ISSN 0954-2388
CMIR, 14 (1995)

Continuous Mortality Investigation Reports

Number 14

Institute of Actuaries

Faculty of Actuaries

Published by the Institute of Actuaries
and the Faculty of Actuaries
1995

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INTRODUCTION

THE Executive Committee of the Continuous Mortality Investigation Bureau of the Institute of Actuaries and the Faculty of Actuaries has pleasure in presenting this, the fourteenth number of its Reports. This number contains several reports on a variety of topics, including a paper prepared in the Republic of Ireland and a research paper prepared by a post graduate at Heriot-Watt University.

Since the last number of CMI Reports there have been several changes in personnel. I have taken over as Chairman of the Executive Committee on the retiral of David Wilkie, but am delighted that he is able to continue to give us the benefit of his advice and wisdom through his continued membership of the PHI and AIDS Sub-Committees. John McCutcheon continues on the Executive Committee after his term as Faculty President, and is now Chairman of the Mortality Sub-Committee. Chris Daykin has become Institute President but will carry on as a member of the Executive Committee—we are fortunate indeed that these busy men devote so much of their time on our behalf.

I record with regret the early retiral of Robert Plumb from the Executive Committee and PHI Sub-Committee. As Chairman of the latter since 1982, he had guided it through the very difficult process of interpreting PHI results, initially on the Manchester Unity basis, and culminating in the tremendous team effort which produced the milestone report in CMIR12. Robert will be sorely missed, but I am sure that we have an excellent successor in Graham Clark, to whom I extend a warm welcome.

The first, and longest, report in this number of CMIR records the mortality experience of assured lives, pensioners and annuitants for the quadrennium 1987–90. This follows the style of previous quadrennial reports, this time using as a comparison basis the "80" Series mortality tables.

There follows a second report on the investigation into the mortality experience of smokers and non-smokers, this time covering the three years 1988, 1989 and 1990. This report confirms the trends highlighted in the paper in CMIR13.

The "mini graduations" paper prepared initially in CMIR13 is updated for 1987–90 in the next report. This shows how the "80" series tables can be adapted to reflect current experience.

Two papers prepared by the Impaired Lives Sub-Committee follow. One shows the mortality experience of impaired lives for the combined quadrennia 1983–86 and 1987–90, which is starting to produce some useful results. The second discusses the causes of death of impaired lives for 1987–90; the equivalent report for 1983–86 appeared in CMIR11.

The next paper is unusual in that it emanates purely from Republic of Ireland data, and is the first cover Irish retirement annuitants. We are

grateful to the Irish Life for allowing us to publish the results, which cover the years 1986–91.

A research paper by Isabel Cordeiro at Heriot-Watt University forms the final paper in this edition and follows up some of the work of the PHI Sub-Committee in CMIR12. The Executive Committee welcomes such contributions and is happy to publish suitable papers which are derived from CMI data or research.

Finally, I should like to thank all those involved in the work of preparing these reports, including those in the contributory offices, the Secretariat of the Bureau, Alden Press and the members of the Executive Committee and the Sub-Committees. We are always looking for new contributors, and it is a particular pleasure to inform you that our new Critical Illness investigation, which started with effect from 1 January 1995, has attracted several new members, some of whom are also interested in joining the existing mortality investigations. We can never have too much data, and I would actively encourage life offices to consider contributing to our Mortality, Impaired Lives, PHI or Critical Illness investigations.

CONTENTS

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THE MORTALITY OF ASSURED LIVES, PENSIONERS AND ANNUITANTS EXPERIENCE FOR 1987-90

THIS report covers the main mortality experiences for the quadrennium 1987-90. For all the experiences the comparison basis used is selected from the "80" series standard tables, published in 1990. For almost all experiences figures for both 1983-86 and 1987-90 are shown. For the long standing investigations figures for previous quadrennia up to and including 1983-86 can be found in *C.M.I.R.* **11** (1991); these however use older standard tables, i.e. A1967-70, FA1975-78, PA(90) and a(90), as comparison bases. Comparisons for the 1983-86 quadrennium based on these older tables as well as on the more recent "80" series were published in *C.M.I.R.* **13** (1993). These provide a link between the two bases allowing long term trends to be studied.

The list of investigations run by the Bureau is extensive. Over the last decade a number of new assured lives investigations have been set up, after consultation with the contributing offices, where the criteria for acceptance of the business have indicated that the mortality experience of the policyholders might be expected to be different from that experienced by holders of traditional style policies. With such a wide range of experiences it is often not easy to pick out the essential differences between them. In this report, the experiences have been grouped in a way which, it is hoped, makes such comparisons easier. The content of the different sections is as follows:

1. *Male lives covered by permanent (whole life and endowment) policies of assurance issued in the United Kingdom*
- 1.1 Non linked assurances on single lives fully medically underwritten;
- 1.2 Unit linked assurances on single lives fully medically underwritten;
- 1.3 Joint life first death assurances fully medically underwritten;
- 1.4 Assurances on single lives issued on minimum medical evidence;
- 1.5 Assurances on joint lives issued on minimum medical evidence;
- 1.6 Guaranteed acceptance assurances issued on single lives.

2. *Female lives covered by permanent (whole life and endowment) policies of assurance issued in the United Kingdom*
- 2.1 Non linked assurances on single lives fully medically underwritten;
- 2.2 Unit linked assurances on single lives fully medically underwritten;
- 2.3 Joint life first death assurances fully medically underwritten;
- 2.4 Assurances on single lives issued on minimum medical evidence;
- 2.5 Assurance on joint lives issued on minimum medical evidence;
- 2.6 Guaranteed acceptance assurances issued on single lives.

3. *Permanent (whole life and endowment) assurances issued in the Republic of Ireland*
- 3.1 Assurances on male lives;
- 3.2 Assurances on female lives.

4. *Temporary assurances issued in the United Kingdom on male lives*
- 4.1 Fully medically underwritten assurances;
- 4.2 Assurances effected under Section 621 of the ICTA 1988;
- 4.3 Assurances effected under Section 637(1) of the ICTA 1988.

5. *Temporary assurances issued in the United Kingdom on female lives*
- 5.1 Fully medically underwritten assurances;
- 5.2 Assurances effected under Section 621 of the ICTA 1988;
- 5.3 Assurances effected under Section 637(1) of the ICTA 1988.

6. *Immediate annuity contracts issued in the United Kingdom*
- 6.1 Male annuitants;
- 6.2 Female annuitants.

7. *Retirement annuity and personal pension policies issued in the United Kingdom*
- 7.1 Male retirement annuitants;
- 7.2 Male personal pension policyholders;
- 7.3 Female retirement annuitants;
- 7.4 Female personal pension policyholders.

8. *Pensioners covered by life office pension schemes*
- 8.1 Male pensioners;
- 8.2 Female pensioners;
- 8.3 Widows;
- 8.4 Widowers.

The reports on the quadrennia 1979-82 and 1983-86 showed the total exposed to risk and deaths for each investigation undertaken by the Bureau. The figures for these two quadrennia, plus those for 1987-90, are brought together in Table 1. The list of offices contributing to the Bureau over that twelve-year period has remained more or less stable, so the table gives an insight into how the mix of business on the books of those offices is changing over time. In particular, it highlights the rise in minimum evidence business at the expense of fully medically underwritten business. It must be stressed that a table of this nature gives indications of trends only; also the mix of business may not be typical of the market as a whole.

When studying the individual tables it is necessary to bear in mind the statistical significance of the results, particularly those shown in the form of the ratio $r = 100A/E$. A good approximation to the standard deviation of r is $10\sqrt{r}/\sqrt{A} = 100/\sqrt{E}$. A less accurate approximation is $100/\sqrt{A}$.

The contributing offices continue faithfully, year by year, to make their returns to the Bureau. This represents an enormous commitment of time and effort on their part. The profession as a whole is in their debt for allowing the results of the investigation of the experiences to be published for the benefit of all.

Table 1. CMI Investigations: exposed to risk, deaths and crude death rates
Permanent (Whole Life and Endowment) Assurances (combined, all durations)

Investigation	1979-82			1983-86			1987-90		
	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)
Males, UK									
Non linked, standard evidence	25,862	95,023	3·7	23,134	91,910	4·0	18,568	77,906	4·2
Linked, standard evidence	1,005	2,734	2·7	1,492	5,077	3·4	1,109	3,736	3·4
Joint life, first death,† standard evidence*	-	-	-	741	873	1·2	1,743	2,434	1·4
Minimum evidence**	-	-	-	279	260	0·9	1,810	1,865	1·0
Joint life first death, minimum evidence**	-	-	-	300	165	0·5	1,883	1,546	0·8
Guaranteed acceptance business	-	-	-	261	391	1·5	307	606	2·0
Total	**26,867**	**97,757**	**3·6**	**26,207**	**98,676**	**3·8**	**25,420**	**88,093**	**3·5**
Females, UK									
Non-linked, standard evidence	4,764	7,390	1·6	5,507	9,715	1·8	5,102	10,639	2·1
Linked, standard evidence	180	419	2·3	517	2,095	4·1	497	1,382	2·8
Joint life, first death,† standard evidence*	-	-	-	741	363	0·5	1,707	1,072	0·6
Minimum evidence**	-	-	-	56	17	0·3	551	292	0·5
Joint life first death, minimum evidence**	-	-	-	300	81	0·3	1,850	726	0·4
Guaranteed acceptance business	-	-	-	77	69	0·9	101	132	1·3
Total	**4,944**	**7,809**	**1·6**	**7,198**	**12,340**	**1·7**	**9,808**	**14,243**	**1·5**
Males, Republic of Ireland									
Standard evidence	**990**	**4,702**	**4·8**	**843**	**3,868**	**4·6**	**536**	**2,126**	**4·0**
Females, Republic of Ireland									
Standard evidence*	**27**	**40**	**1·5**	**123**	**203**	**1·7**	**91**	**105**	**1·2**

Table 1. (continued)
CMI investigations: exposed to risk, deaths and crude death rates
Temporary Assurances (combined, all durations)

Investigation	1979-82			1983-86			1987-90		
	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)
Males, UK									
Temporary, standard evidence	4,252	7,655	1·8	4,805	9,249	1·9	4,392	9,117	2·1
Section 621, ICTA 1988	-	-	-	-	-	-	582	761	1·3
Section 637 (1), ICTA 1988***	-	-	-	-	-	-	188	88	0·5
Total	**4,252**	**7,655**	**1·8**	**4,805**	**9,249**	**1·9**	**5,162**	**9,966**	**1·9**
Females, UK									
Temporary, standard evidence*	-	-	-	1,158	698	0·6	1,559	1,255	0·8
Section 621, ICTA 1988	-	-	-	-	-	-	62	38	0·6
Section 637 (1), ICTA 1988***	-	-	-	-	-	-	55	9	0·2
Total	**-**	**-**	**-**	**1,158**	**698**	**0·6**	**1,676**	**1,303**	**0·8**

Table 1. (continued). Pensions and Annuities (lives, all durations)

Investigation	1979-82			1983-86			1987-90		
	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)	Exposed to risk (000)	Actual deaths	Crude death rate (per 1000)
Males, UK									
Immediate annuities	67	4,893	73·2	53	4,066	76·1	50	4,060	80·5
Retirement annuities in deferment	3,004	12,328	4·1	4,791	17,235	3·6	6,358	18,720	2·9
Retirement annuities in payment	226	8,811	38·9	411	15,563	37·9	648	22,731	35·1
Personal pensions in deferment***	-	-	-	-	-	-	1,332	1,107	0·8
Personal pensions in payment***	-	-	-	-	-	-	2	25	12·7
Pensioners, normal and late	1,420	85,426	60·2	1,394	84,267	60·5	1,220	74,842	61·3
Pensioners, early	527	23,717	45·0	704	29,041	41·3	659	27,625	41·9
Widowers	-	10	29·9	1	33	46·9	1	89	69·2
Total	**5,244**	**135,185**	**25·8**	**7,354**	**150,205**	**20·4**	**10,270**	**149,199**	**14·5**
Females, UK									
Immediate annuities	151	9,943	65·8	119	8,566	72·2	101	7,752	76·4
Retirement annuities in deferment	339	860	2·5	682	1,547	2·3	1,097	2,002	1·8
Retirement annuities in payment	35	692	19·6	74	1,451	19·5	133	2,345	17·5
Personal pensions in deferment***	-	-	-	-	-	-	593	201	0·3
Personal pensions in payment***	-	-	-	-	-	-	1	2	3·4
Pensioners, normal and late	342	10,536	30·8	392	12,266	31·3	389	13,124	33·8
Pensioners, early	91	1,899	20·8	133	2,496	18·7	137	2,780	20·2
Widows	29	692	24·1	78	1,803	23·0	114	3,072	27·1
Total	**987**	**24,622**	**24·9**	**1,478**	**28,129**	**19·0**	**2,565**	**31,278**	**9·2**
Grand total assurances, pensions and annuities	**43,311**	**277,770**	**6·4**	**49,166**	**303,368**	**6·2**	**55,528**	**296,313**	**5·3**

[1] Includes some temporary business, * Investigation started 1st January 1982, ** Investigation started 1st January 1985, *** Investigation started 1st January 1989.

1. MALE LIVES COVERED BY PERMANENT (WHOLE LIFE AND ENDOWMENT) POLICIES OF ASSURANCE ISSUED IN THE UNITED KINGDOM

This section covers six different experiences. The main subdivision is by medical status i.e. fully medically underwritten policies, policies issued after completion of a shortened proposal form (minimum evidence policies) and guaranteed acceptance policies. For the first two groups policies issued on a single life and those issued on a joint life basis are investigated separately. The single life fully medically underwritten policies are further split between those written on a non linked basis (including unitised with profit) and those on a unit linked basis.

The Executive Committee keeps under review the question as to whether some investigations could be combined eg. single and joint life policies or non linked and unit linked. However, it does seem that at present the experiences are sufficiently different to warrant keeping them separate. These differences can be seen from inspection of Table 1.1. Further analysis of these differences is contained in the individual sections. All the tables in this part of the report use as a comparison basis the AM80 Table.

A smoking indicator has been incorporated in the individual sections as from 1st January 1988 and for each of the investigations in this section some of the data is split by smoking status. A report on the mortality experience of smokers and non smokers for the years 1988-90 is included as a separate paper elsewhere in this volume.

Table 1.1 Permanent assurances, males, 1987-90, all investigations: ratios of actual deaths to those expected using the AM80 table

Investigation group	100 A/E, all ages all durations
Single lives, full underwriting, non linked	80
Single lives, full underwriting, unit linked	72
Joint lives, full underwriting	72
Single lives, minimum evidence	97
Joint lives, minimum evidence	81
Single lives, guaranteed acceptance	118

1.1 *Non linked assurances on single lives, fully medically underwritten*

This investigation (together with that into the mortality of immediate annuitants) is the longest running of those carried out by the Bureau. In terms of the number of policies covered it is also by far the largest. However, as can be seen from Table 1, the exposed to risk has fallen substantially over the last three quadrennia. New business is not fully replacing policies moving out of

Table 1.1.1a. Permanent assurances, males, 1987-90, medical and non medical combined*: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-20	62	116	90
21-25	85	104	91
26-30	98	144	127
31-35	61	111	114
36-40	92	127	105
41-45	109	97	94
46-50	141	97	87
51-55	188	85	98
56-60	139	78	93
61-65	140	106	92
66-70	84	76	107
71-	85	99	136
All ages	1,284	98	99
Duration 1			
-20	42	120	88
21-25	73	95	96
26-30	64	87	91
31-35	75	121	106
36-40	95	110	85
41-45	125	87	98
46-50	154	82	84
51-55	252	85	85
56-60	202	77	88
61-65	145	88	98
66-70	157	99	107
71-	143	126	126
All ages	1,527	92	93

the experience due to death, maturity, surrender or lapse. The average age of the exposed to risk is therefore increasing; the rise in the crude death rate over the three quadrennia reflects this. In the Report in *C.M.I.R.* **11** it was noted that new business as reflected in the exposed to risk at duration 0 had dropped by about 30% over the 1983-86 quadrennium. In 1987-90, the exposed to risk at duration 0 has stabilised, albeit at a lower level than previously.

The policies in this investigation are subdivided into those issued after a full

Table 1.1.1a (continued)

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Durations 2 and over			
-20	33	87	103
21-25	213	94	86
26-30	369	88	101
31-35	804	104	101
36-40	1,756	89	96
41-45	3,871	80	89
46-50	5,991	78	89
51-55	9,429	74	86
56-60	14,081	75	88
61-65	14,717	82	94
66-70	5,538	78	86
71-75	5,080	82	87
76-80	5,552	87	94
81-85	4,408	88	97
86-90	2,218	86	94
91-95	796	75	85
96-100	223	49	60
101-	16	11	22
All ages	75,095	80	90

* A proportion of the data received for this investigation is returned with a combined medical code. The figures in Table 1.1.1a are, therefore, greater than the sum of the corresponding figures from Tables 1.1.1b and 1.1.1c.

medical examination and those issued after completion of a full medical questionnaire with, possibly, a medical attendant's report. Fully medically examined business formed almost $12\frac{1}{2}\%$ of the total exposed to risk in this investigation over the quadrennium. However, at duration 0 the proportion is less than 5% reflecting the fact that the increase in medical limits has outstripped the increase in average sums assured. This latter figure has remained stable over the quadrennium.

Tables 1.1.1a, 1.1.1b, and 1.1.1c relate respectively to the combined data, the medically examined data and the non medical data. They show the actual deaths in 1987-90 and the ratio of the actual deaths to those expected using the AM80 table. Corresponding ratios for the quadrennium 1983-86 are also shown. As was mentioned earlier, ratios for earlier quadrennia using as a comparison the 1967-70 based tables and FA1975-78 can be found in *C.M.I.R.* **11** with the tables in *C.M.I.R.* **13** forming a bridge between the two series.

Table 1.1.1b. Permanent assurances, males, 1987-90, medical data: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-30	14	195	149
31-40	7	128	41
41-50	12	100	86
51-60	14	58	95
61-70	29	72	74
71-	15	78	109
All ages	91	84	87
Duration 1			
-30	8	121	159
31-40	7	119	64
41-50	12	85	108
51-60	30	89	82
61-70	52	75	79
71-	32	88	113
All ages	141	85	90
Durations 2 and over			
-30	13	81	111
31-35	45	124	124
36-40	151	99	113
41-45	478	96	93
46-50	777	77	86
51-55	1,412	71	82
56-60	2,274	69	82
61-65	3,002	74	84
66-70	1,967	72	79
71-75	2,342	79	84
76-80	3,228	85	91
81-85	2,900	86	97
86-90	1,565	86	94
91-95	602	78	85
96-100	173	49	60
101-	12	10	22
All ages	20,941	78	86

Table 1.1.1c. Permanent assurances, males, 1987-90, non medical data: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-20	56	106	87
21-25	78	100	91
26-30	97	150	126
31-35	58	110	114
36-40	87	126	108
41-45	102	96	97
46-50	135	98	85
51-55	177	85	97
56-60	135	81	94
61-65	123	104	100
66-70	69	83	126
71-75	47	108	150
76-	22	102	186
All ages	1,186	99	101
Duration 1			
-20	41	119	82
21-25	71	96	95
26-30	58	83	91
31-35	71	120	107
36-40	91	110	87
41-45	117	86	96
46-50	148	83	83
51-55	234	84	85
56-60	189	77	90
61-65	125	90	100
66-70	119	107	122
71-75	66	135	142
76-	41	167	139
All ages	1,371	92	93

Between 1983-86 and 1987-90, at durations 2 and over, the largest improvements in mortality have been over the middle range of ages, from 46 to 65. This continues a trend noted over previous quadrennia. Mortality rates at ages over 65 are continuing to fall, but the improvement is slower than that for the younger lives. At ages below 40 there had been a decline over a number of quadrennia, although this was also smaller than that seen in the middle age groups. By 1983-86 the indications were that rates at these younger ages might

Table 1.1.1c. (continued).

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Durations 2 and over			
-20	30	81	99
21-25	206	93	84
26-30	358	88	100
31-35	749	103	99
36-40	1,583	88	94
41-45	3,339	78	89
46-50	5,105	78	90
51-55	7,851	75	88
56-60	11,476	77	90
61-65	11,375	85	98
66-70	3,367	82	92
71-75	2,506	86	93
76-80	1,985	89	101
81-85	1,174	90	98
86-90	426	81	93
91-95	129	64	86
96-100	34	45	56
101-	3	20	31
All ages	51,696	80	92

be stabilising. The experience for 1987-90 would support that as it shows no overall improvement over that for 1983-86.

It is not customary for this experience to publish results for individual years in these reports as, even with the number of deaths returned to this investigation, the mortality experienced fluctuates from year to year. However, inspection of individual years on this occasion reveals, for males, an interesting shift in the pattern between 1987-88 and 1989-90. The figures are shown in Table 1.1.2. The table indicates that, while mortality levels for males aged over 40 have continued to decline, or have remained stable year on year, the mortality experienced by males up to age 40 improved over 1987 and 1988 but has deteriorated in 1989 and 1990 (the pattern in 1989 and 1990 is repeated in 1991 and in 1992, the latest years for which results are available at the time of writing). The suspicion must be that at least some of this deterioration is due to AIDS deaths coming through in the experience, although this is unlikely to be the full explanation. A similar phenomenon has been noted in England and Wales population statistics.

At duration 1 there has been virtually no overall improvement in mortality

Table 1.1.2. Permanent assurances, males, medical and non -medical combined, durations 2 and over. Ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	1983-86	1987	1988	1989	1990
-20	103	91	75	75	99
21-25	86	90	118	73	95
26-30	101	84	88	96	89
31-35	101	105	98	105	107
36-40	96	86	78	93	101
41-45	89	85	79	76	80
46-50	89	79	81	75	76
51-55	86	79	75	72	68
56-60	88	83	75	74	70
61-65	94	87	86	78	79
66-70	86	79	79	74	80
71-75	87	86	80	81	82
76-80	94	84	88	85	87
81-85	97	84	89	89	89
86-90	94	88	88	81	86
91-95	85	88	79	65	72
96-100	60	49	65	38	46
101-	22	13	3	10	19
All	90	83	81	77	78
-40	97	90	86	94	100
41+	90	83	80	77	77
Ratio of Ratios*	1.08	1.08	1.08	1.22	1.30

* 100A/E for ages up to 40 ÷ 100A/E for ages over 40

over the last two quadrennia. There is no real discernable pattern through the age groups although the mortality at ages 31 to 40 does look particularly heavy in 1987-90.

At duration 0 also, there has been virtually no overall improvement in mortality between 1983-86 and 1987-90. Such improvement as there was has been at ages over 50; the mortality at ages under 40 has been relatively heavy.

Tables 1.1.1b and 1.1.1c show the medical and non medical experience respectively. Overall, the medically examined lives have suffered lighter mortality than lives accepted on a non medical basis. However, at ages 31-45, durations 2 and over, both in 1983-86 and 1987-90, medical lives have experienced heavier mortality than non medical lives. A similar phenomenon

Table 1.1.3. Crude central rates of mortality per 10,000 experienced in individual years, permanent non linked assurances, durations 5 and over, medical and non-medical combined, males 1971-90.

Year of experience	Age last birthday															
	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1971	7	8	7	10	18	36	59	98	169	258	470	717	1,133	1,777	2,553	3,775
1972	11	6	7	11	18	34	62	101	169	289	498	786	1,179	1,827	2,231	3,547
1973	7	7	7	10	18	34	57	101	164	270	456	821	1,216	1,794	2,366	3,582
1974	7	6	7	10	18	31	59	100	165	261	478	710	1,180	1,815	2,647	2,455
1975	7	6	6	9	17	31	58	91	158	252	447	720	1,203	1,838	2,894	3,313
1976	8	6	6	8	17	30	58	86	157	252	433	695	1,151	1,814	2,559	3,241
1977	6	6	6	10	16	29	54	92	157	236	428	712	1,089	1,693	2,323	3,050
1978	8	6	6	10	15	27	54	90	152	244	410	731	1,088	1,763	2,358	2,632
1979	9	6	6	8	15	28	52	86	145	229	417	682	1,054	1604	2,500	2,742
1980	7	6	6	9	15	27	51	90	149	232	405	711	1,128	1,491	2,005	2,162
1981	7	6	6	8	14	25	49	89	141	219	417	648	1,090	1,578	2,302	2,081
1982	8	6	6	8	14	24	47	81	137	218	380	688	1,078	1,669	2,149	2,203
1983	5	6	6	8	14	26	44	82	138	221	379	637	1,084	1,656	2,148	2,730
1984	6	7	5	8	13	25	43	75	137	207	354	600	976	1,511	2,020	2,070
1985	5	6	6	8	13	23	42	73	134	220	347	606	1,031	1,540	2,000	2,254
1986	7	6	6	9	13	23	41	75	130	191	347	608	973	1,409	2,165	2,165
1987	6	5	6	8	12	22	39	72	125	198	356	544	872	1,418	2,237	2,018
1988	11	5	6	7	12	22	36	64	123	191	335	580	921	1,426	2,089	2,443
1989	(4)	5	6	8	11	20	36	63	113	177	335	563	926	1,360	1,625	1,431
1990	(4)	5	7	9	12	20	34	60	113	192	325	574	928	1,428	1,718	1,732

Note: figures in brackets are based on fewer than 10 deaths.

is observed in 1987-90 at durations 0 and 1 although the number of deaths in the medical experience is very small at these durations. This is the reverse of what would be expected and one is led to speculate as to why this should be so. Apart from proposals for larger sums assured where a full medical examination is almost always asked for, a medical is usually requested only where a non medical proposal has indicated a need for further information. In recent years much more latitude has developed as to which lives are acceptable at ordinary rates; a medical is possibly now being used as a path to accepting at ordinary rates lives which might previously have been rated.

Table 1.1.3 shows the central rates of mortality for the combined data at durations 5 and over in individual years from 1971 to 1990 inclusive. It shows quite clearly the pattern of improvement noted in earlier paragraphs. It is interesting to note that at ages 85 and over mortality in 1989 was relatively light, followed by a heavier year in 1990. This pattern was mirrored in the pensioners experience which does, in fact, fluctuate from year to year, although the general trend is an improvement. At all ages up to 69 the mortality rates for assured lives are between 55 and 60 per cent of the rates for the population as a whole. At ages 70 and over, the assured rates move closer to the population rates.

1.2 *Unit linked assurances on single lives, fully medically underwritten*

The exposed to risk for unit linked assurances increased rapidly between 1979-82 and 1983-86 and has declined almost as rapidly between 1983-86 and 1987-90. When considering a decline of this magnitude (from an exposed to risk of 1,492,000 in 1983-86 to 1,109,000 in 1987-90) the first query must be whether the list of offices contributing to the investigation has changed. A total of twenty offices contributed to the investigation at some time during 1983-90, most of them throughout. Such changes as there have been have been relatively minor between the two quadrennia; the explanation therefore has to be sought elsewhere. The main explanation would appear to be a dramatic fall in new business, particularly in 1989 and 1990. The 1987-90 exposed to risk at duration 0 was 60% of that in 1983-86 whereas the ratio at duration 2 and over was 80%. As in the non linked investigation, new business is insufficient to replace that leaving the investigation through death, lapse, surrender or maturity.

The mortality experience for the quadrennium 1987-90 is shown in Table 1.2.1 together with comparative figures for 1983-86. The experience at durations 2 and over for the quadrennium 1987-90 was lighter than that for 1983-86, which in turn was lighter than that for 1979-82 (see *C.M.I.R.* **11**, 29). The improvement in mortality in 1987-90 over that of 1983-86 was present in almost all age groups up to age 80; at ages over 80 the 1987-90 experience was heavier than that in the previous quadrennium.

Overall the linked experience at durations 2 and over is considerably lighter than the non linked experience; this feature is observable in almost every age group. A similar feature was present in the 1983-86 experiences and, at ages

Table 1.2.1. Linked contracts of life assurance, males, 1987-90, medical and non medical combined: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual Deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-20	4	51	68
21-25	15	126	180
26-30	12	116	129
31-35	16	162	98
36-40	6	42	95
41-45	15	66	100
46-50	24	81	73
51-55	32	80	76
56-60	46	111	88
61-65	38	116	130
66-70	30	135	127
71-75	32	234	107
76-80	10	110	223
81-	19	216	149
All ages	299	109	107
Duration 1			
-20	4	83	57
21-25	7	60	105
26-30	10	95	99
31-35	7	66	115
36-40	17	104	112
41-45	20	69	108
46-50	48	124	59
51-55	50	94	110
56-60	41	68	91
61-65	51	114	105
66-70	39	119	132
71-75	24	143	118
76-80	20	216	173
81-	13	172	318
All ages	351	101	112

over 40, in 1979-82. Part of the explanation might lie in the relative duration in force of the two experiences, but it seems unlikely that this is the whole explanation.

Table 1.2.1. (continued).

Age group (nearest ages)	Actual Deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Durations 2 and over			
-20	6	115	159
21-25	23	88	90
26-30	21	71	86
31-35	35	91	129
36-40	62	77	80
41-45	113	59	78
46-50	216	70	83
51-55	328	60	72
56-60	545	62	71
61-65	693	71	70
66-70	450	64	73
71-75	261	68	71
76-80	180	80	91
81-85	103	95	86
86-90	30	74	63
91-	20	129	93
All ages	3,086	68	76

The experience at duration 0 taken overall is heavy using AM80 as a comparison and has not changed much between 1983-86 and 1987-90. However, looking at individual age groups an interesting pattern emerges. The mortality suffered at ages 21 to 35 is very heavy compared to AM80 as is the mortality from age 56 onwards. However, between ages 36 and 55 the mortality is very light, much lighter than that in the non linked experience. A similar pattern, although not so clearly defined, was present in the 1983-86 experience. At duration 1 the pattern is less clear, but the mortality at the older ages, over 60, is noticeably heavy. This latter feature which is, as already noted, present at duration 0 almost certainly reflects the presence of restricted cover cases in the experience. The heavy experience at the lower ages in duration 0 is similar to that noted in the non linked experience.

1.3 *Joint life first death assurances fully medically underwritten*

The policies included in this investigation are those where payment is made on the occurrence of the first death only; it is also limited to policies set up on one male and one female life. As time has passed, in some cases one of the lives has been deleted from the policy, the other life remaining in the experience on a single life basis.

Table 1.3.1. Joint life first death assurances, males, 1987-90, medical and non-medical combined: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-25	11	54	40
26-30	31	93	
31-35	33	97	80
36-40	40	96	62
41-45	36	67	32
46-50	47	90	57
51-55	74	88	77
56-60	49	103	118
61-	21	104	121
All ages	342	88	73
Duration 1			
-25	11	74	83
26-30	18	51	
31-35	35	91	106
36-40	40	81	131
41-45	52	76	100
46-50	55	81	87
51-55	95	78	81
56-60	57	71	73
61-	31	88	83
All ages	394	77	90
Durations 2 and over			
-25	3	32	77
26-30	51	83	
31-35	85	69	77
36-40	164	84	87
41-45	189	66	77
46-50	205	69	75
51-55	310	66	67
56-60	374	65	71
61-65	219	74	83
66-70	70	66	82
71-	28	57	53
All ages	1698	69	76

The experience for 1987-90 is shown in Table 1.3.1. Comparisons for the quadrennium 1983-86 are also shown; as this investigation was only started as from 1st January 1982, those are the only two quadrennia for which experience is available. At durations 2 and over the level of mortality observed in this investigation is very similar to that observed in the linked investigation which was, as was noted in section 1.2., substantially lighter than that observed in the non linked investigation.

The level of mortality experienced at duration 0 is substantially below that observed in either the linked or the non linked investigation. In particular the relatively heavy mortality noted at the younger ages in both investigations is not so marked in the joint life experience.

At duration 1 the mortality in the joint life experience is well below that in either the linked or the non linked experience. However, when individual age groups are considered, the mortality suffered in the joint life investigation is very similar to that experienced in the linked investigation at ages up to 60: at the higher ages the relatively high mortality rates observed in the linked experience are not replicated in the joint life experience.

1.4 *Assurances on single lives issued on minimum medical evidence*

This investigation was started as at 1st January 1985, and 1987-90 is therefore the first full quadrennium for which data are available. The exposed to risk has built up very rapidly from 279,000 in 1985-86 to 1·8 million over 1987-90. However, this rate of growth is unlikely to be maintained in the foreseeable future unless the dramatic decline in new business (as measured by the in force at duration 0) which has occurred over the last two years of the quadrennium is reversed. Much of the business in this investigation is probably written in connection with mortgages, so that the decline in new business in 1989 and 1990 reflects the low level of activity in the housing market. It is possible, therefore, that new business will pick up if and when the housing market picks up.

The experience for 1987-90 is shown in Table 1.4.1, together with comparative figures for 1985-86. Taken overall, at durations 2 and over, the level of mortality suffered by this group of lives appears to be significantly heavier than that in the non linked fully medically underwritten investigation. However, inspection by age group reveals that the additional mortality is almost entirely concentrated in ages up to 40. When comparing the two experiences it should be remembered that the average duration in force of the minimum evidence experience at durations 2 and over is considerably shorter than the average duration in force of the non linked experience.

At durations 0 and 1 the minimum evidence experience is heavier than the non linked fully medically underwritten experience virtually throughout. Again mortality has been particularly heavy at ages up to 40.

Table 1.4.1. Minimum evidence assurances written on one life only, males, 1987-90: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1985-86
Duration 0			
-25	53	96	83
26-30	63	126	151
31-35	60	183	172
36-40	50	132	135
41-45	48	92	112
46-50	56	106	97
51-	8	156	48
All ages	338	118	120
Duration 1			
-25	42	92	74
26-30	72	113	94
31-35	66	157	120
36-40	55	113	34
41-45	60	82	143
46-50	79	98	78
51-	23	109	91
All ages	397	106	91
Durations 2 and over			
-25	19	51	140
26-30	149	118	
31-35	144	119	67
36-40	156	109	
41-45	205	87	128
46-50	221	78	106
51-55	169	72	94
56-60	35	64	93
61-	32	156	-
All ages	1,130	90	101

1.5 *Assurances on joint lives issued on minimum medical evidence*

The exposed to risk for this investigation is similar in size to that of the corresponding single life investigation. From this it might be inferred that minimum evidence business is almost evenly split between single life and joint life cases. However, data for the single life investigation are received from 19 offices, while returns for the joint life investigation are received from just 6 offices, all of whom

Table 1.5.1. Minimum evidence assurances written on one male life and one female life, males, 1987-90: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1985-86
Duration 0			
-25	22	72	83
26-30	43	103	151
31-35	57	140	172
36-40	51	96	135
41-45	56	88	112
46-50	57	109	97
51-	7	156	48
All ages	293	102	120
Duration 1			
-25	16	55	74
26-30	57	105	94
31-35	46	85	120
36-40	63	85	34
41-45	74	73	143
46-50	82	90	78
51-	9	54	91
All ages	347	82	91
Durations 2 and over			
-25	12	41	158
26-30	86	74	
31-35	124	91	65
36-40	160	87	
41-45	206	73	74
46-50	226	78	
51-	92	53	0
All ages	906	75	82

also contribute to the single life investigation. For these six offices the exposed to risk in the joint life investigation is more than three times that in the single life investigation. The probability is, therefore, that minimum evidence business is actually much more likely to be written on a joint life than a single life basis.

There is an even steeper decline over the quadrennium in the exposed to risk at duration 0 in the joint life investigation than in the single life investigation. The total exposed to risk has changed relatively slowly over the quadrennium and could be set to stabilise. However, as mentioned in the previous section, a large proportion of these policies are probably sold in connection with mortgages and this situation could change rapidly were the housing market to revive.

The experience for 1987-90 is shown in Table 1.5.1, together with comparative figures for 1985-86. The pattern of mortality suffered by this group of policyholders at all durations is, in general, similar to that suffered by those in the joint life fully underwritten investigation, albeit at a higher level than in that investigation. The main feature to note is that the relatively heavy mortality among the younger age groups noted in the corresponding single life investigation is less pronounced here.

1.6 *Guaranteed acceptance assurances written on single lives*

The policies in this group have become virtually a closed class, having been superseded by policies written on minimum medical evidence. Table 1.6.1 shows the experience at durations 2 and over; there is very little data now being returned at durations 0 and 1. The level of mortality suffered in this experience has throughout been significantly heavier than that in either the fully medically

Table 1.6.1. Guaranteed acceptance assurances, males, 1987-90; actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Durations 2 and over			
-30	33	115	92
31-35	61	154	129
36-40	69	135	76
41-45	109	132	126
46-50	115	109	126
51-55	143	104	131
56-60	54	106	179
61-	14	102	238
All ages	598	117	121

underwritten or the minimum evidence experiences. The relatively heavy mortality has continued throughout 1987-90. It was expected that the mortality experienced by these policyholders would be relatively heavy at the short durations (although the extent of the adverse experience was perhaps surprising), but that, over time, the additional mortality would decline; this has happened at ages over 45, but not, so far, below those ages.

2. FEMALE LIVES COVERED BY PERMANENT (WHOLE LIFE AND ENDOWMENT) POLICIES OF ASSURANCE ISSUED IN THE UNITED KINGDOM

This section covers six different experiences, corresponding to those for male lives reviewed in Section 1. As was the case there, the main subdivision for those subject to full underwriting is by medical status, and certain groups are investigated separately on both a single life and a joint life basis. An overview of the experience of all six groups is shown in Table 2.1.

The mortality experience of females split by smoking habit is reviewed in the paper on the mortality of smokers and non smokers included elsewhere in this volume.

Table 2.1. Permanent assurances, females, 1987-90, all investigations: ratio of actual deaths to those expected using the AF80 table

Investigation group	100A/E, all ages all durations
Single lives, full underwriting, non linked	87
Single lives, full underwriting, unit linked	84
Joint lives, full underwriting	67
Single lives, minimum evidence	88
Joint lives, minimum evidence	71
Single lives, guaranteed acceptance	117

2.1 *Non linked assurances on single lives, fully medically underwritten*

The exposed to risk for 1987-90 for this investigation is lower than that for the previous quadrennium, 1983-86. This is the first time such a fall between quadrennia has occurred. New business as measured by the exposure at duration 0 has remained stable over the last two quadrennia at about $12\frac{1}{2}\%$ of the total exposure. However, it appears that, as in the corresponding male experience, losses through death, maturity, surrender or lapse now outstrip new entrants. The rise in the crude death rate over recent quadrennia confirms the ageing of the experience.

Table 2.1.1a. Permanent assurances, females, 1987-90, medical and non medical combined; actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-25	29	100	48
26-35	36	93	124
36-45	65	80	86
46-55	100	69	65
56-65	101	89	93
66-	101	118	166
All ages	432	87	95
Duration 1			
-25	27	110	98
26-35	40	84	87
36-45	90	89	86
46-55	160	83	83
56-65	134	77	78
66-	146	76	89
All ages	597	81	84
Durations 2 and over			
-20	6	75	60
21-25	40	84	85
26-30	93	94	90
31-35	184	92	88
36-40	419	99	90
41-45	740	99	96
46-50	922	95	105
51-55	1,254	86	92
56-60	1,634	88	88
61-65	1,174	82	92
66-70	899	81	77
71-75	686	78	79
76-80	710	83	83
81-85	528	91	109
86-90	204	94	134
91-	117	76	104
All ages	9610	87	92

Note: a proportion of the data received for this investigation is returned with a combined medical code. The figures in Table 2.1.1a are, therefore, greater than the sum of the corresponding figures for Tables 2.1.1b and 2.1.1c.

Table 2.1.1b. Permanent assurances, females, 1987-90, medical data: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
All ages	34	86	127
Duration 1			
All ages	44	58	83
Durations 2 and over			
-30	6	167	98
31-35	15	208	124
36-40	32	160	105
41-45	56	132	101
46-50	59	89	101
51-55	106	98	108
56-60	139	89	69
61-65	143	78	73
66-70	157	70	67
71-75	184	68	66
76-80	283	76	70
81-85	258	85	92
86-90	95	78	130
91-	68	78	97
All ages	1,601	81	81

The proportion of fully medically examined lives in the total exposure for non linked policyholders has always been lower in the female investigation than in the male investigation. For all ages combined it is currently 6% of the total (4% at duration 0).

Tables 2.1.1a, 2.1.1b, 2.1.1c relate respectively to the combined data, the medically examined data and the non medical data. They show actual deaths 1987-90 and the ratio of the actual deaths to those expected using the AF80 table. Corresponding ratios for the quadrennium 1983-86 are also shown. Figures for earlier quadrennia, using as a comparison the 1967-70 based tables and FA1975-78 can be found in *C.M.I.R.* **11**, with the tables in *C.M.I.R.* **13** forming a bridge between the two series.

In the combined experience at durations 2 and over the mortality experienced has fallen overall between 1983-86 and 1987-90. This continues a trend noted over many quadrennia. However, inspection of the experience by age groups

Table 2.1.1c. Permanent assurances, females, 1987-90, non medical data: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-25	29	103	46
26-35	33	87	122
36-45	60	77	85
46-55	96	70	65
56-65	92	87	93
66-	86	131	169
All ages	396	88	92
Duration 1			
-25	26	108	91
26-35	38	82	85
36-45	84	86	87
46-55	151	82	82
56-65	125	78	80
66-	123	88	90
All ages	547	84	84
Durations 2 and over			
-20	4	52	61
21-25	36	78	88
26-30	90	95	87
31-35	167	88	87
36-40	383	97	89
41-45	670	96	96
46-50	851	95	106
51-55	1,126	84	91
56-60	1,466	87	91
61-65	995	82	97
66-70	718	85	80
71-75	473	84	89
76-80	388	89	95
81-85	235	101	136
86-90	73	116	145
91-	27	73	122
All ages	7,702	88	94

Table 2.1.2. Crude central rates of mortality per 10,000 experienced in individual years, permanent non linked assurances, durations 5 and over, medical and non-medical combined, females 1975-90.

Year of experience	Age last birthday															
	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1975	(0)	(1)	4	8	8	16	25	29	54	100	181	319	555	735	1,211	(1,418)
1976	(4)	5	5	7	14	26	37	59	92	129	266	468	624	1,461	1,569	(2,405)
1977	(4)	7	7	9	22	31	44	59	91	130	278	474	921	1,427	2,507	3,724
1978	(3)	3	4	6	11	18	33	46	64	111	211	437	716	1,027	2,022	(1,501)
1979	(4)	5	6	8	11	20	41	50	66	120	239	283	723	1,347	2,036	(1,684)
1980	(4)	3	4	8	11	19	35	44	72	106	187	391	735	1,215	1,691	(1,870)
1981	(2)	3	4	5	14	21	34	55	62	116	197	346	890	1,380	2,349	2,911
1982	(3)	3	4	6	8	17	32	49	87	109	273	392	824	1,162	2,031	(2,500)
1983	(2)	3	3	6	10	22	29	41	71	90	224	291	668	1,526	2,515	(3,556)
1984	(2)	4	3	6	10	19	29	44	70	94	159	260	701	985	2,528	(2,130)
1985	(4)	4	4	7	12	20	27	40	71	110	195	359	715	1,311	2,215	2,561
1986	(1)	2	4	6	10	18	28	44	77	101	166	349	714	1,014	1,585	(1,234)
1987	(1)	4	4	7	11	20	29	45	75	106	169	326	454	1,291	1,832	(1,687)
1988	(2)	3	4	7	12	17	27	44	59	97	192	334	567	873	1,758	(1,943)
1989	(4)	3	4	7	11	18	28	45	66	108	183	312	600	799	849	(1,333)
1990	(2)	(2)	4	6	11	18	23	39	64	112	174	298	522	875	1,255	2,983

Note: figures in brackets are based on fewer than 10 deaths.

indicates that the improvement in mortality between the two latest quadrennia is confined to ages over 45. In the last report it was suggested that mortality improvement at ages 36 to 50 may be slowing down or ceasing altogether. The experience of the latest quadrennium reinforces the view that there may indeed be a shift in the pattern of the experience at the younger ages.

At durations 0 and 1 there is an overall decline in the recorded mortality between 1983-86 and 1987-90. Looked at age by age no real pattern emerges.

The medical experience at durations 0 and 1 is relatively small and few conclusions can be drawn from it. At durations 2 and over it is interesting to note that, in all but two age groups up to the age of 80, the mortality recorded in 1987-90 was heavier than that in 1983-86. As would be expected, given that the non medical exposed to risk represents 93% of the total, the non medical experience mirrors that of the medical and non medical experiences combined.

Table 2.1.2 shows the crude central rates of mortality for the combined data at durations 5 and over in individual years from 1975 to 1990 inclusive. While at the young ages in the C.M.I. experience the rates are small and based on relatively few deaths it is probably true to say that, at ages up to 75, female assured lives mortality rates are roughly 60 to 65 per cent of population mortality. The rates for the two groups start to converge at ages beyond 75.

2.2 *Unit linked assurances on single lives, fully medically underwritten*

The exposed to risk for this investigation, having grown very rapidly between 1979-82 and 1983-86, has fallen slightly between 1983-86 and 1987-90. The percentage fall is much smaller than that observed in the corresponding male experience.

The experience for 1987-90, together with corresponding figures for 1983-86, is shown in Table 2.2.1. At durations 2 and over the mortality recorded in 1987-90 was considerably below that recorded for the previous quadrennium. This feature was observed in almost every age group. In almost all age groups up to 75 the level of mortality was well below that observed in the corresponding non linked investigation. This feature was not observed over the previous quadrennium although it was noted in the equivalent male experiences. The mortality which was experienced at ages over 75 is high which suggests the presence in the data base of restricted cover cases.

The experience at duration 0 once again seems heavy while that at duration 1 looks surprisingly light. However, both are based on relatively small numbers of deaths and too much should not be drawn from them.

2.3 *Joint life assurances fully medically underwritten*

As was noted in Section 1.3, the commentary on the experience of male lives in such arrangements, the policies included in this investigation are those where payment is made on the occurrence of the first death only and are restricted to policies set up on one male and one female life.

Table 2.2.1. Linked contracts of life assurance, females, 1987-90, medical and non medical combined: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-30	6	113	93
31-45	13	97	89
46-60	31	102	67
61-75	29	116	115
76-	67	359	499
All ages	146	157	169
Duration 1			
-30	6	112	57
31-45	14	80	101
46-60	34	71	76
61-75	41	92	60
76-	29	98	239
All ages	124	85	125
Durations 2 and over			
-30	10	77	142
31-35	16	127	82
36-40	22	81	99
41-45	37	68	75
46-50	61	75	101
51-55	99	72	75
56-60	183	86	80
61-65	144	66	60
66-70	131	69	82
71-75	75	52	71
76-80	116	97	103
81-85	122	119	130
86-90	66	120	131
91-	30	90	75
All ages	1,112	79	90

The experience for 1987-90 is shown in Table 2.3.1, together with comparisons for 1983-86, the first quadrennium for which analyses were available. Overall, the level of mortality experienced in 1987-90 was slightly heavier than that experienced in 1983-86 although there is no clear pattern when the data are

Table 2.3.1. Joint life first death assurances, females, 1987-90, medical and non-medical combined: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-30	17	56	71
31-40	34	83	11
41-50	32	59	97
51-60	26	64	48
61-	1	21	35
All ages	110	64	57
Duration 1			
-30	24	71	45
31-40	27	48	53
41-50	46	59	77
51-60	41	53	68
61-	5	45	67
All ages	143	56	63
Durations 2 and over			
-25	2	19	36
26-30	26	54	52
31-35	73	75	76
36-40	111	79	54
41-45	125	71	91
46-50	104	62	66
51-55	157	70	54
56-60	144	77	60
61-65	58	72	80
66-	19	46	96
All ages	819	70	67

split by age group. Even so, the level of mortality in this experience in 1987-90 is substantially below that of both the linked and the non linked single life experiences.

At durations 0 and 1 the level of mortality experienced in the joint life investigation in 1987-90 was well below that in either the linked or the non linked single life experiences.

2.4 *Assurances on single lives issued on minimum medical evidence*

Although the number of policies in force in this investigation has grown rapidly, giving a total exposed to risk in 1987-90 of 551,000, the number of deaths over the quadrennium, 292, is relatively small. Also the average duration in force is quite short. Only tentative conclusions can, therefore, be drawn. The results are shown in Table 2.4.1.

In 1987-90, at durations 2 and over, the mortality experienced in this investigation looks surprisingly light when compared with the non linked fully medically underwritten experience. It is very similar to that observed in the linked experience. This result is not what would be expected; background researches reveal no obvious reason why this should be so. The very short average duration in force of the minimum evidence business compared to that of the traditional business may be part of the explanation.

Table 2.4.1. Minimum evidence assurances written on one life only, females, 1987-90: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1985-86
Duration 0			
-30	23	155	
31-40	16	100	55
41-50	19	79	
51-	0		
All ages	58	106	55
Duration 1			
-30	19	105	
31-40	29	123	
41-50	22	62	95
51-	7	163	
All ages	77	94	
Durations 2 and over			
-30	20	85	
31-35	22	91	
36-40	26	89	
41-45	29	70	104
46-50	37	82	
51-55	20	73	
56-	3	77	
All ages	157	81	

The results at durations 0 and 1 are based on a limited number of deaths, mainly at the younger ages, and no firm conclusions can be drawn.

2.5 *Assurances on joint lives issued on minimum medical evidence*

This is a much larger investigation than the corresponding single life investigation, with an exposed to risk in 1987-90 of 1,850,000 and 726 deaths. The

Table 2.5.1. Minimum evidence assurances written on one male life and one female life, females, 1987-90: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1985-86
Duration 0			
-25	11	58	
26-30	12	60	68
31-35	20	92	
36-40	16	57	73
41-45	21	73	
46-50	11	72	68
51-	3	231	0
All ages	94	70	70
Duration 1			
-25	16	73	
26-30	19	60	35
31-35	25	70	
36-40	25	54	107
41-45	47	90	
46-50	23	71	85
51-	0	0	364
All ages	155	69	82
Durations 2 and over			
-25	17	60	
26-30	38	52	
31-35	57	59	
36-40	98	75	
41-45	143	85	55
46-50	99	78	
51-55	23	51	
56-	2	200	
All ages	477	71	55

experience for 1987-90 is shown in Table 2.5.1. As was the case in the corresponding male investigations, the level of mortality suffered in the joint life investigation at each duration was in 1987-90 substantially below that recorded in the single life investigation. When looked at against the fully medically underwritten data set (reported upon in Section 2.3) it can be observed that, at durations 0 and 1, the minimum evidence mortality experience is the heavier. At durations 2 and over the level of mortality experienced is similar in both groups; the average duration in force in the minimum evidence group will be shorter. The quadrennium 1987-90 is the first for which sufficient data on female minimum evidence cases have been available for analysis. The level of mortality experienced relative to other groups may well change as the experience matures. It would be wise to await the results from further quadrennia before firm conclusions are drawn.

2.6 *Guaranteed acceptance assurances issued on single lives*

This is a small investigation with a limited number of deaths. It is also virtually a closed class with almost all the exposure in 1987-90 being at durations 2 and over. The experience for 1987-90 is shown in Table 2.6.1. The mortality experienced is heavy compared to the fully medically underwritten and the minimum evidence cases. There is no sign that additional mortality, expected within this group, is diminishing as the duration in force of the policies increases.

Table 2.6.1. Guaranteed acceptance assurances, females, 1987-90: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Durations 2 and over			
-35	25	179	113
36-45	31	93	87
46-55	61	121	136
56-	14	102	47
All ages	131	118	96

3. PERMANENT (WHOLE LIFE AND ENDOWMENT) ASSURANCES IN THE REPUBLIC OF IRELAND

This section contains commentary on the experience of holders of permanent, non linked, fully medically underwritten policies of assurance written in the Republic of Ireland. The investigation for male policyholders is long estab-

lished, while that for females was only started on 1st January 1982. Although comparisons are shown for previous quadrennia, it should be noted that the list of offices contributing to this investigation has changed, so that the experience for 1987-90 may not be directly comparable with that for earlier quadrennia.

Table 3.1.1a. Permanent assurances, non linked, policies issued in the Republic of Ireland, males, 1987-90, medical and non medical combined: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-30	8	115	57
31-40	6	75	54
41-50	13	102	149
51-60	8	62	178
61-	8	82	228
All ages	43	87	140
Duration 1			
-30	3	46	94
31-40	9	90	101
41-50	15	92	128
51-60	15	81	144
61-	17	140	59
All ages	59	93	111
Durations 2 and over			
-30	9	53	114
31-35	26	94	88
36-40	50	83	93
41-45	115	89	91
46-50	208	100	97
51-55	269	84	93
56-60	362	82	115
61-65	435	97	114
66-70	173	95	128
71-75	131	96	99
76-80	126	97	121
81-85	66	67	117
86-90	36	74	82
91-	18	89	102
All ages	2,024	89	107

The report on the 1983-86 experiences included commentary on the mortality suffered by holders of linked assurances, albeit based on data from two offices only (with their permission). Unfortunately, it has not been possible to provide similar analyses for 1987-90.

3.1 *Assurances on male lives*

As noted above, this investigation is long established. As measured by the number of deaths, over 2,000 during the quadrennium 1987-90, the experience is a large one. It is also a mature experience with very little new business coming in as evidenced by a very low exposure to risk at duration 0. Such new business as there is in this class is clearly being written on a non-medical rather than a medical basis.

Table 3.1.1a shows, on a combined medical basis, the experience for the quadrennium 1987-90, together with the corresponding experience for 1983-86 (note

Table 3.1.1b. Permanent assurances, non linked, policies issued in the Republic of Ireland, males, 1987-90, medical data: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90
Duration 0		
All ages	7	69
Duration 1		
All ages	9	67
Durations 2 and over		
-40	8	81
41-45	33	121
46-50	68	116
51-55	84	79
56-60	111	63
61-65	211	92
66-70	118	92
71-75	101	94
76-80	100	95
81-85	57	67
86-90	31	75
91-	13	72
All ages	936	86

the caveat in paragraph 3). The comparison basis is the AM80 table. The experience for earlier quadrennia, using as a comparison the A1967-70 table, can be found in *C.M.I.R.* **11** with the experience for 1983-86 shown on both bases in *C.M.I.R.* **13**.

At durations 2 and over the figures indicate a substantial improvement in mortality in 1987-90 as compared to 1983-86, with most of the improvement being at ages over 50. Overall the level of mortality in the Irish experience in 1987-90 was about 10% heavier than that in the equivalent UK experience. Although this percentage has fluctuated over previous quadrennia, this is a bit lower than usual and may, in part at least, reflect the different mix of contributing offices.

No firm conclusions can be drawn from the analyses at durations 0 and 1 as there are insufficient data.

Table 3.1.1c. Permanent assurances, non linked, policies issued in the Republic of Ireland, males, 1987-90, non medical data: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90
Duration 0		
All ages	36	91
Duration 1		
All ages	50	100
Durations 2 and over		
-30	8	48
31-35	25	97
36-40	43	83
41-45	82	80
46-50	140	94
51-55	185	87
56-60	251	94
61-65	224	103
66-70	55	101
71-75	30	102
76-80	26	105
81-	19	85
All ages	1,088	93

Tables 3.1.1b and 3.1.1c show the medically examined and the non medical experience respectively. The medical experience contains 45% of the total deaths, but only 23% of the exposed to risk, which reflects the older age distribution of the medical group. Overall the medical experience shows the lighter mortality, although it is interesting to note that, at ages up to 50, the non medical experience is lighter than the medical.

3.2 *Assurances on female lives*

The female experience is a small one with only 91,000 in the exposed to risk in 1987-90 and 105 deaths. The results for 1987-90 are shown in Table 3.2.1 together with corresponding figures for 1983-86, the only other quadrennium for which figures are available. The comparison basis is the AF80 table. The same caveats as to the comparability between quadrennia as apply to the male experience apply here. Having said that, the mortality suffered in 1987-90 appears to be very light, not only when compared to 1983-86, but also when compared to the corresponding UK experience.

Table 3.2.1. Permanent assurances, policies issued in the Republic of Ireland, females, 1987-90, medical and non medical combined: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
All ages	5	72	37
Duration 1			
All ages	6	52	113
Durations 2 and over			
-30	0	0	146
31-35	7	152	128
36-40	6	74	166
41-45	12	98	165
46-50	13	88	161
51-55	11	63	79
56-60	19	103	78
61-65	12	84	91
66-	14	54	91
All ages	94	79	109

Table 4.1.1a. Temporary assurances, level and decreasing combined, males, 1987-90, medical and non medical combined*: actual deaths 1987-90 and ratios of actual deaths to those expected using the TM80 table, and the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by AM80	100A/E 1987-90 by TM80	100A/E 1983-86 by TM80
Duration 0				
-30	38	92	108	152
31-45	133	98	102	111
46-60	175	82	89	92
61-	44	67	87	125
All ages	390	86	94	107
Durations 1-4				
-25	32	109	126	74
26-30	67	85	101	92
31-35	121	92	105	109
36-40	200	87	101	98
41-45	252	62	70	95
46-50	311	67	77	81
51-55	321	58	71	90
56-60	321	61	82	101
61-65	205	61	90	96
66-	133	53	88	85
All ages	1,963	65	82	93
Durations 5 and over				
-30	29	102	105	87
31-35	124	101	108	95
36-40	372	85	96	98
41-45	834	74	81	88
46-50	1,051	69	71	88
51-55	1,344	71	73	82
56-60	1,466	75	76	87
61-65	1,094	75	78	88
66-	450	75	81	83
All ages	6,764	74	77	87

*A proportion of the data received for this investigation is returned with a combined medical code. The figures in Table 4.4.1a are, therefore, greater than the sum of the corresponding figures from Tables 4.1.1b and 4.1.1c.

4. TEMPORARY ASSURANCES ISSUED IN THE UNITED KINGDOM ON MALE LIVES

This section contains commentaries on three experiences. By far the largest, and the longest established, is that for holders of traditional, standalone temporary assurances, fully medically underwritten. Level temporary assurances and decreasing temporary assurances were investigated separately until 1986, after which the two types were merged. This was on the basis that, while there were differences between the two groups of policyholders, these were outweighed by the benefits of a larger data pool with which to work. This report is on the merged data. The standard table, TM80, based on the experience for 1979-82 was constructed using merged data.

The investigation into the experience of temporary assurances effected in conjunction with retirement annuities was set up in 1987. The advent of personal pension policies in 1988 rendered this group virtually a closed class and a new

Table 4.1.1b. Temporary assurances, level and decreasing combined, males, 1987-90, medical data: actual deaths 1987-90 and ratios of actual deaths to those expected using the TM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
All ages	62	67	103
Durations 1-4			
-35	19	149	111
36-45	41	67	94
46-55	90	70	77
56-65	147	82	90
66-	86	86	86
All ages	383	79	88
Durations 5 and over			
-35	18	151	102
36-40	65	129	93
41-45	143	86	88
46-50	172	63	75
51-55	273	75	85
56-60	282	66	72
61-65	347	75	82
66-	259	81	81
All ages	1,559	75	81

investigation into the experience of holders of temporary assurances effected in conjunction with personal pensions was set up as from 1st January 1989. All policies in these investigations are fully medically underwritten. Commentaries on both those experiences are included here.

4.1 *Traditional, fully medically underwritten, standalone policies*

The comparison basis is the TM80 table. An additional comparison, using the AM80 table is included in Table 4.1.1a which shows the results on a combined medical basis. Those for medical data and non medical data separately are shown in Tables 4.1.1b and 4.1.1c respectively.

When compared against the AM80 table it can be seen that the mortality experienced by holders of temporary assurances is, at all durations and all ages, substantially lower than that recorded for holders of non linked permanent assurances as set out in Table 1.1.1.a.

Table 4.1.1c. Temporary assurances, level and decreasing combined, males, 1987-90, non-medical data: actual deaths 1987-90 and ratios of actual deaths to those expected using the TM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
All ages	318	101	109
Durations 1-4			
-35	207	189	98
36-45	397	86	97
46-55	518	79	87
56-65	348	91	106
66-	29	71	80
All ages	1,499	87	95
Durations 5 and over			
-35	134	105	92
36-40	305	93	100
41-45	670	80	89
46-50	844	74	92
51-55	1,014	72	82
56-60	1,101	78	94
61-65	691	80	94
66-	165	82	84
All ages	4,924	78	90

The comparisons against the TM80 table show that, overall, at all durations, the mortality experienced in the quadrennium 1987-90 was substantially lighter than that in 1983-86. At duration 0 this lighter mortality was observed throughout the age range. At durations 1 to 4 and 5 and over the improvement is confined to ages over 40. Below those ages mortality rates are stabilising or even, apparently, deteriorating. However, it should be remembered that where the

Table 4.2.1. Temporary assurances effected under Section 621 of the ICTA 1988 (i.e. in conjunction with retirement annuities), males, 1987-90, medical and non medical combined: actual deaths and ratios of actual deaths to those expected using the TM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90
Duration 0		
-30	12	98
31-35	14	123
36-40	15	78
41-45	19	65
46-50	30	116
51-55	12	65
56-	17	156
All ages	119	94
Durations 1-4		
-30	19	94
31-35	35	106
36-40	55	98
41-45	71	71
46-50	93	93
51-55	65	78
56-60	34	71
61-	15	87
All ages	387	85
Durations 5 and over		
-40	17	77
41-45	46	103
46-50	50	76
51-55	60	72
56-60	57	74
61-	25	55
All ages	255	75

number of deaths is relatively small the experience can fluctuate widely from quadrennium to quadrennium. The pattern of higher Standardised Mortality Ratios (100A/E) at the younger ages compared to those observed for older age groups apparent in this experience is one that has been observed, to a greater or lesser degree, in all the male single life experiences. This suggests that the shape of the underlying mortality curve has changed in recent years. The implication of this is that care should be exercised when adapting for practical use standard tables based on a different experience.

As would be expected, the mortality experienced by medically examined lives (which form about 15% of the exposed to risk) is lighter than that experienced by non medical lives.

4.2 *Assurances effected under Section 621 of the ICTA 1988 (i.e. in conjunction with retirement annuities)*

The first analyses for this investigation were for 1987, so 1987-90 is the first quadrennium for which results are available. The results are set out in Table 4.2.1. The experience is of a reasonable size, with 761 deaths in total. The comparison basis is the TM80 table. The level of mortality suffered is very similar to that observed in the traditional temporary investigation for the same period.

4.3 *Assurances effected under Section 637(1) of the ICTA 1988 (i.e. in conjunction with personal pensions)*

This investigation started as from 1st January 1989, so that this report covers only two years' experience, all at very short durations. The results are shown, using as a comparison basis the TM80 table, in Table 4.3.1. The number of deaths is too small to allow any useful conclusions to be drawn.

Table 4.3.1. Temporary assurances effected under Section 637(1) of the ICTA 1988 (i.e. in conjunction with personal pensions), males, 1989-90, medical and non medical combined: actual deaths and ratios of actual deaths to those expected using the TM80 table.

Age group (nearest ages)	Actual deaths 1989-90	100A/E 1989-90
Duration 0		
All ages	54	55
Durations 1-4		
All ages	34	57

5. TEMPORARY ASSURANCES ISSUED IN THE UNITED KINGDOM ON FEMALE LIVES

The main item in this section is a commentary on the experience of holders of traditional standalone temporary assurance policies. This investigation has been running since 1st January 1982, so this is the second quadrennial report, allowing for the first time conclusions to be drawn as to how mortality levels may have changed over time. The experiences of holders of policies issued under Section 621 of the ICTA 1988 (i.e. in conjunction with retirement annuities) and Section 637(1) of the same Act (i.e. in conjunction with personal pensions) are still very small. The results are presented for completeness, but no useful conclusions can be drawn from them. All policies are fully medically underwritten. The comparison basis in each case is the AF80 table.

Table 5.1.1. Temporary assurances, level and decreasing combined, females, medical and non medical combined: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
All ages	69	70	80
Durations 1-4			
-30	42	82	69
31-40	125	71	72
41-50	153	70	73
51-60	107	69	56
61-	82	78	74
All ages	509	72	69
Durations 5 and over			
-30	7	52	57
31-35	57	114	59
36-40	98	81	77
41-45	168	93	91
46-50	130	90	96
51-55	84	71	76
56-60	77	83	80
61-65	30	56	99
66-	26	73	58
All ages	677	84	82

5.1 *Traditional, fully medically underwritten, standalone policies*

The results for this experience are shown in Table 5.1.1. At all durations apart from duration 0 (where the number of deaths is relatively small) the level of mortality experienced in 1987-90 is very similar to that in 1983-86. This is true throughout the age range. The Standardised Mortality Ratio for this experience at durations 2 and over (all ages combined) is 79 (against AF80). This is well below the ratio of permanent, non linked assurances, although some of this difference may be accounted for by the shorter average duration in force of this business.

5.2 *Assurances effected under Section 621 of the ICTA 1988 (i.e. in conjunction with retirement annuities)*

The results are shown in Table 5.2.1. The number of deaths is too small for any conclusion to be drawn.

Table 5.2.1. Temporary assurances effected under Section 621 of the ICTA 1988 (i.e. in conjunction with retirement annuities), females, 1987-90, medical and non medical combined: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90
Duration 0		
All ages	5	53
Durations 1 to 4		
All ages	22	59
Durations 5 and over		
All ages	11	93

5.3 *Assurances effected under Section 637(1) of the ICTA 1988 (i.e. in conjunction with personal pensions)*

The results (for 1989-90 only as this investigation only started on 1st January 1989) are shown in Table 5.3.1. The small number of deaths, and the very short duration in force, precludes any conclusions being drawn.

Table 5.3.1. Temporary assurances effected under Section 637(1) of the ICTA 1988, (i.e. in conjunction with personal pensions), females, 1989-90, medical and non-medical combined: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Actual deaths 1989-90	100A/E 1989-90
Durations 0-4 All ages	9	35

6. IMMEDIATE ANNUITY CONTRACTS.

This section contains commentary on the experience of holders of immediate annuity contracts. In terms of exposed to risk the investigation is small, that in the male section being particularly so. However, with 4,060 male deaths and 7,752 female deaths there are enough data to give reliable results. The inclusion of annuities with a guarantee period in the investigation from 1988 has boosted the exposed to risk but not by as much as might have been expected. In general, the numbers in force are reducing each year, as deaths outnumber new annuitants entering the experience.

The results for 1987-90, for both male and female annuitants confirm that, contrary to popularly held belief, at almost all ages over 60 immediate annuitant mortality is heavier than that of assured lives (permanent, non linked). It was noted in the report of the "80" series tables in *C.M.I.R.* **10** that the graduation of the base rates for male annuitants at durations 1 and over produced rates which were reasonably close to those for permanent assurances at durations 2 and over. The graduated annuitant rates were above those for assured lives at ages up to 76, fell below those for assured lives between ages 77 to 104 and rose above them again at ages 105 and over. For female annuitants, the graduated rates were higher than those for assured lives at all ages from 52 upwards. It was noted that there was sufficiently large experience in both investigations to support these observations. The phenomenon was also noted in the report on the 1983-86 experiences in *C.M.I.R.* **11**, the differences being greater between the female experiences than between the male experiences. In 1987-90, again, the difference between the two investigations is greater in the female experiences than in the male experiences.

6.1 *Male annuitants*

Tables 6.1.1a and 6.1.1b show the experiences for 1987-90, on the basis of 'lives' and 'amounts' respectively, using as a comparison basis the projected rates for calendar year 2010 from the IM80 table. Comparisons for 1983-86

Table 6.1.1a. Immediate annuitants 1987-90, males, 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the IM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-70	24	160	126
71-80	57	127	132
81-	69	123	116
All ages	150	129	125
Durations 1 and over			
-60	6	214	161
61-65	21	135	221
66-70	111	131	139
71-75	293	124	120
76-80	788	126	124
81-85	1,193	123	126
86-90	864	110	122
91-95	463	104	114
96-100	159	112	107
101-	12	38	45
All ages	3,910	117	122

are also shown. At durations 1 and over there is evidence of some small overall improvement in mortality between 1983-86 and 1987-90 on the basis of both 'lives' and 'amounts'. However, this is not consistent by age group or between 'lives' and 'amounts'. This is a familiar pattern from previous quadrennia, although the trend has been generally downwards.

At duration 0 there is a slight deterioration (on a 'lives' basis) in the level of mortality experienced, following several quadrennia of gentle decline. Too much should not be read into this as the number of deaths at this duration is relatively small.

Table 6.1.2 shows the experience for individual years against the corresponding projected rates from the IM80 table. Overall the projections look reasonable with, if anything, a slight margin for safety.

In Table 6.1.3 the experience of annuitants in 1987-90 at durations 2 and over is compared with that of assured lives (permanent, non linked), at the same durations. The relatively heavy mortality of the annuitants noted above is clearly seen in virtually every age group over age 60; there is very little data in the annuitant experience below this age. Although heavy by reference to

Table 6.1.1b. Immediate annuitants 1987-90, males, 'amounts': actual deaths (£000 pa) and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the IM80 table.

Age group (nearest ages)	Actual deaths 1987-90 (£000 pa)	100A/E 1987-90	100A/E 1983-86
Duration 0			
-70	36	148	107
71-80	198	119	122
81-	403	129	92
All ages	637	127	104
Durations 1 and over			
-60	4	148	64
61-65	19	95	235
66-70	107	138	155
71-75	279	108	110
76-80	773	108	139
81-85	1,542	118	105
86-90	1,298	116	115
91-95	758	114	124
96-100	300	131	77
101-	16	49	36
All ages	5,096	115	117

Table 6.1.2. Immediate annuitants, males, 1983-90, durations 1 and over: actual deaths for individual years on the basis of 'lives', expressed as a percentage of those expected using the projected rates for the relevant calendar year from the IM80 table.

Age group (nearest ages)	1983	1984	1985	1986	1987	1988	1989	1990
-60	167	83	0	222	0	167	194	222
61-65	200	161	133	132	130	116	110	71
66-70	95	85	126	116	93	122	110	88
71-75	88	94	97	94	97	89	123	99
76-80	88	107	102	105	112	109	99	106
81-85	107	100	113	102	107	106	104	110
86-90	101	94	119	108	95	108	100	91
91-95	103	98	104	105	86	80	106	109
96-	82	104	58	126	98	82	88	103
All ages	98	100	107	105	102	101	103	103

Table 6.1.3. Comparison of immediate annuitant and assured lives mortality, males, 1987-90, durations 2 and over: ratios of actual deaths to those expected using the AM80 table for both groups.

Age group (nearest ages)	100A/E using AM80 immediate annuitants	100A/E using AM80 permanent, non linked assurances
61-65	127	82
66-70	100	78
71-75	96	82
76-80	95	87
81-85	93	88
86-90	84	86
91-95	83	75
96-	84	39
All ages over 60	90	82

Table 6.2.1a. Immediate annuitants 1987-90, females, 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the IF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
Duration 0			
-70	5	97	119
71-80	57	114	112
81-	132	94	116
All ages	194	99	115
Durations 1 and over			
-60	6	260	287
61-65	24	212	206
66-70	63	136	140
71-75	230	123	136
76-80	704	109	116
81-85	1,676	112	121
86-90	2,304	109	118
91-95	1,748	106	118
96-100	683	109	117
101-	120	80	92
All ages	7,558	109	119

assured lives, the mortality experienced by immediate annuitants is still lighter than population mortality (by 20% to 25%).

6.2 *Female annuitants*

The experience for 1987-90 is set out, on a 'lives' and 'amounts' basis, in Tables 6.2.1a and 6.2.1b respectively. Comparisons for 1983-86 are also shown. The comparison basis is the projected rates for calendar year 2010 from the IF80 table. At durations 1 and over there has been considerable improvement in mortality between 1983-86 and 1987-90, with very similar results on both a 'lives' and on 'amounts' basis. Apart from ages up to 65, where the data are sparse, the improvement is noted throughout the age range. This follows several quadrennia of only small improvement.

At duration 0 substantial improvement in mortality can be observed between 1983-86 and 1987-90, continuing a trend noted over several previous quadrennia. There is very little difference between the experience on a 'lives' basis and on an 'amounts' basis.

Table 6.2.1b. Immediate annuitants 1987-90, females, 'amounts': actual deaths (£000 pa) and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the IF80 table.

Age group (nearest ages)	Actual deaths 1987-90 (£000 pa)	100A/E 1987-90	100A/E 1983-86
Duration 0			
-70	8	76	542
71-80	145	88	96
81-	656	99	116
All ages	809	97	116
Durations 1 and over			
-60	2	112	97
61-65	17	164	156
66-70	52	125	125
71-75	232	112	114
76-80	704	97	106
81-85	1,618	101	125
86-90	2,350	109	120
91-95	1,890	113	118
96-100	724	117	120
101-	97	83	71
All ages	7,686	107	118

Table 6.2.2. Immediate annuitants, females, 1983-90, durations 1 and over: actual deaths for individual years on the basis of 'lives', expressed as a percentage of those expected using the projected rates for the relevant calendar year from the IF80 table.

Age group (nearest ages)	1983	1984	1985	1986	1987	1988	1989	1990
-60	133	214	250	222	143	143	448	143
61-65	123	115	218	136	216	29	206	189
66-70	113	100	95	106	111	109	114	91
71-75	107	100	120	93	96	92	105	112
76-80	99	95	94	87	84	109	86	95
81-85	103	101	96	108	94	97	101	101
86-90	111	91	108	101	97	94	96	103
91-95	112	98	113	100	107	95	98	91
96-	109	106	102	105	95	101	100	100
All ages	107	97	104	101	97	97	98	99

Table 6.2.2 shows the experience for individual years against the corresponding projected rates from the IF80 table. It is noteworthy that for each year of the quadrennium 1987-90 the mortality experienced has been below that expected using the projections. The projected tables may now, therefore, be including an inadequate degree of future improvement and care should be taken to assess their suitability and, if necessary, make appropriate adjustments when making use of them.

Table 6.2.3. Comparison of immediate annuitant and assured lives mortality, females, 1987-90, durations 2 and over: ratios of actual deaths to those expected using the AF80 table for both groups.

Age group (nearest ages)	100A/E using AF80 immediate annuitants	100A/E using AF80 permanent, non linked assurances
61-65	163	82
66-70	100	81
71-75	99	78
76-80	96	83
81-85	107	91
86-90	110	94
91-95	107	82
96-	102	67
All ages over 60	106	83

The mortality experience of annuitants and assured lives is set out in Table 6.2.3, where the significantly heavier mortality of the annuitants throughout the age range can be clearly seen.

7. RETIREMENT ANNUITY AND PERSONAL PENSION POLICIES.

This section contains commentaries on two investigations, retirement annuity contracts written under Section 620 of the ICTA 1988, and personal pension policies issued under Chapter IV of Part XIV of the same Act. Retirement annuity contracts were withdrawn as from 30th June 1988, being superseded by personal pensions. Retirement annuitants are, therefore, now a closed class of business. However, the male experience, with approximately seven million policy years of exposure in 1987-90 (in deferment and in payment combined), producing over 40,000 deaths, is the second largest run by the Bureau. The female experience is also a large one with an exposed to risk in 1987-90 of over one million giving rise to over 4,000 deaths. There is clearly a large number of policies in force which will require management and valuation in years to come. It is, therefore, still relevant to monitor the experience. Also, the experience in the personal pension investigation, running as from 1st January 1989, will take time to build up and in the early years is not necessarily indicative of the level of mortality to be expected as the experience matures. The retirement annuity experience may give some pointers here, although it is impossible at this stage

Table 7.1.1. Retirement annuity policies in deferment, 1987-90, males: actual deaths and ratios of actual deaths to those expected using the ultimate rates from the AM80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
-25	77	59	87
26-30	171	73	86
31-35	380	100	106
36-40	675	86	99
41-45	1,409	79	92
46-50	2,083	75	88
51-55	3,256	72	81
56-60	4,706	72	86
61-65	4,395	70	77
66-70	1,227	54	65
71-75	326	50	55
All ages	18,705	71	81

to determine whether there is any intrinsic difference between the mortality to be expected in the retirement annuity and personal pension data sets. For this reason there is no suggestion that the two investigations should be combined. In due course the personal pension investigation should produce a substantial experience in its own right, which will then allow more valid comparisons to be made between the two groups.

7.1 *Male retirement annuitants*

The experience for 1987-90 is shown in Table 7.1.1 for policies in deferment, in Table 7.1.2 for policies in payment and in Table 7.1.3 for policies in deferment and in payment combined. In each table comparisons for 1983-86 are also shown. The comparison basis for policies in deferment uses the ultimate rates from the AM80 table. That for policies in payment and for the combined experience uses the ultimate rates for calendar year 2010 from the IM80 table.

The steady downward trend in the level of mortality experienced in the in deferment section, noted over previous quadrennia, has continued between 1983-86 and 1987-90. It is apparent in all age groups. The mortality levels observed in this experience are substantially below the level in the permanent, non linked assured lives experience, again a feature noted in previous quadrennia. This difference is not uniform throughout the age range. At ages up to 60 the two experiences are not dissimilar, although the retirement annuity mortality is the lighter. At ages over 60 the retirement annuity experience is much lighter than the assured lives, suggesting that the poorer lives have retired and moved into the in payment section.

Table 7.1.2. Retirement annuity policies in course of payment, 1987-90, males: actual deaths and ratios of actual deaths to those expected using the ultimate rates from the IM80 table for calendar year 2010.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
-50	75	2,500	1,701
51-55	117	1,017	1,486
56-60	334	414	558
61-65	2,136	164	183
66-70	5,756	122	130
71-75	5,657	117	125
76-80	4,897	112	123
81-85	2,703	112	122
86-90	867	104	106
91-	189	89	79
All ages	22,731	121	130

Table 7.1.3. Retirement annuity policies in deferment and in payment combined, 1987-90, males: actual deaths and ratios of actual deaths to those expected using the ultimate rates from the IM80 table for calendar year 2010.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
-25	77	81	118
26-30	172	100	118
31-35	381	137	145
36-40	685	119	135
41-45	1,424	109	126
46-50	2,131	105	122
51-55	3,373	102	114
56-60	5,040	104	122
61-65	6,531	108	115
66-70	6,983	109	114
71-75	5,983	112	119
76-80	4,897	112	123
81-85	2,703	112	122
86-90	867	104	106
91-	189	89	79
All ages	41,436	108	118

The improvement at ages over 65 in the mortality of retirement annuitants in payment, noted over previous quadrennia, has continued between 1983-86 and 1987-90. At these ages it is well below that of male annuitants at durations 1 and over. At ages below 65 the mortality of retirement annuitants is very heavy, reinforcing the view that poorer lives have retired and entered the in payment section. This view is further confirmed by looking at the in deferment and in payment combined experience at ages 60-65, where the observed mortality is substantially below that of immediate annuitants.

7.2 *Male personal pension policyholders*

As was mentioned above, this investigation started as from 1st January 1989. Already the exposed to risk in the in deferment section, for the years 1989-90, is over one million policy years, giving rise to over 1,000 deaths. The investigation includes 'rebate only' policies as well as standard personal pension arrangements. It is not known what proportion of the total in force is represented by 'rebate only' policies. Contributing Offices were circularised in 1992 asking whether they wished the experience of such policies to be investigated separately from that of standard policies. There was insufficient positive consensus for change, so the investigation remains as originally set up.

Table 7.2.1. Personal pension policies in deferment, 1989-90, males: actual deaths and ratios of actual deaths to those expected using the ultimate rates from the AM80 table.

Age group (nearest ages)	Actual deaths 1989-90	100A/E 1989-90
-25	71	42
26-30	83	63
31-35	55	43
36-40	99	57
41-45	128	41
46-50	139	46
51-55	129	42
56-60	160	41
61-65	167	40
66-	76	25
All ages	1,107	42

Tables 7.2.1 and 7.2.2 show the experience in 1989-90 for policies in deferment and in payment respectively. The comparison basis for the in deferment section uses the ultimate rates from the AM80 table; that for the in payment section uses the ultimate rates for calendar year 2010 from the IM80 table. The level of mortality observed in the in deferment sections is extremely light, much lighter than that seen in the in deferment section of the retirement annuity investigation. Most, if not all, of the difference could well be due to the very short duration in force, and therefore the very select nature, of the personal pension business. More time has to elapse before it is possible to draw

Table 7.2.2. Personal pension policies in payment, 1989-90, males: actual deaths and ratios of actual deaths to those expected using the ultimate rates from the IM80 table for calendar year 2010.

Age group (nearest ages)	Actual deaths 1989-90	100A/E 1989-90
-60	8	150
61-65	6	128
66-	11	90
All ages	25	112

any firm conclusions as to the level of mortality to be expected in this investigation.

Although based on very few deaths, the first indications are of heavy mortality at ages up to 65 in the in payment section. This parallels the experience observed in the retirement annuity investigation.

7.3 *Female retirement annuitants*

Table 7.3.1 shows the experience for 1987-90 for policies in deferment. Table 7.3.2 shows the experience for annuities in payment and Table 7.3.3 shows the experience for policies in deferment and in payment combined. In each table comparisons for 1983-86 are also shown. The comparison basis for the in deferment section uses the ultimate rates from the AF80 table. That for the in payment section and the combined experience uses the ultimate rates for calendar year 2010 from the IF80 table.

In the deferment section the reduction in mortality experienced in 1987-90 continues the downward trend observed when reporting the 1983-86 experience. On this occasion it has occurred virtually throughout the age range. It is considerably lighter than that observed in the permanent, non linked investigation at durations 2 and over. At ages over 60 the retirement annuitant experience is particularly light, suggesting that the poorer lives have retired and transferred to the in payment section of the investigation.

The level of mortality observed in the in payment section in 1987-90 is, overall, considerably lighter than that in 1983-86. Most of the improvement is at

Table 7.3.1. Retirement annuity policies in deferment, 1987-90, females: actual deaths and ratios of actual deaths to those expected using the ultimate rates from the AF80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
-30	14	49	92
31-35	33	86	104
36-40	76	81	101
41-45	177	78	85
46-50	271	75	100
51-55	422	78	76
56-60	549	82	85
61-65	313	72	79
66-70	110	59	66
71-75	35	66	97
All ages	2,000	76	84

Table 7.3.2. Retirement annuity policies in payment, 1987-90, females: actual deaths, and ratios of actual deaths to those expected using the ultimate rates from the IF80 table for calendar year 2010.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
-55	27	1,038	787
56-60	56	322	379
61-65	344	146	135
66-70	488	115	150
71-75	445	103	111
76-80	487	106	106
81-85	325	99	127
86-90	135	94	128
91-	38	83	85
All ages	2,345	112	126

Table 7.3.3. Retirement annuity policies in deferment and in payment combined, 1987-90, females: actual deaths and ratios of actual deaths to those expected using the ultimate rates from the IF80 table for calendar year 2010.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90	100A/E 1983-86
-30	14	78	147
31-35	34	141	166
36-40	76	128	161
41-45	178	125	137
46-50	276	122	162
51-55	442	128	123
56-60	605	135	139
61-65	657	123	122
66-70	598	106	129
71-75	480	101	113
76-80	487	106	106
81-85	325	99	127
86-90	135	94	128
91-	38	83	85
All ages	4,345	114	128

ages over 65. Although this is a large experience, particularly in terms of deaths, the level of mortality observed has fluctuated from quadrennium to quadrennium. Too much should not therefore be read into the large fall in the observed mortality on this occasion. However, it should be noted that the 100A/E ratios on IM80C10 at ages over 80 are less than 100, so caution should be exercised when selecting a suitable table for practical use.

As in the corresponding male in payment investigation, the mortality in the younger age groups is relatively heavy, reinforcing the view that poorer lives are transferring at those ages from the in deferment section. Having said that, the mortality of immediate annuitants at durations 1 and over in 1987-90 was, at all ages over 60, heavier than that of the retirement annuitants.

When looking at the combined in deferment and in payment experience for 1987-90 it is interesting to note that the standardised mortality ratio (100A/E) tends to fall with advancing age. There were indications of this in the previous quadrennium. This suggests that the underlying mortality curve in the IF80 table may not represent the shape of the mortality curve applicable to female retirement annuitants, whereas the corresponding male table, IM80, does provide a reasonable representation of the shape of the mortality curve for male retirement annuitants.

7.4 *Female personal pension policyholders*

This is a small experience, and also highly select. Almost all the data relates to the in deferment section; there were only 2 recorded deaths of pensions in

Table 7.4.1. Personal pension policies in deferment, 1989-90, females: actual deaths and ratios of actual deaths to those expected using the ultimate rates from the AF80 table.

Age group (nearest ages)	Actual deaths 1989-90	100A/E 1989-90
-25	26	51
26-30	14	38
31-35	8	22
36-40	14	26
41-45	29	41
46-50	24	44
51-55	27	46
56-60	29	50
61-65	19	46
66-	11	38
All ages	201	41

payment, with just over 500 in the exposed to risk. As in the corresponding male in deferment experience, the recorded mortality in 1989-90 was extremely light. More experience is required before any useful conclusions can be drawn. Such data as are available, are set out in Table 7.4.1.

8. PENSIONERS COVERED BY LIFE OFFICE PENSION SCHEMES

This section contains commentaries on the experience recorded over 1987-90 for male and female pensioners, and for widows and widowers of pensioners.

When comparing results for the quadrennium 1987-90 with those for earlier quadrennia it should be borne in mind that, while the list of contributors to the pensioner investigations has remained largely constant, not all contributors managed to make returns for each year of the quadrennium 1987-90. In particular, a number of offices had difficulty in producing returns for 1990. It is pleasing that almost all difficulties were resolved and the offices concerned resumed contributing for the 1991-94 quadrennium.

As is customary, the experiences have been investigated on the basis of both 'lives' and 'amounts'. It will once again be noted that the mortality recorded by reference to 'amounts' is significantly lighter than that recorded by reference to 'lives'.

Pensioner returns to the Bureau are currently split between those who retired at or after the normal retirement age (referred to as 'normal') and those who retired before the normal age, referred to as 'early'. Increasingly, during the 1980's and continuing into the 1990's, early retirement for reasons other than ill-health has occurred. It has become a common, and accepted, method of reducing staff if a company is passing through hard times. This could be expected to affect the mortality experience in the 'early' retirement section of the investigation; it could also affect the experience in the 'normal' section if it were customary to select less healthy lives for an early retirement exercise (or poorer lives might opt to go under a voluntary arrangement). Another factor which could affect the experience is equalisation of pension ages. If a company which previously had retirement ages of (say) 65 for men and 60 for women now equalised for both sexes at 60, poorer male lives who previously retired between 60 and 65 on health grounds would have been classed as 'early' retirements but would currently all be included in the 'normal' section. Equally, given an option to retire between (say) 60 and 65, the less healthy lives might choose to retire and the fit lives choose to stay in employment, which could again affect the recorded experience. There are clearly a number of factors, the effects of which are virtually impossible to quantify, which could affect the secular trend of observed mortality in the two experiences. With the foregoing in mind, a table based on the graduated combined experience for 1979-82 (the base quadrennium for the "80" series tables) was published in

C.M.I.R. **13**. A comparison of the combined experience for 1987-90 on an amounts basis against this table, as well as the customary comparisons against the standard table based on normal retirements, is included in this section.

When considering the results from any investigation it is worth bearing in mind the characteristics of the comparison basis being used. This is particularly so in the case of the pensioner experiences where projected tables are being used as comparison bases. This point is illustrated by Table 8.1 where the 1979-82 'amounts' data for males who retired at or after the normal retirement age is compared on three different bases, each apparently showing a very different picture. The PA(90) table was a projected table. However, the projection factors at ages 61 to 95 (the range within which most of the data falls) were almost constant. The PA(90) table is thus virtually parallel to the Peg 1967-70 table upon which it was based. The comparison using PA(90) in Table 8.1. shows that, by 1979-82, the mortality experienced by younger pensioners had improved by significantly more than that of older pensioners over the intervening years. By this time the basic mortality curve of the PA(90) table was the wrong shape for the data and this can be seen by the run of the 100 A/E ratios through the age groups. The PMA80 base table was in effect, a recalibration of the 1979-82 experience, the curve representing the best fit of the data at that time. This is evidenced by the 100A/E ratios being more or less 100 throughout. The PMA80C10 table consists of the mortality rates in the PMA80 base table projected forward for 30 years. The Executive Committee took the view that the mortality experienced by younger pensioners would continue to fall faster than that for older pensioners. The mortality rates in PMA80C10 at the younger ages are therefore much lower relative to the corresponding rates

Table 8.1. Pensioners who retired at or after the normal age, males, 1979-82, 'amounts': ratios of actual deaths to those expected using different comparison bases.

Age group (nearest ages)	100A/E by PA(90)	100A/E by PMA80 base	100A/E by PMA80C10
61-65	81	103	159
66-70	86	99	144
71-75	98	102	141
76-80	100	97	127
81-85	107	100	125
86-90	111	103	123
91-95	101	96	110
All ages	96	100	135

in PMA80 base than those at the older ages. Hence the 1979-82 experience at the younger ages looks relatively very heavy when compared to PMA80C10. The shape of PMA80 base is different from the shape of PMA80C10. These are different again from the shape of the curve for any given year in between. Comparing the experience for different quadrennia only gives an indication of change relative to the comparison basis used. When assessing the suitability of the current series of standard tables for practical work, the most meaningful comparison is with the projected rates for the period under consideration.

8.1 *Male pensioners*

Tables 8.1.1a, 8.1.1b and 8.1.1c give the experience for the quadrennium 1987-90 on the basis of 'lives' for, respectively, 'normal' retirements, 'early' retirements and all retirements combined. Tables 8.1.2a, 8.1.2b and 8.1.2c give the corresponding experience on the basis of 'amounts'. Each table uses as a comparison basis the projected rates for calendar year 2010 from the PMA80 table and includes comparative figures for 1983-86. In addition, in the case of 'lives' who retired at or after the normal retirement age the experience is compared against the projected rates for calendar year 2010 from the PML80 table. The combined experience for 'amounts' is additionally compared against the projected rates for calendar year 2010 from the PCMA80 table.

Whether measured by 'lives' or 'amounts', it is clear that the level of mortality recorded over 1987-90 for 'normal' retirements is significantly lighter than that for 1983-86, which in turn was lighter than in the previous quadrennium. This

Table 8.1.1a. Pensioners who retired at or after the normal retirement age, males, 1987-90, 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the "80" series tables for pensioners.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by PML80C10	100A/E 1983-86 by PML80C10	100A/E 1987-90 by PMA80C10	100A/E 1983-86 by PMA80C10
-60	85	165	189	211	248
61-65	895	130	137	166	175
66-70	8,195	113	127	140	156
71-75	15,927	117	123	138	145
76-80	21,299	112	119	129	137
81-85	17,466	111	119	122	130
86-90	8,428	108	117	114	123
91-95	2,180	107	111	109	112
96-	367	89	105	90	106
All ages	74,842	112	121	127	138

Table 8.1.1b. Pensioners who retired before the normal retirement age, males, 1987-90, 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PMA80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by PMA80C10	100A/E 1983-86 by PMA80C10	Ratio of 100A/E eary ret. to 100A/E normal or late ret. 1987-90	Percentage of total exposed to risk returned as early retirements 1987-90
-55	162	400	559	1.38	89
56-60	853	277	342		
61-65	3,277	207	243	1·25	76
66-70	6,568	178	199	1·27	39
71-75	6,835	157	164	1·14	28
76-80	5,922	135	147	1·05	21
81-85	3,110	120	131	·98	16
86-90	772	107	117	·94	9
91-95	107	92	122	·84	5
96-	18	106	116	1·18	
All ages	27,624	155	180	1·22	35

Table 8.1.1c. Pensioners normal, late and early retirements combined, males, 1987-90, 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PMA80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by PMA80C10	100A/E 1983-86 by PMA80C10
-55	178	387	546
56-60	922	269	335
61-65	4,172	196	229
66-70	14,763	155	170
71-75	22,762	143	149
76-80	27,221	130	138
81-85	20,576	121	130
86-90	9,200	113	122
91-95	2,287	108	112
96-	385	91	
All ages	102,466	134	147

lighter mortality was observable throughout the whole age range. There is one slight caveat; the 'amounts' experience recorded for the year 1990 does look particularly light in comparison with that for the years 1987, 1988 and 1989. This may be a function of the mix of offices contributing for that year. As

Table 8.1.2a. Pensioners who retired at or after the normal retirement age, males, 1987-90, 'amounts': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PMA80 table.

Age group (nearest ages)	Actual deaths 1987-90 (£000pa)	100A/E 1987-90 by PMA80C10	100A/E 1983-86 by PMA80C10
-60	103	82	259
61-65	1,713	117	153
66-70	8,127	107	125
71-75	10,195	111	117
76-80	9,227	106	117
81-85	5,408	103	119
86-90	2,334	110	116
91-95	521	105	117
96-	104	100	112
All ages	37,732	108	121

Table 8.1.2b. Pensioners who retired before the normal retirement age, males, 1987-90, 'amounts': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PMA80 tables.

Age group (nearest ages)	Actual deaths 1987-90 (£000pa)	100A/E 1987-90 by PMA80C10	100A/E 1983-86 by PMA80C10	Ratios of 100A/E early ret. to 100A/E normal or late ret. 1987-90	Percentage of total exposed to risk returned as early retirements 1987-90
-55	165	217	440	2·65	83
55-60	1,275	217	267		
61-65	4,194	149	200	1·27	67
66-70	6,110	143	152	1·34	36
71-75	4,362	134	140	1·21	27
76-80	2,701	121	132	1·14	21
81-85	1,148	117	130	1·14	16
86-90	208	102	108	·93	9
91-95	22	85	178	·81	5
96-	3	112		1·12	
All ages	20,188	140	163	1·30	42

Table 8.1.2c. Pensioners normal, late and early retirements combined, males, 1987-90, 'amounts': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the "80" series tables for pensioners.

Age group (nearest ages)	Actual deaths 1987-90 (£000 pa)	100A/E 1987-90 by PMA80C10	100A/E 1983-86 by PMA80C10	100A/E 1987-90 by PCMA80C10	100A/E 1983-86 by PCMA80C10
-55	196	211	429	61	130
56-60	1,347	193	266	102	141
61-65	5,907	138	186	104	141
66-70	14,237	120	134	111	124
71-75	14,557	117	123	117	122
76-80	11,929	109	119	108	118
81-85	6,557	105	120	102	116
86-90	2,542	109	116	108	114
91-95	543	104	119	104	118
96-	107	100	112	103	111
All ages	57,920	117	132	109	123

against that, the 'lives' experience for 1990 was almost exactly on trend. One feature of the 'lives' experience noted in *C.M.I.R.* **10** in the commentary on the new tables was the unexpectedly high mortality recorded in group 61 to 65 in 1979-82. The graduated rates in the PML80 base table were deliberately lowered at those ages to eliminate this. The relatively high mortality at 61-65 did not continue into subsequent quadrennia. The feature was not present in the 'amounts' experience in 1979-82 but that for years 1984 to 1986 does look a little high; it was also the only age group in 1990 where the observed mortality was not well below that expected on the projection (see Table 8.1.3).

Table 8.1.3 shows the experience for 'normal' retirements, on the basis of 'amounts', for individual years 1983-90 compared with the projected rates for the corresponding year from the PMA80 table. The very light experience for 1990, mentioned earlier, can be clearly seen. It is noteworthy that for every year the actual mortality recorded has been below that expected for the year, indicating that the PMA80 table incorporates an inadequate allowance for improvement for this data set.

The very heavy mortality experienced by those retiring before the normal retirement age can be seen in Tables 8.1.1b and 8.1.2b. The additional mortality relative to that experienced by those retiring at or after the normal age is highest at the youngest age group and falls away as age increases. When looked at on a 'lives' basis the mortality experienced by the two groups converges at about age 80; on an 'amounts' basis the convergence is at about age 85. This pattern of excess mortality has remained remarkably stable over several quadrennia (vide *C.M.I.R.* **11**, 57).

Table 8.1.3. Pensioners who retired at or after the normal retirement age, males, 1983-90: actual deaths for individual years, on the basis of amounts (£pa), expressed as a percentage of those expected using the projected rates for the corresponding year from the PMA80 table.

Age group (nearest ages)	1983	1984	1985	1986	1987	1988	1989	1990
-60	66	187	260	167	75	63	80	28
61-65	94	112	108	120	80	91	92	98
66-70	94	99	95	86	82	90	89	77
71-75	91	93	96	87	96	88	91	88
76-80	101	90	90	97	92	91	91	87
81-85	103	106	100	93	94	86	94	82
86-90	107	99	103	98	105	101	96	91
91-	100	106	120	93	96	92	112	81
All ages	97	97	96	92	91	90	91	85

Tables 8.1.1c and 8.1.2c show the experience for all pensioners combined on the basis of 'lives' and 'amounts' respectively. As would be expected, using the comparison basis PMA80C10 the 100A/E ratios lie between those of 'normal retirements' and those for 'early' retirements, the pattern reflecting the relative proportions of 'early' and 'normal' data in each age group. Comparisons for 1987-90 'amounts' data using the projected rates for 1988 from the combined pensioner table PCMA80 suggest that, at the young ages, the mortality rates in that table are almost certainly too high. As noted in *C.M.I.R.* **13**, careful consideration would be required before utilising the combined pensioner table. The results reinforce that caveat.

Table 8.1.4 shows the size of the data on both a 'lives' and 'amounts' basis and average pensions per annum. Average pensions have increased substan-

Table 8.1.4. Pensioners, males, 1987-90: exposed to risk, deaths and average pensions.

	Exposed to risk			Deaths		
Age group (nearest ages)	Lives	Amounts (£000pa)	Average Pension £pa	Lives	Amounts (£000pa)	Average Pension £pa
Normal or late retirements						
-60	8,176	24,526	3,000	85	103	1,211
61-65	46,803	136,137	2,909	895	1,713	1,914
66-70	313,545	414,849	1,323	8,195	8,127	992
71-75	338,262	275,612	815	15,927	10,195	640
76-80	291,866	155,773	534	21,299	9,227	433
81-85	156,522	58,092	371	17,466	5,408	310
86-90	53,443	15,429	289	8,428	2,334	277
91-	11,441	2,840	248	2,547	625	245
All ages	1,220,058	1,083,258	888	74,842	37,732	504
Early retirements						
-55	13,004	24,200	1,861	162	165	1,018
56-60	52,284	99,842	1,910	853	1,275	1,495
61-65	150,795	271,170	1,798	3,277	4,194	1,280
66-70	198,679	235,274	1,184	6,568	6,110	930
71-75	131,301	100,330	764	6,835	4,362	638
76-80	77,868	40,464	520	5,922	2,701	456
81-85	28,945	11,054	382	3,110	1,148	369
86-90	5,286	1,502	284	772	208	269
91-	649	141	218	125	25	198
All ages	658,811	783,977	1,190	27,624	20,188	730

tially since 1983-86 which in turn showed a substantial increase over 1979-82. The increases are particularly large at the younger ages, which suggests that many schemes are still maturing, with recent retirees able to complete longer service in the scheme as well as having the benefit of wage inflation to retirement. Unlike previous quadrennia, the average pensions for 'normal' retirements are in virtually all cases, age for age, larger than for 'early' retirements; interestingly, for all ages combined, this is not so. As has been noted before, average pensions in the exposed to risk are in all cases larger than those which were in payment to pensioners who have died.

8.2 *Female pensioners*

Tables 8.2.1a, 8.2.1b and 8.2.1c give the experience for 1987-90, on the basis of 'lives' for, respectively, 'normal' retirements, 'early' retirements and all retirements combined. Tables 8.2.2a, 8.2.2b and 8.2.2c give the corresponding experience on the basis of 'amounts'. Each table uses as a comparison basis the projected rates for calendar year 2010 from the PFA80 table and includes comparative figures for 1983-86. In addition, in the case of 'lives' who retired at or after the normal age the experience is compared against the projected rates for calendar year 2010 from the PFL80 table. The combined experience for 'amounts' is additionally compared against the projected rates for calendar year 2010 from the PCFA80 table.

After several quadrennia of improving mortality, that in the quadrennium 1987-90 was, for 'normal' retirements, little different from that in 1983-86. When considered on a 'lives' basis, there was some marginal improvement, mainly concentrated at ages over 75, although significant improvement was also recorded in the age group 61-65. This latter age group, paradoxically, was the only one not to show any improvement through previous quadrennia. On an 'amounts' basis some improvement was recorded at all ages except up to age 60 and between 76 and 85, leaving the overall experience for the two quadrennia virtually the same. As was the case in the male 'lives' data, the mortality for females aged 61-65 in 1979-82, on both a 'lives' and 'amounts' basis, looked unexpectedly high. Again, the graduated rates in the PFL80 and PFA80 tables were lowered to eliminate this feature. The additional mortality has persisted in subsequent quadrennia in both the 'lives' and the 'amounts' experiences. This can be clearly seen, in the case of 'amounts', in Table 8.2.3.

Table 8.2.3. shows the experience, on the basis of 'amounts', for the years 1983-90 using as a comparison basis the projected rates for the corresponding year on the PFA80 table. The experience does fluctuate considerably from year to year. However, in each year, apart from 1986 (which was noted in *C.M.I.R.* **11** as a particularly light year), the overall 100A/E ratio is greater than 100, indicating that the improvement factors incorporated in the PFA80 table are still adequate.

Table 8.2.1a. Pensioners who retired at or after the normal retirement age, females, 1987-90, 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the "80" series tables for pensioners.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by PFL80C10	100A/E 1983-86 by PFL80C10	100A/E 1987-90 by PFA80C10	100A/E 1983-86 by PFA80C10
-60	75	185	168	218	197
61-65	775	152	163	179	191
66-70	1,582	143	140	168	164
71-75	2,083	133	126	152	143
76-80	2,816	117	119	128	130
81-85	2,943	109	113	117	122
86-90	1,982	106	109	115	118
91-95	710	105	117	120	134
96-	158	108	101	128	120
All ages	13,124	119	122	132	136

Table 8.2.1b Pensioners who retired before the normal retirement age, females, 1987-90, 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for the calendar year 2010 from the PFA80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by PFA80C10	100A/E 1983-86 by PFA80C10	Ratio of 100A/E early ret. to 100A/E normal or late ret. 1987-90	Percentage of total exposed to risk returned as early retirements 1987-90
-55	57	368	414	1·26	76
56-60	217	257	303		
61-65	513	227	245	1·27	35
66-70	647	217	198	1·29	25
71-75	442	160	157	1·05	17
76-80	388	126	136	·98	12
81-85	289	116	112	·99	9
86-90	161	111	127	·97	8
91-	66	111	112	·92	8
All ages	2,780	167	179	1·27	26

Table 8.2.1c. Pensioners normal, late and early retirements combined, females, 1987-90, 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PFA80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by PFA80C10	100A/E 1983-86 by PFA80C10
-55	70	369	422
56-60	279	242	274
61-65	1,288	196	207
66-70	2,229	179	171
71-75	2,525	153	145
76-80	3,204	128	130
81-85	3,232	117	121
86-90	2,143	115	119
91-95	772	119	130
96-	162	126	
All ages	15,904	137	142

Tables 8.2.1b and 8.2.2b show the experience of those who retired before the normal retirement age. Unlike those who retired at or after the normal age, the mortality experienced by 'early' retirees has improved markedly between 1983-86 and 1987-90. Considered on a 'lives' basis the improvement is mainly

Table 8.2.2a. Pensioners who retired at or after the normal retirement age, females, 1987-90, 'amounts': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PFA80 table.

Age group (nearest ages)	Actual deaths 1987-90 (£000 pa)	100A/E 1987-90 by PFA80C10	100A/E 1983-86 by PFA80C10
-60	89	235	143
61-65	625	166	171
66-70	798	132	135
71-75	730	123	127
76-80	804	121	114
81-85	608	110	103
86-90	361	113	119
91-95	124	130	138
96-	38	125	142
All ages	4,177	128	127

Table 8.2.2b. Pensioners who retired before the normal retirement age, females, 1987-90, 'amounts': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PFA80 table.

Age group (nearest ages)	Actual deaths 1987-90 (£000 pa)	100A/E 1987-90 by PFA80C10	100A/E 1983-86 by PFA80C10	Ratio of 100A/E early ret. to 100A/E normal or late ret. 1987-90	Percentage of total exposed to risk returned as early retirements 1987-90
-55	44	276	372	·82	70
56-60	122	173	263		
61-65	283	203	230	1·22	27
66-70	243	173	171	1·31	19
71-75	122	131	153	1·07	14
76-80	66	94	122	·78	10
81-85	34	90	100	·82	6
86-90	22	123	125	1·09	5
91-	8	167	123	1·30	4
All ages	944	160	193	1·25	27

Table 8.2.2c. Pensioners normal, late and early retirements combined, females, 1987-90, 'amounts': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the "80" series tables for pensioners.

Age group (nearest ages)	Actual deaths 1987-90 (£000 pa)	100A/E 1987-90 by PFA80C10	100A/E 1983-86 by PFA80C10	100A/E 1987-90 by PCFA80C10	100A/E 1983-86 by PCFA80C10
-55	91	433	360	134	117
56-60	164	159	224	96	137
61-65	908	176	186	145	153
66-70	1,040	140	141	135	136
71-75	853	124	130	123	130
76-80	869	119	115	118	114
81-85	641	109	103	108	102
86-90	384	114	119	114	119
91-95	132	132	137	132	137
96-	39	125	142	125	142
All ages	5,121	133	137	124	127

Table 8.2.3. Pensioners who retired at or after the normal retirement age, females, 1987-90: actual deaths for individual years, on the basis of amounts (£pa), expressed as a percentage of those expected using the projected rates for the corresponding year from the PFA80 table.

Age group (nearest ages)	1983	1984	1985	1986	1987	1988	1989	1990
-60	93	89	85	124	1,415	145	111	185
61-65	132	139	132	92	151	140	109	108
66-70	146	100	87	83	131	110	97	84
71-75	95	97	104	100	101	85	106	105
76-80	93	104	100	77	93	93	113	115
81-85	84	86	95	83	93	96	106	86
86-90	115	94	104	102	94	95	106	116
91-	90	183	130	98	122	123	120	109
All ages	108	105	103	88	112	103	107	102

at ages up to 65 and over 85. The excess of mortality of 'early' retirements compared to 'normal' retirements, (as measured by 'lives'), is greatest at the young ages, the two groups converging at about age 75. As is the case with males, this pattern of excess mortality has remained relatively stable over a number of quadrennia. When considering the experience on an 'amounts' basis it should be noted that at ages above 75 the amounts of pension in individual data cells are small and one would expect the mortality recorded to be very volatile. At ages up to 75 the patterns recorded are not dissimilar from those recorded in the 'lives' experience.

Tables 8.2.1c and 8.2.2c show the experience for all pensioners combined on the basis of 'lives' and 'amounts' respectively. The 100A/E ratios on the PFA80 basis are closer to those for 'normal' retirements than is the case for males, reflecting the lower proportion of the data returned as 'early' retirements in the female experience. Consideration of the comparison using the PCFA80 table suggests that the projections underlying that table are valid for the 1987-90 quadrennium.

Table 8.2.4. shows the size of the data on both a 'lives' and 'amounts' basis and average pensions per annum. As was the case with males, average pensions in 1987-90 were substantially higher than those in 1983-86, which in turn were substantially higher than in 1979-82. As has been the case in previous quadrennia, average pensions for 'normal' retirements were in all cases, age for age, greater than those for 'early' retirements. As was the case for males, for all ages combined the average pension for 'early' retirements was larger than for

Table 8.2.4. Pensioners, females, 1987-90: exposed to risk, deaths and average pensions.

Age group (nearest ages)	Exposed to risk			Deaths		
	Lives	Amounts (£000pa)	Average Pension £pa	Lives	Amounts (£000pa)	Average Pension £pa
Normal or late retirements						
-60	10,738	12,805	1,192	75	89	1,185
61-65	77,285	68,236	883	775	625	807
66-70	98,303	64,166	653	1,582	798	504
71-75	76,405	33,873	443	2,083	730	351
76-80	63,918	19,512	305	2,816	804	285
81-85	40,324	8,991	223	2,943	608	206
86-90	17,006	3,180	187	1,982	361	182
91-	4,618	795	172	868	162	187
All ages	388,597	211,558	544	13,124	4,177	318
Early retirements						
-55	8,539	9,310	1,090	57	44	790
56-60	25,370	21,278	839	217	122	562
61-65	40,914	25,692	628	513	283	552
66-70	31,909	15,090	473	647	243	375
71-75	15,608	5,393	346	442	122	277
76-80	9,125	2,130	233	388	66	169
81-85	4,025	612	152	289	34	116
86-90	1,446	184	127	161	22	139
91-	393	31	79	66	8	119
All ages	137,329	79,720	581	2,780	944	340

'normal' retirements. Also, average pensions among the exposed to risk were, in general, greater than those for pensioners who had died.

8.3 *Widows*

Tables 8.3.1a and 8.3.1b show the mortality experience of pensioners' widows over the quadrennium 1987-90 on the basis of 'lives' and 'amounts' respectively, together with comparative figures for 1983-86. Two comparison bases are used, the projected rates for calendar year 2010 from both the PFA80 table and the WA80 table.

As can be seen from the PFA80 comparison for 'lives', while the mortality experienced by widows has improved considerably between 1983-86 and 1987-90, it is still, overall, heavier than that suffered by women drawing

Table 8.3.1a. Widows, 1987-90 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the WA80 table and the PFA80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by WA80C10	100A/E 1983-86 by WA80C10	100A/E 1987-90 by PFA80C10	100A/E 1983-86 by PFA80C10
-55	53	201	212	298	313
56-60	79	157	189	228	274
61-65	208	148	147	213	211
66-70	428	132	161	187	228
71-75	634	125	118	163	155
76-80	639	105	112	122	130
81-85	569	113	118	120	126
86-90	324	100	95	107	102
91-	138	102	97	112	107
All ages	3,072	117	127	140	154

Table 8.3.1b. Widows, 1987-90. 'amounts': actual deaths (£000 pa) and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the WA80 table and the PFA80 table.

Age group (nearest ages)	Actual deaths 1987-90 (£000 pa)	100A/E 1987-90 by WA80C10	100A/E 1983-86 by WA80C10	100A/E 1987-90 by PFA80C10	100A/E 1983-86 by PFA80C10
-55	82	204	188	302	258
56-60	62	110	138	159	201
61-65	239	182	151	261	216
66-70	287	107	147	152	209
71-75	358	99	120	129	157
76-80	354	97	92	112	106
81-85	247	99	101	105	108
86-90	135	109	100	117	106
91-	40	76	91	84	101
All ages	1,804	110	123	135	155

pensions in their own right. As has been noted in previous quadrennia the excess mortality occurs at the younger ages and tails off as age increases. At ages over 70 the mortality of the two groups is little different; if anything that of widows is the lighter. The experience for 'amounts' shows a different pattern from that for 'lives' and is more difficult to interpret. In a relatively small data base such as this it is to be expected that mortality recorded on an 'amounts' basis would be less stable than on a 'lives' basis. Too much should not, therefore, be read into the 'amounts' results. When considered on the WA80 comparison basis the indications are that mortality has improved rather more than has been allowed for in the projections at ages above 75. Caution should therefore be exercised when utilising this table.

8.4 *Widowers*

The widowers' experience is still very limited, with only 86 deaths. The results for the quadrennium 1987-90 are shown in Tables 8.4.1a and 8.4.1b, for 'lives'

Table 8.4.1a. Widowers, 1987-90. 'lives': actual deaths and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PMA80 table.

Age group (nearest ages)	Actual deaths 1987-90	100A/E 1987-90 by PMA80C10	100A/E 1983-86 by PMA80C10
-65	11	306	160
66-75	22	175	154
76-85	31	246	184
86-	22	262	308
All ages	86	232	182

Table 8.4.1b. Widowers, 1987-90, 'amounts': actual deaths (£000 pa) and ratios of actual deaths to those expected using the projected rates for calendar year 2010 from the PMA80 table.

Age group (nearest ages)	Actual deaths 1987-90 (£000 pa)	100A/E 1987-90 by PMA80C10	100A/E 1983-86 by PMA80C10
-65	6	271	276
66-75	10	109	90
76-85	10	130	132
86-	6	251	163
All ages	32	149	146

and 'amounts' respectively, together with comparative figures for 1983-86. Looked at on a 'lives' basis the mortality recorded has deteriorated significantly between 1983-86 and 1987-90. This is true in all but the oldest age group. The pattern is mixed in the 'amounts' experience. Both experiences are really too small for reliable conclusions to be drawn, except that the mortality of widowers, overall, appears to be heavier than for men drawing pensions in their own right.

CMIR, **14** (1995) 79-84

THE MORTALITY OF SMOKERS AND NON-SMOKERS, 1988-90

The first report on the mortality of smokers and non-smokers, based on statistics collected by the Bureau, was published in *C.M.I.R.* **13** and covered the experience of the two years 1988 and 1989. This report adds in the experience for 1990. Both the exposed to risk and deaths have increased by substantially more than the 50% that might have been expected by the addition of a third year's data. This is because, as in any new investigation, a number of contributors were not able to make returns for the first year of the investigation but began contributing in the second year. The list of contributors for 1990 is the same as for 1989, comprised of six offices in the permanent assurances section and nine in the temporary assurances section. While this provides a very respectably sized data pool, it would be an encouragement to those who do contribute, and beneficial to all, if more offices were to join the investigation making it more representative of the industry as a whole.

THE DATA

In the investigations the designation 'smoker' relates primarily to lives who have taken out policies where a non-smoker discount was available at the date of issue of the policy but who have not availed themselves of the offer. The term 'non-smoker discount' includes not only cases where a monetary or percentage reduction is allowed against the standard premium but all cases where non-smokers are offered preferential terms e.g. the use of an age deduction when determining the premium rate. 'Non-smoker' relates to lives who have been granted policies on a non-smoker basis. This may vary from office to office but the most frequent requirement appears to be that the proposer has not smoked cigarettes for at least twelve months prior to the date of the proposal. There is additionally a small amount of data where, although the terms of the policy do not differentiate, the smoking status is known to the issuing company. There is no information available on the number of cigarettes smoked or on the experience of smokers of pipes or cigars.

As before, the bulk of the data received has been for permanent assurances. The exposed to risk for all durations combined for male lives over the three years was 326,227 policy years in the smoker category and 706,896 in the non-smoker category. The corresponding figures for policies on female lives were 152,793 and 481,702 respectively. In the case of temporary assurances the combined exposed to risk for male lives in the smoker category was 72,078, with 201,242 in the non-smoker category. The corresponding figures

Table 1. Permanent assurances, males, medical and non-medical combined, 1988-90: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Smokers Actual deaths	Smokers 100 A/E	Non-Smokers Actual deaths	Non-Smokers 100 A/E	All policies* Actual deaths	All policies* 100 A/E	Excess Mortality Index** (per cent)
Duration 0							
-30	7	170	48	157	62	138	47
31-45	29		27	80	66	125	
46-60	43	154	54	65	116	92	137
61-75	12	90	32	73	51	81	23
76-	-		3		4		
All ages	91	146	164	84	299	103	74
Duration 1							
-30	16	221	17	64	40	104	245
31-45	23	179	29	74	63	102	142
46-60	54	154	60	57	130	78	170
61-75	14	118	40	84	59	79	140
76-	4		9		13	152	
All ages	111	157	155	67	305	87	134
Durations 2 and over							
-30	23	145	55	90	123	94	61
31-45	118	106	133	65	1,397	76	63
46-60	483	90	356	50	6,153	70	80
61-75	297	92	266	55	4,892	78	67
76-	126	100	73	64	2,018	86	56
All ages	1,047	94	883	56	15,170	75	68

* Includes cases where smoking habits are not known

** The percentage by which the Standardised Mortality Ratio for smokers exceeds the corresponding ratio for non-smokers i.e.100 × (100 A/E Smokers ÷ 100 A/E Non-Smokers − 1)

for females were 38,312 and 125,642 respectively. For cases where the smoking category is known, therefore, the grand total of policy years of exposure in the experience was over two million.

As in the previous report, for completeness, policies issued before the start of the investigation where the smoking category was unknown have been included where indicated in the analyses. In the tables which follow, the columns headed

Table 2. Permanent assurances, females, medical and non-medical combined, 1988-90: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Smokers Actual deaths	100 A/E	Non-Smokers Actual deaths	100 A/E	All policies* Actual deaths	100 A/E	Excess Mortality Index** (per cent)
Duration 0							
-30	3	75	10	54	14	103	39
31-45	4		6		10	35	
46-60	20	148	20	46	43	69	222
61-75	16	376	19	107	41	155	251
76-	5		5		12	286	
All ages	48	169	60	63	120	89	168
Duration 1							
-30	3	111	14	164	19	160	37
31-45	7		11	49	20	62	
46-60	22	136	39	73	67	85	86
61-75	16	164	19	55	35	70	198
76-	1		3		4		
All ages	49	138	86	69	145	81	100
Durations 2 and over							
-30	2	103	12	69	22	63	18
31-45	34		78	91	300	87	
46-60	119	134	132	55	909	88	144
61-75	56	108	72	45	465	73	140
76-	24	108	40	52	248	78	108
All ages	235	119	334	58	1,944	82	105

* Includes cases where smoking habits are not known

** The percentage by which the Standardised Mortality Ratio for smokers exceeds the corresponding ratio for non-smokers i.e. $100 \times (100 \text{ A/E Smokers} \div 100 \text{ A/E Non-Smokers} - 1)$

"All policies" thus represent the full data for those offices contributing to this investigation. When comparing the full data with the split data it should be borne in mind that the average duration in force of the full data is longer than that of the split data. Different degrees of selection could, therefore, be affecting the observed mortality levels in the two groups.

Table 3. Temporary assurances, males, medical and non-medical combined, 1988-90: actual deaths and ratios of actual deaths to those expected using the AM80 table.

Age group (nearest ages)	Smokers		Non-Smokers		All policies*		Excess Mortality Index** (per cent)
	Actual deaths	100 A/E	Actual deaths	100 A/E	Actual deaths	100 A/E	
Duration 0							
-30	3	171	4	62	7	91	176
31-45	16		16		34		
46-60	22	176	15	40	42	77	340
61-	4		6		11	73	
All ages	45	174	41	48	94	82	262
Duration 1							
-30	2	118	2	50	5	68	236
31-45	9		12		22		
46-60	10	83	20	49	32	57	69
61-	-	-	10	78	10	61	-
All ages	21	87	44	54	69	62	61
Duration 2							
-30	2	76	7	62	14	92	23
31-45	16		31		335	74	
46-60	50	102	54	43	888	67	137
61-	16	75	23	36	370	76	108
All ages	84	90	115	46	1,607	70	96

* Includes cases where smoking habits are not known

** The percentage by which the Standardised Mortality Ratio for smokers exceeds the corresponding ratio for non-smokers i.e. 100 × (100 A/E Smokers ÷ 100 A/E Non-Smokers − 1)

COMPARISON BASES AND RESULTS

The experience of male lives has been investigated using as a comparison basis the AM80 table for assured lives. The comparison basis for female lives is the AF80 table. The results for permanent assurances are shown in Table 1 for males and in Table 2 for females. For temporary assurances the results for males are in Table 3 and those for females in Table 4. Results for permanent and temporary assurances combined, all durations combined, are shown, separately for males and females, in Table 5. In Table 6 the six categories

Table 4. Temporary assurances, females, medical and non-medical combined, 1988-90: actual deaths and ratios of actual deaths to those expected using the AF80 table.

Age group (nearest ages)	Smokers		Non-Smokers		All policies*		Excess Mortality Index** (per cent)
	Actual deaths	100 A/E	Actual deaths	100 A/E	Actual deaths	100 A/E	
Duration 0							
All ages	6	107	8	44	18	72	143
Duration 1							
All ages	7	114	13	61	22	75	87
Durations 2 and over							
-30	1	128	2	55	8	87	133
31-45	11		15		113		
46-60	3	58	14	69	113	91	-
61-	3		8		24	68	
All ages	18	91	39	62	258	86	47

* Includes cases where smoking habits are not known

** The percentage by which the Standardised Mortality Ratio for smokers exceeds the corresponding ratio for non-smokers i.e. 100 × (100 A/E Smokers ÷ 100 A/E Non-Smokers − 1)

(smokers, non-smokers, combined for both males and females) are ranked according to the level of mortality suffered, using as a comparison the AM80 table throughout.

The results shown in Tables 5 and 6, which relate to the largest data pools, are remarkably similar to those for 1988-89 published in *C.M.I.R.* **13**. They indicate that, overall, the mortality suffered by male smokers is almost 175 per cent of the level suffered by male non-smokers, while the mortality of female smokers is about double that of female non-smokers. Also, the mortality of female smokers is roughly equivalent to that of all males combined, whereas the mortality of male non-smokers is not dissimilar to that of all females combined.

When the database is split down by policy type and duration, the individual cells are smaller and the results are, as would be expected, more volatile. However, even here there is nothing to contradict the general conclusions drawn in the last report. There is no escaping the conclusion, that, for this data pool at least, smoking as an indicator is linked to a very serious additional mortality risk.

Table 5. Permanent and temporary assurances combined, medical and non-medical combined, all durations combined, 1988-90: actual deaths and ratios of actual deaths to those expected using the AM80 table for males and the AF80 table for females.

Age group (nearest ages)	Smokers Actual deaths	Smokers 100 A/E	Non-Smokers Actual deaths	Non-Smokers 100 A/E	All policies* Actual deaths	All policies* 100 A/E	Excess Mortality Index** (per cent)
Males							
-30	53	136	133	99	251	102	38
31-45	211	122	248	65	1,917	77	88
46-60	662	98	559	50	7,561	72	95
61-75	343	91	374	57	5,387	78	61
76-	130	100	88	67	2,024	86	48
All ages	1,399	100	1,402	58	16,940	75	73
Females							
-30	10	83	41	91	70	92	-
31-45	60	105	115	67	453	81	57
46-60	169	130	212	57	1,145	87	127
61-75	93	135	121	54	569	76	149
76-	31	123	51	55	270	80	121
All ages	363	124	540	60	2,507	83	107

* Includes cases where smoking habits are not known

** The percentage by which the Standardised Mortality Ratio for smokers exceeds the corresponding ratio for non-smokers i.e. 100 × (100 A/E Smokers ÷ 100 A/E Non-Smokers − 1)

Table 6. Permanent and temporary assurances combined, medical and non-medical combined, 1988-90: ratios of actual deaths to those expected using the AM80 table for both males and females for smokers, non-smokers and all smoking categories combined.

All ages	Duration 0 100 A/E by AM80	Duration 1 100 A/E by AM80	Duration 2+ 100 A/E by AM80	All durations 100 A/E by AM80
Males, Smokers	154	139	93	100
Males, Combined*	97	81	75	75
Females, Smokers	83	87	69	73
Males, Non-Smokers	73	64	55	58
Females, Combined*	45	52	49	49
Females, Non-Smokers	31	44	34	35

* Includes cases where smoking habits are not known.

CMIR, **14** (1995) 85-104

MINI-GRADUATIONS OF THE MORTALITY EXPERIENCES OF ASSURED LIVES, PENSIONERS AND ANNUITANTS, 1987-90

THE first series of mini-graduations, relating to the mortality experiences 1983-86, was published in *C.M.I.R.* **13** (1993). For each of the experiences for which sufficient data were available a linear relationship was derived linking the observed mortality rates to those in the "80" series standard tables. This report repeats the process in respect of the 1987-90 experiences.

In each case the function to be graduated is q_x, using the formula

$$q_x = a + (1 - b)q_x^*$$

where q_x^* is the value of q_x from an appropriate standard table. The form using $(1-b)$ is chosen so that the value of b can be compared with zero rather than unity. The values of the parameters, a and b, have been calculated using the graduation methods described by Forfar, McCutcheon and Wilkie (1988), using the method of maximum likelihood.

The results are presented in tabular form, with a limited commentary. Each table shows:

1. The table used as the basis of the graduation. For annuitants and pensioners, where projection factors have been incorporated into the table, the comparison is against the projected rates for the calendar year 1988. All tables have been selected from the "80" series standard tables, published in 1990.
2. The age range used in the calculations. This is normally the range used for the original main calculations for the comparison basis, i.e. the range over which reliable data were available in sufficient quantity to produce acceptable rates.
3. The ratio 100A/E on the comparison basis before the mini-graduation was attempted.
4. The values of the parameters a and b, together with the corresponding T-ratios, at the optimum point. A T-ratio of less than 2.0 indicates that the parameter is not significantly different from zero.

In some of the mini-graduations of the 1983-86 assured lives experiences a 'variance ratio' was used in an attempt to eliminate possible distortions in the recorded mortality due to lives having more than one policy in the investigation. This was based on the distribution of the number of policies per policyholder as recorded over the corresponding period in the cause of death investigation. In the permanent non linked experiences for both males and females the use of variance ratios made very little difference to the parameters at the optimum point. In the case of permanent linked assurances the variance

ratios themselves were very erratic, possibly due to the presence of cluster policies in the data, which rendered their use suspect. Variance ratios have not been used in connection with the assured lives mini-graduations on this occasion.

In the case of the pensioner amounts experiences the exposed to risk and numbers of actual deaths were, for the 1983-86 experiences, divided by a constant, R (also termed a 'variance ratio'), equal to the average amount of pension per life in the exposed to risk of the experience being studied. This has been continued for the 1987-90 experiences. These variance ratios are included in the relevant tabular presentations.

The following experiences have been graduated:

1. *Male lives covered by permanent, fully medically underwritten policies of assurance issued in the United Kingdom.*
   1.1 Non linked assurances on single lives.
   1.2 Unit linked assurances on single lives.
   1.3 Joint life first death assurances.

2. *Female lives covered by permanent, fully medically underwritten policies of assurance written in the United Kingdom*
   2.1 Non linked assurances on single lives.
   2.2 Unit linked assurances on single lives.
   2.3 Joint life first death assurances.

3. *Permanent, fully medically underwritten assurances issued in the Republic of Ireland*
   3.1 Assurances on male lives.

4. *Temporary, fully medically underwritten assurances issued in the United Kingdom on male lives*
   4.1 Traditional standalone policies.

5. *Temporary, fully medically underwritten assurances issued in the United Kingdom on female lives*
   5.1 Traditional standalone policies.

6. *Immediate annuity contracts issued in the United Kingdom*
   6.1 Male annuitants.
   6.2 Female annuitants

7. *Retirement annuity policies issued in the United Kingdom*
   7.1 Male retirement annuitants.
   7.2 Female retirement annuitants.

8. *Pensioners covered by life office pension schemes*
   8.1 Male pensioners.
   8.2 Female pensioners.
   8.3 Widows.

It should be noted that, in this report, the assessment of the goodness of fit of a particular graduation is made on purely statistical grounds. It does not imply that the mini-graduated rates are suitable for any particular purpose. The selection of a particular set of rates is a matter for the judgement of the actuary, bearing in mind the task in hand. Particular care is required in the selection of rates for annuitants and pensioners to ensure that an adequate allowance for future improvement is built in.

1. MALE LIVES COVERED BY PERMANENT, FULLY MEDICALLY UNDERWRITTEN POLICIES OF ASSURANCE ISSUED IN THE UNITED KINGDOM

1.1 *Non Linked Assurances*

The statistics for the graduation, utilising the AM80 table, are shown in Table 1.1. At duration 0 the fit is good, with all the diagnostic tests, signs, runs, K-S, serial correlation and χ^2 , giving satisfactory results.

At duration 1 the fit is good at ages up to the middle 60's; thereafter the rates are on the low side. The diagnostics are satisfactory, except that χ^2 is a bit high. This is mainly due to a series of large deviations between actual and expected deaths at ages over 67.

Table 1.1. Non linked assurances, males, United Kingdom, durations 0,1 and 2+
Statistics for graduations of $q_x = a + (1-b)q_x^*$.

Duration	0	1	2+
Comparison basis	AM80 DO	AM80 D1	AM80 D2+
Age range	15 to 90	15 to 90	15 to 90
Number of deaths	1,283	1,526	74,059
100 A/E on comparison basis	97·534	91·841	79·964
Values of parameters at optimum point:			
a	0·000185	0·000068	0·000044
T-ratio	4·65	1·66	4·07
b	0·154989	0·116364	0·207408
T-ratio	4·26	3·77	60·02

The ratio of actual deaths at durations 2 and over to those expected using the AM80D2+ table is 80%, reflecting the overall improvement in mortality rates for this group of lives over the 8 years between the base dates for the "80" series tables and 1987-90. The graduation is not satisfactory. Actual deaths at almost all ages from 22 to 39 are higher than expected, while at ages 46 to 60 inclusive actual deaths are consistently below those expected. At all ages over 69 actual deaths are again higher than expected. This outcome reflects the changing shape over time of the underlying mortality curve within this group of lives. If this continues, the relatively simple mini-graduation technique will become less and less appropriate and consideration will need to be given to carrying out a full graduation on up to date experience.

1.2 *Unit linked assurances*

There is no standard table based on the experience of holders of unit linked policies. The experience has therefore been compared against the table for non linked lives, AM80. The statistics for the graduation are shown in Table 1.2. At duration 0, the mortality experience overall was 105% of AM80D0 unadjusted. The experience was consistently heavy at ages up to 34 and over 65, while it was consistently light between ages 39 and 54. However, bearing in mind the small number of deaths, 270, the fit of the mini-graduation can be considered reasonable.

At duration 1 (actual deaths 97% of those expected on AM80D1) the pattern is similar to that at duration 0, with relatively heavy mortality at the younger and older ends of the age range and lighter mortality in the middle. The total number of deaths is 318 and again, the fit of the mini graduation is reasonable.

Table 1.2. Linked contracts, males, United Kingdom
Statistics for graduations of $q_x = a + (1-b)q^s_x$.

Duration	0	1	2+
Comparison basis	AM80 DO	AM80 D1	AM80 D2+
Age range	15 to 75	15 to 75	15 to 90
Number of deaths	270	318	3,066
100A/E on comparison basis	105·381	96.502	67·493
Values of parameters at optimum point:			
a	-0·000096	-0·000151	0·000044
T-ratio	-1·08	-1·65	1·01
b	-0·116171	-0·035413	0·332038
T-ratio	-1·32	-0·50	23·53

At durations 2 and over actual deaths are only 67% of those expected using AM80D2+. Even so, the fit of the mini-graduation is very close although unexpectedly large deviations from the expected deaths at a few ages contribute to a high value for χ^2.

1.3 *Joint life first death assurances*

The investigation into the mortality experienced by those effecting joint life first death assurances only started in 1982. There is no standard table available based on the experience for this class of business, so the basis selected is the AM80 table. The statistics for the graduation are shown in Table 1.3. The mortality experienced by this class of life is well below AM80 at all durations. However, the fit of the mini-graduation is in each case good.

Table 1.3. Joint life first death assurances, males, United Kingdom
Statistics for graduations of $q_x = a + (1-b)q_x^*$.

Duration	0	1	2+
Comparison basis	AM80 DO	AM80 D1	AM80 D2+
Age range	20 to 90	20 to 90	20 to 90
Number of deaths	342	394	1,698
100A/E on comparison basis	88·186	77·006	68·767
Values of parameters at optimum point:			
a	−0·000027	−0·000018	0·000061
T-ratio	−0·43	−0·31	1·72
b	0·092962	0·217268	0·337814
T-ratio	1·22	3·80	15·53

2. FEMALE LIVES COVERED BY PERMANENT, FULLY MEDICALLY UNDERWRITTEN POLICIES OF ASSURANCE ISSUED IN THE UNITED KINGDOM

2.1 *Non linked assurances*

The statistics for the graduation, using as a comparison basis the AF80 table, are shown in Table 2.1. At duration 0 the fit is quite good overall. However, the curve is a little skew giving rates generally a bit on the high side at ages up to 59, with the reverse at ages 60 and over. At duration 1 the fit is good, with all diagnostics being satisfactory.

Table 2.1. Non linked assurances, females, United Kingdom
Statistics for graduations of $q_x = (1-b)q^*_x$.

Duration	0	1	2+
Comparison basis	AF80 DO	AF80 D1	AF80 D2+
Age range	15 to 90	15 to 90	15 to 90
Number of deaths	431	596	9,493
100A/E on comparison basis	87·301	81·194	87·071
Values of parameters at optimum point:			
a	−0·000009	0·000054	0·000066
T-ratio	−0·32	1·50	3·83
b	0·114970	0·226828	0·153015
T-ratio	2·07	5·58	14·42

At durations 2 and over the fit is in general good, although the value of χ^2 is high, due to a wide actual minus expected deviation at a small number of ages. There is also a long run, from ages 40 to 49 inclusive, where the new rates are consistently on the light side.

2.2 *Unit linked assurances*

There is no standard table based directly on the experience of female unit linked policyholders. The comparison is, therefore, against the AF80 table. The statistics for the graduation are shown in Table 2.2. At duration 0 the

Table 2.2. Linked contracts, females, United Kingdom
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	0	1	2+
Comparison basis	AF80 D0	AF80 D1	AF80 D2+
Age range	15 to 75	15 to 75	15 to 90
Number of deaths	79	95	1,082
100A/E on comparison basis	106·638	82·122	79·068
Values of parameters at optimum point:			
a	0·000004	0·000049	−0·000008
T-ratio	0·04	0·49	−0·15
b	0·062438	0·209256	0·205239
T-ratio	−0·41	2·04	7·52

number of deaths, 79, is very small. These are distributed over just 12 data cells, giving rise to the suspicion that there are a number of duplicates in the data. While the diagnostics are satisfactory, inspection shows that the graduated rates are consistently on the high side through the middle age ranges, the 40's and the 50's. Similar remarks apply to the graduation at duration 1. The number of deaths is 95, located in just 13 data cells. The age range over which the graduated rates are consistently high is 50 to 65. Low values of the *T*-ratio at both durations indicate that the distributions would be equally well represented by the AF80 table unadjusted, which is not surprising considering the small number of actual deaths.

At durations 2 and over the fit of the mini-graduation is not good. The value of χ^2 is high (although this is due in large measure to a few very large differences between actual and expected deaths) and the number of runs is significantly low. The fit is best between ages 40 and 60. Below age 40 and above age 78 the graduated rates are consistently too low, while from ages 51 to 70 they are consistently too high.

2.3 *Joint life first death assurances*

As is the case with the corresponding male investigation, this investigation was started in 1982. There is no standard table available based on this class of business, so comparisons have been made against the AF80 table. The statistics for the graduation are shown in Table 2.3. The mortality experienced by this class of life is well below AF80 at all durations. However, the fit of the mini-graduation is in all cases good, although the value of χ^2 is at each duration high owing to the presence of isolated erratic deviations.

Table 2.3. Joint life first death assurances, females, United Kingdom

Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	0	1	2+
Comparison basis	AF80 D0	AF80 D1	AF80 D2+
Age range	20 to 90	20 to 90	20 to 90
Number of deaths	109	143	819
100 A/E on comparison basis	63·928	55·757	69·739
Value of parameters at optimum point:			
a	0·000025	0·000031	−0·000011
T-ratio	0·66	0·75	−0·39
b	0·414381	0·483837	0·293230
T-ratio	4·22	6·91	8·44

3. PERMANENT, FULLY MEDICALLY UNDERWRITTEN ASSURANCES ISSUED IN THE REPUBLIC OF IRELAND

3.1 *Assurances on male lives*

There is no standard table for assured lives with policies issued in the Republic of Ireland. The comparisons have, therefore, been made against the AM80 table. The statistics for the graduation are shown in Table 3.1.

The numbers of deaths at durations 0 and 1 are small, 43 and 59 respectively. Both mini-graduations are satisfactory, although the low T-ratios indicate that the experiences could equally well be represented by the appropriate section of AM80 unadjusted. Interestingly, at duration 1, although the unadjusted A/E ratio is 93% the mini-graduation produces negative values for both a and b; ie the unadjusted value of q_x is multiplied by a factor greater than unity and then a constant is deducted.

At durations 2 and over the value of A/E using AM80 unadjusted is 89%, higher than in the corresponding UK investigations. The mini-graduation fit is good. The diagnostics are satisfactory except that χ^2 is high owing to erratic deaths at a few ages.

Table 3.1. Permanent assurances, males, Republic of Ireland
Statistics for graduations of $q_x = a + (1-b)q_x^*$.

Duration	0	1	2+
Comparison basis	AM80 DO	AM80 D1	AM80 D2+
Age range	15 to 90	15 to 90	15 to 90
Number of deaths	43	59	2,006
100A/E on comparison basis	86·940	92·928	89·263
Values of parameters at optimum point:			
a	0·000075	−0·000232	−0·000040
T-ratio	0·43	−1·35	−0·64
b	0·193097	−0·079302	0·099961
T-ratio	1·01	−0·45	4·25

4. TEMPORARY, FULLY MEDICALLY UNDERWRITTEN ASSURANCES ISSUED IN THE UNITED KINGDOM ON MALE LIVES

4.1 *Traditional standalone policies*

This experience represents level and decreasing temporary assurances

Table 4.1. Temporary assurances, males, United Kingdom, level and decreasing combined
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	0	1–4	5+
Comparison basis	TM80 DO	TM80 D1-4	TM80 D5+
Age range	15 to 90	15 to 90	10 to 108
Number of deaths	390	1,963	6,764
100A/E on comparison basis	94·344	82·010	77·089
Values of parameters at optimum point:			
a	0·000140	0·000119	0·000141
T-ratio	2·15	3.47	4·88
b	0·174489	0·246251	0·272621
T-ratio	2.54	9.64	21·77

combined. It is compared to the TM80 table which relates to this class of business. The statistics for the graduation are shown in Table 4.1. At duration 0 the fit is good and all the diagnostics are satisfactory. At durations 1 to 4 the fit is satisfactory, but the number of runs is low. The graduated rates tend to be on the high side between ages 41 and 56 inclusive while generally on the low side at ages 57 and above.

At durations 5 and over the ratio A/E against the unadjusted rates is 77% indicating that the experience has moved well away from the standard. The fit of the graduated rates is reasonable, although, as with durations 1 to 4, the rates are a bit high in the middle age range and a bit low at the upper end. The ranges affected are 43 to 57, and 58 and over respectively.

5. TEMPORARY, FULLY MEDICALLY UNDERWRITTEN ASSURANCES ISSUED IN THE UNITED KINGDOM ON FEMALE LIVES

5.1 *Traditional standalone policies*

There is no standard table relating to this class of business. Comparisons have therefore been made against the AF80 table. The statistics for the graduation are shown in Table 5.1.

The mortality experience is well below that which would have been expected using the AF80 table. The A/E ratios are 70%, 72% and 84% at durations 0, 1 to 4 and 5 and over respectively. The number of deaths at duration 0 is very small, just 69. The graduations give a good fit at all durations, although that at durations 5 and over is not quite as good as those for earlier durations. At

Table 5.1. Temporary assurances, females, United Kingdom, level and decreasing, combined
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	0	1–4	5+
Comparison basis	AF80 DO	AF80 D1	AF80 D2+
Age range	15 to 90	15 to 90	10 to 108
Number of deaths	69	509	677
100A/E on comparison basis	69·847	72·109	83·576
Values of parameters at optimum point:			
a	0·000041	0·000013	0·000095
T-ratio	0·79	0·39	1·85
b	0·383100	0·313329	0·239342
T-ratio	3·02	7·01	4·80

durations 5 and over the graduated rates are consistently on the low side at ages up to 36 and at most ages from ages 42 to 51. They have a tendency to be too heavy at ages 52 and over.

6. IMMEDIATE ANNUITY CONTRACTS ISSUED IN THE UNITED KINGDOM

6.1 *Male annuitants*

The experience has been compared against the projected rates for calendar year 1988 from the IM80 table, the table relating to this class of business. The statistics for the graduation are shown in Table 6.1.

At duration 0 the ratio A/E against the standard is 110%; the number of deaths is 150. Overall, the graduation is good. However, the low values of the parameters, together with the small T-ratios, indicate that, given the number of deaths, the experience would adequately be represented by the standard rates unadjusted.

At durations 1 and over, the A/E ratio against the unadjusted standard is 102%, i.e. the experience is much as expected. The graduation is good, although the value of χ^2 is high due to erratic deaths at a few ages. However, the low values of the T-ratio indicate that the experience can equally well be represented by the standard rates unadjusted.

6.2 *Female annuitants*

The experience has been compared against the projected rates for calendar

Table 6.1. Immediate annuities, males
Statistics for graduations of $q_x = a + (1-b)q_x^*$.

Duration	0	1+
Comparison basis	IM80C88 DO	IM80C88 D1+
Age range	60 to 108	60 to 108
Number of deaths	150	3,904
100A/E on comparison basis	110·386	102·223
Values of parameters at optimum point:		
a	0·001833	0·003858
T-ratio	0·30	2·01
b	-0·061416	0·027568
T-ratio	-0·38	1·03

year 1988 from the IF80 table, the table relating to this class of business. The statistics for the graduation are set out in Table 6.2.

At duration 0 the experience has improved considerably as against that expected by the standard table; the ratio A/E is 86%. The graduation is good, with all diagnostics being satisfactory. However, the number of deaths is fairly small, 193, and the small values of the T-ratios indicate that the experience could reasonably also be represented by the standard rates unadjusted.

Table 6.2. Immediate annuities, females
Statistics for graduations of $q_x = a + (1-b)\, q_x^*$.

Duration	0	1+
Comparison basis	IF80C88 DO	IF80C88 D1+
Age range	60 to 108	60 to 108
Number of deaths	193	7,553
100A/E on comparison basis	86·462	97·296
Values of parameters at optimum point:		
a	-0·002084	0·001155
T-ratio	-0·90	1·16
b	0·089224	0·041327
T-ratio	1·09	2·66

At durations 1 and over, the experience is close to that expected on the standard table (A/E = 97%). The graduation is good with all diagnostics being satisfactory. However, the lowish values of the *T*-ratios suggest that the standard table unadjusted is also a not unreasonable representation of the experience.

7. RETIREMENT ANNUITY POLICIES ISSUED IN THE UNITED KINGDOM

7.1 *Male retirement annuitants*

The data which were graduated relate to policies in deferment and in payment combined. There is no standard table relating to this class of life. Statistics are shown using as a base three standard tables. These are the projected rates for calendar year 1988 from the IM80 table and the PML80 table, and the ultimate rates from the AM80 table. The statistics for the graduations are set out in Table 7.1.

The best fit is that using the PML80 table, even though the A/E ratio using the unadjusted rates was the lowest of the three tables used, 73% against 81% for AM80 and 85% for IM80. For each of the latter two tables, the number of runs was low, giving wide ranges of ages over which the graduated rates were consistently too high or too low. For the PML80 graduation all the diagnostics give reasonable results, with the exception of χ^2, which is somewhat high.

Table 7.1. Retirement annuities, in deferment and in payment combined, males
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	All	All	All
Comparison basis	1M80C88 D1+	AM80 D2+	PML80C88
Age range	30 to 95	30 to 95	30 to 95
Number of deaths	41,223	41,223	41,223
100A/E on comparison basis	84·981	81·113	72·948
Values of parameters at optimum point:			
a	−0·000040	0·000016	0·000054
T-ratio	−2·33	0·92	3·16
b	0·142692	0·190527	0·276465
T-ratio	30·21	42·56	68·91

7.2 *Female retirement annuitants*

The data which were graduated relate to policies in deferment and in payment combined. There is no standard table based on the experience of this class of business. Statistics are shown using as a base three standard tables. These are the projected rates for the calendar year 1988 from the IF80 table and the PFL80 table and the ultimate rates from the AF80 table. The statistics for the graduations are shown in Table 7.2. All three graduations give acceptable results. There is little to choose between them, that using IF80 being very marginally preferable.

Table 7.2. Retirement annuities, in deferment and in payment combined, females
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	All	All	All
Comparison basis	IF80C88 D1+	AF80 D2+	PFL80C88
Age range	30 to 95	30 to 95	30 to 95
Number of deaths	4,332	4,332	4,332
100A/E on comparison basis	90·035	84·218	79·096
Values of parameters at optimum point:			
a	0·000077	−0·000045	0·000039
T-ratio	2·04	−1.21	1·04
b	0·118426	0·146810	0·217824
T-ratio	7·42	9·64	15·43

8. PENSIONERS COVERED BY LIFE OFFICE PENSION SCHEMES

8.1 *Male pensioners*

The experiences for pensioners retiring at or after the normal retirement age have been graduated on both a lives and amounts basis. The standard tables relating to these experiences are the PML80 table and the PMA80 table for lives and amounts respectively; in each case the rates selected are the projected rates for the calendar year 1988. The statistics for the graduations are shown in Table 8.1a. In the case of the amounts data the exposed to risk and actual deaths were divided by a constant 'variance ratio', R, with a value 884·66 which represents the average amount of pension per life among the exposed to risk. The age range over which the graduations were carried out was 55 to 100 in each case. Below age 55 the data are sparse.

On a lives basis the ratio A/E on the unadjusted rates is 95%. The fit of the

Table 8.1a. Male pensioners retiring at or after the normal retirement age
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration Investigation	All Lives	All Amounts (£000)
Variance ratios used?	No	Yes R = 884·66
Comparison basis	PML80C88	PMA80C88
Age range	55 to 100	55 to 100
Number of deaths	74,823	42,624
100A/E on comparison basis	95·037	88·938
Values of parameters at optimum point:		
a	–0·001183	–0·001381
T-ratio	–3·55	–5·92
b	0·031143	0·075087
T-ratio	5·14	10·36

graduated rates is quite good; the value of χ^2 is a bit high, due mainly to erratic numbers of deaths at a few of the younger ages. The ratio A/E on an amounts basis on the unadjusted rates is 89%, well below the projection. The fit of the amounts graduation is not so good. In particular, the graduated rates are below the experience rates at almost all ages above 84. The χ^2 value is much too high, as is usual in amounts graduations. Both graduations produce negative values of q_x at younger ages, for lives at age 39 and below and at ages below 44 for amounts. Rates according to the formulae, for the age range 55 to 100, are shown in Table 8.1b. Improvement factors would have to be built into the rates for practical use.

The experiences for all pensioners combined have been graduated using as a standard the projected rates for the calendar year 1988 from the combined pensioners tables, PCML80 and PCMA80 for lives and amounts respectively, published in CMIR13. The statistics for the graduations are shown in Table 8.1c. The ratio A/E against the unadjusted rates is 95% on a lives basis and 89% on an amounts basis. A variance ratio, R, with the value 992·63, has been used for the amounts data.

None of the diagnostics is really satisfactory for either graduation. In the lives graduation there are too few runs and the graduated rates are generally above the experience rates at most ages except ages 70 to 77 inclusive. The amounts graduation is marginally better than that for lives, but it is still not good. The

Table 8.1b. Male pensioners retiring at or after the normal retirement age; adjusted q_x based on PML80C88 and PMA80C88, for lives and amounts respectively, using the formulae shown in Table 8.1a.

Age x	Lives	Amounts
55	0·005537	0·003641
56	0·006274	0·004192
57	0·007102	0·004811
58	0·008043	0·005515
59	0·009109	0·006314
60	0·010316	0·007217
61	0·011722	0·008270
62	0·013311	0·009461
63	0·015100	0·010802
64	0·017111	0·012309
65	0·019332	0·014001
66	0·021620	0·015891
67	0·024136	0·018002
68	0·026929	0·020349
69	0·030019	0·022956
70	0·033428	0·025842
71	0·037173	0·029029
72	0·041275	0·032538
73	0·045750	0·036392
74	0·050616	0·040612
75	0·055886	0·045221
76	0·061573	0·050239
77	0·067687	0·055687
78	0·074235	0·061584
79	0·081219	0·067948
80	0·088641	0·074797
81	0·096494	0·082141
82	0·104774	0·089994
83	0·113463	0·098365
84	0·122549	0·107257
85	0·132007	0·116673
86	0·141810	0·126610
87	0·151931	0·137063
88	0·162332	0·148022
89	0·172976	0·159470
90	0·183819	0·171388
91	0·195105	0·183755
92	0·208349	0·196540
93	0·222277	0·209719
94	0·236732	0·223398
95	0·251850	0·237707
96	0·267640	0·252659
97	0·284103	0·268250
98	0·301231	0·284477
99	0·319017	0·301332
100	0·337448	0·318803

Table 8.1c. Male pensioners, combined early, normal and late retirements
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	All	All
Investigation	Lives	Amounts (£000)
Variance ratios used	No	Yes R = 992·63
Comparison basis	PCML80C88	PCMA80C88
Age range	50 to 100	50 to 100
Number of deaths	102,420	58,328
100A/E on comparison basis	94·771	88·938
Values of parameters at optimum point:		
a	−0·001760	−0·002930
T-ratio	−6·68	−13.88
b	0·022319	0·027274
T-ratio	4·19	3·85

graduated rates are generally too low from ages 65 to 76 inclusive and too high at most ages from age 77 to age 93.

8.2 *Female pensioners*

As with males, the experiences for female pensioners retiring at or after the normal retirement ages have been graduated on both a lives and an amounts basis. The standard tables relating to these experiences are the PFL80 table and the PFA80 table for lives and amounts respectively; in each case the selected rates are the projected rates for the calendar year 1988. The statistics for the graduations are shown in Table 8.2a. In the case of the amounts data a variance ratio, R, with the value 538·98, has been used representing the average pension per life among the exposed to risk. The graduations cover the age range 55 to 100 in each case. Below age 55 the data are sparse.

On the lives basis the ratio A/E on the unadjusted rates is 101%. The fit of the graduated rates is adequate with most of the diagnostics within reasonable bounds. The value of χ^2 is a bit high, owing to erratic numbers of deaths at a couple of ages. The ratio A/E on an amounts basis is 105%, indicating that the experience has not improved as much as expected. The fit of the graduation is quite good, although χ^2 is too high, as is usual for amounts data. Rates according to the formulae for the age range 55 to 100 are shown

Table 8.2a. Female pensioners retiring at or after normal retirement age
Statistics for graduations of $q_x = a + (1-b)^*_x$.

Duration	All	All
Investigation	Lives	Amounts (£000)
Variance rations used?	No	Yes R = 538·98
Comparison basis	PFL80C88	PFA80C88
Age range	55 to 100	55 to 100
Number of deaths	13,100	7,687
100A/E on comparison basis	101·043	104·886
Values of parameters at optimum point:		
a	0·002401	0·001485
T-ratio	7·76	5·63
b	0·061349	0·028293
T-ratio	5·15	1·63

in Table 8.2b. These are experience rates and do not contain any improvement factors.

The experiences for all pensioners combined have been graduated using as a standard the projected rates for 1988 from the combined pensioners tables, PCFL80 and PCFA80 for lives and amounts respectively, published in CMIR13. The statistics for the graduations are shown in Table 8.2c. The ratio A/E against the unadjusted rates is 101% on both a lives and an amounts basis. The 'variance ratio' R, with the value 548·65, has been used for the amounts data. The diagnostics for the lives graduation are not satisfactory. In particular there are too few runs; the graduated rates are generally too low between ages 65 and 76, and in the 90's. At ages in between they are generally too high. The amounts graduation is better, giving an acceptable fit.

8.3 *Widows of pensioners*

The standard tables for these experiences are the WL80 table and the WA80 table for lives and amounts respectively. The rates selected are those projected for the calendar year 1988. For amounts data the variance ratio, R, with the value = 867·45, has been applied to the exposed to risk and deaths before graduation. This represents the average amount of pension per life in the exposed to risk. The statistics for the graduations are shown in Table 8.3. The age range over which the graduation has been carried out is 40 to 100.

The graduation for lives produces a very good fit with all the diagnostics

Table 8.2b. Female pensioners retiring at or after the normal retirement age; adjusted q_x based on PFL80C88 and PFA80C88, for lives and amounts respectively, using the formulae shown in Table 8.2a.

Age x	Lives	Amounts
55	0·005879	0·004546
56	0·006250	0·004873
57	0·006662	0·005235
58	0·007117	0·005637
59	0·007621	0·006080
60	0·008179	0·006571
61	0·008819	0·007134
62	0·009529	0·007760
63	0·010317	0·008455
64	0·011191	0·009225
65	0·012161	0·010080
66	0·013237	0·011029
67	0·014422	0·012072
68	0·015706	0·013208
69	0·017182	0·014540
70	0·018886	0·016112
71	0·020847	0·017952
72	0·023093	0·020097
73	0·025656	0·022578
74	0·028567	0·025431
75	0·031860	0·028689
76	0·035569	0·032385
77	0·039728	0·036550
78	0·044369	0·041209
79	0·049525	0·046383
80	0·055225	0·052090
81	0·061497	0·058336
82	0·068364	0·065120
83	0·075846	0·072433
84	0·083955	0·080254
85	0·092701	0·088551
86	0·102082	0·097281
87	0·112093	0·106391
88	0·122718	0·115816
89	0·133933	0·125479
90	0·145706	0·135299
91	0·157995	0·145183
92	0·170751	0·155034
93	0·183917	0·164751
94	0·197429	0·174229
95	0·210733	0·183386
96	0·221537	0·192611
97	0·232449	0·202373
98	0·243987	0·212723
99	0·256181	0·223693
100	0·269062	0·235317

Table 8.2c. Female pensioners, combined early, normal and late retirements
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	All	All
Investigation	Lives	Amounts (£000)
Variance ratios used?	No	Yes R = 548.65
Comparison basis	PCFL80C88	PCFA80C88
Age range	50 to 100	50 to 100
Number of deaths	15,873	9,272
100A/E on comparison basis	100·753	101·222
Values of parameters at optimum point:		
a	0·001725	–0·000127
T-ratio	6·43	–0·52
b	0·050385	–0·019774
T-ratio	4·47	–1·14

Table 8.3. Widows of pensioners
Statistics for graduations of $q_x = a + (1-b)q^*_x$.

Duration	All	All
Investigation	Lives	Amounts (£000)
Variance ratios used?	No	Yes R = 867·45
Comparison basis	WL80C88	WA80C88
Age range	40 to 100	40 to 100
Number of deaths	3,067	2,075
100A/E on comparison basis	88·281	90·200
Values of parameters at optimum point:		
a	0·000228	0·001695
T-ratio	0·51	4·64
b	0·124366	0·180271
T-ratio	5·98	7·30

being satisfactory. For amounts the graduation is not quite so good, but is still quite acceptable.

CONCLUSIONS

The mini-graduations in this report represent a relatively simple attempt to relate up to date mortality to the latest standard tables. They are in no way put forward as new standard tables in themselves. Any actuary using these adaptations should be quite clear as to the purpose for which they are being used and build in any required margins accordingly.

In the case of assured lives the graduated rates and actuarial functions dependent thereon can be easily calculated via the Standard Tables Program. In the case of pensioner and annuity tables, where allowance for improvement is required, the process is not quite so straightforward but can be done with ingenuity.

References

C. M. I. (1993). Mortality Tables based on the Combined Pensioners Experience, 1979–82—*C.M.I.R.* **13**, 77.

FORFAR, D. O., MCCUTCHEON, J. J. & WILKIE, A. D. (1988). On Graduation by Mathematical Formula. *J.I.A.* **115**, 1 and *T.F.A.* **41**, 97.

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THE MORTALITY OF IMPAIRED ASSURED LIVES 1983-90

1. Introduction

The last report on the mortality of impaired assured lives appeared in *C.M.I.R.* **11**, 91 and covered the period 1983-86. The Bureau now has data returned up to investigation year 1990. Normally Bureau reports on the mortality experiences cover a quadrennium. However, as the impaired lives investigation only includes business written on, or after, 1st January 1982, it was considered preferable to base this report on the full data for the period 1983-90 (1992 being regarded as a trial year). This gives a larger body of experience with which to work, in particular a larger number of deaths; at the same time it is believed the period is short enough to preclude secular changes in mortality influencing the results. Twenty offices have contributed data during the period; they are listed in the Appendix.

As was mentioned in the last report, the profession has been fortunate in having access to a series of reports on the impaired lives experience of one office. This office has continued to monitor its own experience whilst also contributing to the CMI investigation. It has once again generously agreed to extract its own results for many of the impairments in the CMI experience for the same period using the same bases of comparison as used in the report. The results (referred to under the heading 'pilot office') are shown alongside the CMI results in Tables 2a and 2b. The pilot experience is highly valuable in that it both supports and extends the information available from the CMI investigation while the latter is still in the relatively early stages of building up its own experience.

Section 2 of this report looks at the data upon which the report is based, while Sections 3 and 4 contain commentary on the results. General conclusions are in Section 5. An analysis by cause of the deaths in the years 1987-90 follows on pages 121 to 124; a similar report for deaths in 1983-86 can be found in *C.M.I.R.* **11**, 107.

2. The data

Tables 1a and 1b show, for males and females respectively, the exposed to risk and the deaths in the same impairment groups as were shown in the last report. No changes have been made to the list of impairments over the period stated; minor changes to the list have been made from 1991. As before, the investigation includes policies from all the major categories of life assurance examined by the Bureau i.e. permanent (whole life and endowment), temporary, unit linked and joint life first death. Although each type of assurance is coded separately, in

Table 1a. Impaired lives, 1983-90, males; deaths and exposed to risk in impairment groups, by curtate duration.

Impairment	Duration 0		Duration 1		Durations 2 and over		All durations	
	Deaths	Exposed to Risk	Deaths	Exposed to Risk	Deaths	Exposed to Risk	Deaths	Exposed to Risk
Hypertension	35	6,015	41	5,846	221	17,893	297	29,754
Ischaemic heart disease without surgery	107	4,787	98	4,325	358	11,460	563	20,572
Ischaemic heart disease with surgery	7	544	7	439	20	938	34	1,921
Cerebrovascular disease	10	436	2	382	20	948	32	1,766
Nervous disorders	9	4,066	10	3,680	38	10,582	57	18,328
Disseminated sclerosis	2	372	3	330	5	914	10	1,616
Peptic ulcer	9	3,020	12	2,991	40	9,333	61	15,344
Ulcerative colitis	2	726	2	685	5	1,876	9	3,287
Crohn's disease	0	447	2	397	5	948	7	1,792
Epilepsy	7	1,389	4	1,272	14	3,447	25	6,108
Diabetes mellitus	26	4,650	20	4,080	77	9,500	123	18,230
Respiratory disorders	28	6,784	22	5,928	88	15,223	138	27,935
Urinary disorders	2	742	1	744	12	2,412	15	3,898
Tumour (breast malignant)	0	34	0	22	1	65	1	121
Overweight	4	10,706	13	9,005	66	23,560	83	43,271
All impairments in investigation	248	44,718	237	40,126	970	109,099	1,455	193,943

Table 1b. Impaired lives, 1983-90, females; deaths and exposed to risk in impairment groups, by curtate duration.

Impairment	Duration 0		Duration 1		Durations 2 and over		All durations	
	Deaths	Exposed to Risk	Deaths	Exposed to Risk	Deaths	Exposed to Risk	Deaths	Exposed to Risk
Hypertension	9	2,588	17	2,586	86	8,174	112	13,348
Ischaemic heart disease without surgery	13	1,066	20	978	48	2,681	81	4,725
Ischaemic heart disease with surgery	1	64	1	52	1	132	3	248
Cerebrovascular disease	2	218	5	196	8	555	15	969
Nervous disorders	16	5,022	14	4,668	28	12,782	58	22,472
Disseminated sclerosis	0	394	2	373	14	1,049	16	1,816
Peptic ulcer	0	541	1	509	12	1,415	13	2,465
Ulcerative colitis	1	378	1	360	2	946	4	1,684
Crohn's disease	0	352	0	290	4	649	4	1,291
Epilepsy	0	1,007	2	872	8	2,176	10	4,055
Diabetes mellitus	5	1,828	3	1,550	28	3,722	36	7,100
Respiratory disorders	11	4,399	4	3,773	26	8,714	41	16,886
Urinary disorders	1	386	0	384	1	1,072	2	1,842
Tumour*	7	802	6	753	33	2,189	46	3,744
Overweight	13	13,874	6	10,619	32	23,058	51	47,551
All impairments in investigation	79	32,919	82	27,963	331	69,314	492	130,196

* Breast malignant, breast non-malignant and uterine fibroids.

order to maximise the data, all classes are combined for the purposes of this report. The exposed to risk for the period 1983-90 includes, in addition to the exposure for 1983-86 included in the last report, up to four years more exposure for each policy in force on 1 January 1987 plus the exposure for new business over the period 1987-90. While it can be seen that the total exposure over the period 1983-90 is substantially greater than that for the period 1983-86, it is perhaps not as large as might have been expected. There are two main reasons for this. Firstly, two of the contributing offices were unable to provide data for every year of the quadrennium. Secondly, the decline in new business of this type, noted in the last report, appears to have continued; as we suggested then, the continuing expansion up to 1990 of new business written on a minimum evidence basis is almost certainly a contributing factor.

Notwithstanding the above, there is now a substantial pool of data. In particular, most of the groups in the male experience and about half of the groups in the female experience have produced sufficient deaths to give at least an indication of the degree of extra risk associated with such lives.

3. The results: general comments

The results are considered under the main impairment groups, sub-divided where the statistics so justify, and are presented in Tables 2a and 2b for males and females, respectively. These show the exposed to risk, the actual deaths, a mortality ratio giving the relationship between actual and expected deaths on the standard tables AM80 select and AF80 select, for males and females respectively and the excess deaths per 1,000 exposed to risk. When looking at the mortality ratios, using as comparison bases the "80" series tables, it is worth bearing in mind that unrated assured lives mortality over the period in question has moved away from the standard. It is difficult to give a precise comparison between unrated and impaired lives mortality because of the very different distribution of the exposed to risk in the two experiences; the impaired exposure builds up year on year as new business far outweighs deaths, lapses and maturities, while the long established unrated investigation shows a much more even pattern of exposure year by year. The median point of the impaired experience 1983-90 is probably some time in early 1988, so the nearest comparative unrated experience would be that for 1987-90, with a median at the end of 1988. Unrated mortality for the period 1987-90, for all durations combined was 80% of AM80 for males and 87% of AF80 for females. However, for males at least, this ratio is almost certainly too low as a comparison as it is heavily weighted by a much higher proportion of duration 2 & over business than is present in the impaired experience; the unrated mortality ratios at durations 0, 1 and 2 & over are 98%, 92% and 80% respectively. The unrated all

Table 2a. Impaired lives, 1983-90, males, all investigations and all durations combined; exposed to risk, actual deaths, ratios of actual deaths to those expected using the AM80 (select) table (100A/E) and excess deaths per 1000 exposed to risk (A−E‰) for the CMI and the Pilot Office experiences.

	Impairment		CMI				Pilot Office			
			Exposed to risk	Actual deaths	100A/E	A−E ‰	Exposed to risk	Actual deaths	100A/E	A−E ‰
Hypertension										
Entry ages	SAP	DAP								
Under 40	all	all	5,965	6	87	-	25,714	127	142	1.5
40-59	155 & over	under 95	4,486	39	142	2.6	9,717	116	102	0.2
40-59	155 & over	96-105	11,051	67	111	0.6	23,404	246	115	1.4
40-59	under 155	95 & over								
40-59	155 & over	over 105	3,188	33	168	4.2	5,764	94	182	7.3
40-59	all	all	18,725	139	129	1.7	38,885	456	120	2.0
60 & over	160 & over	under 100	2,525	65	92	-	3,342	151	102	0.9
60 & over	160 & over	100-110	2,166	70	123	6.0	2,358	105	117	6.5
60 & over	160 & over	over 110	373	17	165	18.0	422	20	116	6.5
60 & over	all	all	5,064	152	110	2.8	6,122	276	108	3.4
Ischaemic heart disease (without surgery)										
Entry ages	Onset									
under 50	within 4 years		2,660	38	567	11.8	2,450	35	484	11.3
under 50	4 years & over		2,326	38	566	13.5	1,949	34	547	14.3
50 & over	within 2 years		3,390	89	203	13.3	2,089	54	181	11.6
50 & over	2-4 years		3,266	91	211	14.7	2,040	76	251	22.4
50 & over	4-6 years		2,870	101	258	21.6	2,235	63	175	12.1
50 & over	6 years & over		6,060	206	207	17.6	4,513	178	214	21.0

Table 2a (continued).

Impairment		CMI Exposed to risk	CMI Actual deaths	CMI 100A/E	CMI A–E ‰	Pilot Office Exposed to risk	Pilot Office Actual deaths	Pilot Office 100A/E	Pilot Office A–E ‰
Ischaemic heart disease (with surgery)		1,921	34	219	9.6	1,261	38	363	21.8
Cerebrovascular disorders		1,766	32	183	8.2	1,151	23	189	9.4
Nervous disorders									
Mild or moderate		12,554	29	63	-	89,570	387	85	-
Severe (including schizophrenia and attempted suicide)		5,774	28	148	1.6	17,804	114	151	2.2
Disseminated sclerosis		1,616	10	193	3.0	534	3	227	3.1
Peptic ulcer									
Without surgery		11,350	37	72	-	14,785	43	74	-
With surgery		3,994	24	110	0.6	5,703	24	80	-
Ulcerative colitis		3,287	9	95	-	3,219	4	45	-
Crohn's disease		1,792	7	213	2.1	1,833	8	216	2.3
Epilepsy		6,108	25	182	1.9	9,699	22	121	0.4
Diabetes mellitus									
Entry ages	Years since diagnosis (at entry)								
Under 50	all	13,048	40	242	1.8				
50 & over	under 10	3,119	45	115	1.9	11,998	186	273	9.8
50 & over	10 & over	2,063	38	175	7.9				

Table 2a (continued).

Impairment		CMI Exposed to risk	CMI Actual deaths	CMI 100A/E	CMI A–E ‰	Pilot Office Exposed to risk	Pilot Office Actual deaths	Pilot Office 100A/E	Pilot Office A–E ‰
Respiratory disorders									
Bronchial asthma		25,239	73	114	0.4	39,086	93	117	0.3
Chronic bronchitis without emphysema		1,582	23	118	2.2	3,117	46	175	6.3
Chronic bronchitis with emphysema		872	35	261	24.8	1,980	62	206	16.1
Emphysema without bronchitis		242	7	302	19.4	419	12	259	17.6
Urinary disorders		3,898	15	98	-	30,648	161	83	-
Tumours									
Breast malignant		121	1	170	3.4	88	0	-	-
Overweight									
Entry ages	Overweight %								
Under 30	20-30	9,338	4	72	-	52,949	98	88	-
Under 30	over 30	6,053	0	-	-	28,277	60	123	0.4
30-49	20-30	11,856	19	113	0.2	49,271	363	129	1.7
30-49	over 30	11,380	22	124	0.4	31,710	173	131	1.3
50 & over	20-30	2,478	22	92	-	3,170	59	77	-
50 and over	over 30	2,166	16	71	-	2,490	45	97	-

Table 2b. Impaired lives, 1983-90, females, all investigations and all durations combined; exposed to risk, actual deaths, ratios of actual deaths to those expected using the AF80 (select) table (100A/E) and excess deaths per 1000 exposed to risk (A−E‰) for the CMI and the Pilot Office experiences.

Impairment			CMI				Pilot Office			
			Exposed to risk	Actual deaths	100A/E	A−E ‰	Exposed to risk	Actual deaths	100A/E	A−E ‰
Hypertension										
Entry ages	SAP	DAP								
Under 40	all	all	1,776	2	130	0.3	3,079	4	112	0.1
40-59	all	all	7,298	29	116	0.6	10,830	66	124	1.2
60 & over	all	all	4,274	81	98	-	5,012	127	87	-
All	all	all	13,348	112	102	0.2	18,921	197	97	-
Ischaemic heart disease (without surgery)										
Entry ages	Onset									
Under 50	all durations		736	3	219	2.2	398	0	-	-
50 & over	within 4 years		1,754	40	228	12.8	795	28	254	21.4
50 & over	4 years & over		2,235	38	144	5.2	973	22	139	6.3
Ischaemic heart disease (with surgery)			248	3	170	5.0	97	3	310	21.0
Cerebrovascular disorders			969	15	244	9.1	432	8	302	12.4
Nervous disorders										
Mild or moderate			15,495	25	73	-	41,381	94	88	-
Severe (including schizophrenia & attempted suicide)			6,977	33	256	2.9	10,963	30	137	0.7
Disseminated sclerosis			1,816	16	400	6.6	555	6	984	9.7
Peptic ulcer										
With or without surgery			2,465	13	141	1.5	1,982	8	120	0.7

Table 2b (continued).

Impairment		CMI Exposed to risk	CMI Actual deaths	CMI 100A/E	CMI A–E ‰	Pilot Office Exposed to risk	Pilot Office Actual deaths	Pilot Office 100A/E	Pilot Office A–E ‰
Ulcerative colitis		1,684	4	174	1.0	1,353	4	198	1.5
Crohn's disease		1,291	4	296	2.1	1,149	1	87	-
Epilepsy		4,055	10	194	1.2	4,324	15	273	2.2
Diabetes mellitus		7,100	36	198	2.5	1,534	18	346	8.3
Respiratory disorders		16,886	41	138	0.7	16,031	39	141	0.7
Urinary disorders		1,842	2	85	-	5,872	14	99	-
Tumours									
Breast, malignant		2,424	44	352	13.0	706	11	271	9.8
Breast, non-malignant and uterine fibroids		1,320	2	74	-	1,126	4	47	-
Overweight									
Entry ages	Overweight %								
All	20-40	31,629	27	76	-	59,279	72	89	-
All	over 40	15,922	24	102	-	23,421	28	86	-
All	all	47,551	51	86	-	82,700	100	88	-

durations ratio for females is similarly weighted but the ratios by duration are more even; it therefore offers a more reasonable comparison.

With 143 different impairment codes it is not to be expected that new business emanating from the offices over eight years would supply sufficient data for a significant comment to be made on each subdivision, and the purpose of this report is to give concisely what information is possible in reasonable groups and sub-groups.

As mentioned earlier, the experience of the pilot office is shown alongside that of the Bureau in Tables 2a and 2b (Table 2a for males and Table 2b for females). While for most impairments the pilot office exposed to risk is still significantly greater than that in the CMI experience, it will be noted that for ischaemic heart disease and diabetes mellitus the CMI experience is the larger. However, even in these groups, the great value of the pilot office experience lies in the maturity of the business being investigated. The maximum curtate duration of any policy in the CMI experience is eight years, and the average is considerably shorter. It will be some years yet before the CMI experience can match that of the pilot office in this respect.

For some impairment groups there are sufficient deaths to carry out an analysis by duration. The results for these groups are shown in Tables 3a and 3b (for males and females respectively).

Inspection of the figure in Tables 3a and 3b suggests that, for the impairments listed, the additional risk is heavily front loaded, particularly in the case of ischaemic heart disease without surgery. The exception to this is early onset diabetes mellitus (in males) where the additional risk is more evenly spread. However, caution should be exercised when considering these results as the numbers of deaths at durations 0 and 1 for all impairments except hypertension and ischaemic heart disease in males are still relatively small.

All the comparisons discussed so far have utilised the "80" series select mortality rates as this reflects the way such cases are handled in the market. The assumption is that selection in the impaired lives population operates in the same way as in the unrated population. Tables 3a and 3b suggest that this may not be the case. It is instructive, therefore, to look at both populations using as a comparison the ultimate mortality rates from the "80" series tables. Illustrative results, for males are, shown in Table 4.

Table 4 reinforces the view that the pattern of mortality from cases with early onset diabetes may not be dissimilar to that for unrated lives, albeit at a much higher level. For other impairments, however, the pattern of mortality in the early durations is not the same as that for unrated lives. How long these apparently different patterns persist cannot be ascertained at this stage. However, records returned to the Bureau allow selection to be traced for up to five years. A further

Table 3a. CMI experience. Mortality ratios (100A/E using the AM80 select table) by duration in force, males.

Impairment	Duration 0	1	2 & over	All
Hypertension	160	133	111	118
Ischaemic heart disease without surgery	423	302	198	236
Diabetes mellitus—early onset	209	239	195	204
Diabetes mellitus—late onset	328	90	86	115
Respiratory disorders	238	152	121	139
Unrated lives 1987-90	98	92	80	80

Table 3b. CMI experience. Mortality ratios (100A/E using the AF80 select table) by duration in force, females.

Impairment	Duration 0	1	2 & over	All
Hypertension	123	112	99	102
Ischaemic heart disease without surgery	319	261	143	179
Unrated lives 1987-90	87	81	87	87

Table 4. CMI experience. Mortality ratios (100A/E using the AM80 ultimate table) by duration in force, males.

Impairment	Duration 0	1	2 & over	All
Hypertension	89	89	111	103
Ischaemic heart disease without surgery	217	193	198	200
Diabetes mellitus—early onset	128	181	195	179
Diagetes mellitus—late onset	166	57	86	96
Respiratory disorders	135	106	121	121
Unrated lives 1987-90	59	69	80	79

quadrennium may yield sufficient additional data to make a more detailed investigation worthwhile. Meanwhile, one must caution again against reading too much into results based on limited data; each impairment group in Table 4 consists of a number of sub-sets, the experience of which shows considerable variation.

4. The results by impairment

The following paragraphs comment only on those impairments for which the statistics are large enough for significant interpretation.

Hypertension

For the youngest group, under age 40 at entry, no conclusions can be drawn for either sex from the CMI experience, but that of the pilot office suggests there is a significant extra risk for both males and females. For the two higher age groups, it is clear that hypertension is again a significant additional risk for both sexes. The pattern of the additional mortality for males is similar in both experiences with the additional risk, in general, increasing with the severity of the hypertension. There are insufficient deaths to make a similarly detailed analysis for females.

Ischaemic heart disease (without surgery)

While the exposed to risk is limited, the mortality is high and so the number of deaths is adequate for an analysis to be made. The medical profession regards the prognosis of ischaemic heart disease as being the most severe for young males, and this view is strikingly borne out by the statistics where the additional mortality is fivefold. However, because the excess death rate for males is relatively constant, it seems appropriate that such lives should be charged a rating of a percentage extra mortality along with a fixed constant addition, which will be independent of age.

Relatively few females suffer from ischaemic heart disease before the onset of the menopause. Above that age there appears to be a significant extra risk, but not overall as high as for males of a similar age.

Ischaemic heart disease (with surgery)

There are fewer cases in this category than for ischaemic heart disease without surgery, and it is difficult to draw conclusions, beyond saying that the additional risk is certainly severe. As with the without surgery cases, the risk would appear to be higher for males than for females.

Nervous disorders

The division of data into mild/moderate and severe psychoneuroses highlights significant differences for both males and females, and the pattern is repeated in the experience of the pilot office. Mild or moderate psychoneurosis is shown on all four occasions to exhibit a mortality which is considerably less than standard, the conclusion perhaps being that such lives are more likely to take care of themselves. However, severe psychoneurosis, which encompasses many conditions, reveals a considerable additional extra mortality, particularly for females.

Peptic ulcer

The additional risk for peptic ulcer without surgery appears to be minimal. The more severe cases would go for surgery and this appears to be reflected in higher mortality. However, in the pilot office the levels of mortality in the two groups are closer together.

Epilepsy

Although the exposed to risk is not high, the additional mortality is considerable at a time when most epileptics would be accepted on standard terms. A possible explanation is that some offices may only submit data for epileptics they had rated and hence this investigation omits many of the standard risk cases so the recorded mortality is higher; such cases should really be included to obtain a more realistic statistic.

Diabetes mellitus

The medical profession now regards diabetes with an early and a late age at onset as two distinct disorders with the former being considered more severe. This is shown in the CMI results for males. Further analysis of the female data suggests a similar distinction.

Respiratory disorders

The progression of the disease is likely to be from bronchial asthma to chronic bronchitis without emphysema to chronic bronchitis with emphysema (which, in today's parlance is chronic obstructive airways disease) and hence lives accepted for life assurance in the later categories would be expected to exhibit higher mortality than the earlier. This is reflected in the male data for both CMI and pilot office data. The mortality ratios for males where emphysema is present are the highest recorded in the male investigation, apart from ischaemic heart disease, indicating the relative seriousness of the individual risk. The experience for females is not large enough to give reliable results when split by condition.

Tumours

The female mortality from malignant breast tumours is very high in the CMI experience. It is less so, but still high, in the pilot office. The CMI experience is the larger, but that of the pilot office has been running for longer. The very heavy mortality shown in the CMI experience does seem to be genuine; there are, as far as can be ascertained, no duplicates and the deaths are not concentrated in any one office, which could have indicated underwriting bias.

Overweight

The pattern of additional male mortality relating to obesity for both the CMI investigation and the pilot office, is similar, although the pilot office experience (which is the more mature) exhibits the heavier rates. For females overweight on its own does not appear to be a significant risk. In recent years, life offices have reduced their ratings for obesity and most proposers in the category of 20% to 40% overweight would, if they had no other impairment, be accepted on standard terms. Such indications as there are suggest that for male proposers below age 50 this may not be wholly wise.

5. Conclusion

It was realised when the investigation was inaugurated, that it would be several quadrennia before the Committee could obtain full results from a mature set of statistics, and possibly even longer before the durations approach those of the data which formed the basis of the reports by Preston, Clarke and Leighton. Nevertheless, the present report indicates that the statistics are sufficient to produce worthwhile results which the Committee hopes are of use to offices. As from 1 January 1993 a smoking indicator has been added to the data records, which should further enhance the usefulness of the results.

The Committee expresses its gratitude to those offices who have supported the investigation this far, enabling it to become well established. Other offices could best show their appreciation by contributing their own data to the pool; the larger the experience, the greater the credibility which can be attached to the results. The Bureau will be very pleased to discuss this with any interested office.

Appendix

The following offices contributed to the Impaired Assured Lives Investigation (short names only).

Britannic	Refuge
Commercial Union	Royal Life
Eagle Star	Scottish Amicable
Equitable	Scottish Equitable
Equity and Law	Scottish Life
General Accident	Scottish Mutual
National Provident	Scottish Provident
Norwich Union	Scottish Widows
Pearl	Sun Alliance
Prudential	United Kingdom Provident

CMIR, **14** (1995) 121-124

THE MORTALITY OF IMPAIRED LIVES 1987-90 ACCORDING TO CAUSE OF DEATH

The first report on the mortality of impaired lives according to cause of death was published in *C.M.I.R.* **11**, 107, and related to the years 1983-86. There were only 264 cases (199 male and 65 female) with particulars of both the impairment code and the cause of death out of a total of 652 deaths in the impaired lives investigation itself, and this would have been too small a proportion for reliable exposed to risk and cause-specific expected deaths to be calculated. Instead, the proportions of cases were calculated (for each impairment group) where the impairment was linked to, or associated with, the cause of death.

The data for 1987-90 were more substantial, consisting of 813 male deaths and 288 female deaths (excluding duplicates) of which only 49 males and 9 females were cases where the causes of death were not reported to the Bureau. The complete impaired lives experience contained 959 male and 336 female deaths, the shortfall in the cause of death data arising because some offices submitting impaired lives data do not submit returns for cause of death.

The Committee are of the opinion that the numbers of deaths in each impairment group are still too small for a full actual and expected analysis by cause to yield useful results. As for the previous report, therefore, each case has been individually examined, and categorized according to whether:

(a) the impairment and the underlying cause of death were identical or linked by the linkage rules;
(b) the impairment could be regarded as associated with the underlying cause, or was stated on the certificate as a contributory cause without coming under (a);
(c) there was no apparent connexion between the impairment and the causes mentioned on the certificate, even though the impairment could have accelerated the death; or
(d) the cause of death was not reported.

Table 1 shows the distribution of deaths, after removing the cases where the cause was unknown. The percentages are shown, separately for males and females, for each impairment group where there were 10 or more deaths. In the following paragraphs the results are discussed under the headings of the different impairment groups.

Hypertension

For between 60% and 70% of the deaths, the impairment was identical with,

Table 1. Impaired lives 1987-90; males and females; relationship between impairment recorded by underwriters and cause of death on death certificate.

Impairment		No. of cases where impairment and underlying cause were linked or identical	No. of cases where impairment was an associated or contributory cause	Cases with no certain connexion	Total
Hypertension	M	85 (59%)	11 (8%)	48 (33%)	144
	F	36 (57%)	3 (5%)	24 (38%)	63
Ischaemic heart	M	233 (76%)	23 (7%)	51 (17%)	307
without surgery	F	32 (80%)	0	8 (20%)	40
Ischaemic heart	M	13 (65%)	2 (10%)	5 (25%)	20
with surgery	F	2	0	1	3
Cerebrovascular	M	6 (29%)	3 (14%)	12 (57%)	21
disease	F	3	2	2	7
Nervous disorders	M	1 (4%)	5 (19%)	20 (77%)	26
	F	0	4 (13%)	26 (87%)	30
Disseminated	M	2	2	0	4
sclerosis	F	8 (80%)	0	2 (20%)	10
Peptic ulcer	M	1 (4%)	3 (11%)	23 (85%)	27
	F	0	0	8	8
Ulcerative	M	0	0	2	2
colitis	F	1	0	1	2
Crohn's disease	M	0	1	4	5
	F	0	1	3	4
Epilepsy	M	2 (13%)	2 (13%)	11 (73%)	15
	F	5	1	1	7
Diabetes mellitus	M	7 (10%)	26 (39%)	34 (51%)	67
	F	4 (18%)	9 (41%)	9 (41%)	22
Respiratory	M	14 (18%)	27 (36%)	35 (46%)	76
disorders	F	4 (15%)	9 (35%)	131 (50%)	26
Urinary disorders	M	0	0	12 (100%)	12
	F	0	0	1	1
Tumour	M	1	0	0	1
	F	23 (85%)	1 (4%)	3 (11%)	27
Overweight	M	0	1 (3%)	36 (97%)	37
	F	0	0	29 (100%)	29
All impairments	M	365 (48%)	106 (14%)	293 (38%)	764
	F	118 (42%)	30 (11%)	131 (47%)	279

linked to, or contributory to the cause of death. The male and female experiences were similar, as opposed to the previous quadrennium when the difference between the experiences of the sexes was probably due to sparsity of data. In the 1983-86 report an attempt was made to divide the cases according to severity of the impairment, with the apparently contradictory result that those accepted with moderate hypertension were more likely to die from a linked cause than those accepted with severe hypertension.

The Committee has not continued with this line of analysis. This particular impairment group covers an extremely wide range of conditions and there will be different factors, possibly conflicting, affecting the mortality experience of each individual group. At this stage it is probably more misleading than useful to put data into groups, the contents of which are not homogeneous. Future quadrennia may yield sufficient data for a more sophisticated analysis to be made.

Ischaemic heart disease without surgery
For both sexes, in a high proportion of cases the impairment was identical with, linked to, or contributory to the cause of death.

Ischaemic heart disease with surgery
The number of deaths is small, but they show a similar pattern to the without surgery cases with a high proportion of linked or contributory causes of death.

Cerebrovascular disease
More than half the male deaths were from causes unconnected with the impairment. The female experience was not large enough to be significant.

Nervous disorders
The large majority of these cases were unconnected with the impairment.

Disseminated sclerosis
In most of the cases there was linkage or connexion between the impairment and the cause of death.

Peptic ulcer, ulcerative colitis, and Crohn's disease
41 out of the 48 deaths were unconnected with the impairments.

Epilepsy
73% of the male deaths were unconnected with the impairment, whereas 6 of the 7 female deaths were linked or connected.

Diabetes mellitus
The deaths were, broadly speaking, equally divided between those connected, and those unconnected with the impairment.

Respiratory disorders
These, too, divide equally between those connected and those unconnected.

Urinary disorders
The deaths were 100% unconnected with the impairment.

Tumour
A large majority of the deaths were due to the recorded impairment.

Overweight
In only 1 of the 66 deaths was there any recorded connexion with the impairment. However, it is worth remembering that it is most unusual for overweight to be recorded on a UK death certificate as a direct cause of death, or even a contributory cause. To be useful, even a relatively simple analysis of deaths by cause for this particular group will have to await the accumulation of more data than is currently available.

It is inevitable that, in an investigation limited to new business after a given start date, the number of deaths will take time to build up, so that any sophisticated analysis will not be possible in the early years. The Committee sincerely hope that the relatively simple analysis which is currently possible, when read in conjunction with the main report, will provide something of interest to underwriters and others operating in this field. It remains to thank the offices for continuing loyally to send in their returns; without them no report would be possible at all.

CMIR, **14** (1995) 125-128

THE MORTALITY OF RETIREMENT ANNUITANTS UNDER APPROVED PENSION ARRANGEMENTS IN THE REPUBLIC OF IRELAND 1986-91

No investigation of Irish retirement annuitant mortality has so far been published. This report relates to the experience of those holding retirement annuity policies issued by the Irish Life Assurance Company. The policyholders included in the investigation are covered by group insured schemes, the schemes having purchased compulsory immediate annuities to cover their immediate pension liabilities. The project for publication was initiated by the late Brendan Hayes and it has been completed with the assistance of Bruce Maxwell. The Bureau is extremely grateful to these two gentlemen, and to Irish Life, for their generosity in making this data available to the profession.

The investigation covers the calendar years 1986 to 1991. No information is available to distinguish between persons retiring at or after the normal retirement age and those retiring before the normal age, whether for health or other reasons. All amounts are in Irish pounds (IR£). The basic calculations were undertaken by Irish Life; the role of the Bureau has been limited to introducing additional comparison bases and the preparation of results for publication.

Data were available for both males and females, each on the basis of both lives and amounts of pension. The figures for individual years have been combined to provide a larger data set for analysis. When looking at the combined figures it should be kept in mind that the exposed to risk is not evenly distributed over the period, but has been building up steadily year by year. Each experience has been compared against the PA(90) table, for males or females as appropriate. In addition, the experiences have been compared against appropriate projected rates for calendar year 2010 from the "80" series tables for pensioners. These latter tables were used as comparisons for the corresponding group of UK lives over the period 1987-90, as written up on pp?? in this volume.

The male experience is of a goodly size, with 2,202 deaths over the six-year period. The results using the PA(90) table show that the experience measured on the basis of 'lives' is substantially heavier than that measured on the basis of 'amounts'. A similar differential between 'lives' and 'amounts' can be observed in the case of UK pensioners in insured group pension schemes. On an 'amounts' basis PA(90) is clearly not light enough to represent the experience of Irish pensioners over the period studied. When looked at on the basis of PML80C10 it can be seen that the mortality in the Irish 'lives' experience is heavier than that in the UK 'lives' experience at all ages over 65. On the 'amounts' basis using PMA80C10 the Irish experience is heavier than that in the UK at ages up to 70. Beyond that age the two experiences are similar.

The female experience is much smaller. As was the case with males, the mortality measured on the basis of 'amounts' was much lighter than that measured on the basis of 'lives'. However, in the case of female 'amounts', PA(90) is a not unreasonable representation of the level of mortality observed over the six-year period. Looked at on the basis of PFL80C10 the mortality in the Irish 'lives' experience is substantially heavier than that in the UK 'lives' experience at all ages over 65. At ages below 65 the Irish experience is comparatively light. A similar pattern can be observed in the 'amounts' experience, using as a comparison the PFA80C10 table.

Too much should not be read into the experience over one six-year period. However, it is hoped that the results can at least provide indications which are useful to actuaries concerned with business in Ireland.

Table 1a. Pension annuity policies in payment, 1986-91, males, 'lives': exposed to risk, actual deaths and ratios of actual deaths to those expected on the bases specified.

Age group (ages last birthday)	Exposed to risk	Actual deaths	100A/E by PA(90) males	100A/E by PML80C10
-60	6,745	67	84	148
61-65	8,777	202	105	161
66-70	13,466	459	105	141
71-75	11,482	636	111	134
76-80	6,189	526	115	128
81-85	1,771	239	123	132
86-90	395	73	115	123
Total	48,825	2,202	110	136

Table 1b. Pension annuity policies in payment, 1986-91, males, 'amounts': exposed to risk, actual deaths and ratios of actual deaths to those expected using the table specified.

Age group (ages last birthday)	Exposed to risk IR£000pa	Actual deaths IR£000pa	100A/E by PA(90) males	100A/E by PMA80C10
-60	11,139	121	87	195
61-65	20,510	385	86	166
66-70	29,541	809	85	141
71-75	18,226	710	79	113
76-80	7,158	431	82	104
81-85	1,490	138	85	101
86-90	268	45	105	118
Total	88,332	2,639	83	127

Table 2a. Pension annuity policies in payment, 1986-91, females, 'lives': exposed to risk, actual deaths and ratios of actual deaths to those expected on the bases specified.

Age group (ages last birthday)	Exposed to risk	Actual deaths	100A/E by PA(90) females	100A/E by PFL80C10
-60	3,075	23	153	218
61-65	3,477	35	101	143
66-70	5,270	101	115	160
71-75	4,709	166	126	164
76-80	3,133	164	112	133
81-85	1,542	152	129	142
86-90	655	99	119	128
Total	21,861	740	120	146

Table 2b. Pension annuity policies in payment, 1986-91, females, 'amounts': exposed to risk, actual deaths and ratios of actual deaths to those expected using the table specified.

Age group (ages last birthday)	Exposed to risk IR£000 pa	Actual deaths IR£000 pa	100A/E by PA(90) females	100A/E by PFL80C10
-60	5,048	21.2	87	146
61-65	5,179	38.6	74	125
66-70	7,116	139.1	119	194
71-75	4,438	124.4	102	152
76-80	2,165	102.7	103	114
81-85	760	67.0	117	139
86-90	277	34.3	97	115
Total	24,983	527.3	104	144

CMIR, **14** (1995) 129-153

SENSITIVITY ANALYSIS IN A MULTIPLE STATE MODEL FOR PERMANENT HEALTH INSURANCE

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KEYWORDS

Multiple state model; Transition intensities; Inception rates; Premium rates

1. INTRODUCTION

"The Analysis of Permanent Health Insurance Data" (*C.M.I.R.* **12** (1991)) presented a multiple state model for permanent health insurance. In this report, the parameters of the model, i.e. the set of the transition intensities between the states, were estimated and graduated using the male, Standard experience, data for 1975-78. Also, some relevant quantities and monetary functions were calculated (e.g. claim inception rates, several annuities, premium rates).

In the present paper we analyse how claim inception rates and premium rates behave when we change the values of σ_x, $\rho_{x,z}$, μ_x and $\nu_{x,z}$ (i.e. the transition intensities from healthy to sick, from sick to healthy, from healthy to dead and from sick to dead, respectively) obtained in *C.M.I.R.* **12**.

This kind of sensitivity analysis is of practical interest since future experience will not necessarily follow the experience of 1975-78 and has the added advantage of providing greater insight into the mathematical model described in *C.M.I.R.* **12**.

We should note that, although we had in advance some indication that only changes in σ_x and $\rho_{x,z}$ were likely to produce interesting and noticeable effects on claim inception rates and on premium rates, we decided to change also μ_x and $\nu_{x,z}$. Most of the information we had about this matter was of an intuitive nature (the values of μ_x and $\nu_{x,z}$, especially of μ_x, are very small when compared with the values of the two other intensities). The only actual results we had available were some results obtained in *C.M.I.R.* **12**, Part E, Section 1.3 for changes in μ_x. Therefore, we considered that on the whole this information was not very reliable.

We should note also that, in this paper, the graduations of the transition intensities are changed only in their levels and not in their shapes, i.e. they are multiplied by some constant factors.

*This work was supported by JNICT-Junta Nacional de Investigação Científica e Tecnológica, Lisbon, Portugal, under grant BD/2234/92-RO.

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The claim inception rates and the premium rates which are analysed in Sections 2 and 3 were calculated using the numerical algorithms described in *C.M.I.R.* **12**, Part D with a step size h of 1/156 of a year (i.e. one-third of a week, assuming there are exactly 52 weeks in a year).

2. EFFECTS ON CLAIM INCEPTION RATES

2.1. *Introduction*

First of all, we should note that the basic graduations used throughout this paper, i.e. before multiplying by some constant factors, are those given in *C.M.I.R.* **12**, Parts B and C with no 'run-in' period for the recovery intensity and with 'non-reported' claims added in for deferred periods 4, 13 and 26 weeks. This means that the basic recovery intensities (as well as the mortality intensities from healthy and from sick) are the same for all four deferred periods we consider (1, 4, 13 and 26 weeks), but the sickness intensities differ.

The basic sickness intensities in *C.M.I.R.* **12**, in general, decrease as the length of the deferred period increases: the ratio of the values of σ_x for deferred periods 1 week and 26 weeks being about 3:1. There is a brief discussion of this point in *C.M.I.R.* **12**, Part C, Sections 9.7 to 9.9, where it is shown that, for deferred period 26 weeks, an increase in σ_x by a factor of 3 and an increase in $\rho_{x,z}$ by about 10% to 30% would be consistent with the observed numbers of claim inceptions (including 'non-reported' claims). These considerations provided some motivation for our choice of factors to multiply σ_x and $\rho_{x,z}$.

As far as the factors to multiply μ_x and $\nu_{x,z}$ are concerned, we have based our choice on the comparison of the values of the overall mortality intensity in our model (a weighted average of μ_x and the average mortality intensity of the sick weighted by duration of sickness) with the values of the force of mortality for durations 2 and over for Male Permanent Assurances 1979-82 (AM80 ultimate) at several attained ages (see *C.M.I.R.* **12**, Part E, Table E1). The ratios of the former values to the latter ones range between 1·11 and 1·82.

In this Section we consider the effects on the 'type (a) inception rate' of changing separately the levels of σ_x, $\rho_{x,z}$, μ_x and $\nu_{x,z}$, and simultaneously those of σ_x and $\rho_{x,z}$. This inception rate at age x for deferred period d is defined by:

$$ia(x,d) = \frac{ca(x,d)}{L_x} \tag{1}$$

where $ca(x,d)$ is the expected number of claim inceptions between ages x and $x+1$ for a given deferred period d, out of a given number of individuals who were healthy at an earlier age x_0 (the entry age); and L_x is the expected number of years lived between ages x and $x+1$ by these individuals. A fuller description is given in *C.M.I.R.* **12**, Part D, Section 5.4. L_x can be also interpreted as the expected number of individuals alive at a certain age in the interval $[x,x+1]$

(this age is given by the mean value theorem for integrals). To simplify matters, an obvious approximation we could propose for L_x would be the expected number of individuals alive at age $x + \frac{1}{2}$. However, since it suits our purposes better, we have used throughout this paper the following interpretation: L_x is (approximately) the expected number of individuals alive at age $x + \frac{1}{2} - d$.

The tables which are analysed in this Section show the 'type (a) inception rates' (multiplied by 10,000) obtained after changing the level of either σ_x, $\rho_{x,z}$, μ_x or $\nu_{x,z}$, or of σ_x and $\rho_{x,z}$ simultaneously, and the ratios between these values and the claim inception rates (multiplied by 10,000) calculated with the basic transition intensities. We have constructed a table for each combination deferred period/factor (factors) chosen to multiply σ_x, $\rho_{x,z}$, μ_x or $\nu_{x,z}$ (σ_x and $\rho_{x,z}$). In each table we consider five entry ages (20, 30, 40, 50 and 60) and the attained age x increases from each entry age until age 60 in steps of 10 years (attained age 64 is also included). We have found that the claim inception rates at the intermediate attained ages did not add significant information to the tables since, for a given entry age, the ratios vary very smoothly with the attained age.

2.2 *Changes in* σ_x

Now consider the effects on claim inception rates of changes in the level of σ_x. It is not hard to see that multiplying σ_x by some factor $k > 1$ will increase $ia(x,d)$ by a factor less than k. To see this consider the following rough approximation:

$$ia(x,d) \simeq \frac{H_x \sigma_{x+\frac{1}{2}-d}\, \pi_{x+\frac{1}{2}-d,d}}{L_x} \tag{2}$$

Table 1. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 1 week.

Attained age, x	Entry age, x_0 = 20		30		40		50		60	
	$ia(x,d)$[1]	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	2128·81	1·986								
30	2411·57	1·980	2373·57	1·983						
40	2458·76	1·970	2460·85	1·971	2437·43	1·980				
50	2627·93	1·939	2629·13	1·940	2638·71	1·943	2668·14	1·973		
60	3188·65	1·825	3189·59	1·825	3197·12	1·827	3248·52	1·842	3575·74	1·950
64	3460·55	1·701	3461·47	1·701	3468·90	1·703	3519·50	1·716	3866·92	1·800

[1] This should be read as 10,000 $ia(x,d)$ in all the tables displaying claim inception rates.

Table 2. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 4 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	140·22	1·992								
30	303·89	1·986	281·73	1·988						
40	449·77	1·978	450·03	1·979	418·98	1·986				
50	673·52	1·957	673·73	1·957	675·52	1·960	638·43	1·981		
60	1337·70	1·867	1337·97	1·868	1340·24	1·869	1355·38	1·880	1367·54	1·961
64	1922·67	1·756	1923·01	1·756	1925·95	1·758	1945·53	1·767	2085·36	1·830

where H_x is (approximately) the expected number of healthy individuals at age $x + \frac{1}{2} - d$ and $\pi_{x,d}$ denotes the probability of an individual, who falls sick at age x, remaining sick for at least a period d. Since $L_x = H_x + S_x$, where S_x is (approximately) the expected number of sick individuals at age $x + \frac{1}{2} - d$, we can write:

$$ia(x,d) \simeq \frac{\sigma_{x+\frac{1}{2}-d}\,\pi_{x+\frac{1}{2}-d,d}}{1 + S_x/H_x} \tag{3}$$

Table 3. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 13 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	15·27	1·992								
30	40·54	1·988	30·69	1·990						
40	70·27	1·983	70·31	1·984	53·40	1·990				
50	131·48	1·969	131·51	1·969	131·79	1·971	101·35	1·987		
60	323·35	1·909	323·41	1·909	323·83	1·910	326·51	1·918	263·46	1·976
64	507·99	1·838	508·07	1·838	508·66	1·840	512·39	1·846	537·78	1·892

If we multiply σ_x by a factor k greater than 1, the numerator of (3) will be multiplied by the same factor ($\pi_{x,d}$ does not depend on σ_x) whilst the denominator is likely to increase somewhat since the ratio (S_x/H_x) will probably rise. The result is likely to be an increase in $ia(x,d)$, but by a factor less than k.

This is confirmed by our calculations. In fact, we can see that if we multiply σ_x by 2 (Tables 1, 2, 3 and 4), for example, the inception rates will increase by a factor less than 2 for all the deferred periods and entry ages considered.

We can see also from the tables mentioned above that the inception rates increase less and less as the attained age x increases from the entry age x_0. This is obvious if we consider (3) again because the ratio (S_x/H_x) will increase more and more as x increases from x_0, at which age all individuals were healthy. This result can be explained in another way: although, near the entry age, the number of sick individuals can increase almost by the factor used to multiply σ_x, as the attained age becomes higher and the number of sick lives grows further, the number of healthy individuals (those exposed to the risk of falling sick) will be reduced in such a way that the impact on inception rates of the increase in σ_x will be lessened.

Other features that can be observed from Tables 1 to 4 are: in general, for a given duration since entry, the increase in $ia(x,d)$ is a decreasing function of the entry age and this is more noticeable for shorter deferred periods. The explanation for the former feature is similar to that in the previous paragraph: the higher the entry age, the higher the ratio of sick to healthy individuals is likely to be and the smaller will be the effect of an increase in the level of σ_x. The latter feature will become clear in the next paragraph.

Table 4. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 26 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	2·09	1·994								
30	7·90	1·993	4·03	1·994						
40	18·22	1·990	18·22	1·990	9·36	1·994				
50	50·22	1·978	50·23	1·978	50·29	1·979	26·15	1·991		
60	161·02	1·929	161·04	1·929	161·17	1·930	162·14	1·936	87·78	1·983
64	261·20	1·876	261·23	1·876	261·41	1·877	262·80	1·882	273·52	1·920

Table 5. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 0·5, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 1 week.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	537·80	0·502								
30	612·13	0·503	600·91	0·502						
40	628·93	0·504	629·07	0·504	618·52	0·503				
50	688·08	0·508	688·16	0·508	688·78	0·507	680·85	0·503		
60	915·24	0·524	915·30	0·524	915·82	0·523	919·37	0·521	928·63	0·506
64	1103·07	0·542	1103·14	0·542	1103·68	0·542	1107·42	0·540	1133·07	0·528

Finally, we can see that, in general, for a given combination entry age/duration since entry, the longer the deferred period, the greater is the increase in the inception rates. As has been stated in the beginning of Section 2.1, generally, the level of σ_x decreases with the length of the deferred period. With this fact in mind and with the same kind of argument we have used before, it is easy to explain this feature in the inception rates.

We have also multiplied σ_x by 3 and 4 and the results are similar to those described above. These results are not shown here.

We have obtained also results for σ_x multiplied by some factors between 0 and 1, i.e. we have decreased the level of σ_x. As we would expect, the results are, in general terms, the inverse of those obtained for the factors greater than 1. Therefore, we show only, as an example, the results for σ_x multiplied by 0·5 and deferred period 1 week (Table 5).

2.3 *Changes in* $\rho_{x,z}$

In the last Section we have analysed the consequences for claim inception rates of changes in the level of σ_x. Now consider the effects on inception rates of changing the level of $\rho_{x,z}$.

If, for example, we multiply $\rho_{x,z}$ by some factor greater than 1 (this means that sick individuals recover more quickly), we expect, on the one hand, that claim inception rates will decrease since fewer sicknesses will last beyond the deferred period (obviously, we expect this feature to be more prominent for longer deferred periods). But, on the other hand, the fact that individuals spend less time sick implies that those exposed to the risk of sickness will increase and

Table 6. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by 1·1, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 1 week.

Attained age, x	Entry age, x_0									
	20		30		40		50		60	
	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	952·76	0·889								
30	1104·92	0·907	1084·78	0·906						
40	1155·76	0·926	1155·97	0·926	1137·03	0·924				
50	1283·77	0·947	1283·89	0·947	1285·06	0·946	1272·86	0·941		
60	1711·33	0·979	1711·43	0·979	1712·39	0·979	1720·32	0·975	1759·06	0·959
64	2034·80	1·000	2034·91	1·000	2035·91	1·000	2044·19	0·997	2111·07	0·983

so will the claim inception rates. Since these two effects work in opposite directions, the overall effect is not clear. Nevertheless, we have a feeling that the former effect will be stronger than the latter (because this one seems less direct) and in the end the claim inception rates will decrease.

We can confirm this feeling analysing Tables 6 to 9 where we multiply $\rho_{x,z}$ by

Table 7. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by 1·1, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 4 weeks.

Attained age, x	Entry age, x_0									
	20		30		40		50		60	
	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	50·55	0·718								
30	116·38	0·760	107·72	0·760						
40	183·00	0·805	183·02	0·805	169·56	0·804				
50	293·45	0·853	293·47	0·853	293·66	0·852	273·54	0·849		
60	651·86	0·910	651·88	0·910	652·15	0·910	654·28	0·908	625·18	0·897
64	1030·23	0·941	1030·27	0·941	1030·63	0·941	1033·58	0·939	1058·50	0·929

Table 8. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by 1·1, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 13 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	4·47	0·583								
30	12·91	0·633	9·77	0·633						
40	24·36	0·687	24·36	0·687	18·44	0·687				
50	49·87	0·747	49·88	0·747	49·90	0·746	38·00	0·745		
60	138·06	0·815	138·07	0·815	138·11	0·815	138·44	0·813	107·65	0·807
64	234·30	0·848	234·31	0·848	234·37	0·848	234·86	0·846	238·81	0·840

1·1. In fact, we can see that the claim inception rates decrease for almost all the cases considered and that the decrease is greater as the deferred period becomes longer.

Other noticeable features are that, for each entry age, the inception rates fall less and less as the attained age increases and, for each deferred period, the same

Table 9. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by 1·1, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 26 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	0·54	0·512								
30	2·25	0·567	1·15	0·568						
40	5·75	0·628	5·75	0·628	2·95	0·629				
50	17·68	0·696	17·69	0·696	17·69	0·696	9·15	0·696		
60	64·69	0·775	64·69	0·775	64·70	0·775	64·82	0·774	34·09	0·770
64	112·96	0·811	112·96	0·811	112·98	0·811	113·15	0·810	114·73	0·805

Table 10. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by 1/1·1, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 1 week.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	1191·75	1·112								
30	1328·96	1·091	1307·55	1·093						
40	1335·60	1·070	1336·83	1·071	1322·07	1·074				
50	1416·88	1·046	1417·60	1·046	1422·41	1·048	1428·18	1·056		
60	1765·11	1·010	1765·69	1·010	1769·58	1·011	1792·15	1·016	1902·93	1·038
64	2007·96	0·987	2008·55	0·987	2012·51	0·988	2035·45	0·993	2171·19	1·011

happens for a given duration since entry as the entry age increases. Both these features can be explained by the fact that the higher the attained age (or the higher the entry age, in the other case), the stronger the second effect mentioned above will be (for instance, we can see from Table 6, where $\rho_{x,z}$ is multiplied by 1·1 and the deferred period is 1 week, that for entry ages 20, 30 and 40 this effect is so strong at attained age 64 that it cancels out completely the first effect, leaving the inception rates unchanged). This happens because at higher attained ages (or higher entry ages) there are more sick lives and, subsequently, there will be more individuals that return to the healthy state sooner, increasing those exposed to the risk of falling sick.

We have also obtained results for $\rho_{x,z}$ multiplied by 1·2 and 1·3. Since these results are similar to those in Tables 6 to 9, they are not shown.

The function $\rho_{x,z}$ was also multiplied by some factors between 0 and 1 (1/1·1, 1/1·2, 1/1·3) and, as we expected, the results are, in general terms, the inverse of those obtained earlier. The only remarkable thing about these results is that, in a few cases, the effect just mentioned above (in this case, the decrease in the number of healthy individuals) is even stronger than the other one, implying a slight fall in the claim inception rates. This happens only for deferred period 1 week, so we show only, as an example, the results for this deferred period and $\rho_{x,z}$ multiplied by 1/1·1 (Table 10).

2.4 *Simultaneous changes in* σ_x *and* $\rho_{x,z}$

Up to this point, we have discussed the effects on claim inception rates of changes in the level of either σ_x or $\rho_{x,z}$, but not both. It is of obvious practical interest to consider the effects of changes in the levels of both intensities simultaneously.

Together with an increase in the level of σ_x, we could consider either an increase or a decrease in the level of $\rho_{x,z}$. We have chosen to concentrate on combining an increase in σ_x with an increase in $\rho_{x,z}$ for two reasons. The first is that these two changes will tend to work against each other: the increase in σ_x will raise the inception rates and the increase in $\rho_{x,z}$ will lower the inception rates, as we have already seen. Since part of our objective is to provide greater insight into the model, this combination of effects is potentially more interesting than a combination of two effects working in the same direction. The second reason is more immediately practical. In practice, a given set of claim inception rates is, loosely speaking, compatible with any number of combinations of values for σ_x and $\rho_{x,z}$ (and μ_x and $\nu_{x,z}$ as well). From a data analysis point of view it is of interest to know roughly what level of increase in $\rho_{x,z}$ is required to 'balance' an increase in the level of σ_x (we have already seen in Section 2·1 that this problem is discussed briefly in *C.M.I.R.* **12**, Part C, Sections 9·7 to 9·9).

For these two reasons, we will restrict ourselves in this paper to investigating the combined effects of increases in the levels of both σ_x and $\rho_{x,z}$, and, in particular, to attempting to find combinations which 'balance' as far as their effect on inception rates is concerned.

Considering (3) and ignoring its denominator, it is not difficult to obtain rough approximations of the values we are looking for. In fact, if we consider an attained age x near the entry age x_0 and multiply σ_x by a given factor $k>0$, an approximation $w>0$ of the factor by which we must multiply $\rho_{x,z}$ to keep $ia(x,d)$ unchanged is given by the following equation:

$$\sigma_{x+\frac{1}{2}-d}\exp\left\{-\int_0^d(\nu_{x+\frac{1}{2}-d+u,u}+\rho_{x+\frac{1}{2}-d+u,u})du\right\}= \\ k\sigma_{x+\frac{1}{2}-d}\exp\left\{-\int_0^d(\nu_{x+\frac{1}{2}-d+u,u}+w\rho_{x+\frac{1}{2}-d+u,u})du\right\} \tag{4}$$

where the exponentials on both sides of the equation are, from left to right, $\pi_{x+\frac{1}{2}-d,d}$ before and after $\rho_{x,z}$ is multiplied by w, respectively (a derivation of the formula for $\pi_{x,d}$ can be found in *C.M.I.R.* **12**, Part A, Section 5). The denominator of (3) is ignored in these calculations because we have strong reasons to suspect that, near the entry age, the ratio of sick to healthy lives after changing the levels of σ_x and $\rho_{x,z}$ will not be very different from that before the changes. We have seen that the effect on the ratio S_x/H_x following a change either in σ_x or in $\rho_{x,z}$ becomes stronger as the attained age x increases from the entry age x_0.

The solution of (4) is

$$w=\frac{\log k}{\int_0^d\rho_{x+\frac{1}{2}-d+u,u}du}+1 \tag{5}$$

Considering $x = x_0$ in (5), it is obvious that, for a given k, w depends on the entry age x_0 and on the deferred period d. Values of w for $k = 2,3,4$ and for the deferred periods and entry ages considered in the tables analysed earlier in this Section are shown in Table 11.

The most noticeable features we can observe in Table 11 are: for a given combination deferred period/factor k, the factor w increases as the entry age becomes higher and, for a given combination factor k/entry age, the factor w decreases as the length of the deferred period increases. If, instead of considering the effects on inception rates of a change in σ_x and of a change in $\rho_{x,z}$ separately, we think in terms of their interaction, it is quite easy to explain these features.

We have seen before that when we raise the level of σ_x, for a given deferred period and a given duration since entry, the increase in the inception rates decreases as the entry age increases. We have concluded that this happens because the number of individuals who are exposed to the risk of falling sick is a decreasing function of the entry age. However, in this case, this effect is lessened since we are raising also the level of $\rho_{x,z}$ and, consequently, sick individuals are returning to the healthy state sooner, increasing the number of those exposed to the risk of sickness. Furthermore, as we have stated earlier, the latter effect is stronger as the entry age becomes higher.

On the other hand, we have observed that, for a given combination deferred period/duration since entry, the decrease in the inception rates caused by an increase in the level of $\rho_{x,z}$ is smaller at higher entry ages. The reason for this feature is precisely the increase in the number of healthy individuals mentioned in the last paragraph. In the new situation this effect is strengthened since we have to add to the rise in the number of the exposed to the risk of sickness, the increase in the level of σ_x.

Summing up the aspects discussed in the previous two paragraphs, we can conclude that, when we increase the level of σ_x by a given constant factor, the factor by which we must multiply $\rho_{x,z}$ to keep the inception rates unchanged is an increasing function of the entry age.

The other noticeable feature (mentioned above) observed in Table 11 is due mainly to the fact that the fall in the inception rates following an increase in the level of $\rho_{x,z}$ is more prominent for longer deferred periods.

The values of w shown in Table 11 are only rough approximations. To see how these approximations perform their task of keeping the inception rates unchanged and to know more about the behaviour of the inception rates when σ_x and $\rho_{x,z}$ are increased simultaneously, we have applied every combination of factors k and w shown in Table 11 to these transition intensities and have constructed some more tables. We have constructed a table for each combination factor k/deferred period. In each of these tables, we use a different w for each entry age considered. The values of w used in each table were taken from the corresponding row in Table 11.

Table 11. Factors w by which the transition intensity from sick to healthy, $\rho_{x,z}$, must be multiplied to keep claim inception rate, $ia(x,d)$, unchanged when the transition intensity from healthy to sick, σ_x, is multiplied by $k=2,3,4$.

	Deferred period, d, 1 week Entry age, x_0				
k	20	30	40	50	60
2	1·625595	1·726202	1·865369	2·070519	2·403163
3	1·991545	2·151003	2·371577	2·696732	3·223960
4	2·251190	2·452404	2·730737	3·141038	3·806326
	Deferred Period, d, 4 weeks Entry age, x_0				
k	20	30	40	50	60
2	1·216574	1·257506	1·317514	1·413989	1·594678
3	1·343262	1·408137	1·503248	1·656157	1·942542
4	1·433149	1·515011	1·635028	1·827977	2·189356
	Deferred period, d, 13 weeks Entry age, x_0				
k	20	30	40	50	60
2	1·131067	1·153372	1·184825	1·232508	1·313348
3	1·207736	1·243088	1·292941	1·368516	1·496645
4	1·262133	1·306743	1·369650	1·465015	1·626696
	Deferred period, d, 26 weeks Entry age, x_0				
k	20	30	40	50	60
2	1·105064	1·123323	1·149264	1·189025	1·257660
3	1·166523	1·195463	1·236578	1·299597	1·408381
4	1·210128	1·246647	1·298528	1·378049	1·515320

Analysing Table 12, where $k=2$ and the deferred period is 1 week, if we consider only the first row for each entry age, i.e. only $x=x_0$, we can see that the ratio between the inception rate after the changes in σ_x and $\rho_{x,z}$ and that before the changes is an increasing function of the entry age. It begins being greater

Table 12. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2 and the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by a different factor for each entry age (from Table 11) together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 1 week.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	1000·82	0·934								
30	1295·42	1·064	1145·22	0·957						
40	1505·48	1·206	1385·71	1·110	1210·89	0·984				
50	1857·11	1·371	1744·88	1·287	1599·03	1·178	1377·45	1·019		
60	2781·49	1·592	2675·19	1·530	2528·27	1·445	2317·88	1·314	1967·62	1·073
64	3499·29	1·720	3411·32	1·677	3278·19	1·610	3071·22	1·498	2737·75	1·275

than 0·9 for entry age 20 and then increases until becoming slightly greater than 1 for the two last entry ages.

The most plausible explanation for this feature is the increase in the number of individuals who are exposed to the risk of sickness that follows a rise in the

Table 13. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2 and the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by a different factor for each entry age (from Table 11) together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 4 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	68·34	0·971								
30	168·00	1·098	138·94	0·980						
40	281·78	1·239	257·69	1·133	209·23	0·992				
50	480·43	1·396	449·90	1·307	408·44	1·185	324·17	1·006		
60	1117·72	1·560	1075·64	1·501	1015·24	1·416	922·95	1·280	717·30	1·029
64	1763·36	1·611	1722·77	1·574	1660·59	1·516	1557·87	1·415	1371·96	1·204

Table 14. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2 and the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by a different factor for each entry age (from Table 11) together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 13 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	7·53	0·982								
30	22·29	1·093	15·24	0·988						
40	43·10	1·216	39·65	1·119	26·71	0·995				
50	90·13	1·350	84·48	1·265	77·12	1·154	51·17	1·003		
60	250·84	1·481	239·94	1·416	225·32	1·329	205·01	1·205	135·08	1·013
64	418·93	1·516	404·67	1·464	385·20	1·393	357·48	1·288	317·52	1·117

level of $\rho_{x,z}$. In fact, this increase, which makes the inception rates decrease less and is more prominent for higher entry ages, affects the ratio S_x/H_x in the denominator of (3) and we are ignoring it in the calculation of w.

Another point we can make about this feature is that w produces better

Table 15. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2 and the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by a different factor for each entry age (from Table 11) together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 26 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	1·03	0·987								
30	4·35	1·098	2·01	0·993						
40	11·19	1·222	10·28	1·123	4·69	0·999				
50	34·45	1·357	32·25	1·270	29·39	1·156	13·20	1·005		
60	124·36	1·490	118·82	1·423	111·36	1·334	100·95	1·205	44·87	1·014
64	212·98	1·530	205·36	1·475	194·96	1·400	180·13	1·290	158·70	1·114

approximations for the middle entry ages (more precisely for entry ages 40 and 50). This means that the ratio S_x/H_x for the new situation is closer to the basic one for the middle entry ages.

From Table 12 we can observe also that, for a given entry age, the ratio between the inception rate for the new situation and that calculated with the basic transition intensities increases as the attained age becomes higher. This pattern can be explained partially by the fact that the decrease in the inception rates following a rise in $\rho_{x,z}$ is also smaller at higher attained ages. In addition we have to consider that this effect, which is due to the increase in the number of individuals who are exposed to the risk of sickness caused by the rise in $\rho_{x,z}$, is strengthened by the simultaneous increase in the level of σ_x.

We should note that the effect of the decrease in the number of individuals exposed to the risk of sickness caused by the rise in σ_x, and that also affects the ratio S_x/H_x , cannot be traced in Table 12. We have seen before that this effect is lessened precisely by the effect in the opposite direction mentioned in the previous paragraphs. Furthermore, now we can see that the former effect is overwhelmed by the latter.

We have also obtained results for $k=2$ and deferred periods 4, 13 and 26 weeks (Tables 13, 14 and 15, respectively). These results are similar to those in Table 12.

From Tables 12 to 15, if we consider only $x=x_0$ for each entry age, we can observe that w produces better approximations as the deferred period becomes longer (except for deferred period 26 weeks and entry ages 50 and 60). This is probably due to the fact that, although we are multiplying σ_x by $k=2$ for all cases, we are, for each entry age, using simultaneously a value of w which is a decreasing function of the length of the deferred period. In fact, this means that, as the deferred period becomes longer, the situation (more specifically, the ratio S_x/H_x) turns out to be closer to that before the changes in the transition intensities and, therefore, the quality of the approximations improves.

Results for $k=3$ and $k=4$ have also been obtained. These results are similar to those in Tables 12 to 15. Therefore, they are not shown.

2.5 *Changes in μ_x and $\nu_{x,z}$*

Now consider the effects on claim inception rates of (separate) changes in the levels of μ_x and $\nu_{x,z}$. Based on the information mentioned in Section 2.1, we have decided to multiply μ_x and $\nu_{x,z}$ by 2 and 0·5.

As we have stated in Section 1, some results for changes in μ_x are already available (see *C.M.I.R.* **12**, Part E, Section 1.3). However, these results are not very clear. In that report, it is said that the quantities calculated in the investigations carried out were, in general, insensitive to the different assumptions made about μ_x, but it is not specified which were the particular quantities considered.

Our results for μ_x multiplied by 2 and 0·5 confirm those described in the

previous paragraph: the effects on claim inception rates of these changes in μ_x are negligible for all the deferred periods and entry ages considered. These results are not shown.

As we have said above, we have also multiplied $\nu_{x,z}$ by 2 and 0·5. Although these changes have more impact on claim inception rates than the corresponding ones in μ_x, we cannot consider the results obtained very significant. However, as we have noticed some points which deserved our attention, we decided to show and comment on, as examples, the results for deferred periods 1 and 26 weeks in the case where $\nu_{x,z}$ is multiplied by 2 (the results obtained for $\nu_{x,z}$ multiplied by 0·5 are, in general terms, the inverse of those which are going to be described in the following paragraphs).

To analyse how claim inception rates behave when an increase in $\nu_{x,z}$ occurs, we have to consider the effects of such a change both on the number of claim inceptions and on L_x (see formula (1)). A higher number of deaths among the sick lives implies clearly a reduction in the number of claim inceptions since some of the additional policyholders who die do not have the opportunity to claim. Obviously, we expect this reduction to be greater for longer deferred periods. As $\nu_{x,z}$, for a given duration of sickness, in general, increases with the attained age, we expect also that the reduction in the number of claim inceptions will be more pronounced for higher attained ages. On the other hand, an increase in $\nu_{x,z}$ will also decrease L_x (through a reduction in the number of sick individuals alive) and this decrease will be greater for higher attained ages (the proportion of sick policyholders in the basic L_x increases with the attained age).

Table 16. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from sick to dead, $\nu_{x,z}$, is multiplied by 2, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 1 week.

Attained age, x	Entry age, x_0									
	20		30		40		50		60	
	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	1070·97	0·999								
30	1217·21	0·999	1195·74	0·999						
40	1248·02	1·000	1248·40	1·000	1229·70	0·999				
50	1358·05	1·002	1358·23	1·002	1359·85	1·002	1350·93	0·999		
60	1774·43	1·015	1774·54	1·015	1775·55	1·015	1783·98	1·012	1831·82	0·999
64	2099·56	1·032	2099·66	1·032	2100·61	1·031	2108·49	1·028	2175·35	1·013

Table 17. Claim inception rates, 10,000 $ia(x,d)$, if the transition intensity from sick to dead, $\nu_{x,z}$, is multiplied by 2, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Deferred period, d, 26 weeks.

	Entry age, x_0									
	20		30		40		50		60	
Attained age, x	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio	$ia(x,d)$	Ratio
20	1·00	0·955								
30	3·78	0·953	1·93	0·953						
40	8·68	0·948	8·68	0·948	4·45	0·947				
50	23·83	0·938	23·83	0·938	23·84	0·938	12·30	0·937		
60	77·55	0·929	77·55	0·929	77·56	0·929	77·70	0·928	40·79	0·922
64	129·33	0·929	129·34	0·929	129·35	0·929	129·53	0·928	131·23	0·921

Analysing Table 16, which displays the results for deferred period 1 week, we can see that the ratios between the claim inception rates after and before $\nu_{x,z}$ is doubled are, for a given entry age, slightly lower than 1 for the first attained ages and, after that, increase as the attained age becomes higher.

In the light of what has been said above, the results in Table 16 can be explained easily. As, in this case, the deferred period is very short, the number of claim inceptions suffers only a very small reduction (the increase in $\nu_{x,z}$ affects mostly the sick policyholders already claiming). This effect implies that, for each entry age, the claim inception rates increase slightly for most of the attained ages. On the other hand, the increasing ratios for a given entry age are explained by the reduction in L_x being an increasing function of the attained age.

Let us now consider the results for deferred period 26 weeks (Table 17). As we can see, the ratios in this table are lower than the corresponding ones for deferred period 1 week. In this case, the reduction in the number of claim inceptions outweighs the reduction in L_x: all the ratios are less than 1. These results are not surprising since, with a long deferred period, the reduction in the number of claim inceptions is likely to be much more pronounced (the increase in $\nu_{x,z}$ affects a much greater proportion of sick policyholders not yet claiming). Furthermore, in the present case, this reduction is reinforced due to the fact that the basic $\nu_{x,z}$ is relatively high during the first weeks of sickness duration, reaching a peak between the 15th and the 20th week (see *C.M.I.R.* **12**, Part B, Table B2). The decreasing ratios observed for each entry age can be

also explained easily if we consider that, as we have stated above, the reduction in the number of claim inceptions tends to increase with the attained age.

3. EFFECTS ON PREMIUM RATES

3.1 *Introduction*

In this Section we analyse the consequences for premium rates of changes in the levels of σ_x, $\rho_{x,z}$, μ_x and $\nu_{x,z}$ (separately), and of σ_x and $\rho_{x,z}$ (simultaneously).The premium rates we calculate here are continuous net premium rates. The benefit is 1 p.a. payable continuously whenever the policyholder is sick with duration of sickness greater than the deferred period. This benefit is payable until age 65 or until death, whichever occurs first. The premiums are also payable continuously and whenever the policyholder is healthy or sick with duration of sickness less than the deferred period. Thus, the net premium rate for a policy with deferred period d effected by an individual aged x, is given by:

$$\bar{P}_{x,d} = \frac{\int_0^{65-x} v^t pS(x+t, d^+)dt}{\int_0^{65-x} v^t(pH(x+t) + pS(x+t, d^-))dt} \tag{6}$$

where $v = 1/(1+i)$ and i is the interest rate, $pH(x+t)$ is the probability of an individual being healthy at age $x+t$ given that he was healthy at age x and $pS(x+t,d^+)$ is the probability of an individual being sick at age $x+t$ with duration of sickness greater than d given that he was healthy at age x ($pS(x+t,d^-)$ is the same probability but with the duration of sickness being less than d). It is important to note that x in $\bar{P}_{x,d}$ denotes the entry age and not the attained age as in the previous Section. We should note also that we have calculated the integrals in (6) numerically, using the repeated trapezoidal rule with the same step size used in the algorithms which evaluate the basic probabilities for the model, and that the interest rate is $i = 0{\cdot}06$.

The tables introduced in this Section are very similar to those in Section 2. Each table shows, for a given factor (several combinations of factors) used to change the level of either σ_x, $\rho_{x,z}$, μ_x or $\nu_{x,z}$ (σ_x and $\rho_{x,z}$), the premium rates obtained with the changed transition intensities and the ratios between these values and the premium rates calculated with the basic transition intensities. Each pair of columns shows the premium rates and the ratios for a given deferred period whilst each row shows the premium rates and the ratios for a given entry age. The deferred periods and entry ages considered in these tables are those used in the previous Section.

We know that premium rates have a strong connection with claim inception rates and, therefore, we might expect that, when we change any of the intens-

ities, the behaviour of the former will follow in some way that of the latter. However we have also to take into consideration the other factors that affect premium rates such as the time policyholders remain sick and the ratio of sick to healthy lives. Thus, we cannot expect that the behaviours of premium rates and claim inception rates following changes in the intensities will be identical.

3.2 *Changes in* σ_x

Let us now consider the effects on premium rates of changes in the level of σ_x.

Analysing Table 18, where σ_x is multiplied by 2, we can see that, for all the deferred periods and entry ages considered (except for deferred period 1 week and entry age 60), the premium rates increase by a factor less than 2, as the claim inception rates did. However, unlike the inception rates, for a given deferred period, the increase in the premiums rises as the entry age becomes higher.

This last feature in Table 18 is explained by the fact that the increase in the ratio of sick to healthy lives, that makes the increase in the inception rates decrease as the entry age becomes higher, has an effect on premium rates that works in the opposite direction: it diminishes the number of individuals who pay premiums. It can be noted that for deferred period 1 week and entry age 60 this effect is so strong that the premium rate increases by a factor slightly greater than 2.

Another feature we can observe in Table 18 is that, with only a few exceptions, the increase in the premium rates rises faster with the entry age as the deferred period becomes shorter. This happens because the second effect of

Table 18. Continuous net premium rates, $\bar{P}_{x,d}$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2, together with ratios of these rates to the corresponding rates calculated using basic intensities. Interest rate 6%.

Entry age, x	Deferred period, d							
	1 Week		4 Weeks		13 Weeks		26 Weeks	
	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio
20	0·024803	1·931	0·013498	1·928	0·007977	1·946	0·005222	1·954
30	0·039374	1·937	0·023425	1·938	0·013955	1·953	0·009333	1·959
40	0·063225	1·952	0·039660	1·951	0·023797	1·964	0·016637	1·968
50	0·099776	1·979	0·065152	1·972	0·038414	1·978	0·027867	1·980
60	0·118651	2·005	0·081645	1·992	0·042171	1·988	0·027758	1·988

Table 19. Continuous net premium rates, $\bar{P}_{x,d}$, if the transition intensity from healthy to sick, σ_x, is multiplied by 0·5, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Interest rate 6%.

Entry age, x	Deferred period, d							
	1 Week		4 Weeks		13 Weeks		26 Weeks	
	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio
20	0·006545	0·509	0·003567	0·510	0·002079	0·507	0·001352	0·506
30	0·010334	0·508	0·006143	0·508	0·003616	0·506	0·002406	0·505
40	0·016399	0·506	0·010294	0·506	0·006117	0·505	0·004261	0·504
50	0·025348	0·503	0·016644	0·504	0·009767	0·503	0·007071	0·502
60	0·029534	0·499	0·020530	0·501	0·010637	0·501	0·007004	0·502

the increase in the ratio of sick to healthy lives mentioned above is stronger for shorter deferred periods. In fact, the shorter the deferred period, the more weight have the healthy policyholders among those who pay premiums. Thus, a decrease in the number of healthy individuals will make more difference when we consider shorter deferred periods.

We have also obtained results for σ_x multiplied by 3 and 4. As we would expect, these results are similar to those in Table 18 and, therefore, they are not shown.

We have also multiplied σ_x by some factors between 0 and 1, and as happened with the claim inception rates, the results obtained are, in general terms, the inverse of those mentioned above. We show only, as an example, the results for σ_x multiplied by 0·5 (Table 19).

3.3 *Changes in* $\rho_{x,z}$

To analyse how premium rates respond to changes in $\rho_{x,z}$, we have increased (and decreased) the level of this intensity by the same factors used in the case of the claim inception rates.

Considering Table 20, where $\rho_{x,z}$ is multiplied by 1·1, we can see that, in general, these results follow those obtained for the inception rates: the premium rates fall for all the deferred periods and entry ages considered; for a given deferred period, the decrease diminishes as the entry age becomes higher; and, for a given entry age, the reverse happens as the deferred period becomes longer (except for entry age 20 and deferred period 26 weeks).

These results are not surprising since, in this case, all the factors that affect premium rates work in the same direction, producing effects that together contribute to the decrease in the premium rates. In fact, increasing the level of $\rho_{x,z}$

Table 20. Continuous net premium rates, $\bar{P}_{x,d}$, if the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by 1·1, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Interest rate 6%.

Entry age, x	Deferred period, d							
	1 Week		4 Weeks		13 Weeks		26 Weeks	
	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio
20	0·009273	0·722	0·004732	0·676	0·002631	0·642	0·001719	0·643
30	0·014723	0·724	0·008310	0·688	0·004703	0·658	0·003133	0·658
40	0·023802	0·735	0·014384	0·708	0·008279	0·683	0·005738	0·679
50	0·038252	0·759	0·024400	0·738	0·013950	0·718	0·010008	0·711
60	0·047929	0·810	0·032360	0·790	0·016334	0·770	0·010654	0·763

implies: a fall in the inception rates (as we have seen in Section 2.3), a reduction in the time that policyholders remain sick and, finally, a decrease in the ratio of sick to healthy lives (and, therefore, an increase in the number of policyholders who pay premiums).

The results for $\rho_{x,z}$ multiplied by 1·2 and 1·3 are similar to those in Table 20. These results are not shown.

As usual, the results obtained for $\rho_{x,z}$ multiplied by factors between 0 and 1, are, in general terms, the inverse of those discussed above. The results for $\rho_{x,z}$ multiplied by 1/1·1 are displayed in Table 21.

Table 21. Continuous net premium rates, $\bar{P}_{x,d}$, if the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by 1/1·1, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Interest rate 6%.

Entry age, x	Deferred period, d							
	1 Week		4 Weeks		13 Weeks		26 Weeks	
	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio
20	0·017759	1·382	0·010205	1·458	0·006266	1·528	0·004074	1·524
30	0·027874	1·372	0·017280	1·430	0·010602	1·484	0·007061	1·482
40	0·043568	1·345	0·028143	1·385	0·017276	1·426	0·012108	1·432
50	0·065509	1·299	0·043806	1·326	0·026334	1·356	0·019234	1·367
60	0·072080	1·218	0·050957	1·243	0·026923	1·269	0·017869	1·279

3.4 *Simultaneous changes in σ_x and $\rho_{x,z}$*

Within our purpose of providing greater insight into the model we are working with, we think that it would be interesting to investigate how premium rates respond to simultaneous changes in the levels of σ_x and $\rho_{x,z}$. As a way to accomplish this, we have decided to apply the combinations factor k/factor w presented in Table 11 also to the calculation of premium rates.

We have constructed a table for each factor k considered in Table 11 and, in each of these tables, we use a different value of w to calculate the premium rate for each different combination deferred period/entry age.

In this case, we cannot expect that premium rates will stay unchanged when we raise the levels of σ_x and $\rho_{x,z}$ by k and w because, as we have seen in Section 3.1, premium rates depend not only on inception rates but also on the time that policyholders remain sick and on the ratio of sick to healthy lives. Besides, we have also to bear in mind that, when we calculate the premium rate for a given combination deferred period/entry age, we are considering information referring not only to $x = x_0$ but also to $x = x_0 + 1, \ldots, 64$. We have seen in Tables 12 to 15 that the inception rates after the changes in σ_x and $\rho_{x,z}$ stay unchanged only around the entry age, increasing more and more in relation to those before the changes as the attained age becomes higher.

Analysing Table 22, where σ_x is multiplied by $k = 2$, we can see that, for a given entry age, the ratios of the premium rates calculated with the changed transition intensities to the basic premium rates increase as the deferred period becomes longer. We can notice also that, in general, the ratios for the shorter

Table 22. Continuous net premium rates, $\bar{P}_{x,d}$, if the transition intensity from healthy to sick, σ_x, is multiplied by 2 and the transition intensity from sick to healthy, $\rho_{x,z}$, is multiplied by a different factor for each combination of entry age and deferred period (from Table 11), together with the ratios of these rates to the corresponding rates calculated using basic intensities. Interest rate 6%.

Entry age, x	Deferred period, d							
	1 Week		4 Weeks		13 Weeks		26 Weeks	
	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio
20	0·004843	0·377	0·005991	0·856	0·004500	1·097	0·003296	1·233
30	0·006273	0·309	0·009323	0·771	0·007425	1·039	0·005598	1·175
40	0·007961	0·246	0·013881	0·683	0·011888	0·981	0·009384	1·110
50	0·009966	0·198	0·019459	0·589	0·017916	0·922	0·014688	1·044
60	0·011929	0·202	0·021001	0·512	0·018635	0·879	0·013833	0·990

deferred periods are less than 1 whilst the ratios for the longer deferred periods are greater than 1.

The increasing ratios are easily explained by the fact that we are multiplying $\rho_{x,z}$ by a value of w which is a decreasing function of the length of the deferred period (see Table 11). A decreasing w implies longer claims and, hence, higher premiums.

Concerning the latter feature, recall from Table 11 that all the values of w are greater than 1 and, hence, this has the effect of reducing premiums. The reason why some premium rates increase as a result of the changes in σ_x and $\rho_{x,z}$ is that, as we have stated above, the claim inception rates increase for attained ages which are not near the entry age.

Finally, also from Table 22, we can observe that, for a given deferred period, the ratio between the premium rate after the changes in the transition intensities and that before the changes decreases as the entry age becomes higher. This feature is mainly due to the fact that the factor w by which we are multiplying $\rho_{x,z}$ is an increasing function of the entry age.

The results for $k=3$ and $k=4$ are similar to those for $k=2$. These results are not shown.

3.5 *Changes in μ_x and $\nu_{x,z}$*

Finally, consider the effects on premium rates of (separate) changes in the levels of μ_x and $\nu_{x,z}$. As in Section 2.5, we have multiplied μ_x and $\nu_{x,z}$ by 2 and 0·5.

Consider Table 23, where μ_x is multiplied by 2. Although the effects on premium rates of this change in μ_x are almost insignificant, we can notice some interesting features. First, the premium rates calculated with the changed transition intensity are, except for entry age 60, lower than those obtained with the

Table 23. Continuous net premium rates, $\bar{P}_{x,d}$, if the transition intensity from healthy to dead, μ_x, is multiplied by 2, together with the ratios of these rates to the corresponding rates calculated using basic intensities. Interest rate 6%.

Entry age, x	Deferred period, d							
	1 Week		4 Weeks		13 Weeks		26 Weeks	
	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio
20	0·012658	0·985	0·006864	0·981	0·004020	0·981	0·002615	0·978
30	0·020062	0·987	0·011898	0·984	0·007036	0·985	0·004683	0·983
40	0·032091	0·991	0·020106	0·989	0·012001	0·990	0·008368	0·990
50	0·050285	0·997	0·032929	0·996	0·019385	0·998	0·014056	0·999
60	0·059292	1·002	0·041083	1·002	0·021290	1·004	0·014034	1·005

Table 24. Continuous net premium rates, $\bar{P}_{x,d}$, if the transition intensity from sick to dead, $\nu_{x,z}$, is multiplied by 2, together with the ratios of those rates to the corresponding rates calculated using basic intensities. Interest rate 6%.

Entry age, x	Deferred period, d							
	1 Week		4 Weeks		13 Weeks		26 Weeks	
	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio	$\bar{P}_{x,d}$	Ratio
20	0·011213	0·873	0·005831	0·833	0·003260	0·795	0·002065	0·773
30	0·017415	0·857	0·009983	0·826	0·005651	0·791	0·003667	0·770
40	0·027347	0·844	0·016668	0·820	0·009555	0·788	0·006501	0·769
50	0·042596	0·845	0·027273	0·825	0·015458	0·796	0·010923	0·776
60	0·052652	0·890	0·035752	0·872	0·017842	0·841	0·011414	0·817

basic one. Second, for a given deferred period, the ratios of the premium rates calculated with the changed μ_x to those obtained with the basic intensity increase with the entry age.

These features are not surprising. An increase in μ_x implies a reduction in the number of healthy policyholders or, equivalently, a reduction in those who can become sick. A smaller number of claim inceptions, in turn, means lower premium rates. However, we must not forget that a smaller number of healthy policyholders means also a decrease in the total amount of premiums being paid and, consequently, premium rates will tend to rise. Obviously, this last effect is likely to be stronger for higher entry ages, when the proportion of healthy policyholders is lower. This explains why the ratios increase with the entry age. This effect is so strong for entry age 60 that it makes the ratios slightly greater than 1.

The results obtained for μ_x multiplied by 0·5, although even less significant, are, in general terms, the inverse of those described above. These results are not shown.

Analysing Table 24, where $\nu_{x,z}$ is multiplied by 2, we can see that the impact on premium rates of doubling $\nu_{x,z}$ is greater than that caused by the same change in μ_x. We were expecting this result since, in the present case, the effects on premium rates are much more direct. In fact, a higher number of deaths among the sick policyholders has the following consequences: the corresponding claims become shorter; some of these sick people do not have even the opportunity to claim (this effect is likely to be more prominent for longer deferred periods) and, finally, all these policyholders will never claim in the future. Obviously, we should also mention that a greater number of deaths

among the sick has a negative effect on the total amount of premiums paid. However, this effect is not likely to be very significant since, anyway, many of the sick policyholders to whom we are referring are not paying premiums at the time of their death.

From Table 24 we can also see that, for a given entry age, the ratios of the premium rates calculated with the changed $\nu_{x,z}$ to those obtained with the basic intensity decrease as the deferred period becomes longer. One of the explanations for this feature has been already mentioned above: the longer is the deferred period, the less opportunity have the sick policyholders who die to make claims. Another reason for this pattern is the fact that when long claims become shorter, the reduction in the premium rates for long deferred periods is greater than in the premium rates for short deferred periods.

We should note that the results we have obtained for $\nu_{x,z}$ multiplied by 0·5 are, in general terms, the inverse of those presented in the previous paragraphs. These results are not shown.

ACKNOWLEDGEMENTS

I would like to thank Prof. Howard Waters for his helpful suggestions and for the discussions we had about this work. I want also to thank Prof. David Wilkie for reading this paper and for making some interesting remarks. Finally, I am grateful to an anonymous referee for his useful comments.

References

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

C.M.I. (1991) The Analysis of Permanent Health Insurance Data. *C.M.I.R.*, **12**, 1-263.

Waters, H.R. (1984) An Approach to the Study of Multiple State Models. *J.I.A.*, **111**, 363-374.

Waters, H.R. and Wilkie, A.D. (1987) A Short Note on the Construction of Life Tables and Multiple Decrement Tables. *J.I.A.*, **114**, 569-580.

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