7	1.022
1950-85	10.51	5.93	1.043
1960-85	11.61	6.73	1.046
1965-85	12.20	7.82	1.041

Table 8 shows that there has consistently been a growth in excess health care intensity. The growth in NHE as a percentage of GNP has been greater since 1965. This may lead to the conclusion that intensity has been greater during that period and to the further conclusion that the increased growth is due to government-induced demand stemming from implementation of the Medicare and Medicaid programs in 1965. This conclusion is examined later and found wanting.

TABLE 8

Years	Real NHE Growth Factor	Nominal GNP Growth	Change in CPI, All Items	Real GNP Growth Factor	Health Care Intensity Growth Factor
1950-60	1.036	6.0%	2.1%	1.038	0.999
1960-65	1.066	6.5	1.3	1.051	1.014
1965-70	1.059	7.6	4.2	1.032	1.026
1970-75	1.049	9.5	6.7	1.026	1.022
1975-80	1.034	11.3	8.9	1.022	1.012
1980-85	1.022	7.9	5.5	1.023	0.999
1950-85	1.043	7.80	4.37	1.033	1.010
1960-85	1.046	8.54	5.30	1.031	1.014
1965-85	1.041	9.06	6.32	1.026	1.015

The analysis above could be repeated for derivation of an intensity factor showing the excess of health care growth over the growth of the portion of GNP which does not contain health care. The results are only slightly different. Likewise, more detailed approaches could be taken, as was true in the study discussed next.

COMPONENT ANALYSIS AND THE FERF STUDY

An important study which used a method similar to the one being advocated here is *Retiree Health Benefits; Field Test of the FASB Proposal* by Coopers & Lybrand, published by the Financial Executives Research Foundation (FERF) and referred to hereafter as the FERF Study. It includes a chapter on the health care trend which should be read closely by anyone interested in this topic. Since the chapter is not clear on several connections between analysis and assumptions and because there has been no backup documentation published, it is not known how closely the methods follow those of this paper. The following comments concern the study's use of components of cost and projected trend.

The FERF study chose to base future projections on analysis of changes in price and intensity at a component level of national health care costs. The component analysis is based on national data for six health care services since 1965. The analysis, and subsequent projections, use considerably more detail at the national data level than advocated in this paper. The detail adds considerable complexity to the actuary's work, although it is not evident that the complexity is correlated with additional accuracy for the estimate of future retiree health care costs.

Component analysis can provide valuable insights as to the past course of health care which may be helpful for estimating the future. At some point, however, these insights need to be translated to take account of the past history of the given benefits plan. The history of the plan components is unlikely to replicate that of the national component.

Component analysis of a limited plan history will be of limited credibility concerning matters way in the future. My paper does not recommend ignoring component analysis but does suggest more useful areas of investigation when actuarial and economic resources are limited. It advocates using easily available, and thus easily confirmable, national data to establish general guidelines for the future course of health care costs. Considerable attention must be paid to the past history of the benefit plan itself and comparing that with the national data.

Selecting the future trend of plan costs should have as much to do with where the plan has been in the past as it does with where the nation's health care is going in the future. Before turning to the topic of differences and similarities between national and plan trends, the subject of demographic mix is discussed to determine its impact on national cost levels.

NATIONAL DEMOGRAPHICS

While the Medicare and Medicaid programs have undoubtedly influenced the supply and demand for health care services, the simple demographic analysis below suggests that the expanded demand for health care and expanded supply of health care, relative to the rest of the economy, has been proceeding steadily for at least 40 years and probably longer. The simple analysis is based on a few assumptions about changes in the demographics of the country and the effect those have had on health care costs.

The first assumption is that, although health care cost patterns differ between men and women, the proportion of men and women have not changed over the 60 years in a way that would change cost growth patterns. Thus, gender will be ignored as a factor affecting national cost levels. (This is not to say an actuary preparing a valuation for a specific plan should ignore gender if cost differences are appropriate and gender mix is anticipated to change.)

The second assumption is that longer life expectancies, higher birth rates and similar demographic changes can be expressed as either a population change or an average

age change. In most actuarial projection models these changes will be included somewhere other than in trend. In the national model, the population changes are acknowledged in the per capita calculations but the age change is embedded in the intensity factor.

The third assumption is that all other demographic changes are irrelevant to the question of growth in national health care costs. This assumption is convenient and probably wrong but no other demographic factors significantly affecting growth have made themselves evident.

These assumptions on which the demographic analysis is based lead to a premise that the only demographic factor affecting growth is the average age of the population. By removing the age factor from the intensity growth figure discovered above, the remaining growth amount will be assumed to be the underlying utilization factor at the national level which can be assumed to continue in the future, all other things being equal.

The historical median age figures shown in Table 9 were found in Table 19 of the 1990 Statistical Abstract with the projected median ages based on calculations from census projections. The assumption about the effect of average national age on health care cost is that for each additional year of age national costs rise 4%. (Entirely too simple an assumption for much actuarial work in health care, this 4% per year assumption has some basis in fact. The reader is referred to Society of Actuaries studies or Medicare data or invited to substitute his or her own factor.)

TABLE 9

Year	Median Age Estimate	Cost Factor Due to Age
1950	30.2	
1960	29.5	0.97
1965	28.0	0.94
1970	28.0	1.00
1980	30.0	1.08
1985	31.4	1.06
1990 Projected	32.9	1.06
2000 Projected	36.3	1.14
2010 Projected	38.7	1.10

While the average age in the U.S. has changed relatively little in the last 40 years, there have been some changes which can be expected to have some effect on cost change through the intensity factor. The effect is likely to be more dramatic if the population projections hold true. If we separate the age factor from the intensity factor, we get an age-adjusted utilization factor.

Introduction of the age factor casts a different light on the reason for cost increases over the last 40 years (see Table 10). While the intensity factor shows that the period of 1965-85 had a greater excess of health expenditure growth over general economic growth than the entire period of 1950-85, the analysis in Table 10 indicates the excess can be attributed to the age variable. The utilization factor has been adjusted for age and is actually lower during the 1965-85 period than during the longer period. An implication is that causation linking high costs of the last 25 years as being due to the shock of government entrance as a major payer for Medicare and Medicaid is not supported by the data.

TABLE 10

Years	Annual Excess Intensity Factor	Annual Age/Cost Factor	Annual Utilization Factor
1950-85	1.010	1.001	1.009
1965-85	1.015	1.007	1.008

This analysis also indicates that the utilization or intensity factor needed for the projection of future health care costs is about 0.9% annually when age changes are eliminated. This is useful for retiree health projections since it is generally agreed that age changes should be handled separately from the trend factor.

The analysis is hardly a proof. For one thing, there are many variables other than age affecting the national costs during the period examined. Also, the 4% increase factor is a simplification, as is the use of the median age, rather than the mean age or a distribution of ages and cost factors. Nevertheless, the analysis uses readily available data to point out the impact at the national level of the changing demographics influencing demand for health care and to remind the actuary that some factors increasing costs should not be included in trend.

COMPONENTS OF COST INCREASE

The analysis to this point has been predicated on finding national equivalents for elements of employee benefit plan trend rates. The elements of national increase have been examined. There are, however, elements of plan trend which have not been examined. An examination of the elements of cost increase will now be conducted from the plan perspective.

Since employee benefit plans comprise about a third of personal health expenditures, the Health Care Financing Administration factors affecting cost growth for personal health care expenditure also affect benefit plan cost growth. These three variables, price inflation, intensity, and population growth, can be used by actuaries to analyze the growth of benefit plan costs. A brief comparison of the way in which these interact at the national level and at the plan level follows.

Population changes are an obvious cause for changes in aggregate costs. Because the actuary will forecast future population levels separately and then apply per capita cost to the predicted populations, a key to accuracy is adjustment of historical costs to a per capita cost basis. Due to the usual uncertainty about the number of dependents and the fractional years of coverage for new and terminating employees and dependents, this figure would seem more susceptible to error on the plan level than on the national level. Nationally, population, total cost and per capita cost are often estimated jointly whereas at the plan level, total paid costs will be available for a time period while the population covered during that period may be less easy to determine. In general, however, if population is determined consistently from period to period, per capita costs for a plan can be obtained on a consistent basis over time, and growth in per capita cost can be measured on a consistent basis.

The two basic factors affecting per capita growth in costs at the national level are price change and intensity. Each basic factor can be further subdivided. At the plan level, price and intensity are joined by other factors if the usual cost data are analyzed. Under certain conditions or definitions, however, they are the only two factors of plan cost.

Specifically, if a plan always pays for the same supplies and services regardless of cost, then the only factors affecting costs will be price and intensity. But most plans have payment limits (deductibles, coinsurance, out-of-pocket maximums, annual or lifetime maximums) and change them and change coverages from time to time. Such limits and changes will affect costs for a plan while the national figures, which do not contend with similar limits and changes, remain affected only by price and intensity. This leveraging effect is one reason plan costs rise at a faster rate than national costs.

As the survey cited earlier indicated, a 21% increase for medical indemnity plans can be reconciled with a 17% increase when HMOs, dental and vision plans are included. This in turn can be reconciled (generally but usually not specifically) with a lower, say 15%, increase when leveraging from deductibles and maximums is eliminated and possibly an even lower increase when plan expansions are factored in (plan contractions are usually excluded in most talk of trends while expansions often creep in due to the changing nature of medical care).

Finally, benefit plans tend to more liberally reimburse certain expenditures than the government (at this writing, psychiatric care seems to be an example) and this may account for the remaining 3% or 4% discrepancy between national increases and plan increases.

In such a way, the 21% increase of the benefit plan survey can be reconciled with the 11% increase of national figures. Much of this difference can be attributed to payment increases above and beyond coverage increases within the plan, not to increases in price or intensity.

The above discussion serves to show how the actuary might analyze the increases in plan costs to understand the difference between what is happening in the nation as a whole and what is happening with the plan under examination. For the purposes of a retiree health valuation, the plan which should be most closely examined is the retiree health plan (or plans, where coverage is expected to change over a participant's retirement, such as at Medicare eligibility), but the data for a similar active employee plan may be more extensive and therefore more credible.

If the retiree data are credible, an additional factor that must be included is Medicare reimbursement. It is almost always changing at a different rate than the national totals or a plan's gross or net charges. Over the last 25 years the portion of the health costs of those over age 65 which has been paid by Medicare has decreased. This may not happen on a year-to-year basis, however. For instance, if the Part A deductible increases at a rate less than the underlying coverage cost, then the portion covered by Medicare might be expected to increase and the resulting retiree benefit plan trend to be less than the trend of the underlying coverage. Allowance must be made for past and future effects of Medicare.

(A brief mention should be made of the manner in which the term "health care cost trend" is used in the *Statement of Financial Accounting Standard No. 106*, issued in late 1990 and covering employers' accounting for postretirement benefits other than pensions. Generally, the term is used in the accounting standard to refer to the increases in the dollar amount of gross covered charges before any of the inner limits or reimbursements are subtracted. This is a different definition than historically used and means that simply transferring a trend from one usage to another must be done with caution. The cautionary use of trends is, of course, a main thrust of this whole paper.)

When a reconciliation is still not evident, an explanation might be found in the natural variation of claims incidence and frequency (the law of large numbers is not as good at smoothing at the plan level as it is at the national level), geographical influences, or the possibility that the mix of plan coverages is different than the national medical mix, and therefore subject to different price and intensity factors (in which case component analysis similar to the FERF study might be appropriate). One also should not overlook the likelihood that the nominal trend is not the same as the developed trend. A brief discussion of this point follows.

NOMINAL TREND VERSUS DEVELOPED TREND

Prior to its use in retiree health care projections, trend was usually not an assumption about the future but rather a statement about the present or past. Earlier an example was given where the monthly rate rose from $100 per month to $120. A $120 rate may be considered an appropriate rate for the upcoming year due to many factors, price inflation being only one of them.

One of those factors may be a recognition in hindsight that $100 was not an appropriate rate for the past year. Retrospective analysis of developments of claims reserve runoff or other items may suggest that the previous rate should have been $105. In such a case, the cost increase for the period appears to be only $15, which is a 14.3% increase on a base of $105. The actuary may be inclined to see the change in developed rates as the true increase but, in the more popular parlance, "trend" is the increase in nominal rates from last year to this year.

In regards to the retiree health rates which are projected for the future, this difference between the change in nominal rates and the change in developed rates is largely a moot point. From the actuary's vantage point, the prospective developed rate for each future year is the prospective nominal rate for that year. Prospectively, there is no difference between nominal trend and developed trend.

Nevertheless, the retrospective analysis of claims costs with which the actuary begins his valuation should establish the historic developed trend. Projections based on historic nominal trends are subject to approximation errors made in the past. The difference between the historic developed trend and the historic nominal trend is an adjustment for developed reserves and, possibly, other new information about the past.

Developed reserves lead to developed incurred claims, which are likely to be different than nominal incurred claims. Thus, while some actuaries speak of the need to use incurred claims rather than paid claims, it is important to note that nominal incurred claims may contain more misleading information than paid claims, particularly when the goal is to derive a trend or set initial claim costs for a retiree health projection. Developed incurred claims are the most accurate figures but it is necessary to wait for such accuracy. This leads to a loss of immediacy, not a desirable characteristic in the fast moving health care arena.

The nature of the differences between developed and nominal reserves and claims is usually such that, when viewed over a number of years, they offset each other. That is one of several reasons why trend rates and initial-year claim costs should be based on analysis of at least three years of cost data.

POSSIBLE DIFFERENCES BETWEEN NATIONAL AND PLAN TRENDS

The paper has taken a major diversion to discuss why the plan trend may be different from the national trend in health care cost increases. The reason for the diversion is to point out that it is simply not enough to say that plan trend must be lower because if the national health expenditures rose at the rate the plan has followed in the recent past those national expenditures would soon pass society's "breaking point" and rise at a more reasonable rate. In fact, a plan's costs can rise at a rate twice the national expenditure increase rate for a very long time, maybe forever, before anyone on the national scene flinches. An actuarial projection which states that future plan costs will rise at national rates when they rarely have in the past is wishful thinking that needs to be questioned. There needs to be an understanding of why the plan's costs are different from national levels and why rates of increase are different.

A dozen reasons for possible differences between the national and the plan's cost increases have been discussed. They are listed below with an indication of which are likely to consistently result in future increases for a retiree health plan's per capita cost in excess of NHE increases and which are likely to have a random effect.

	Consistent Increase	Random Effect
Population variation		XXX
Leveraging	XXX	
Plan design changes		XXX
Medical, not other health	XXX	
Liberal payment policy	XXX	
Expansion of coverage	XXX	
Retiree data versus employee		XXX
Medicare reimbursement	XXX	
National variation in cost		XXX
Geographic variation		XXX
Mix of medical coverage	XXX	
Nominal versus developed		XXX

(These factors should serve as an example of how the analysis proceeds, rather than as a definite dozen. Some of the terms usually seen in trend analysis have been left out on purpose, however. "New technology" may be a factor in cost increase but it should not be a factor in determining why benefit plan costs increase differently than other health costs. If a benefit plan is the first to pay for new technology, the cost differential would show up under "liberal payment policy" or "expansion of coverage."

"Cost-shifting" is a term which would prove fuzzy and unproductive in the type of analysis I suggest.

A few reviewers who have been considerate enough to share their comments with me have pointed out that Medicare's efforts to hold down its costs can be expected to have the effect of holding down all medical costs for those over the age of 65. This is an important insight which needs to be verified on a national basis and considered on a plan basis. If true, Medicare reimbursement will less consistently be an excess increase factor and the trend forecast and analysis will be still more complex.

Actuarial analysis of plan data should be conducted separately for retirees over age 65 and those under age 65. I have implied throughout this paper that data for active employees have their place in trend analysis, but active employee data are not to be preferred to credible data from retiree plans. At the same time, when making forecasts, the possibility that costs for those over age 65 will not increase as steeply as the costs for those under age 65 needs to be considered in the larger context of national costs. A forecast that over-age-65 costs will rise at a trend two points below that of under-age-65 costs for as short a time as 15 years results in the implication that average gross costs at the end of that period will be 30% higher for a 64-year-old than for a 65-year-old. At 50 years, it is 150% higher. This seems even less likely to me than that the cost will be $623 million per person.)

It may be tempting to say that the difference between a 21% increase at the plan level and a much lower increase at the national level is all an anomaly and then proceed to ignore the plan increase. This temptation needs to be balanced with the possibility that the plan increases may continue to stay higher than the national increases. Each factor needs to be considered for its likelihood for influencing the future of the retiree health benefits being valued.

THE CRUX OF THE MATTER

Once a reconciliation with national figures is made, the relation between the national figures and the future course of the plan's costs can be established. The future of the national costs are then incorporated. Further analysis is still needed to accommodate the projection model and the national constraints. For one thing, a trend of 11% annually may be a lot lower than a trend of 21% annually but it still results in huge future costs. Using the individual employee examples mentioned toward the beginning of the paper, a 40-year-old employee who reaches age 80 will find costs 65 times higher at age 80 than they were at age 40. And if an employee who was age 25 when retiree health costs per capita were $1,000 per year were to live to be 95, an 11% annual increase results in an average cost 70 years later of $1,500,000 per year.

From the standpoint of the basic GNP analysis outlined above, an 11% annual health care cost increase at a time of 8% growth in the rest of the GNP results in health care being 15% of GNP in the year 2000, 20% of GNP in 2013, 25% in 2023, and 30% in 2033. Seventy years out health care would be 48% of GNP.

Many who work on the projection of future health care costs feel that a continuation of health care growth that is three percentage points above the national GNP growth rate cannot last for long. The national health care growth rate they would use for a retiree health valuation would be subject to constraints which would also bring the trend rate down. This paper will now turn to a discussion of what constraints might be appropriate in projecting future national health care expenditure levels and trend rates within a retiree health benefit valuation.

There are two basic limitations on health care costs of a benefit plan. The more obvious limitation is the limit that plan sponsors will put on individual plans through their decisions as to coverage and cost sharing. Future changes which might affect trend may already be defined. To the extent that future changes in present day limitations have not been articulated by the plan sponsor, the actuary will be constrained to follow the coverage and cost sharing as it currently is described. (For plans which have reserved the right to make changes but have not defined those changes, valuation options are discussed in my paper, "Life Expectancy, Rising Health Costs and the FASB Rule," in the January/February 1991 issue of *Contingencies.*)

The second limitation is the natural limit of how much a society can, or is willing to, devote to health care. This limit is much speculated upon but little has been set forth to aid the actuary in making a "best estimate." If this limit is based entirely on art and not at all on science, then the credibility of both the actuary and the profession will suffer. By looking at the history of health care GNP in the U.S. and relating it to economic and demographic theory, the actuary can locate some past relationships which might be taken into account in projecting future health care GNP.

AN EXAMPLE AT THE NATIONAL LEVEL

The national data analyzed in the earlier sections of this paper might be used in the following way to project future national health care cost. As a starting point, medical inflation might be expected to increase 1.7% points above general inflation. (This figure and others were derived using analysis of compounding effects, not additive ones, but for the ending discussion it will be assumed the effects are additive.)

If general inflation for the nonhealth sector is assumed to be 5.0%, then medical inflation is 6.7%. Real growth for the nonhealth sector is assumed to be 2.0%. Nominal growth for the nonhealth sector is then 7.0%. Real NHE growth is an extra 0.9% before the aging effect is included. (NHE and GNP here ignore population changes and are on a per capita basis.) Age-adjusted nominal NHE growth is then 9.6%.

To see how the national rate might change on an annual basis the age factor must be added. If the average age is assumed to rise evenly between 1990 and 2010, from 32.5 to 37.5, and then stabilize, the basic nominal NHE growth rate is 10.6% annually until 2010 and 9.6% thereafter. (This uses the 4% increase for each year of age.) Is such growth sustainable when the rest of the economy is growing at a 7% rate? Earlier we saw that an 11% rate tops 25% of GNP after 33 years.

Whether the NHE growth is sustainable or not only time will tell. Any upper limits set now can only be estimates that are disproved. They can never really be proven because if the limits are not exceeded there will be a myriad of unforeseen events that have taken place which might be the cause of lower growth. Whether those future events tie in with the general principle that NHE as a portion of GNP can only go so high will undoubtedly differ according to judgment.

To put it another way, the determination of whether continued NHE growth is sustainable is probably as much a political question as an economic one, and the assignment of cause if it is not sustainable will be as much political as historical. In effect, anybody can play the game of picking an upper limit without fear of total contradiction later on. The exception would be anyone who picks an ultimate figure too low, which now seems to be anywhere below 15% of GNP.

In the mid-1980s several parties, including HCFA and this author, predicted NHE as a portion of GNP would attain 15% around the year 2000. This continues to seem very likely, just as it seemed unlikely back in 1970 when the portion was half of 15%. With that piece of hindsight before us, a doubling of the current likely number to 30% probably yields a reasonable upper limit to the upper limit while a figure much below 18% would be labeled quite naive. There is simply too high a demand for health in relation to the other goods and services available to set a number as low as the current 15% horizon. The timing as to when these upper limits would be reached and whether they would recede substantially thereafter will be left to another time.

Continuing with the example, assume that 25% of GNP for NHE is the upper limit. Begin the projection with the known NHE percent of GNP for the base year. In Table 11 we have a beginning index in 1989 of 0.116 for NHE and 0.884 for the rest of GNP. Further assume that as the upper limit is approached, NHE growth will slow somewhat so that just before the limit is reached, NHE growth will approximate the 7% GNP growth. Thereafter the NHE growth will remain at 7% and the NHE portion of GNP will remain at 25%. Then the NHE growth rate above which started at 10.6% in 1990 and fell a percentage point in 2010 might proceed in the following way.

TABLE 11

Year	NHE Index	Other GNP Index	NHE Increase	Other GNP Increase	NH as % of GNP
1989	$0.116	$0.884			11.6%
1990	0.128	0.946	10.6%	7.0%	11.9
1995	0.212	1.327	10.6	7.0	13.8
2000	0.351	1.861	10.5	7.0	15.9
2005	0.578	2.610	10.5	7.0	18.1
2010	0.944	3.660	9.5	7.0	20.5
2015	1.464	5.134	9.0	7.0	22.2
2020	2.216	7.200	8.4	7.0	23.5
2025	3.270	10.099	7.9	7.0	24.5
2030	4.707	14.164	7.3	7.0	24.9
2035	6.622	19.866	7.0	7.0	25.0
2040	9.288	27.863	7.0	7.0	25.0
2045	13.026	39.079	7.0	7.0	25.0
2050	18.270	54.810	7.0	7.0	25.0

Some have said that the NHE growth must ultimately fall to the inflation rate but that is not true if NHE is to maintain its portion of GNP. As long as there is positive growth in real GNP, the inflation rate will be below nominal GNP growth and any cost growing at the rate of inflation will be shrinking as a portion of GNP. For NHE to be stable as a portion of GNP, it will grow at the same rate as GNP. An assumption equivalent to this is for medical inflation to equal general inflation and for health care intensity to equal real GNP growth.

A CORRESPONDING EXAMPLE AT THE PLAN LEVEL

The age-adjusted nominal NHE growth rate would be the basis for the plan trend rate. If leveraging and Medicare reimbursement were handled outside of the trend factor and the additional cost for the plan's medical coverage mix, benefit expansion, and liberal payment policy was an additional 2.5% annually, then the beginning trend would be 13.1%. How would that change over time?

In Table 11 the age-adjusted nominal NHE growth rate dropped one-tenth of a percentage point after 10 years and after another 10 years began to drop about a tenth of a percentage point each year for 25 years. It then leveled off at the nominal GNP growth rate, having attained 25% of GNP. To the extent that, at the plan level, major changes vis-a-vis national health care have not been articulated, these national changes should be considered as also resulting at the plan level.

The plan specific reasons which add to the plan trend can be expected to diminish at about the same rate as the national items, unless specifically targeted. In other words, a plan managed passively would be expected to incur additional costs for gradual benefit expansion, an emphasis on medical over other health care coverage, and liberal payment policy as long as the NHE was growing at a greater rate than GNP. Once NHE and GNP were growing at similar rates, the additional pressure on plan costs could be expected to dissipate and the plan trend would equal the GNP growth rate. The trend would drop very little from 13.1% for 20 years and then more steeply for 25 years before settling at 8.0%.

For a plan taking more aggressive cost containment action in the future the additional cost can be forecast to drop sooner. For example, targeting payment policy and coverage expansion successfully might drop the 2.5 additional percentage points to 1.0 in three years. (There could also be one-time effects which decreased the base figure, although anticipating those in advance is probably not good actuarial practice unless the plan changes more dramatically in some other way.)

Gradual conversion of retirees to HMOs or similar programs might eliminate the remaining 1.0 excess over the course of 10 years. In this fashion, the plan trend can be expected to drop to the age-adjusted nominal NHE growth rate by the year 2000. The age-adjusted growth rate will at that point be a percentage point below the actual NHE growth rate, but at the plan level, trend does not take into account age. The expected plan trend, and its relation to the national growth in health cost, would then be as in Table 12.

TABLE 12

Year	NHE Increase	Plan Trend
1989	11.0%	21.6%
1990	10.6	12.1
1995	10.6	10.1
2000	10.5	9.5
2005	10.5	9.5
2010	9.5	9.5
2015	9.0	9.0
2020	8.4	8.4
2025	7.9	7.9
2030	7.3	7.3
2035	7.0	7.0
2040	7.0	7.0
2045	7.0	7.0
2050	7.0	7.0

Finally, mention should be made of the relation between the discount rate and the GNP growth implicit in the valuation trend rate. To the extent that the discount rate is based on a long-term risk-free interest rate, that figure needs to be reconciled with the long-term GNP growth used in the trend rate determination. For an economic system as a whole, the risk-free interest rate cannot significantly exceed the economic growth rate over the long term.

A CAVEAT

Consideration of the role that the totality of health care will play in the future of this country's economy is important for a valuation of the future costs of a retiree health plan. To quantify the interaction between the microeconomics of a retiree health plan and the future macroeconomics of health care, the best tool seems to be analysis of past and future GNP. Nevertheless, the actuary and the client should be aware of shortcomings to such analysis which provide limits to its accuracy and efficacy.

First, by looking only at this country's GNP, the interaction of the health care sector of the U.S. economy with the rest of the world is ignored. It is true that health care decisions, both those decisions affecting supply of services as well as those affecting demand for services, are made on a local level. There is an international aspect, however, which should not be overlooked. In particular, if other countries are supplying us with our oil, autos, and electronics, international trade demands that we must supply something in return.

As we approach the turn of the century, America's competitive advantage appears to rest with weapons, agriculture, entertainment, and medicine. The international demand for American health care technology will be encouraged by U.S. government support and will result in a higher availability and use of that technology to Americans than to anyone else. To the extent that the primacy of American medical technology holds, there is an economic and social reason why the U.S. economy will be disproportionately devoted to health care.

This suggests any international comparisons of the percentage of health care in countries' GNP will continue to show higher American percentages than anywhere else. This is likely to be true not only in relation to those countries which have a lower standard of living than the U.S. does but also those that have a higher standard of living. In this perspective, it is not surprising that our economy is alone in having as much as 10% devoted to health care or that those that have the next highest percentages, such as Sweden, the Netherlands, and Germany, have stabilized their percentage while we have not. Health care not only has importance to Americans seeking physical health, it has importance as an export item in a world where we have lost our competitive advantage in other goods.

THE SHORTCOMINGS OF GNP AS A MEASURE OF WELFARE AND PROSPERITY

Finally, while percentage of GNP is now the most readily available gauge of the importance of health care to Americans and of the likely upper limits of that importance, it may not be for long. GNP is an economic construct which has only been around for 50 years. There is a growing sense, particularly among environmentalists, but also among national leaders, political scientists and others, including some economists, that the shortcomings of GNP as an indicator of well-being necessitate its replacement. The literature on this topic is growing, as is research on alternative measures of well-being.

Two examples here will show why GNP may not be the best denominator of economic or social welfare. First, the Exxon Valdez oil spill in Alaska in 1989 created an ecological disaster but it also increased GNP, although no one considered the spill a good thing. The money spent on cleaning up the oil slick and surrounding beaches, on litigation and public relations, added to GNP and meant that, if all other things were equal, 1989 was a better year than the previous year in terms of GNP growth simply because of the cleanup. GNP calculations make no reduction for loss of resources but make additions for items of questionable value.

Second, and more immediately relevant to this paper, since there is no strong correlation between the amount of money spent on health care for an individual and the quality of that individual's health (or life), there is good reason to question whether the growth GNP attributes to increased health care is an increase in social well-being and progress. Some of the alternative measures of well-being which have been developed to supplement or replace GNP subtract large portions of health care spending (including benefit plan expenditures) from the gross consumption figures before arriving at the final measure.

In short, it is possible to get a statistical answer when adding apples and oranges and dividing by kumquats but that statistic may not tell us much about apples, oranges, kumquats or fruit salad. Thus while the use of GNP statistics in the projection of future health care costs for an employee benefit program for retirees may be helpful and even necessary at the present time, the actuary who practices in this field must be cautioned not to place too much emphasis on the predictive accuracy of the results.

Figures from the past are simply correlations between quantitative measures of goods and services which are constantly changing in quality and may not be subject to similar demand or supply in the future. Actuaries should continue to seek other correlations and sources of data which may be better predictors of future health care demand.

CONCLUSION

In conclusion, the use of national economic data, particularly national health care figures, in establishing trend rates for use in retiree health benefits is helpful but far from conclusive. Three drawbacks to the use of national data are: (1) plan-specific trends necessary for cost projection may have only a tenuous relation with national trends; (2) future limits on national health care growth must be based on subjective judgments as to what the limiting portion is and at what rate it will be approached; and, (3) the most readily available measures at the national level are subject to criticism as being of restricted relevancy.

On the other hand, plan-specific trends based solely on past trends of the given plan are not assured of relevancy, do not entirely eliminate subjectivity, and, if they deviate significantly from national history, can be expected to have only a tenuous relation with the likely future trend of the plan 10, 20 or 50 years in the future. Thus, it is helpful to have the national data as a guideline. It can aid in the determination of plan trends which are internally consistent. Discussion of the assumptions about the future of national variables and their connection to the assumptions in the retiree health projection can provide analysts with information to compare the external consistency of valuations. Potential changes in national trends can be linked to changes in valuation variables to model the impact on future plan costs.

The useful aspect of including national data comparisons in a retiree health valuation exists only if both the plan data and the national data -- past, present and future -- are clearly understood as to their strengths and weaknesses. Open discussion of such topics is essential for the integrity of the actuarial projection of retiree health benefits.

BIBLIOGRAPHY

Doran, Phyllis A., MacBain, Kenneth D., and Reimert, William A. *Measuring and Funding Corporate Liabilities for Retiree Health Benefits.* Employee Benefit Research Institute, Washington, D.C., 1987.

Dankner, Harold, Bald, Barbara S., Akresh, Murray S., Bertko, John M., and Wodarczyk, Jean H. *Retiree Health Benefits, Field Test of the FASB Proposal.* Financial Executives Research Foundation, Morristown, N.J., 1989.

FASB Statement No. 106, "Employers' Accounting for Postretirement Benefits Other Than Pensions." Financial Accounting Standards Board, Norwalk, CT, December 1990.

Geisel, Jerry. "Employers' Health Costs Rise 17.1%." *Business Insurance,* Chicago, IL, January 28, 1991. Quotes survey by A. Foster Higgins & Co. Inc. entitled "Indemnity Plans: Cost, Design and Funding."

Locke, Adrienne. "Health Care Cost Hikes Won't Moderate: Agency." *Business Insurance,* Chicago, IL, January 7, 1991. Quotes report by Health Care Financing Administration.

National Center for Health Statistics. *Health, United States, 1989.* Public Health Service, U.S. Government Printing Office, Hyattsville, MD, 1990.

Petertil, Jeffrey P. "An Actuarial Model of the Cost Projection of Retiree Health Benefits." Study Note, Society of Actuaries, Schaumburg, IL, 1988.

Petertil, Jeffrey P. "Life Expectancy, Rising Health Costs and the FASB Rule." *Contingencies,* January/February 1991.

United States Bureau of the Census. *Statistical Abstract of the United States: 1990,* 110th edition. Washington, D.C., 1990.

United States Bureau of the Census. *Historical Statistics of the United States, Colonial Times to 1970, Bicentennial Edition*, Washington, D.C., 1975.

SECTION MEETING

MODELING FLEXIBLE BENEFIT SELECTION

by Charles S. Fuhrer and Arnold F. Shapiro

ABSTRACT

A mathematical framework for benefits and choices must be created in order to model benefit selection. This paper creates such a framework by defining benefit plans as reimbursement functions. These are then used with a defined choice function to calculate the cost deviation due to selection. Finally, utility functions can be applied to this framework to predict choice.

INTRODUCTION

The problem of selection has been recognized by actuaries since the early days of the profession and has been a continuing concern since then. Highan [14] in 1851, for example, authored an article in the first volume of the *Journal of the Institute*, entitled "On the Value of Selection as Exercised by the Policyholder Against the Company." Similarly, McClintock [19] in 1892, in an early volume of the *Transactions of the Actuarial Society of America*, published an actuarial essay "On the Effect of Selection."

During the early periods, the analysis was primarily descriptive and concerned with identifying situations conducive to adverse selection and the associated hazards. In recent years, the emphasis has changed towards an attempt to model the selection process and an analysis of the sensitivity of those models. Moreover, while the initial concern was raised by actuaries in the context of insurance, it has come to be recognized as an issue common to a number of commodities, and as such, has become an important field of study in economics.

A number of issues have emerged. The optimal form of an insurance contract for a risk-adverse insured was studied by Borch [5], Arrow [2], Raviv [22], Bühlmann and Jewell [7] and Blazendo [4]. Models which addressed the difficulty created by asymmetric market information regarding the riskiness of the insured where developed by Akerlof [1], Rothchild and Stiglitz [23], Wilson [25], Miyazaki [20], and Spence [24]. Others have studied the role of wealth in this decision process. These have included Gould [13] who concluded that it was not appropriate to consider demand without regard for the wealth position of the individual, Mayers and Smith [18], and Doherty and Schlesinger [11], who showed how assets correlate with the demand for insurance.

This paper extends the analysis by dealing with some of the statistical aspects of choice in benefit plans. Although the techniques presented could be used for any choice in insurance plans the focus will be on group health benefit plans. By group health benefit plan we will mean a system in which the members of a group are eligible to receive insurance benefits for some part of the cost of their (and sometimes their family's) medical care. The insurance benefits may require the payment of premiums. Generally the particular plan of benefits and premiums are unique to each group. The group is usually formed for some other purpose than the insurance coverage. The most common groups are the employees of a single employer.

Most of the remarks will deal with the traditional health insurance indemnity plans in which the group members obtain health care from licensed health care providers and then are reimbursed for a portion of the charges made by these providers. Some benefit plans include a provision for an employee choice between more than one formula for the amount of reimbursement. The employee may be required to contribute different premiums for each option.

Employee choice in group health benefits has only started to become popular in the last 5 or 10 years in the United States. Of course, most plans have always allowed the choice of rejecting the coverage if the employee is required to pay premiums for the coverage. There is a choice between the benefit plan and a null plan.

REIMBURSEMENT

Before we can write some expressions for the effects of selection or predict it, we need to express the whole set of choices and outcomes in a functional and probabilistic setting.

Let the random variable X be the covered charges for an individual during a period, usually one year. Assume that X is a one dimensional positive random variable.

We define the notation: $x^+ = \max\{0,x\} = \begin{cases} 0 & x<0 \\ x & x\geq 0 \end{cases}$.

Let r(X) be the amount of reimbursement in a benefit plan for covered charges equal to X, where r is a function called here a reimbursement function. Note that we are assuming now that the amount of reimbursement is determined only by the total of covered charges during the year and not by when the services were performed or by which providers.

Although any function r could be a reimbursement function, we note that they generally have the following properties:

I. They are continuous: $\lim_{x \to a} r(x) = r(a)$;

II. They are nondecreasing: $x > y \Rightarrow r(x) \geq r(y)$;

III. $x > y \Rightarrow r(x) - r(y) \leq x - y$; and

IV. $r(0) = 0$

Property I says that the amount reimbursed cannot vary too much for small changes in covered charges. Property II says that as the covered charges increase the reimbursement cannot decrease. Property III says that amount of reimbursement cannot increase faster than covered charges. Property IV says that there is no reimbursement when there are no covered charges.

Example 2.1

The reimbursement function can be the identity function: $r(x) = x$. This is full reimbursement for all covered charges.

Example 2.2

The reimbursement function can be identically equal to zero: $r(x) = 0$ for all x. This is the case of no benefits.

Example 2.3
For a given fixed constant d,

$$r(x) = (x - d)^+ = \begin{cases} 0 & x \leq d \\ x-d & x>d \ . \end{cases}$$

This is called full coverage after a deductible. The constant d is the deductible.

Example 2.4
For a constant c, $0<c<1$, $r(x) = cx$. The constant is called the coinsurance rate.

Example 2.5
We can have both a deductible and coinsurance (a combination of examples 2.3 and 2.4):

$$r(x) = c(x - d)^+ = \begin{cases} 0 & x \leq d \\ c(x-d) & x>d \ . \end{cases}$$

Example 2.6
There can be a limit on the coinsurance of example 2.4. For constant $L>0$ and c, $0<c<1$:[1]

$$r(x) = cx + [(1 - c)x - L]^+ = \begin{cases} cx & x<L/(1-c) \\ x-L & x \geq L/(1-c) \ . \end{cases}$$

Here L is known as the coinsurance limit. Note that L is not the amount of covered charges that has to be reached before full reimbursement but rather is the maximum that is not reimbursed.

Example 2.7
Examples 5 and 6 can be combined to get a plan with deductible, coinsurance, and coinsurance limit.

$$r(x) = c(x - d)^+ + [(1 - c)(x - d) - L]^+ = \begin{cases} 0 & x<d \\ c(x-d) & d \leq x<L/(1-c)+d \\ x-d-L & L/(1-c)+d \leq x \ . \end{cases}$$

In this case $L+d$ is sometimes called the out-of-pocket limit.

Example 2.8
Often there is an overall individual annual benefit maximum. For a constant M:

$$r(x) = \min\{x,M\} = \begin{cases} x & x<M \\ M & x \geq M \ . \end{cases}$$

Example 2.9
There can be the combination of examples 2.7 and 2.8. This would be a plan with deductible, coinsurance, coinsurance maximum, and overall annual maximum:

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[1] Note that we have deviated from the usual convention of reserving the uppercase for random variables.

$$r(x) = \min\{c(x-d)^+ + [(1-c)(x-d)-L]^+, M\} = \begin{cases} 0 & x<d \\ c(x-d) & d \le x < L/(1-c)+d \\ x-d-L & L/(1-c)+d \le x < M+d+L \\ M & M+d+L \le x \end{cases}.$$

For this example we will define the intervals: B = [d,L/(1 −c)+d), C = [L/(1 −c)+d, M+d+L), and D = [M+d+L,∞). Even though this looks rather complicated, this is often just called a comprehensive major medical plan of benefits. Of course, examples 2.1 through 2.8 can be treated as special cases of this example 2.9. All of the r's in examples 2.1-2.9 satisfy the properties I through IV above.

Table 1 illustrates some sample r's: r_1 is a very rich plan, r_2 reimburses less, r_3 is a cheap plan, r_4 is the null or 0 reimbursement of example 2.2, and r_5 is the full reimbursement of example 2.1.

TABLE 1
Some Sample Reimbursements Functions

Reimbursement	1	2	3	4	5
d (Deductible)	$100	$500	$1,000		0
c (Coinsurance)	80%	80%	75%	0%	100%
L (coinsurance max)	$400	$1,000	$3,000		
M (Maximum)	$1,000,000	$1,000,000	$500,000		None

Example 2.10
Assume that the random variable X has the discrete distribution:
Pr{X=ks} = p_k for k=0, 1, 2, . . . and a constant s called the unit or span.[2]

Of course, $\sum_{k=0}^{\infty} P_k = 1.$ Using the r's of example 2.9, we can calculate some values:

$$E[r(X)] = \sum_{ks \in B} c(ks-d)\, p_k + \sum_{ks \in C} (ks-d-L)\, p_k + \sum_{ks \in D} M\, p_k\ ,$$

$$E[r^2(X)] = \sum_{ks \in B} c^2(ks-d)^2 p_k + \sum_{ks \in C} (ks-d-L)^2 p_k + \sum_{ks \in D} M^2 p_k\ ,$$

and

$$\mathrm{Var}[r(X)] = E[r^2(X)] - E^2[r(X)].$$

Where we have used the notation: $r^2(X) = [r(X)]^2$ or $E^2(X) = [E(X)]^2$.

Table 2 shows an example of such a distribution. This distribution was based on some data obtained from the Health Care Service Corp. (Blue Cross Blue Shield of Illinois).

[2]This formulation has the advantage of simplicity. An alternate formulation would be that the $\Pr\{ks \le X < (k+1)s\} = p_k$.

TABLE 2
Sample Discrete Distribution

s=1: Mean = 1.433, Variance = 28.175, Standard Deviation = 5.308

k	p(k)	k	p(k)	k	p(k)	k	p(k)
0	0.600839	43	0.000139	85	0.000023	131	0.000005
1	0.212998	44	0.000126	86	0.000019	132	0.000004
2	0.057230	45	0.000097	87	0.000023	133	0.000005
3	0.033316	46	0.000082	88	0.000015	134	0.000003
4	0.022218	47	0.000136	89	0.000005	135	0.000003
5	0.015504	48	0.000107	90	0.000011	136	0.000008
6	0.011159	49	0.000095	91	0.000017	137	0.000009
7	0.008179	50	0.000048	92	0.000018	138	0.000009
8	0.006329	51	0.000060	93	0.000009	139	0.000003
9	0.004906	52	0.000077	94	0.000004	140	0.000002
10	0.003751	53	0.000098	95	0.000006	142	0.000005
11	0.002734	54	0.000077	96	0.000015	145	0.000001
12	0.002257	55	0.000044	97	0.000007	146	0.000005
13	0.001984	56	0.000050	98	0.000021	147	0.000006
14	0.001629	57	0.000067	99	0.000014	148	0.000005
15	0.001230	58	0.000092	100	0.000005	150	0.000004
16	0.001179	59	0.000066	101	0.000013	151	0.000005
17	0.001041	60	0.000055	102	0.000015	152	0.000004
18	0.000854	61	0.000024	103	0.000015	153	0.000003
19	0.000741	62	0.000033	104	0.000012	158	0.000001
20	0.000633	63	0.000027	105	0.000011	159	0.000016
21	0.000554	64	0.000031	106	0.000003	160	0.000006
22	0.000529	65	0.000041	107	0.000004	169	0.000001
23	0.000528	66	0.000036	108	0.000007	170	0.000004
24	0.000485	67	0.000043	111	0.000002	172	0.000004
25	0.000397	68	0.000041	112	0.000007	173	0.000007
26	0.000387	69	0.000046	113	0.000005	185	0.000003
27	0.000352	70	0.000038	114	0.000007	186	0.000002
28	0.000403	71	0.000010	115	0.000006	197	0.000006
29	0.000333	72	0.000017	116	0.000001	202	0.000003
30	0.000306	73	0.000029	117	0.000009	203	0.000003
31	0.000253	74	0.000033	118	0.000002	204	0.000004
32	0.000258	75	0.000012	119	0.000005	205	0.000001
33	0.000245	76	0.000011	120	0.000004	206	0.000005
34	0.000228	77	0.000014	121	0.000005	245	0.000005
35	0.000204	78	0.000012	122	0.000010	263	0.000006
36	0.000231	79	0.000016	123	0.000004	285	0.000005
37	0.000193	80	0.000007	125	0.000002	292	0.000005
38	0.000172	81	0.000011	126	0.000003	323	0.000002
39	0.000177	82	0.000002	127	0.000005	324	0.000003
40	0.000133	83	0.000021	128	0.000013	519	0.000003
41	0.000121	84	0.000020	130	0.000005	520	0.000002
42	0.000136						

Table 3 shows the expectation and variance of the five reimbursements of example 2.9 when using this distribution, with s = \$1,000.

Example 2.11
Similarly, let X have the mixed distribution where

$$Pr\{X=0\}=p_0 \text{ and } Pr\{a<x\leq b\} = \int_a^b f(t)dt \quad \text{for } a\geq 0$$

and a density function f such that $\int_0^\infty f(t)dt=1-p_0$. See Hogg and Klugman [15, page 50] for a discussion of mixed distributions. Again, assuming the r's of example 2.9, we have the values,

$$E[r(X)]=\int_B c(t-d)f(t)\ dt+\int_C (t-d-L)f(t)\ dt+\int_D Mf(t)\ dt,$$

and

$$E[r^2(X)]=\int_B c^2(t-d)^2f(t)dt+\int_C (t-d-L)^2f(t)dt+\int_D M^2f(t)dt.$$

Table 3 also shows a calculation of these values using the Pareto distribution with the same mean and variance as the discrete distribution and $p_0=0$. The Pareto distribution is discussed in [9] and [15]. It is often used for claim size distributions. The Pareto has density: $f(x) = \alpha\lambda^{\alpha}(\lambda+x)^{-\alpha-1}$ and expectation of $\lambda/(\partial-1)$.

COST DEVIATIONS DUE TO SELECTION
We assume that a group is composed of m individuals, $m\geq 1$. The covered charges for individual i will be denoted with the positive random variable X_i, $1\leq i\leq m$. Now assume that each individual is given a choice at the beginning of the year between n reimbursement functions: $r_1(x), \ldots, r_n(x)$. In order to avoid long subscripts we will write $r_j(x) = r(j,x)$, $1\leq j\leq n$. We define the "mean group reimbursement at r_j" as the random variable

$$\Psi(j) = \frac{1}{m}\sum_{i=1}^{m} r(j,X_i) \ .$$

In the prechoice environment, insurers have been estimating $E(\psi_j)$ by using relatively complicated manual rating formulas that take into account the characteristics of the group, the individuals in the group, and r_j. The formulas are complicated because they must reflect the deductible, the coinsurance, and so on.[3] Incidentally, insurer's will often use the group's experience to estimate $E(\psi_j)$

[3]Of course, this is not true for simple reimbursement functions such as in examples 2.1, 2.2, and 2.4, where:

$$E[\Psi(j)] = r_j\left\{\frac{1}{m}\sum_{i=1}^{m} E(X_i)\right\} \ .$$

TABLE 3

Calculation of Values for the Reimbursements

Reimbursement #:	1	2	3	4	5
Discrete Distribution					
s = $1,000					
Mean	$ 1,282.10	$ 1,091.57	$ 846.98	$0.00	$ 1,433.67
Variance	27,313,585	25,789,764	22,912,997	0	28,175,197
Standard Deviation	5,226.24	5,078.36	4,786.75	0.00	5,308.03
Pareto Distribution					
Mean	$ 2,865.45	$ 2,436.31	$ 1,955.29	$0.00	$ 3,207.80
Variance	67,725,832	65,540,408	52,346,277	0	141,052,606
Standard Deviation	8,229.57	8,095.70	7,235.07	0.00	11,876.56

Assume that the i-th member of the group, $1 \le i \le m$, chooses reimbursement level $X(i)$, $1 \le X(i) \le n$. Thus $X(i)$ is a function $X:\{1,2,\ldots,m\} \to \{1,2,\ldots,n\}$ called the choice function. Also, we define $P(j)$, $1 \le j \le n$ as the annual premium payable by an individual for reimbursement j. The total reimbursement to the group $R=\sum_{i=1}^{m} r(\chi(i),X_i)$, the total premiums paid $P=\sum_{i=1}^{m} P(\chi(i))$, and $G = P - R = \sum_{i=1}^{m} [P(\chi(i)) - r(\chi(i),X_i)]$ is the insurer's gain.

EXAMPLE 3.1
We have a set of X_i, $1 \le i \le m$, mutually independent and identically distributed as in example 2.10. The set of functions $r_j(x) = r(j,x)$, $1 \le j \le n$, are as in example 2.9 where d(j), c(j), L(j) and M(j) correspond to r_j and therefore we have the intervals B(j), C(j) and D(j). For a choice function X, we can calculate the values:

$$E[r(\chi(i),X_i)] = \sum_{ks \in B(\chi(i))} c(\chi(i))[ks - d(\chi(i))]p_k + \sum_{ks \in C(\chi(i))} [ks - d(\chi(i)) - L(\chi(i))]p_k + \sum_{ks \in D(\chi(i))} M(\chi(i))p_k$$

and

$$E[r^2(\chi(i),X_i)] = \sum_{ks \in B(\chi(i))} c^2(\chi(i))[ks - d(\chi(i))]^2 p_k + \sum_{ks \in C(\chi(i))} [ks - d(\chi(i)) - L(\chi(i))]^2 p_k + \sum_{ks \in D(\chi(i))} M^2(\chi(i))p_k.$$

From these we can then calculate:

$$E[R] = \sum_{i=1}^{m} E[r(\chi(i),X_i)] \ ,$$

$$Var[R] = \sum_{i=1}^{m} Var[r(\chi(i),X_i)] \ ,$$

(given a set of P_i's) E[G], and Var[G].

Example 3.2
We can let the X_i have the distribution of example 2.11. We can also have the reimbursements r_j's and the choice function $X(i)$ of example 3.1. Then:

$$E[r(\chi(i),X_i)] = \int_{B(\chi(i))} c(\chi(i))[t - d(\chi(i))]\, f(t)\, dt + \int_{C(\chi(i))} [t - d(\chi(i)) - L(\chi(i))]\, f(t)\, dt + \int_{D(\chi(i))} M(\chi(i))\, f(t)\, dt$$

and

$$E[r^2(\chi(i),X_i)] = \int_{B(\chi(i))} c^2(\chi(i))\,[t-d(\chi(i))]^2 f(t)\;dt + \int_{C(\chi(i))} [t-d(\chi(i))-L(\chi(i))]^2 f(t)\;dt$$

$$+\int_{D(\chi(i))} M^2(\chi(i))\; f(t)\;dt.$$

The expressions for Var[r(X(i), X_i)], E[R], Var[R], E[G], and Var[G] are the same as in example 3.1.

Now we define the "cost deviation due to selection," a random variable for a group with m individuals as:

$$A = R - \sum_{i=1}^{m} \Psi[\chi(i)]$$

$$= \sum_{i=1}^{m} r(\chi(i),X_i) - \sum_{i=1}^{m} \left[\frac{1}{m} \sum_{k=1}^{m} r(\chi(i),X_k) \right].$$

This is called the cost deviation due to selection because A is equal to the deviation in the reimbursement due to the choice χ. Since

$$R = A + \sum_{i=1}^{m} \Psi[\chi(i)],$$

and

$$E[R] = E[A] + E\left[\frac{1}{m}\sum_{i=1}^{m} \Psi[\chi(i)]\right] = E[A] + \frac{1}{m}\sum_{i=1}^{m} E[\Psi(\chi(i))]\,,$$

the problem of estimating E[R] is reduced to estimating E[A] and using the traditional rating techniques (e.g., manual rates as discussed above) for $E[\varphi X(i))]$ in the second term.

Here are some of the properties of A (proofs omitted):

I. A is exactly equal to the amount that the actual reimbursement exceeds what the reimbursement would have been if each individual was reimbursed at the mean rate for the group. That is, if we define the mean reimbursement for the group

$$\bar{r}(x) = \frac{1}{m}\sum_{k=1}^{m} r(\chi(k),x),$$

then

$$A = \sum_{i=1}^{m} \left[r(\chi(i),X_i) - \bar{r}(X_i) \right] = \sum_{i=1}^{m} A(i)$$

for

$$A(i) = r(\chi(i),X_i) - \bar{r}(X_i).$$

II. If the X_i are identically distributed then $E(A)=0$.
III. If X is a constant, $X(1) = X(2) = \ldots = X(m)$, then $A=0$.
IV. Often the insurer sets $P(i) = E[\Psi(i)]$. In which case $E(G) = -E(A)$.
V. If the values of $X(i)$ are treated as random variables, that are independent of the X_i, then $E(A)=0$.

Example 3.3
Table 4 presents a hypothetical group with $m=100$. Shown for each individual is $E(X^i)$ and the choice $X(i)$. Here $n=4$ and the four choices are 1 through 4 of example 2.9. Table 5 shows the expectations and variances of $\Psi(j)$ $(1 \leq j \leq 4)$, R/m, and A/m. These have been calculated under the two assumptions: (1) Each X_i has the distribution of example 2.10 with $s=E(X_i)/1433.67$, and 2) Each X_i has the distribution of example 2.11 (Table 3, Pareto) with $\lambda=E(X_i)(1.15738)$. This value of λ will give a Pareto distribution with the required expectation.

Table 4 also shows for each individual in the group an example outcome of values for X_i, the corresponding values of $r(j,X_i)$ for $j=1,2$, and 3, and the value of A(i). Thus there were covered charges of \$153,970 (compare to the expected value of 141,360), reimbursements R of \$129,546 and A of \$30,007.

The values of $E(X_i)$ can be thought of as the expected covered charges due to known (to the insurer) characteristics of the individuals in the group, such as their ages. In such a case, E(A) can be thought of as the expected cost deviation due to demographic selection. If the actual value of A greatly exceeds this $E(A)$, then the insurer might wonder if the individuals knew more about their health status and used this knowledge to antiselect. We can approximate the probability that a value of A was realized randomly by using $E(A)$ and $Var(A)$ with the normal approximation.

PRIOR YEAR'S CHARGES
Let us assume that each individual has a, possibly unknown, parameter for the distribution of his covered charges. We will call this parameter $y = \{y(i) \mid 1 \leq i \leq m\}$ where y(i) pertains to individual i. Note that the y(i)'s could themselves be treated as realizations of random variables Y(i)'s and may be multidimensional. In any case, if we knew the values of the y(i)'s we could calculate $E[A|y]$. Since there is generally a correlation between successive years' charges, we could take a set of y(i)'s to be each individual's prior year's charges.[4]

Example 4.1
Table 6 expands Table 4. The values that were previously called X_i are now taken to represent last year's claims and are identified as y(i). Table 6 also shows a value of $E[X_i|Y_i=y(i)]$. Here we have set $E[X_i|y(i)] = 0.75E[X_i] + 0.25y(i)$. Table 7 shows the $E[\Psi(j)|y]$, $(1 \leq j \leq 5)$, $Var[\Psi(j)|y]$, $E[R/m|y]$, $Var[R/m|y]$, $E[A/m|y]$ and $Var[A/m|y]$. These are computed using the two assumptions of example 3.3. We have assumed that the X_i always have the same distributions except for a scale change.

[4]Fuhrer (1988), p. 403, found a correlation of 24.35% and Cookson (1989), p. 1602, reported seeing estimates of 15-25%.

TABLE 4

i	E[Xi]	Chi(i)	Xi	r(1,Xi)	r(2,Xi)	r(3,Xi)	r[chi(i),Xi]	A(i)
1	$286.73	1	$5	$0	$0	$0	$0	$0
2	286.73	1	3,358	2,858	2,287	1,769	2,858	951
3	286.73	1	4,090	3,590	2,872	2,317	3,590	1,158
4	286.73	2	0	0	0	0	0	0
5	286.73	2	0	0	0	0	0	0
6	286.73	2	0	0	0	0	0	0
7	286.73	3	478	302	0	0	0	(73)
8	286.73	3	0	0	0	0	0	0
9	286.73	3	0	0	0	0	0	0
10	286.73	4	0	0	0	0	0	0
11	286.73	4	0	0	0	0	0	0
12	286.73	4	0	0	0	0	0	0
13	286.73	4	0	0	0	0	0	0
14	645.15	3	1,000	720	400	0	0	(269)
15	645.15	3	1,522	1,138	818	392	392	(226)
16	645.15	3	0	0	0	0	0	0
17	645.15	3	0	0	0	0	0	0
18	645.15	3	0	0	0	0	0	0
19	645.15	3	1,211	889	569	158	158	(252)
20	645.15	3	707	486	166	0	0	(156)
21	645.15	4	102	2	0	0	0	(0)
22	1,146.94	3	512	330	10	0	0	(81)
23	1,146.94	3	0	0	0	0	0	0
24	1,146.94	3	0	0	0	0	0	0
25	1,146.94	3	0	0	0	0	0	0
26	1,146.94	3	0	0	0	0	0	0
27	1,146.94	3	0	0	0	0	0	0
28	1,146.94	4	551	360	40	0	0	(96)
29	1,577.04	1	2,115	1,615	1,292	836	1,615	600
30	1,577.04	2	0	0	0	0	0	0
31	1,577.04	2	0	0	0	0	0	0
32	1,577.04	2	0	0	0	0	0	0
33	1,577.04	3	0	0	0	0	0	0
34	1,577.04	3	1,798	1,359	1,039	599	599	(204)
35	$1,863.78	1	15,396	14,896	13,896	11,396	14,896	3,655
36	1,863.78	2	0	0	0	0	0	0
37	1,863.78	2	0	0	0	0	0	0
38	1,863.78	3	213	90	0	0	0	(22)
39	1,863.78	3	0	0	0	0	0	0
40	1,863.78	3	295	156	0	0	0	(37)
41	2,293.88	1	0	0	0	0	0	0
42	2,293.88	1	0	0	0	0	0	0
43	2,293.88	1	0	0	0	0	0	0
44	2,293.88	2	0	0	0	0	0	0
45	2,293.88	2	0	0	0	0	0	0
46	2,293.88	3	0	0	0	0	0	0
47	3,154.08	1	5,795	5,295	4,295	3,596	5,295	1,627
48	3,154.08	1	6,588	6,088	5,088	4,191	6,088	1,813
49	3,154.08	1	15,649	15,149	14,149	11,649	15,149	3,691
50	3,154.08	1	39,806	39,306	38,306	35,806	39,306	7,073
51	3,154.08	2	0	0	0	0	0	0
52	4,014.29	1	0	0	0	0	0	0
53	4,014.29	1	593	394	74	0	394	282
54	4,014.29	1	4,960	4,460	3,568	2,970	4,460	1,405
55	4,014.29	2	0	0	0	0	0	0
56	573.47	1	0	0	0	0	0	0
57	573.47	2	0	0	0	0	0	0
58	573.47	2	1,084	787	467	63	467	142
59	573.47	2	0	0	0	0	0	0
60	573.47	3	794	555	235	0	0	(190)
61	573.47	3	1,104	803	483	78	78	(260)
62	573.47	3	275	140	0	0	0	(34)

TABLE 4
(Continued)

63	573.47	3	0	0	0	0	0	0
64	573.47	3	0	0	0	0	0	0
65	573.47	3	0	0	0	0	0	0
66	573.47	3	0	0	0	0	0	0
67	573.47	4	0	0	0	0	0	0
68	$573.47	4	0	0	0	0	0	0
69	573.47	4	39	0	0	0	0	0
70	573.47	4	0	0	0	0	0	0
71	573.47	4	0	0	0	0	0	0
72	573.47	4	0	0	0	0	0	0
73	1,003.57	1	1,891	1,433	1,113	668	1,433	568
74	1,003.57	2	1,780	1,344	1,024	585	1,024	233
75	1,003.57	3	0	0	0	0	0	0
76	1,003.57	3	965	692	372	0	0	(256)
77	1,003.57	3	2,261	1,761	1,409	946	946	(174)
78	1,003.57	3	0	0	0	0	0	0
79	1,003.57	4	0	0	0	0	0	0
80	1,003.57	4	0	0	0	0	0	0
81	1,146.94	1	5,563	5,063	4,063	3,422	5,063	1,572
82	1,146.94	2	0	0	0	0	0	0
83	1,146.94	2	0	0	0	0	0	0
84	1,146.94	3	0	0	0	0	0	0
85	1,146.94	3	0	0	0	0	0	0
86	1,146.94	3	0	0	0	0	0	0
87	1,146.94	3	0	0	0	0	0	0
88	2,007.14	1	7,311	6,811	5,811	4,733	6,811	1,983
89	2,007.14	2	997	717	397	0	397	130
90	2,007.14	2	1,218	895	575	164	575	160
91	2,007.14	2	4,536	4,036	3,229	2,652	3,229	477
92	2,007.14	2	232	106	0	0	0	(25)
93	2,437.25	1	1,883	1,426	1,106	662	1,426	567
94	2,437.25	1	3,754	3,254	2,603	2,066	3,254	1,063
95	2,437.25	2	0	0	0	0	0	0
96	2,437.25	3	0	0	0	0	0	0
97	2,867.35	1	6,751	6,251	5,251	4,313	6,251	1,851
98	2,867.35	2	0	0	0	0	0	0
99	3,297.45	1	2,708	2,208	1,767	1,281	2,208	767
100	3,584.19	1	2,079	1,583	1,263	809	1,583	593
Tot	$141,360		$153,970	$139,349	$120,037	$98,122	$129,546	$30,007
i	E[Xi]	Ci	Xi	r1(Xi)	r2(Xi)	r3(Xi)	rci(Xi)	Ai

Number Selecting Reimbursements

j	#
1	24
2	24
3	38
4	14
Tot	100

TABLE 5

Expectation, Variance, & Standard Deviations of Mean Reimbursements, R/m, & A/m Sample Selection, Distributions Based on Unadjusted Expected Values

Reimbursement #	1	2	3	4	5	R/m	A/m
Number Selecting	24	24	38	14	0		
Discrete Distribution							
Mean	$ 1,871	$ 1,668	$ 1,411	$0	$ 2,027	$ 1,564	$178.54
Variance	818,820	796,109	693,181	0	851,073	774,686	33,655
Standard Deviation	905	892	833	0	923	880	183
Pareto Distribution							
Mean	$ 2,764	$ 2,457	$ 2,083	$0	$ 3,021	$ 2,472	$427.44
Variance	1,301,139	1,284,966	1,008,308	0	3,407,162	1,272,618	53,851
Standard Deviation	1,141	1,134	1,004	0	1,846	1,128	232

TABLE 6

i	E[Xi]	Chi(i)	Xi=y(i)	E[Xi|y(i)]	---Chi(i)---- (1)	(2)	(3)	a(i)
1	$286.73	1	$5	$216	3	3	3	$6,000
2	286.73	1	3,358	1,055	3	1	2	8,500
3	286.73	1	4,090	1,238	2	1	2	3,600
4	286.73	2	0	215	2	2	2	3,400
5	286.73	2	0	215	3	3	3	6,800
6	286.73	2	0	215	3	3	3	7,600
7	286.73	3	478	335	3	3	3	7,500
8	286.73	3	0	215	2	2	3	4,400
9	286.73	3	0	215	2	2	3	4,900
10	286.73	4	0	215	3	3	3	7,200
11	286.73	4	0	215	3	3	3	6,500
12	286.73	4	0	215	2	2	3	4,100
13	286.73	4	0	215	3	3	3	8,500
14	645.15	3	1,000	734	3	3	2	11,000
15	645.15	3	1,522	864	3	3	2	14,500
16	645.15	3	0	484	3	3	3	9,500
17	645.15	3	0	484	3	3	3	13,100
18	645.15	3	0	484	2	2	3	5,400
19	645.15	3	1,211	787	3	3	2	12,300
20	645.15	3	707	661	3	3	3	9,000
21	645.15	4	102	509	1	2	2	3,800
22	1,146.94	3	512	988	1	2	2	19,800
23	1,146.94	3	0	860	1	3	2	23,500
24	1,146.94	3	0	860	1	2	2	6,500
25	1,146.94	3	0	860	1	3	2	19,600
26	1,146.94	3	0	860	1	3	2	17,500
27	1,146.94	3	0	860	1	3	2	20,900
28	1,146.94	4	551	998	1	2	2	14,400
29	1,577.04	1	2,115	1,712	1	1	2	31,800
30	1,577.04	2	0	1,183	1	1	2	20,100
31	1,577.04	2	0	1,183	1	1	2	30,300
32	1,577.04	2	0	1,183	1	1	2	31,400
33	1,577.04	3	0	1,183	1	1	2	25,200
34	1,577.04	3	1,798	1,632	1	1	2	7,700
35	$1,863.78	1	15,396	$5,247	1	1	2	$11,300
36	1,863.78	2	0	1,398	1	1	2	28,400
37	1,863.78	2	0	1,398	1	1	2	36,000
38	1,863.78	3	213	1,451	1	1	2	26,600
39	1,863.78	3	0	1,398	1	1	2	7,800
40	1,863.78	3	295	1,472	1	1	2	21,700
41	2,293.88	1	0	1,720	1	1	2	35,000
42	2,293.88	1	0	1,720	1	1	2	15,900
43	2,293.88	1	0	1,720	1	1	2	27,600
44	2,293.88	2	0	1,720	1	1	2	20,800
45	2,293.88	2	0	1,720	1	1	2	39,300
46	2,293.88	3	0	1,720	1	1	2	45,200
47	3,154.08	1	5,795	3,814	1	1	2	17,400
48	3,154.08	1	6,588	4,013	1	1	2	10,800
49	3,154.08	1	15,649	6,278	1	1	2	59,900
50	3,154.08	1	39,806	12,317	1	1	2	8,200
51	3,154.08	2	0	2,366	1	1	2	49,800
52	4,014.29	1	0	3,011	1	1	2	6,500
53	4,014.29	1	593	3,159	1	1	2	79,900
54	4,014.29	1	4,960	4,251	1	1	2	10,000
55	4,014.29	2	0	3,011	1	1	2	40,200
56	573.47	1	0	430	3	3	3	9,500
57	573.47	2	0	430	3	3	3	9,900
58	573.47	2	1,084	701	3	3	2	8,300
59	573.47	2	0	430	3	3	3	8,300
60	573.47	3	794	629	3	3	3	14,300
61	573.47	3	1,104	706	3	3	2	7,400
62	573.47	3	275	499	3	3	3	6,900

TABLE 6
(Contined)

63	573.47	3	0	430	3	3	3	14,200
64	573.47	3	0	430	3	3	3	6,300
65	573.47	3	0	430	1	2	2	3,800
66	573.47	3	0	430	3	3	3	12,600
67	573.47	4	0	430	3	3	3	9,400
68	$573.47	4	0	$430	2	2	3	$4,700
69	573.47	4	39	440	3	3	3	13,400
70	573.47	4	0	430	3	3	3	8,500
71	573.47	4	0	430	3	3	3	7,600
72	573.47	4	0	430	3	3	3	5,700
73	1,003.57	1	1,891	1,225	2	1	2	14,700
74	1,003.57	2	1,780	1,198	1	1	2	5,900
75	1,003.57	3	0	753	1	3	2	8,700
76	1,003.57	3	965	994	2	2	2	13,900
77	1,003.57	3	2,261	1,318	2	1	2	13,000
78	1,003.57	3	0	753	1	3	2	8,400
79	1,003.57	4	0	753	1	1	2	5,000
80	1,003.57	4	0	753	2	3	2	12,300
81	1,146.94	1	5,563	2,251	1	1	2	12,800
82	1,146.94	2	0	860	1	1	2	4,700
83	1,146.94	2	0	860	1	1	2	4,300
84	1,146.94	3	0	860	1	3	2	16,300
85	1,146.94	3	0	860	1	3	2	16,700
86	1,146.94	3	0	860	1	2	2	6,500
87	1,146.94	3	0	860	1	3	2	23,900
88	2,007.14	1	7,311	3,333	1	1	2	28,900
89	2,007.14	2	997	1,755	1	1	2	4,200
90	2,007.14	2	1,218	1,810	1	1	2	31,600
91	2,007.14	2	4,536	2,639	1	1	2	34,200
92	2,007.14	2	232	1,563	1	1	2	9,000
93	2,437.25	1	1,883	2,299	1	1	2	24,700
94	2,437.25	1	3,754	2,766	1	1	2	14,600
95	2,437.25	2	0	1,828	1	1	2	28,400
96	2,437.25	3	0	1,828	1	1	2	18,200
97	2,867.35	1	6,751	3,838	1	1	2	10,400
98	2,867.35	2	0	2,151	1	1	2	27,700
99	3,297.45	1	2,708	3,150	1	1	2	47,400
100	3,584.19	1	2,079	3,208	1	1	2	45,100
Tot	$141,360		$153,970	$139,349				

Number Selecting Reimbursements

j	Sample	(1)	(2)	(3)
1	24	60	49	0
2	24	11	13	72
3	38	29	38	28
4	14	0	0	0
Tot	100	100	100	100

TABLE 7

Expectation, Variance, & Standard Deviations of Mean Reimbursements, R/m, & A/m Sample Selection, Distributions Based On *y* Conditioned Expected Values

Reimbursement	1	2	3	4	5	R/m	A/m
No. Selecting:	24	24	38	14	0		
Discrete Distribution:							
Mean	$,919	$ 1,721	$ 1,465	$0	$ 2,072	$ 1,657	$226.30
Variance	1,134,917	1,112,045	902,406	0	1,295,754	1,104,684	48,116
Standard Deviation	1,065	1,055	950	0	1,138	1,051	219
Pareto Distribution:							
Mean	$ 4,178	$ 3,892	$ 3,366	$0	$ 4,599	$ 3,959	$742.95
Variance	5,435,419	5,423,544	3,243,718	0	37,442,838	5,421,039	359,771
Standard Deviation	2,331	2,329	1,801	0	6,119	2,328	600

Example 4.2
Very often the parameter y would be unknown. If we assume that it is equal to the prior year's charges we could assume that each y(i) has the distribution of X_i. If we set $E[X|Y_i=y(i)] = 0.75E[X_i] + 25y(i)$, then we can calculate $E[R] = E[E(R|Y)]$ and $Var[R] = Var[E(R|Y)] + E[Var(R|Y)]$. The calculations involved are long and tedious so no example values have been calculated. A Monte Carlo simulation technique could be used instead.

PREDICTING CHOICE
In order to predict employee choice we assume that each of the individuals, i ($1 \leq i \leq m$) has a utility function $u_i(w)$ for wealth $w \geq 0$.[5] Now we assume that each individual will select the reimbursement that maximizes his expected utility. That is, if each individual's initial wealth is w(i) and there exists a $1 \leq k \leq n$ such that:

$$E\left(u_i[w(i)-X_i+r(k,X_i)-P(k)]\right) \geq E\left(u_i[w(i)-X_i+r(j,X_i)-P(j)]\right)$$

for every j, $1 \leq j \leq n$, then $X(i)=k$. Trivially, if there are two (or more) reimbursements for which the expected utility is equal and greater than all of the other reimbursements we will assume an arbitrary selection.

For simplicity we want to use the same form of a utility function for each individual. In order to model the actual situation we will need each individual to have a different aversion to risk. In order to do this we will select a utility function that is decreasingly risk averse. That is, the larger the individual's initial wealth the less risk averse he is. Common measures of risk aversion are the Arrow-Pratt ([2] and [21]) measures of absolute risk aversion and relative risk aversion: $\rho_u(w) = -u''(w)/u'(w)$ and $\delta_u(w) = w\,\rho_u(w)$, respectively.[6]

Example 5.1
We can use the assumptions of example 3.3 with the choice depending on the utility function: $u_i(w) = \ln(w+a(i))$ for a positive constant a(i). This utility function is convenient because the property that almost any level of risk adverseness can be selected based on the size of the parameter a(i).[7] Table 6 shows some sample values of a(i) for our sample group and the resulting choice in column (1) using the discrete distribution to calculate expectations. Note that we have slightly changed the reimbursements to not have a maximum M. The end of Table 6 summarizes the choices and Table 8 shows the calculated values. We have assumed that $P(j) = E(\Psi(j))$.

[5]See [6], Chapter 1, for an introduction to risk averse utility functions. A good reference on utility functions is [16], particularly Chapter 4, which has an excellent section on various types of utility functions.

[6]Kimball [17, p.2] suggests "standard risk aversion" as another alternative. It is characteristic of utility functions associated with constant relative risk aversion.

[7]For $u(w)=\ln(w)$, the absolute risk aversion is $\rho_u(w) = 1/w$, which is a decreasing function of w, and the relative risk aversion is $\delta_u(w) = 1$.

Example 5.2
For this example, use the assumptions of example 4.1, with a fixed known parameter set y(i), with the utility based choice of example 5.1. The calculated values are also shown in Table 8. example 5.3

Example 5.3
This is example 5.1, except we use the parameter adjusted discrete distribution of example 4.1 to calculate the expected utilities and determine the choices. Table 6 shows the choices in column (2) and Table 8 shows the calculated values using the parameter adjusted distributions as in example 5.2. Note that the choices (2) have a larger E[A] than choices (1).

Example 5.4
Here we combine example 4.4 with the utility function of example 5.1. Now that the choice is random, we could calculate, for each i and j, Pr{X(i) = j}. We define N(j) as the number of individuals for whom X(i) = j. We could also calculate E[N(j)], $1 \leq j \leq 4$.

Example 5.5
Let S(j) = {i:X(i) = j}. Then let

$$P(j) = \frac{1}{N(j)} \sum_{i \in S(j)} r(y(i))$$

in example 5.2. That is, we set the premiums for a reimbursement equal to the experience of those that selected it (using the sample selection). The resulting choice (Table 6, column 3) is much more heavily weighted towards the cheaper plans. This illustrates the selection spiral that can occur if premium rates are based only on the experience of those that choose a particular reimbursement plan.

CONCLUSION AND AREAS FOR FURTHER RESEARCH
The framework of this paper allows us to predict employee choice and cost deviations due to selection given any arbitrary combination of individual charge distributions, a set of reimbursement plans and their premiums, and a set of utility functions. Using this method various combinations of plans and premiums can be explored until the plan administrator can pick the combination that best fits the group's needs.

The calculations of examples 4.2 and 5.4 could be completed. A few more distributions could be used to calculate the values. A term could be added to each reimbursement's wealth to model affinities that individuals may have for a particular plan. This might be used in the HMO choice, as individuals might prefer the traditional plan over the HMO so that they could continue with their current physicians.

The parameters of the utility function could be estimated from some actual choice data. These could then be used to predict actual past choices and then see how accurate the predictions were.

TABLE 8

Values for R/m and A/m

		Discrete Distribution			Pareto Distribution		
		Mean	Variance	Standard Deviation	Mean	Variance	Standard Deviation
5.1	R/m	$1,779	812,894	$902	$2,715	1,300,147	$1,140
	A/m	63	2,011	45	182	5,907	77
5.2	R/m	$1,831	1,129,125	$1,063	$4,129	5,434,103	$2,331
	A/m	65	4,412	66	218	58,528	242
5.3	R/m	$1,795	1,126,295	$1,061	$4,104	5,433,383	$2,331
	A/m	74	7,302	85	272	100,422	317
5.5	R/m	$1,697	1,110,082	$1,054	$3,887	5,423,368	$2,329
	A/m	48	3,605	60	142	54,459	233

REFERENCES

1. Akerlof, G.A. "The Market for Lemons: Quality, Uncertainty, and the Market Mechanism," *Quarterly Journal of Economics* 84 (1970): 488-500.

2. Arrow, K.J. "The Theory of Risk Aversion." Lecture 2 in *Aspects of the Theory of Risk Bearing*, Yrjö Jahnssonin Säätio, Helsinki; Reprinted in *Collected Papers of Kenneth J. Arrow, Vol 3: Individual Choice under Certainty and Uncertainty* (1984): The Belnap Press of Harvard University Press, Cambridge.

3. Arrow, K.J. *Essays in the Theory of Risk Bearing*, New York: Elsevier (1976).

4. Blazenko, G. "Optimal Indemnity Contracts." *Insurance: Mathematics and Economics*, (1985).

5. Borch, K. "Equilibrium in a Reinsurance Market," *Econometrica*. (1962).

6. Bowers, N.L. Jr., Gerber, H.U., Hickman, J.C., Jones, D.A., and Nesbitt, C.J. *Actuarial Mathematics*, Society of Actuaries: Itasca, IL (1986).

7. Bühlmann, H. and Jewell, W. "Optimal Risk Exchanges," *Astin Bulletin* (1979).

8. Cookson, J.P. "High Cost Claimants in Medical Benefit Plans," Panel Discussion, *Record*, Vol. 15, Society of Actuaries (1989): 1593.

9. Degroot, M. *Optimal Statistical Decisions*, New York: McGraw-Hill (1970).

10. Doherty, N.A. and Schlesinger, H. "Optimal Insurance in Incomplete Markets," *Journal of Political Economy*. 91 (1990): 1045-1054.

11. Doherty, N.A. and Schlesinger, H. "Rational Insurance Purchasing: Consideration of Contract Nonperformance." *Quarterly Journal of Economics* 105 (1990): 243-253.

12. Fuhrer, C.S. "Some Applications of Credibility Theory to Group Insurance." *TSA* XL, Pt. 1 (1988): 387.

13. Gould, J.P. "The Expected Utility Hypothesis and the Selection of Optimal Deductibles for a Given Insurance Policy." *Journal of Business* 42(2) (1969): 143-151.

14. Highan, J.A. "On the Value of Selections as Exercised by the Policyholder Against the Company," *Journal of the Institute* I (1851): 179.

15. Hogg, R. and Klugman, S. *Loss Distributions*. New York: John Wiley and Sons, (1984).

16. Keeney, R.L. and Raiffa, H. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. New York: John Wiley and Sons, (1976).

17. Kimball, M. "Standard Risk Aversion." working paper, University of Michigan (1989).

18. Mayers, D. and Smith, C.W. Jr. "The Interdependence of Individual Portfolio Decisions and the Demand for Insurance." *Journal of Political Economy* 91:2 (1983): 304-311.

19. McClintock, E. "On the Effect of Selection." *TASA* III (1892): 59.

20. Miyazaki, H. "The Rat Race and Internal Labor Markets." The Bell Journal of Economics 8 (1977): 394-418.

21. Pratt, J.W. "Risk Aversion in the Small and the Large." *Econometrica* 32 (1964): 122-136.

22. Raviv, A. "The Design of an Optimal Insurance Policy." *American Economic Review* 69 (1979): 84-96.

23. Rothchild, M. and Stiglitz, J. "Equilibrium in Insurance Markets: An Essay on the Economics of Imperfect Information." *Quarterly Journal of Economics* 90 (1976): 629-649.

24. Spence, M. "Product Differentiation and Performance in Insurance Markets." *Journal of Public Economics* 10 (1978): 427-447.

25. Wilson, C. "A Model of Insurance Markets with Incomplete Information." *Journal of Economic Theory* 97 (1977): 167-207.