Practical Example of a Split Benefit Accelerated Critical Illness Insurance Product

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Abstract

This dissertation proposes a new multi-state modelling framework for a general buy-back accelerated critical illness (ACI) product. This product allows the insured to receive a critical illness benefit payable on each of two occasions, when one of the ACI qualifying treatments is satisfied, rather than only once as in the standard ACI product. The additional premium cost of this general buy-back product is illustrated for different ages and different proportions of buy-back benefit reinstated, compared to a standard ACI product.

Further examples are provided which take into consideration that only certain qualifying conditions are to receive a reinstatement. By introducing another state for the remaining non-qualifying conditions in this model, we can allow for the higher subsequent incidence rate to be considered for these qualifying conditions.

Keywords: Accelerated Critical Illness, Buy-Back Model, Cancer Model, Morbidity, Multi-State Modelling

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1 Introduction

The following dissertation is primarily concerned with the insurer offering the policyholder the option to pay a relatively small additional flat premium at the policy inception in order to be able to obtain reinstatement of coverage automatically, following a qualifying critical illness (CI) claim incident after a waiting period. A typical list of medical conditions which qualify as a CI incident is provided in Appendix 12.1.

The purpose of this option is to overcome the main limitation of the standard ACI product, in that only a single claim can be made on the first incidence. Although a new ACI product could be purchased following a CI event, the premium is likely to be considerably more expensive than a healthy life, at the same older age, exclusions may be applied or coverage refused. The reason for the higher premium cost is that the claimant is perceived to be at a higher risk of further incidences or of earlier death compared to a healthy policyholder.

The problem of finding reinstatement of coverage at a reasonable premium would not exist if the required "buy-back" option had been purchased in advance at the policy inception for a small additional amount. This is because only a small proportion of all policyholders will have a 1^{st} qualify incident before the end of the policy term, so the effect of insurance pooling will be to reduce the cost of this buy-back option.

The purpose of this dissertation is to determine the additional "buy-back" premium required at inception for a healthy policyholder, relative to the corresponding premium for a model with no "buy-back" assuming all policyholders choose the "buy-back" option. We shall illustrate the value of this "buy-back" premium option for the same female 10-year term policy assuming one of the following four different possible sets of qualifying conditions:

***Example 1:* General Buy-Back Model**

The main aim is to provide a product with a general "buy-back" option at inception that allows a currently healthy policyholder to fully reinstate their ACI coverage automatically following a qualifying event. This allows a further benefit payment on a 2^{nd} incident for any of the original ACI conditions, provided this 2^{nd} incident occurs after a suitably long time period since the 1^{st} incident. The full modelling details of this *example 1* will be considered in Chapter 5.

***Example 2:* General Restricted Model**

In practice, as the "buy-back" option is a new product feature we should also compare with a simpler product that has a restricted list of qualifying conditions for the benefit payment on both the 1^{st} and 2^{nd} incident, e.g. a cancer only product, which we shall denote by our *example 2*. This will also allow us to include policyholders who may have a past non-cancer medical history that would normally lead to exclusion from a standard ACI product. However, we still need to allow for the possibility that if the policyholder succumbs to a non-qualifying condition, this may then increase the subsequent incidence of the qualifying condition. We shall provide full details of the theory in Chapter 6.

***Example 3:* Exclusion Model**

Finally, to show the adaptability of the modelling framework that we shall propose, we will extend *example* 2 a step further and determine the effect on the "buy-back" option if we exclude certain medical treatments rather than a complete CI condition, e.g. a cancer only product which excludes breast cancer, which we shall denote by our *example 3*.

***Example 4:* General Restricted Model**

To demonstrate that the premiums for individual condition models are not additive we shall repeat *example 2* for a cardiovascular only product, which we shall denote by our *example 4*.

The actual “buy-back” premiums for all these examples will be calculated in Chapter 7, with comparisons made in Chapter 8.

The choice of a female, rather than a male policyholder was to avoid publishing competitive data on the far more widely used male incidence rates found in pricing. As the theory is identical for both genders, and our results are only meant to be illustrative, repeating the analysis for males would not provide any more additional theoretical insight.

2 Overview

In Chapter 3 we begin with an overview of the current CI product and the premium "buy-back" options currently available in the market place to the policyholder with the restrictions placed on the reinstatement.

In Chapter 4 we discuss the characteristics of a large U.K. private medical insurance (PMI) database that we shall use throughout the dissertation to provide illustrative examples, once we have found suitable graduated morbidity incidence rates in section 4.9.

In Chapter 5 we propose to use a multiple state Markov chain model to provide the framework for determining the cash flows and emerging costs in the standard stand-alone and accelerated models, before repeating for our new extended models which include additional states after the reinstatement or "buy-back" of benefit coverage.

In Chapter 6 we adapt our previous extended Markov chain model to allow for the possibility of a policyholder succumbing to one of the non-qualifying conditions before the qualifying condition, as this incidence rate is likely to be far higher than for the healthy policyholders. In section 6.4 we extend the previous cash flows and emerging cost theory, before presenting the prospective reserves and expected profit vector for both our extended and the standard models in sections 6.7 and 6.8.

In Chapter 7 we apply the previous theory to our PMI data to determine the premium required for a 20% profit margin for various "buy-back" proportions in our extended stand-alone and accelerated model. In sections 7.1 and 7.4 we consider the corresponding "buy-back" premium option required for a restricted cancer product (including and excluding breast cancer), before looking at a cardiovascular only product in section 7.5.

In Chapter 8 we compare the relative buy-back option premiums between these examples. Finally in Chapters 9 and 10 we present our conclusions and further work.

3 Critical Illness Product

3.1 Characteristics of Critical Illness Product

The stand-alone critical illness product provides a single fixed benefit payment if the policyholder suffers any one of the qualifying conditions listed in the policy prospectus (see Appendix 12.1 for a full list) in return for regular policyholder premiums over the term of the policy.

As the benefit payment is not linked to the degree of severity of the condition it could lead to popular windfall payments for the policyholder which can be spent on anything. Alternatively, in the majority of cases the policy will expire with no benefit payment occuring, thus allowing the effect of insurance pooling to provide a large benefit payment relative to a much smaller premium.

In addition, to distinguish from a death policy, the critical illness benefit will not be paid if death occurs within a specified survival period, say 28 days. As this is an unpopular exclusion, which can be viewed by the policyholder as the insurer reneging on its promise to pay a CI benefit or being predantic if death occurs on the 27^{th} day, the policy is normally sold as a rider to a term or life assurance policy. This also has the advantage in the case of a whole of life assurance policy that a death benefit will eventually be paid, even if the policyholder never satisfies one of the qualifying critical illness conditions. There is little additional cost to the life office in providing the additional critical illness benefit to the life policy, as the accelerated policy simply brings forward the timing of the death benefit payment (ST1, unit 2, pp.14), i.e. an accelerated death benefit.

The defined qualifying condition needs to be perceived to be "serious and to occur frequently" (ST1, unit 2, pp.11), "defined clearly" (ST1, unit 2, pp.12) to avoid claim ambiguity, and "sufficient data" (ST1, unit 2, pp.12) to ensure that the critical illness product can be priced competitively.

3.2 Current Critical Illness Market Interest

At the Institute and Faculty of Actuaries Life Convention in 2003, a presentation by Dinani indicated that new sales of individual critical illness policies had increased from 170,000 to 1,173,000 from 1992 to 2002 (Dinani, slide 3, 2003). This indicated a potentially growing market at a time when the annual number of new life cover policies has fallen slightly in 1998 to 90% of the 1991 value (Dinani *et al.* pp.5, 2000).

In particular, due to the advantages mentioned above, there has being a substantial increase in the sale (as a % of all new critical illness policies) of the accelerated term assurance product from 32% in 1997 to 85% in 2002 (Dinani, slide 4, 2003).

The main reason given for the aforementioned rapid growth in the critical illness market is the value the policyholder places on "simplicity" – with simplicity in the eyes of the policyholder delivered in the form of a single "lump sum benefit" (Dinani, slide 14, 2003), mortgage repayment vehicle, "standardisation of definitions, and guaranteed premium rates" (Dinani, slide 14, 2003).

However, future development may be lower than expected as the product is "not needs based" (Dinani, slide 44, 2003), and "has become too complex" (Dinani, slide 44, 2003), with "too many illnesses covered" (Dinani, slide 44, 2003) and is prone to "ambiguity over claims" (Dinani, slide 44, 2003).

The simplest way to reduce the complexity of the critical illness product is to focus solely on one illness as undertaken by the Virgin Cancer Care (2007) tiered product, which provides a different level of benefit depending on the severity of the cancer as stated in the policyholder prospectus. Cancer may have been chosen as it accounts for 54% of all critical illness claims (Dinani *et al*. pp.10, 2000) and policyholders are likely to feel a genuine need for insurance with the future NHS provision of expensive cancer drugs being uncertain (Hawkes, 2006). Further details on structuring a tiered product are provided by Temple (2008).

However, complexity is introduced in the Virgin Cancer Care through these "tiered" cancer levels. For example, say 10% is paid-out on more minor stages of some types of cancer, which may not normally be covered by the standard critical illness product as falls below the qualifying criteria, then say 30%, and finally the remaining 60% for the most severe level of a particular cancer.

However, critics (Greenwood 2006) have suggested that to obtain a 100% pay-out for some types of cancer the stage of cancer would need to be fairly life threatening, whereby a usual CI policy would have already paid out a full benefit before reaching such a severity level.

The ABI 2005 consultation paper (ABI 2005) proposed a two-tier approach to cancer definition with either a "full" cancer definition to cases of "malignant and invasive" cancer or a "restricted" definition for "specified sites".

However, the wide variation in how companies define cancer could lead to potential inconsistencies in coverage. Companies may construct a more "restricted" cancer definition from the "full" definition (for some or all of the cancer conditions) resulting in situations where a policyholder being covered if they take a policy out with one insurer but not with another. To avoid such "gaps" a "staged" approach was recommended by the ABI, whereby insurers have to offer all levels of cover for each cancer to avoid 'cherry picking'. In the end, this proposal was abandoned in the final April 2007 ABI paper because of possible policyholder confusion over definitions for each cancer severity level and difficulty in claims administration.

However, a tiered approach nonetheless has the advantage of allowing a higher payment for the most advanced stages of a particular cancer condition, whilst providing a lower payment for the least advance cancer stages. We therefore feel that there is still an opportunity in the market place for such a product. To overcome, the complexity issue we shall consider an option to "buy-back" or reinstate the cancer coverage after the 1st cancer event. By adjusting the relative size of the "buy-back" benefit this is practically equivalent to a two-stage approach.

The development of such a fixed benefit cancer product with such a "buy-back" option, having the advantages of an accelerated (critical illness) term assurance product is the objective of this dissertation.

Before we proceed with this objective, we will first review the current research on critical illness, which centres on determining population critical illness incidence rates. These rates will provide a benchmark to compare with our own experience in Chapter 4 .

3.3 Latest Research on Critical Illness

A brief history of the Institute of Actuaries Continuous Mortality Investigations (CMI) into critical illness is provided by Grimshaw (2006) and Friedwald (2006), with the latest results in Heeney and Grimshaw (2008). The corresponding working papers 14 (CMI WP14 1999) and 18 (CMI WP18 1999) are directed to determine the ultimate claims from the paid critical illness data provided by the CMI participants.

In addition, graduation of the 1999-02 critical illness experience from the CMI contributing life offices is discussed in working paper 18 (pp. 7, CMI WP18 1999). The main conclusion of this paper is that rather than publish an insured life table it was felt more sensible to provide guidance on adjustments that could be made to the existing population critical illness table CIBT93[1], which has now being revised to the CIBT02 table.

These CMI working papers all look at the standard ACI products. However, we wish to consider ACI products with a full (or partial) "buy-back" option. The "buy-back" option allows automatic reinstatement of CI and life coverage after a qualifying CI event

1 The CIBT93 and CIBT02 table are based on the addition of individual incidence rates from cancer population registrations and hospital episode statistics for those conditions which match the CI definitions. There are problems with using these general population tables for our insured population, which has been underwritten, and we potentially require more severe condition definitions for inclusion in our CI policy.

without requiring additional underwriting at the time of the CI event (although there will usually be restrictions on the timing before the next CI event and whether the same or related conditions are included). The "buy-back" option usually needs to be chosen at the time the original policy is taken out, with the additional premium usually payable until the 1st or possibly 2nd event.

As far as the CI benefit is concerned this is identical to a split benefit product which offers half (or some) of the benefit on the 1st incident and the other half (remaining) on the 2nd incident. Alternatively, if we adjusted the level of the partial payment on the 1st incident according to the level of severity of the condition, i.e. low payout if minor or high payout if major trauma (or vice versa), then we have a two "tiered" CI product.

3.4 Current Buy-Back Critical Illness Products

The buy-back option is currently available from some insurers in the U.K. and Australia.

This typically provides:

- "100% of the amount of any claim will be reinstated, with no further medical evidence, one year from the date your claim was accepted."

Although no "further medical evidence" seems like an additional feature of the product, if this was the case then the policyholder could probably have obtained similar terms from other insurers after the 1st incident and after having taken account of any increase in policyholder age. Thus they would not have needed to pay any buy-back option premium before the 1st incident.

The presence of this one year moratorium has the consequence that the policyholder will be uninsured for this time period. This reduces the cost of the buy-back premium as there will be no further benefit payments for 2nd incidents until the time period is completed.

In addition, for an accelerated CI buy-back policy there will also be no further benefits for subsequent deaths in this interval. This will be a significant premium saving for some severe CI conditions, as only a proportion of claimant's would be expected to survive beyond one year, with the non-survivors not eligible for any death benefit.

Care needs to be given in the definition of the time period, as it may be intended to be from the date of last treatment for the 1st incident, i.e. a claim free period, whereas it could be interpreted from the above wording as from the original date of diagnosis of 1st incident. We shall assume the former interpretation and illustrate the resulting interval in Appendix 12.2.

In some buy-back products the following policy exclusions/adjustments may apply to reduce the buy-back premium required to a more marketable level:

1. The same condition or connected (e.g. stroke after heart attack) is excluded.
2. Particular conditions are excluded, e.g. Terminal Illness (T.I.), Total Permanent Disability (T.P.D.), paralysis, etc.
3. Only certain conditions can be reinstated, e.g. cancer, heart attack, stroke.
4. Limit reinstatement to 50% of sum assured.
5. A stepped annual reinstatement to full benefit.
6. A maximum purchase age of 60, with any buy-back reinstatement ceasing at age 70.
7. Waiver (or reduction) of premiums after 1st incident.
8. Reviewable at the reinstatement date with revised mortality and morbidity assumptions using the current age rather than the initial age.

Alternatively, the buy-back premium could be increased to offer the policyholder a more enhanced buy-back product:

9. Reduce the moratorium post 1st incident below the standard 1 year.
10. A minimum number of years post-reinstatement.

We shall consider each of the above policy exclusions in more detail below:

1. The reoccurrence of the same condition is far more likely than a new condition. We shall not apply this 1st exclusion. Instead, we shall assume that whichever (or

all) of the conditions are selected for the 1st qualifying incident, are also valid for the 2nd qualifying incident. This was done as the policyholder will have the greatest need for a reoccurrence of the same condition, and to make direct comparisons of the additional premium against the standard product with no buy-back. In addition, this was done for practical data reasons in order to obtain sufficient 2nd incidents to model more accurately.

2. To define a 2nd incident for T.I., T.P.D. and paralysis conditions is very difficult as full recovery from the 1st incident is not likely in order to satisfy criteria of "terminal" or "permanent". Our list of conditions also excludes T.I., T.P.D. and paralysis, due to no data.

3. An advantage of offering reinstatement of those conditions with the highest 1st incidence rates is that these are more likely to satisfy the policyholder's needs, as well as having the majority of the 2nd incidence rate data allowing more accurate premium rates to be achieved.

4. Providing half the limit on buy-back, will approximately halve the premium, for the same profit margin. We shall consider the full range of reinstatement proportions from 0% to 100%, as this is more transparent to the policyholder, than excluding individual conditions from the buy-back.

5. Alternatively, a stepped annual reinstatement of 33⅓% on each 1st incident policy anniversary until the policyholder's benefit reaches the full 100% benefit after 3 years. These tie in with a low benefit following 1st incident to match a higher expected probability of a 2nd incident or death, compared to a high benefit in a few years time when the expected probability has reduced. The choice of these time intervals will be discussed in section 4.1 as this affects the overall level of premium required. For simplicity and comparison with other models, we shall assume a flat reinstatement benefit throughout following the 1st incident.

6. Some products have lower maximum purchase ages by up to 10 years. However, we shall keep to the maximum purchase age of 60, and buy-back ceasing at age 70, by considering a policyholder aged 20, 30, 40, 50 or 60 at the policy inception for a 10 year term.

7. A waiver of premiums is sensible as the policyholder may be in poor health following the 1st incident and have other more urgent priorities. However, this will load the additional premium payable upfront, which may seem unfair to spread the premium among all the policyholders, especially if they never have a 1st incident. In the extreme case this could lead to a moral hazard of trying to obtain a first incident in order to avoid paying premiums. Alternatively, continuing to pay a full premium will be unmarketable if the reinstatement is less than 100%, i.e. the policyholder could lapse and take out a full benefit policy for the full premium (provided not severely penalised against after the 1st incident). To avoid the above we shall consider a premium in proportion to the remaining reinstated benefit payable on the 2nd incident.

8. Reinstatement of coverage will be based on the current age (rather than the initial age) with a possible revised set of more conservative assumptions for mortality or morbidity, i.e. reviewable at reinstatement date. This will allow an initial lower annual buy-back premium for the healthy policyholders, at the expense of a higher reinstatement annual premium.

Generally, numbers 1, 2 and 6 are offered by all providers, with 3, 4, 5 and 7 offered by none or only one of the current providers, possibly to differentiate themselves.

Alternatively, the premium could be increased.

9. Reduce the moratorium from 1 year to 30 days! In particular, if the same or related conditions are excluded, then this will reduce the increase in premium. We shall consider 180 days for the same condition, and 30 days for an unrelated condition in our assumption 1 discussed in section 4.1 below.

10. A minimum number of years post-reinstatement may be provided, e.g. 2 years, even if this extends beyond the original policy term.

Generally, none or only one of the conditions in 9 or 10 is offered by the current providers, possibly to differentiate themselves, especially if greater premium savings are possible in conditions 1 to 8 to offset this increase in premium.

4 Investigations into our own Client (PMI) Data

In this chapter we discuss the characteristics of a large U.K. private medical insurance (PMI) database that we shall use throughout this dissertation to provide illustrative examples.

The U.K. private medical insurance database used is that of a client of our company who are very interested in the potential commercial viability of an ACI product with the buy-back option discussed in section 3.4.

However, they have indicated that their current critical illness data is of limited use. The reason for this is that if a policyholder qualifies for one of the included critical illnesses, they receive a single benefit payment and are no longer insured. They therefore do not receive a follow up to determine if they need further treatment or have died (as required for my proposal).

In the meantime in order to allow an illustrative analysis until more appropriate data is collected, our client is willing to provide private medical insurance (PMI) from 1994 to 2007 claimant data by sex and age, for one of 146 specific PMI treatment conditions. The majority of the treatment conditions corresponding to different types of cancer. The PMI data does not explicitly record every treatment episode as distinct events; instead every claim payment made by the policyholder is recorded. In order to determine the 1^{st} and 2^{nd} treatment episode required for our buy-back ACI model we will need to make the following seven assumptions.

4.1 Assumptions Required to Utilise the Client (PMI) Data to Obtain Transition Intensity Estimates

The following are a list of the assumptions we have made in this dissertation in order to utilise our PMI data.

1) **Large time interval, say 6 months, corresponds to separate treatment episodes for the same condition**

   As different treatment episodes for the same condition are not distinguished in our PMI data, we thereby require the assumption that a sufficiently large time interval; say 180 days, between the end of one treatment and the start of the next treatment means that the two treatments are considered as two separate episodes for the same condition.

   As this assumption is consistent with our post 1st treatment waiting period of 180 days, we do not need to be overly concerned about whether any 2nd treatment payments before 180 days are for a new or on-going occurrence of the same condition.

   The numerical details are discussed in Appendix 12.2.

2) **Not all treatments will be claimed under the insurance policy**

   We have ignored the possibility that our PMI policyholders are free to seek alternative healthcare provider treatment, e.g. NHS accident and emergency cover for cardiovascular conditions may be used as they are immediately available on arrival in hospital. However, for the aftercare treatment the advantages of private health care, e.g. own room for stroke rehabilitation, may mean that a fair proportion of claims are likely to be eventually paid by the PMI policy and fall into either our 1st or 2nd incident.

3) **The type of claim definition are similar between our PMI data and CI data**

We have sorted our PMI claims data into lists of conditions which most closely match the CI conditions, e.g. all the different types of common cancers, cardiovascular conditions etc. as listed in Appendix 12.1. The degree of severity for the qualifying criteria has been selected to be as similar as possible, e.g. we have only included malignant cancers satisfying the ICD10 C00-C99 codes, ignoring the benign PMI cancer claims.

4) **The qualifying criteria or severity are similar between our PMI data and CI data**

Although PMI data may generally have a lower qualifying criteria than CI, this will generally be for the smaller claims (which we discuss below), whereas the larger claims are more likely to be for the more severe events which have similar qualifying criteria to the CI claims.

5) **The policyholder profiles are similar between our PMI data and CI data**

The PMI product is marketed to a different type of policyholder who are more concerned with indemnity of medium to large sized hospital expenses, whereas CI policyholders are looking for a very large lump sum in case of a traumatic life threatening-event (likely to cause loss of all future income). The main difference will be related to the size of payments which we discuss below, with other differences difficult to adjust for and we have presumed that these will be far smaller compared to the other assumptions we have needed to make.

6) **Previous treatment history will not be significant**

We shall be assuming that the policyholders joining our PMI dataset are all healthy and have not recently undergone any treatment whether with the NHS or other private healthcare providers. Underwriting at the time of purchase or on claiming should ensure that this is the case, with any non-disclosure on the

application form leading to potential for claim refusal if relevant (as in the case of CI underwriting).

7) Incidence rates are not select

PMI and CI policies have an underwriting moratorium to reduce adverse selection after the policy is taken out, which we shall consider in section 4.8. Similarly, after a 1st incident has occurred there is a far higher probability of a 2nd incidence or death. This is investigated in section 4.8, where we find that a 1st year no-claim interval is sufficient to remove 69% (389/559) of the 2nd paid claim incidents in Table 40. As such a feature is likely to cause complaints and ill-feeling among policyholders, we shall assume 180 days instead, which instead removes only 33% (183/559) of the paid claims from the 2nd incident. However, as we still require the premium to be payable throughout this period, we shall allow the insurer to pay a benefit for any condition that is not the same as the 1st condition after 30 days. From Table 46 this leaves 82% (458/559) of the paid claims.

In principle, with these seven assumptions, it is possible to utilise the PMI data to determine the number of transitions to and from the 1st and 2nd post-treatment states in our models discussed in section 4.6. However, we shall first investigate the adequacy of our PMI data in the next section.

4.2 PMI Claim Amount Threshold

We shall determine an appropriate threshold level for our PMI data in order that we are left with a frequency of claims similar to the 1st incidence rate of an insured CI policyholder table, say CIIT00[2] Female Non-Smokers (pp. 12, Brett and DuTolt 2007).

2 In 2005 the CMI committee released to contributing CI members the original 1999-2002 CI claims and exposure database, allowing the members to graduate their own CI tables. Brett & DuToit (2006) published their own male/female smoker/non-smoker tables which they named CIIT00.

Otherwise, we will have a product that would be viewed as inadequate, as the insurer is paying a flat average fixed benefit that is slightly more than is required to indemnify the majority of small claims, but not if a large claim occurs. In addition, we would also have relatively large administration and expense costs for all these small claims, which outweigh any benefit to the policyholder.

Therefore, if we are to provide a fixed benefit payout, we need to determine a suitable minimum PMI claim threshold in order to leave just the medium to large claims which would be closer to that of a CI policy.

The following Table 1 indicates the number of female paid claims by the main conditions with amounts greater than the threshold levels shown.

Table 1: The number of female paid claims at each threshold level for the main condition groups (ages 20-89).

Females Ages 20-89	No. of 1st Incidents			No. of 2nd Incidents		
Threshold Level	**>£0**	**>£2,000**	**>£10,000**	**>£0**	**>£2,000**	**>£10,000**
Malignant Cancer	10,137	3,595	1,494	5,299	458	93
Benign Brain tumor	163	42	13	64	3	-
All Cardiovascular	1,426	628	85	367	35	1
All Neurological	349	29	2	148	4	-
Deafness	392	20	2	107	2	-
Blindness	606	71	1	145	10	-
All Conditions	**13,073**	**4,385**	**1,597**	**6,130**	**512**	**94**

From Table 1, on increasing the threshold level from £0 we reduce the total number of paid claims on the 1st incident across all conditions by 33% at a threshold level of £2,000, and to only 10% at a threshold level of £10,000. As can be seen at a threshold level of £10,000 this leaves far too few 2nd incidents.

We note that the majority of our female paid claims are for malignant cancer (77% for £0 threshold), followed by cardiovascular conditions (10% for £0 threshold) as can be seen in the following Figure 1.

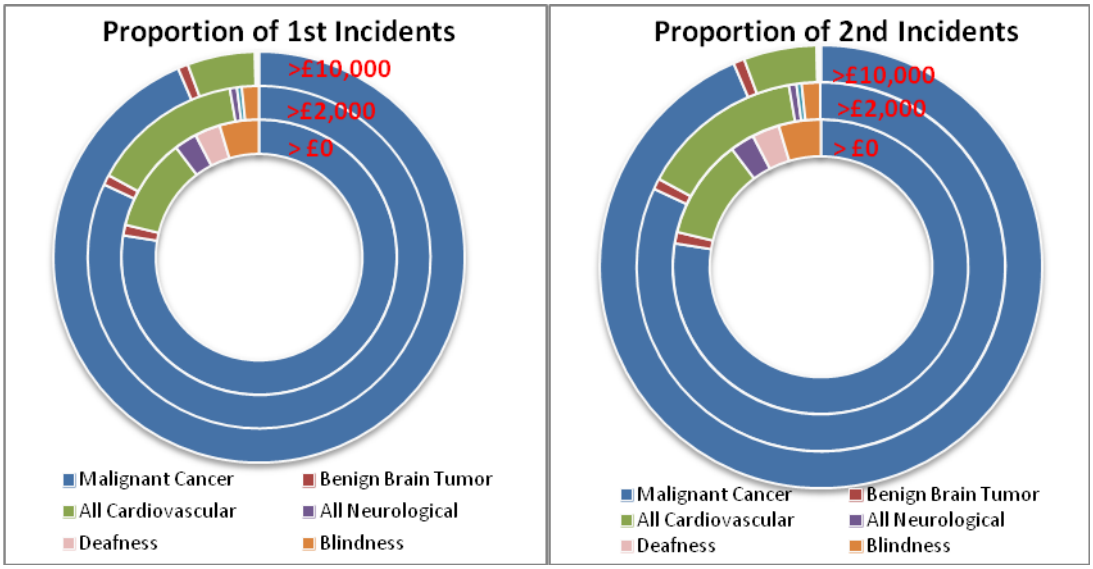


Figure 1: The female paid claim proportions for the main condition groups at increasing claim threshold levels £0, £2,000 and £10,000, for ages 20 to 89.

In Figure 1, we note that as we increase the threshold level from £0 to £10,000 the proportion of malignant cancer claims increases, cardiovascular remain fairly constant, while the blindness, deafness and all neurological claims rapidly decrease in proportion for both the 1st and 2nd paid incidents.

A more detailed split of claims by age is only really practical in excess of a threshold level of £2,000, as shown in the following Table 2.

Table 2: The number of female paid 1st incident claims with amounts greater than £2,000 for the main condition groups, split by 10-yearly policyholder age intervals.

Age Range	Malignant Cancer	All Cardiovascular	All Neurological	All Accidental	Benign Brain Tumor (BBT)	All Conditions
20-29	89	5	4	3	2	103
30-39	333	9	3	3	3	351
40-49	748	55	4	8	9	824
50-59	1053	117	5	15	18	1208
60-69	811	194	7	24	4	1040
70-79	435	180	4	23	6	648
80-89	126	68	2	15	0	211
20-89	**3595**	**628**	**29**	**91**	**42**	**4385**

The full table broken down by the individual conditions is shown in Table 29 (Appendix 12.3). Therefore, we need to bear in mind that a very high threshold may be more realistic for a CI policy, but we are unlikely to have sufficient (or any) PMI data by age to determine any meaningful incidence rates for most of our individual conditions. So a compromise between the threshold level and data availability will be needed.

4.3 Diagnosis to Settlement

The above numbers refer to the number of paid PMI claims, rather than the number of diagnosed claims required to determine the incidence rates at the latest date of our data. There are therefore claims which have being diagnosed but have yet to be paid which will be missing from our data. To correct for this feature we need to increase our paid claims using a "diagnosed to settled" development pattern to find the expected number of settled claims.

For our PMI data all we can be sure of is that the date of 1st diagnosis must have occurred between the last known date the policyholder was healthy (e.g. on inception or last renewal) and the 1st incident (payment) date. Assuming the diagnosed to settled morbidity pattern shown below in Table 3 (Brett and DuTolt, pp.30, 2007), we can develop the claim count to the current valuation date to allow for any expected future unknown claims for a particular claimant.

Table 3: Diagnosed to settled cancer morbidity and mortality payment patterns from Brett and DuTolt (pp. 30, 2007)

Days Since Date of Diagnosis	0	30	60	91	182	365	547	730	1,000	2,000
Diagnosis to Settled Morbidity	0%	4.3%	25.0%	49.3%	79.3%	90.8%	94.1%	95.9%	97.6%	100.0%
Diagnosis to Settled Mortality	0%	24.8%	44.2%	64.8%	84.5%	97.4%	98.4%	99.4%	99.4%	100.0%

We have a choice of applying the "% diagnosed to settled" value shown in Table 3 to either the number of days since the policyholder was healthy, or when the incident payment occurred, up to the current valuation date. As the actual value lies between these two extreme factors, we have assumed for simplicity the average of these two "% diagnosed to settled" when calculating the value to divide our paid claim number by. The advantage of this method (rather than taking the average time between these two dates) is that due to the shape of the diagnosed to settled curve with time, we are choosing a date much closer to the payment date than the last renewal date. A full step-by-step example of this development is provided in Appendix 12.4.

The result of applying the "% diagnosed to settled" to our paid data in Table 2 is shown below in Table 4.

Table 4: The number of female 1st incident developed paid claims with amounts greater than £2,000 for the main condition groups, split by 10-yearly policyholder age intervals.

Age Range	Malignant Cancer	All Cardiovascular	All Neurological	All Accidental	Benign Brain Tumor (BBT)	All Conditions
20-29	91.3	5.2	4.2	3.1	2.0	105.9
30-39	357.4	9.2	3.1	3.1	3.1	375.8
40-49	780.3	56.3	4.1	8.2	9.2	858.1
50-59	1,084.7	119.8	5.1	15.5	18.4	1,243.6
60-69	843.5	198.6	7.2	24.5	4.1	1,077.9
70-79	453.7	184.4	4.1	23.6	6.1	671.9
80-89	130.7	69.8	2.0	16.0	-	218.6
20-89	**3,741.7**	**643.4**	**29.8**	**93.9**	**43.0**	**4,551.7**

The full developed table broken down by individual conditions is shown in Table 31 (Appendix 12.5). Similarly for the 2nd incident, we have a range for the "% diagnosed to settled" from either the end of the waiting period after the 1st incident, or the 2nd paid date up to the valuation date. On dividing the 2nd paid claim by the average of these extreme "% diagnosed" values, we created the developed claim Table 32 and Table 33.

4.4 Exposure

Our client has provided us with the number of actual female exposures from 2002 to 2007 in each 5-yearly age interval as shown in Table 34 (Appendix 12.6). For the earlier years all the client has being able to provide are the number of new joiners and estimated withdrawals in each year starting from the 1st policy underwritten in 1994 (Table 35 and Table 36).

From Table 34 we linearly extrapolated the trend in the proportion of exposure in each 5-yearly age interval backwards from the known 2007 to 2002 years, to the earliest available year 1994 (as shown in Table 37).

As we know from column 5 in Table 35 the total estimated population of females across all ages, we can fill in Table 34 to determine the approximate exposure from 1994 to 2001 for each 5-yearly interval, as shown in Table 38.

Finally, summing the exposure for each 5-yearly age interval over all the calendar years provides us with the total exposure shown in Table 5 below. I have also deducted half the annual exposure for any claimants claiming for a 1st incident or death in each year to determine the central exposed to risk.

4.5 Calibration

By changing the level of the cedant's minimum claim amount before inclusion in our analysis, we aim to calibrate the crude central incidence rate shown for malignant cancer in Table 5 at different thresholds with the female non-smoker (FNS) insured table CIIT00[2] 1st incidence rate.

Table 5: The female malignant cancer developed crude central incidence rate for increasing threshold amount.

		Malignant Cancer Developed Counts (ex BBT)			Malignant Cancer crude Incidence Rates (ex BBT)			Published Tables for Cancer Incidence		
Age Range	Exposure in Healthy State (years)	>£0	>£2,000	>£10,000	>£0	>£2,000	>£10,000	CIBT02	CIIT00 FNS	ONS C00-C99, ex C44
20-24	79,995	206	35	14	0.0026	0.0004	0.0002	0.00026	0.00018	0.0003
25-29	154,680	245	56	31	0.0016	0.0004	0.0002	0.00048	0.00033	0.0006
30-34	143,068	408	119	64	0.0028	0.0008	0.0004	0.00083	0.00059	0.0009
35-39	147,786	627	239	122	0.0042	0.0014	0.0008	0.00132	0.00097	0.0014
40-44	140,525	838	317	163	0.0060	0.0023	0.0012	0.00207	0.00149	0.0023
45-49	137,763	1,149	463	213	0.0083	0.0034	0.0015	0.00338	0.00237	0.0035
50-54	143,562	1,405	545	240	0.0098	0.0038	0.0017	0.00520	0.00331	0.0053
55-59	133,347	1,446	540	234	0.0108	0.0040	0.0018	0.00715	0.00427	0.0068
60-64	86,285	1,269	442	225	0.0147	0.0051	0.0026	0.00905	0.00541	0.0092
65-69	71,670	1,046	401	150	0.0146	0.0056	0.0021	0.01103	0.00659	0.0118
70-74	59,416	809	265	105	0.0136	0.0045	0.0018	0.01393	-	0.0134
75-79	46,884	636	189	63	0.0136	0.0040	0.0013	0.01703	-	0.0165
80-84	34,335	343	99	26	0.0100	0.0029	0.0007	-	-	-
85-89	15,112	136	32	5	0.0090	0.0021	0.0003	-	-	-
20-69	1,238,680	8,639	3,157	1,455	0.0069	0.0025	0.0012			
20-89	1,394,427	10,562	3,742	1,653	0.0075	0.0027	0.0012			

In addition, we can compare the U.K. female population table CIBT02[1] and the ONS ICD10 C00-C99[3] (ex C44) incidence rates with these values as shown in Figure 2 below.

[3] The U.K. Office of National Statistics (ONS) cancer registrations of new cancers diagnosed in 2005 for England, and registered by October 2007.

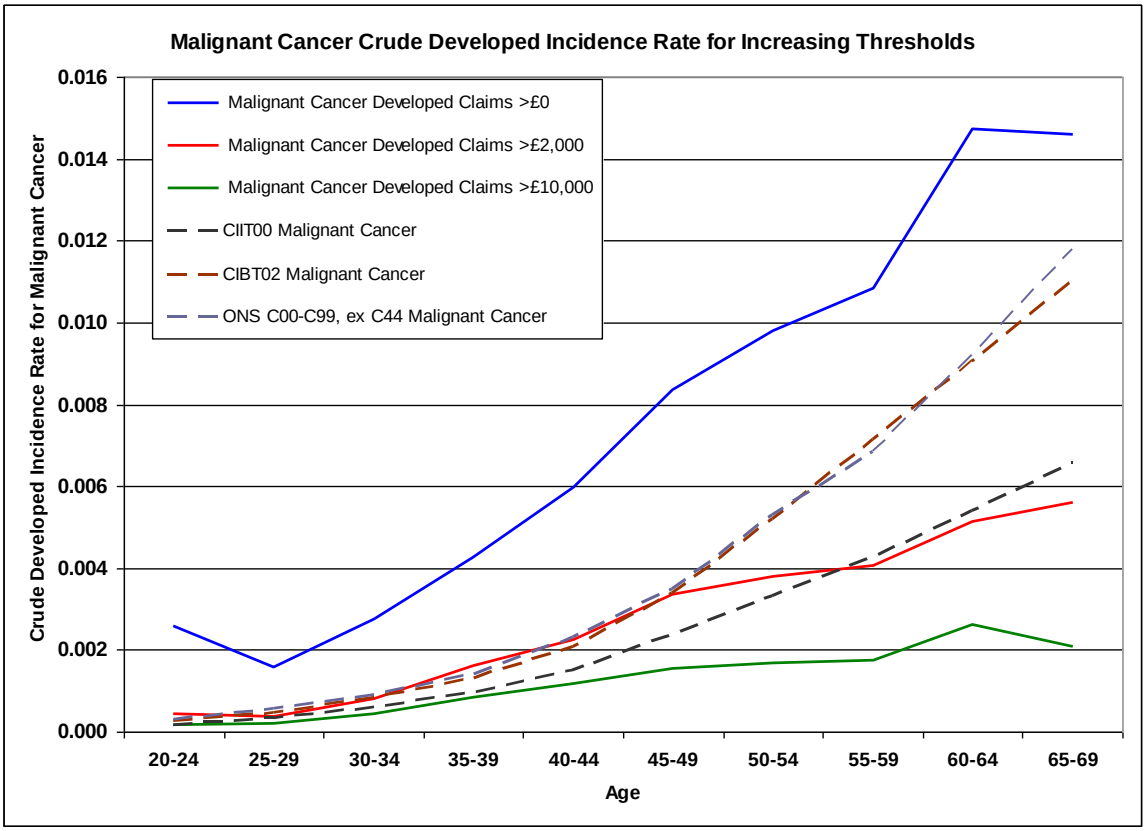


Figure 2: The female malignant cancer developed 1st crude incidence rates, compared with the corresponding non-smoker CIIT00 and CIBT02 incidence rate tables.

In Figure 2 we note that at a threshold level of only including PMI claims above £2,000, our crude cancer incidence rate (red curve) is similar to the general population ONS incidence table C00-C99 (broken grey curve) until age 45. Then our rate drops to be more similar to the CIIT00 incidence rate (broken black curve) from age 55 to 65.

4.6 The 1st Crude Incidence Rate

For our choice of £2,000 threshold, we obtained the following paid counts, exposure and crude 1st incidence rate for all the conditions in the following Figure 3.

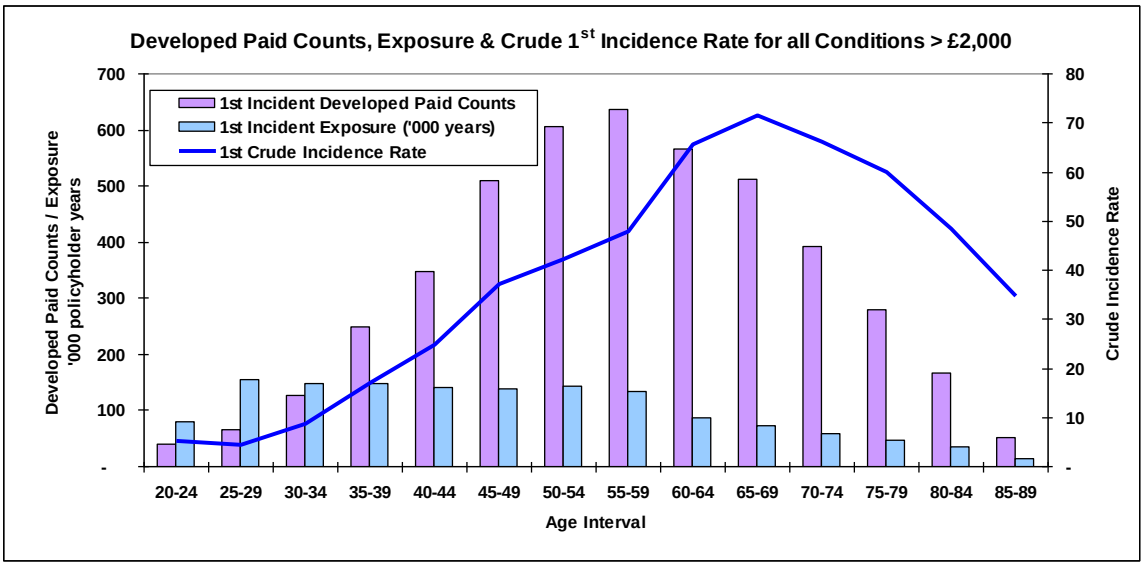


Figure 3: The developed paid counts, exposure and corresponding crude central 1st incidence rate.

Figure 3 shows a fairly high exposure in the age range 25 to 59, with a dropping off after age 60. There are several possible reasons for this decrease in exposure:

- The portfolio is still fairly young and yet to reach a mature state.
- The portfolio includes policies which were part of a company scheme that was only funded until retirement age.
- An increase in the withdrawal rate because of a rapid increase in age-related premiums post-retirement which become unaffordable.

Similarly, the developed paid claims rise steadily to a peak at ages 50 to 59, before dropping off. This may be because our portfolio is still fairly young and yet to reach a mature state.

On dividing the developed paid claims by the exposure, the corresponding 1st incidence rate line is shown in Figure 3. This increases to a peak of 70 per 10,000 at ages 65-69, before falling to 35 per 10,000 at ages 85-89. This is unusual and as we would expect the incidence rate to continue to increase as occurs in the standard tables, e.g. CIBT02. Due to a new growing book of policyholders our data possibly has too few paid claims to allow credible incidence rates beyond age 70.

4.6.1 Actual versus Expected

To check numerically whether the actual claims satisfying our assumption of £2,000 looks reasonable for the other conditions, we compared the ratio of actual to expected for each of the individual conditions shown below in Table 6.

Table 6: The Expected versus Actual claims experience (subject to a minimum paid amount of £2,000 and age group 20-69).

		Paid Counts > £2,000		Expected E	Developed A
		Original	Developed	CIIT00	Expected E
Grouped Conditions	Age Range Individual Conditions	20-69	20-69	20-69	20-69
Malignant Cancer	***All Malignant Cancer (inc BBT)***	**3070**	**3,194**	**2,886**	**111%**
Cardiovascular	**Heart Attack**	98	100	258	39%
	Stroke	64	65	187	35%
	Coronary Artery By-Pass	131	134	41	326%
	Aorta Graft Surgery	43	44	4	
	Heart Valve Replacement	44	45	-	
Sub Total	***All Cardiovascular***	**380**	**389**	**489**	**80%**
Neurological	**Multiple Sclerosis**	17	18	136	13%
	Parkinson's Disease	4	4	2	194%
	Motor Neurone Disease	2	2	18	12%
Sub Total	***All Neurological***	**23**	**24**	**156**	**15%**
Other	**Deafness**	18	18	2	871%
	Blindness	35	36	4	823%
	Kidney Failure	0	-	19	
Sub Total	***All Other***	**53**	**54**	**26**	**211%**
Total	***All Conditions***	**3,526**	**3,661**	**3,557**	**103%**

Note: The expected rates are based on the female non-smoker CIIT00 mortality table.

Table 6 shows the slight increase in paid counts on including our above "settled to diagnosed" factor, which increases the cancer A/E from 107% to 111%. These values would expected to be in the region of 100% as the threshold level was chosen (by visual inspection in section 4.5) to allow our actual incidence rate to be approximately equal to the CIIT00 expected cancer incidence rate from age 20-69.

On comparing individual conditions we note that we have far fewer heart attacks (A/E = 39%) and strokes (A/E = 35%) than would be expected, but far higher Coronary Artery Bypass Graft (CABG A/E = 326%). This may be a reflection that heart attacks and strokes tend to be immediately life-threatening with instant access to treatment in the public sector. Whereas the PMI insurance may be used for the majority of non-immediate life threatening CABG in order to obtain instant access. Overall, the combined picture is that our paid claims account for around 80% of the expected cardiovascular claims.

On applying our minimum paid claim amount criteria of £2,000, we lose 92% (1 - 29/349 from Table 1) of our neurological paid claims across all ages. This is probably due to the persistent long-term nature of these conditions requiring relatively low ongoing medical costs rather than expensive one-off surgical treatment.

The resulting actual paid claims are far lower than expected for a CI product, with an overall A/E of 15%. This low A/E is mainly due to 136 expected multiple sclerosis CI claims compared to our 18. This may suggest that the CI product is more "tailored" towards the policyholder's needs of paying out a large fixed amount, e.g. for loss of future income or to adapt a claimants home for disabled access. In contrast, the PMI product is only indemnifying the claimant for hospital costs, which may be a relatively small amount in comparison.

For the other conditions we obtained far more blindness and deafness claims than would be expected under CI. This is due to the PMI policy paying any relatively small medical costs associated with partial blindness and deafness rather than the stricter definition under CI typically requiring full blindness and deafness. We shall not consider these individual groups further in the dissertation as the paid amounts are all below our choice of threshold level.

Overall, our choice of threshold of £2,000 in Figure 2 looks reasonable for calibrating the claims to allow similar overall A/E (assuming CIIT00) for cancer and all the conditions

combined as shown in the following Table 7 (obtained by developing the claims in Table 6 using the method discussed in section 4.3).

Table 7: The female developed paid claims 'A' / 'E' for malignant cancer, cardiovascular and all conditions combined, where the claims > £2,000 and the expected values are from the CIIT00 non-smoker table.

		Malignant Cancer			Cardiovascular			All Conditions		
Age Range	Exposure (Policy-holder Years)	A	E	A / E	A	E	A / E	A	E	A / E
20-24	79,995	35	15	231%	1	2	54%	41	21	192%
25-29	154,680	52	52	100%	3	5	66%	60	71	84%
30-34	143,068	107	86	125%	3	7	44%	117	114	103%
35-39	147,786	202	144	140%	5	13	40%	213	187	114%
40-44	140,525	294	213	138%	17	23	75%	328	268	122%
45-49	137,763	422	329	128%	33	38	86%	469	400	117%
50-54	143,562	506	478	106%	31	63	49%	564	574	98%
55-59	133,347	502	571	88%	66	95	69%	600	697	86%
60-64	86,285	407	469	87%	88	103	85%	533	593	90%
65-69	71,670	365	478	76%	78	141	56%	481	637	76%
20-69	1,238,680	**2,892**	**2,835**	**102%**	**325**	**489**	**66%**	**3,406**	**3,563**	**96%**

From Table 7 we find that for individual 5-yearly age ranges, the developed PMI actual paid malignant cancer counts are noticeably higher than the expected values below age 55, suggesting our threshold may be too low. However, this is offset by the actual counts being slightly below the expected for ages between 55 and 69, with A/E of 88% and 76%.

For cardiovascular conditions, the actual claims are always noticeably less than the expected claims, suggesting possible under-reporting in the PMI data because policyholders are utilising free NHS services instead.

On combining these two main condition groups with the other minor conditions, we find that this choice of threshold provides an overall A/E ratio across all the ages and conditions close to 100%. Although for individual ages the A/E ratio various within the range of 79% to 126%, for ages 25 to 69. This is reasonable as for the age range we are

interested in from 30 to 59, the developed PMI actual paid will generally be greater than the expected, so we will be slightly conservative when pricing from our fitted actual incidence rates.

4.6.2 Crude Central 1st Incidence Rate for Individual Conditions

On dividing the developed paid counts (>£2,000) for the individual conditions shown in Table 31 (Appendix 12.6) by the exposure shown in Table 7, we have the following crude central incidence rates (x10,000) for the individual and grouped conditions in Table 8.

Table 8: The female crude developed central incidence rates (x10,000) for the individual or grouped condition shown.

1st incident condition	Age Range	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	20-69
	Exposure '000	**80.0**	**154.7**	**143.1**	**147.8**	**140.5**	**137.8**	**143.6**	**133.3**	**86.3**	**71.7**	**59.4**	**46.9**	**34.3**	**15.1**	**1,394.4**
Malignant Cancer	**Breast**	0.5	1.1	2.4	5.9	8.9	13.5	12.6	10.8	10.3	11.0	8.9	3.8	3.7	2.0	7.4
	Melanoma of skin	0.9	0.9	2.2	3.1	6.2	7.4	7.6	9.2	10.2	9.0	6.4	7.7	4.8	3.5	5.5
	Other skin	0.3	0.2	0.8	1.1	1.4	2.0	3.2	3.5	4.4	4.6	2.9	6.1	2.7	5.4	2.2
	Ovarian	-	-	0.5	0.7	1.1	1.4	1.7	2.0	3.3	4.5	1.6	1.1	0.3	-	1.3
	Colon	0.3	0.1	0.1	0.4	0.9	1.2	2.1	2.6	4.9	4.1	6.9	5.1	1.8	3.4	1.8
	Bladder	-	-	-	0.1	0.1	0.1	0.6	0.8	1.7	2.0	1.2	2.0	2.7	2.0	0.6
	Lung	-	-	0.1	0.2	0.2	1.3	0.9	0.8	1.9	2.7	2.0	3.3	1.5	0.9	0.8
	Stomach	-	-	-	0.1	0.2	0.1	0.4	1.2	0.4	1.4	0.7	0.7	0.9	-	0.4
	Colo-rectal	-	-	-	-	0.2	0.4	0.3	0.9	1.1	1.9	1.2	1.1	1.5	-	0.5
	Pancreatic	-	-	-	0.1	0.1	0.2	0.6	0.8	0.8	1.6	1.6	0.2	0.6	-	0.4
	Kidney & urinary	-	0.1	-	-	0.1	0.5	0.7	0.7	1.6	0.9	0.3	1.1	0.6	-	0.4
	Cervix uteri	0.4	0.1	0.7	0.3	0.4	0.3	0.5	0.6	0.2	0.3	0.2	0.2	-	-	0.4
	Body of uterus	-	-	0.1	0.1	-	0.5	0.4	0.3	0.4	0.9	0.2	0.4	-	0.7	0.2
	Brain	0.1	0.1	0.2	0.1	0.4	0.7	0.4	0.7	1.2	1.3	0.2	-	-	-	0.4
	Other Malignant	1.9	1.0	1.2	1.5	2.4	4.0	6.2	5.7	8.9	9.9	10.5	7.5	7.8	3.1	4.2
	All Malignant Cancer	**4.4**	**3.7**	**8.3**	**13.5**	**22.6**	**33.6**	**38.0**	**40.5**	**51.3**	**56.0**	**44.6**	**40.2**	**28.8**	**21.0**	**26.3**
	Benign Brain Tumour	**0.3**	**-**	**0.1**	**0.1**	**0.4**	**0.2**	**0.6**	**0.7**	**0.4**	**0.1**	**0.5**	**0.7**	**-**	**-**	**-**
Cardiovascular	**Heart Attack**	-	-	-	0.2	0.4	1.0	1.2	2.0	2.0	2.1	2.2	2.6	3.3	3.5	6.2
	Heart Valve	0.1	0.1	0.1	-	0.1	0.1	0.3	0.7	1.1	1.9	2.4	2.8	0.3	-	-
	Aorta Graft	0.1	-	-	0.1	0.1	0.2	0.3	0.5	1.7	2.0	1.4	2.6	1.5	0.7	0.2
	By-Pass	-	-	-	0.1	0.4	0.7	0.6	2.1	5.2	5.1	6.2	3.0	2.1	-	-
	Stroke	-	0.1	0.1	0.1	0.4	0.6	0.5	0.6	1.5	2.7	6.4	4.7	8.3	6.8	1.5
	All Cardiovascular	**0.3**	**0.2**	**0.2**	**0.3**	**1.4**	**2.7**	**2.9**	**5.9**	**11.5**	**13.9**	**18.6**	**15.8**	**15.5**	**10.9**	**34.3**
Neurological	**Parkinson's**	-	-	-	-	-	-	0.1	-	0.1	0.3	0.5	0.2	0.3	0.7	0.5
	Multiple Sclerosis	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	-	-	-	-	-	0.5
	Motor Neurone	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	1.4
	All Neurological	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.3**	**0.1**	**0.6**	**0.3**	**0.5**	**0.2**	**0.3**	**0.7**	**4.5**
Accidental	**Deafness**	**-**	**0.1**	**-**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.4**	**0.1**	**0.2**	**0.2**	**-**	**-**	**0.3**
	Blindness	**-**	**0.1**	**0.1**	**-**	**0.1**	**0.1**	**0.3**	**0.4**	**1.5**	**1.0**	**1.5**	**2.6**	**3.8**	**2.0**	**1.0**
All Conditions		**5.1**	**4.2**	**8.9**	**14.1**	**24.8**	**37.0**	**42.2**	**47.8**	**65.6**	**71.4**	**65.9**	**59.7**	**48.4**	**34.6**	**0.1**

As highlighted in Table 8, we note that the modal ages for breast cancer incidence are 45-54, whereas for the melanoma and other skin cancers the modal ages are 55-69 and 50-79, respectively. For colon cancer the modal incidence is at a far higher age range of 60-79. For the remaining cancers the modal incidence is between ages 60 to 89, because of the sparseness of the data resulting in a wide possible range. Overall, taking all the cancer conditions (including those components not shown) this modal incidence centres around ages 60-69.

For cardiovascular conditions the overall modal age of incidence centres around ages 70-84, because of the large number of incidences for by-pass at the younger ages of 60-79, together with the stroke and heart incidences at the older ages from 70 to 89.

Overall, combining the lower modal age range for cancer (60-69) with the older modal age range for cardiovascular (70-84), we have a range for the modal age for all the conditions over the age range 60-79.

The last few individual cancer conditions shown and the other minor neurological, accidental conditions shown in Table 8 have too sparse data to determine the precise modal age or attempt to perform a graduation in order to obtain smooth fitted incidence rates. Therefore, we shall only graduate the 1st few cancers individually. This will allow the possibility of these main cancers to be excluded in a product where there is no coverage for pre-existing condition as undertaken in section 7.4. In addition, we shall graduate the overall cancer, cardiovascular and total crude incidence rates in sections 4.7 to 4.9.

4.7 The 2nd Crude Central Incidence Rate

For our choice of a £2,000 claim threshold, we obtain the following female paid claims, exposure and crude 2nd incidence rate for all the conditions combined in Figure 4.

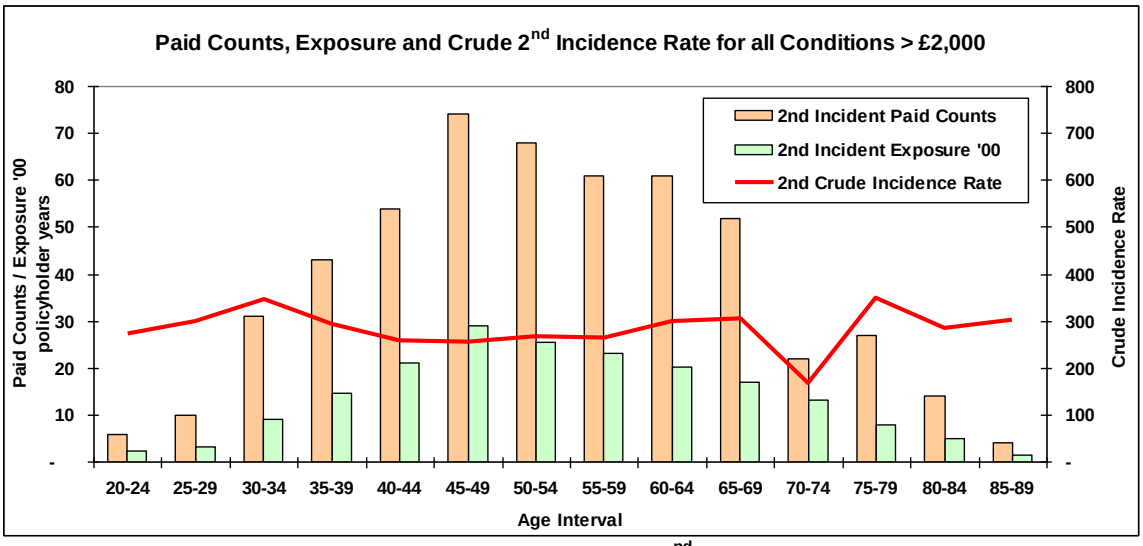


Figure 4: Paid claims, exposure and corresponding crude 2nd central incidence rate

From Figure 4 we note that the female paid counts on the 2nd incident follow the relative size of the total exposure fairly well across all the ages resulting in the approximately flat crude 2nd central incidence rate. The exposure is the total policy year exposure from any one of the 1st qualifying conditions to either any 2nd qualifying condition, death, withdrawal or the latest available policy renewal date.

For our data we shall consider the two alternatives of the 2nd incident occurring from any of the possible CI conditions (as discussed in section 4.7.1), or strictly the same 2nd incident condition (as discussed in section 4.7.2).

4.7.1 Crude 2nd Central Incidence Rate for Any Individual Conditions

The following Table 9 shows the calculation of the crude 2nd central incidence rate for any individual condition given that the 1st incident was either breast cancer, skin cancer, any of the cancers, any of the cardiovascular conditions, or any of the conditions.

Table 9: The female crude 2nd central incidence rate (i/E) for any individual condition given that the 1st incident was either breast cancer, skin cancer, any of the cancers, any of the cardiovascular conditions, or any of the conditions.

	post 1st Breast Cancer Incident			post 1st Skin Cancer Incident			post 1st All Malignant Cancer Incident			post 1st Cardio-vascular Incident			Post 1st All Condition Incident		
Age Group	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate i/E	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate i/E	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate i/E	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate A/E	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate i/E
20-24	-	17	-	-	16	-	2	119	0.017	-	7	-	3	133	0.023
25-29	3	60	0.056	1	25	0.041	9	174	0.049	1	8	0.134	11	200	0.053
30-34	9	132	**0.066**	7	88	**0.085**	19	402	**0.048**	-	19	-	19	446	0.043
35-39	21	303	**0.070**	6	115	0.054	38	673	**0.056**	-	18	-	38	701	0.054
40-44	17	473	0.037	13	176	0.076	47	989	**0.047**	2	60	0.034	49	1,093	0.045
45-49	35	839	0.041	13	271	0.046	69	1,653	0.042	2	135	0.015	72	1,821	0.039
50-54	25	766	0.033	5	289	0.018	68	1,810	0.037	3	120	0.026	73	1,992	0.037
55-59	21	597	0.035	12	335	0.035	58	1,753	0.033	4	257	0.016	63	2,080	0.030
60-64	14	362	0.040	10	197	0.049	64	1,330	**0.048**	5	396	0.013	77	1,800	0.043
65-69	5	354	0.014	8	150	0.051	50	1,129	**0.045**	8	337	0.024	62	1,504	0.041
70-74	4	211	0.019	2	96	0.022	21	770	0.027	5	372	0.014	28	1,198	0.023
75-79	1	55	0.019	10	91	**0.108**	32	482	0.065	3	212	0.015	36	739	0.048
80-84	1	44	0.023	3	33	**0.094**	13	256	0.052	2	168	0.012	15	463	0.033
85-89	2	12	0.168	-	5	-	4	76	0.055	-	42	-	5	126	0.041
20-89	**159**	**4,225**	**0.038**	**90**	**1,888**	**0.048**	**494**	**11,617**	**0.043**	**36**	**2,151**	**0.017**	**550**	**14,297**	**0.038**

From Table 9 the crude 2nd central incidence rate of any condition from breast cancer decreases from a peak of 7% at ages 35-39, to 2% by ages 70-79. This peak may be an anomaly due to the profile of our age range, with a growing book of business and the small number of 2nd incidents making the incidence rates volatile. Similarly, for malignant skin cancer which decreases from a peak of 8.5% at ages 30-34, to 2.2% by ages 70-74.

Alternatively, this may be a true feature for each of these conditions, so we shall keep this feature in our graduations. One rationale may be if the policyholder is unlucky to be part of the small minority that is susceptible to contract breast cancer or skin cancer at a young age, then further treatment is probably more likely compared to an older population where the common background 2nd incidence rate across all ages and conditions is more prevalent.

On adding over all the other cancer conditions the overall fitted "all cancer curve" becomes flatter as the higher incidence at the youngest ages is not present in the remaining cancers.

The "all cardiovascular" curve has no clear pattern across ages, possibly due to lots of volatility in the component conditions which make up this aggregate value. So a flat 2nd incidence rate is the best that we can estimate.

For the other individual conditions the crude central incidence rates are shown in Table 42 (Appendix 12.9), which indicates that the data is too sparse when split by age to perform any graduation and we shall just assume the overall all CI conditions 2nd incidence rate in section 4.9.

4.7.2 Crude 2nd Central Incidence Rate for the Same Individual Condition

We can also consider the alternative narrower possibility that the individual condition for the 2nd incident is required to be exactly the same condition as the 1st incident. For example, in Table 10 we have selected breast cancer, skin cancer, all the cancers, all the cardiovascular conditions, or all the conditions.

Table 10: The female crude 2nd incidence rate (i/E), where the condition is equal to the 1st incident condition of either breast cancer, skin cancer, all the cancers, all the cardiovascular conditions, or all the conditions.

	post 1st Breast Cancer Incident			post 1st Skin Cancer Incident			post 1st All Malignant Cancer Incident			post 1st Cardio-vascular Incident			Post 1st All Condition Incident		
Age Group	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate i/E	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate i/E	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate i/E	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate A/E	Number of 2nd Incidents i	Exposure E	Crude Incidence Rate i/E
20-24	-	17	-	-	16	-	2	119	0.017	-	7	-	3	133	0.023
25-29	-	60	-	3	25	0.127	5	174	0.030	-	8	-	5	200	0.026
30-34	2	132	0.015	6	88	0.072	9	402	0.023	-	19	-	9	446	0.021
35-39	12	303	**0.041**	2	115	0.018	21	673	0.030	-	18	-	21	701	0.029
40-44	12	473	**0.026**	8	176	0.047	30	989	0.031	1	60	0.017	31	1,093	0.029
45-49	21	839	**0.025**	9	271	0.035	41	1,653	0.025	2	135	0.015	44	1,821	0.024
50-54	18	766	0.023	3	289	0.011	41	1,810	0.023	-	120	-	43	1,992	0.022
55-59	12	597	0.021	9	335	0.028	40	1,753	0.023	-	257	-	40	2,080	0.019
60-64	6	362	0.017	2	197	0.011	28	1,330	0.021	1	396	0.003	35	1,800	0.020
65-69	4	354	0.012	4	150	0.029	23	1,129	0.021	1	337	0.003	25	1,504	0.017
70-74	4	211	0.019	-	96	-	12	770	0.016	3	372	0.008	16	1,198	0.013
75-79	-	55	-	3	91	0.036	14	482	0.028	2	212	0.010	16	739	0.021
80-84	-	44	-	2	33	0.062	4	256	0.016	-	168	-	4	463	0.009
85-89	-	12	-	-	5	-	1	76	0.013	-	42	-	2	126	0.016
20-89	**92**	**4,225**	**0.022**	**54**	**1,888**	**0.028**	**271**	**11,617**	**0.023**	**10**	**2,151**	**0.005**	**294**	**14,297**	**0.021**

Note: The exact total exposure time E is the number of policyholder years post 1st incident (before 2nd incident, death or withdrawal).

As expected in Table 10 the 2nd incidence rate for strictly the same condition are smaller than for 'any' 2nd incidence rate in Table 9. In particular, we are seeing 29% (10/36) of the 2nd cardio-vascular incident is for a repeated 2nd cardio-vascular incident, rather than for a new condition. In contrast 55% (271/494) of the 2nd cancer incidents are due to an identical cancer condition. This suggests a far higher proportion of 2nd conditions post a cardiovascular 1st condition are for non-cardiovascular conditions, compared to a non-cancer 2nd condition after a cancer 1st condition.

For skin cancer we note a very high reoccurrence at ages 25 to 34 for the same or any other condition in Table 9. This is possibly due to the nature of the condition meaning that repeated hospital visits for regular checking of the same skin area could take place

annually with on-going long-term treatment, rather than a being a separate new skin cancer incident which is ideally what we wish to capture.

There is not the same degree of curvature for the crude breast cancer incidence rate curve, possibly suggesting that the previous local peak at around ages 30-34 was due to incidents from breast cancer to other CI conditions, rather than further breast cancer incidents.

The full table of fitted values are shown in Table 43, in Appendix 12.9.

4.8 Malignant Cancer Duration

As an aside before considering graduation of the above developed incidence rates, we shall consider whether there is any duration effect for the cancer condition since the policy inception or after the 1st treatment date. We have chosen cancer in order to consider a more homogeneous population for detecting a duration effect, otherwise with all the conditions an apparent higher incidence at a particular age and duration may just be an artefact of having a higher proportion of certain "high incidence" conditions at a particular age. We have insufficient data to determine whether there is a duration effect for non-cancers.

4.8.1 Duration from Policy Inception until the 1st Incident of Malignant Cancer

As we have the full information for each claimant we know how soon after the policy inception that the start of the 1st claim occurred. So we can determine the select incidence rates and whether there is a duration effect. This is important as we need to determine the shortest time interval after each treatment to apply a no claims moratorium which captures most of the historical claims experience.

For each of our paid malignant cancer claims (without development) in a particular age interval we determined which duration year since the policy inception the claim corresponded together with the corresponding total actual exposure. The exposure was based on the number of days from the policy inception until either the start of the 1st claim, death, withdrawal or the end of the interval (as shown in Table 44, Appendix 12.10). On taking the ratio of the number of paid claims (greater the £2,000) to this exposure the corresponding crude incidence rates were determined in Table 11 below.

Table 11: The female malignant cancer (ex BBT) paid crude central incidence rate at each duration since policy inception.

Age Interval	Incidence Rate x10,000 (Paid Claims / Exposure) at Duration								
	0 - 0.25	0.25 - 1	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5+	All
20-29	2.3	0.4	4.5	2.7	2.0	3.8	1.2	3.4	**3.2**
30-39	10.2	2.2	18.9	7.7	8.1	6.5	10.5	11.5	**11.4**
40-49	19.1	4.5	39.9	24.4	26.1	23.4	26.9	27.4	**29.1**
50-59	26.0	5.8	52.0	32.8	38.0	40.9	33.9	34.4	**39.4**
60-69	19.2	5.0	76.9	48.4	50.2	62.5	58.7	55.6	**59.8**
70-79	8.4	3.7	62.9	40.7	29.4	35.0	45.6	34.9	**42.7**
80-89	3.3	0.9	43.3	30.2	38.6	19.1	21.4	17.9	**29.6**
20-89	**88.4**	**22.5**	**37.1**	**22.3**	**23.0**	**23.9**	**24.1**	**23.1**	**26.3**

From Table 11 we note that the crude central incidence rate is far higher for the 1st year after policy inception (duration 1) compared to the subsequent years. The overall incidence rate in duration year 1 (37.1 per 10,000) across all ages 20-89 is 66% higher compared to duration year 2 (22.3 per 10,000). The incidence rate in each age interval is fairly steady from duration year 1-2 to duration year 4-5, and in line with the "ultimate" duration at year 5+.

There is probably a selection effect in the 1st year of the policy, which would apply to the standard SACI/ACI product, as well as the product with the "buy-back" option.

In practice, a moratorium of say 3 months, would remove a fair proportion of the higher claim incidence in the 1st duration year. For our PMI claims data we find in Table 44 (Appendix 12.10) that approximately 50% of the 1st year duration claims occur within the first 3 months.

Assuming (conservatively) an even split of exposure across the 1st year leaves the remaining 9 months of the 1st duration year with an overall incidence rate of 22.5 per 10,000 (comparable to duration years 2 to 5+). In practice, the exposure in the first 3 months would be smaller due to the portfolio growing, resulting in an even lower incidence rate for the last 9 months of the 1st year.

So overall, we can be reasonably sure that after 3 months there is no dramatic duration effect with the PMI malignant cancer claims > £2,000. For simplicity in our analysis, we shall ignore the duration effect from the policy inception to the 1st incident, and include all these claims when graduating, even though this will lead to slightly more conservative results than in practice with a typical 3 month moratorium in place from policy inception.

4.8.2 Duration from the 1st Incident of any condition, until the 2nd Incident of Malignant Cancer

A similar exercise was performed in Appendix 12.10 for calculating the incidence rate form the end date of the 1st incident of any condition, to the start date of the 2nd incident of malignant cancer claims, as shown in Table 12 below.

Table 12: The female malignant cancer (ex BBT) paid crude 2nd central incidence rate at each duration since the 1st incident of any condition, with no moratorium in place.

	Incidence Rate x10,000 (Paid Claims / Exposure) at Duration								
Age Interval	0 - 0.5	0.5 - 1	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5+	All
20-29	717	1,020	858	253	-	-	-	-	**199**
30-39	855	1,050	948	289	72	90	122	57	**264**
40-49	1,052	1,269	1,156	298	127	89	-	44	**272**
50-59	1,058	1,441	1,241	283	52	136	-	100	**328**
60-69	1,363	1,230	1,300	254	162	63	89	69	**338**
70-79	666	1,450	1,041	294	164	110	89	12	**275**
80-89	1,337	955	1,152	545	581	-	-	56	**306**
20-89	**1,046**	**1,283**	**1,159**	**289**	**119**	**95**	**41**	**59**	**297**

The incidence rates in Table 12 show a far greater select effect than Table 11 with the incidence rate in the 1st duration year (1,159 per 10,000) considerably higher than the remaining years. From Table 45 (Appendix 12.10) this 1st year accounted for 69% (388/559) of the paid claims. This higher 1st select year incidence rate is reasonable as we would expect a higher 2nd incidence rate shortly after the 1st incidence rate, while the

patient is still recovering and most of the claims are a possible consequence of the 1st claim (whose effect diminishes over time).

We could, as undertaken by the current insurance providers, assume a 1 year moratorium to remove these claims from our analysis. However, in order to provide a more worthwhile product to the consumer, we could pay all claims after 180 days (about half of the incidence in the 1st year) and only those claims from a different condition after 30 days, as shown in the following Table 13.

Table 13: The female malignant cancer (ex BBT) paid crude 2nd central incidence rate at each duration since the 1st incident of any condition, with our 180 day same condition (30 days different condition) moratorium in place.

	Incidence Rate x10,000 (Paid Claims / Exposure) at Duration								
Age Interval	**0 - 0.5**	**0.5 - 1**	**0 - 1**	**1 - 2**	**2 - 3**	**3 - 4**	**4 - 5**	**5+**	**All**
20-29	472	930	682	240	-	-	-	-	**180**
30-39	315	929	604	264	68	87	118	37	**203**
40-49	475	1,165	803	299	121	86	-	16	**220**
50-59	421	1,311	844	219	49	131	-	60	**247**
60-69	773	1,135	944	215	154	61	87	67	**286**
70-79	279	1,222	729	274	155	160	-	-	**221**
80-89	702	792	744	494	572	-	-	60	**272**
20-89	**487**	**1,156**	**804**	**258**	**113**	**97**	**39**	**37**	**238**

From Table 13 we note that we would be paying 70% (804/1159) of the incidence rate in the 1st duration year compared to Table 12 with no moratorium. In terms of the total number of historical paid claims from Table 45 this would have corresponded to 82% (458/559) of the paid claims rather than 31% (1-388/559) with the 1 year moratorium in Table 46.

Overall, as our choice of moratorium reduces the 2nd incidence rate by 50% in the 1st 6 months this hopefully removes the biggest impact of the duration effect and assuming non-select rates for the remainder of the dissertation will be more reasonable than trying to obtain unrealistic select rates once we split the data further by age.

4.9 Graduation of Client (PMI) Data

The last few individual cancer and other minor conditions shown previously in Table 8 (section 4.6) have too sparse data to perform a graduation in order to obtain smooth fitted incidence rates. Therefore, we shall only graduate the 1st few cancers individually, as well as graduating the overall cancer, cardiovascular and the total incidence in the following section 4.9.1.

4.9.1 MLE of Gompertz-Makeham Curves

We have assumed that the number of transitions m_x^{jk} from say a state *j* to a state *k* follows a Poisson distribution. Then the corresponding logarithm of the central force of mortality

$$\ln (\mu_x^{jk}) = \ln (m_x^{jk} / E_x^{jk})$$

can be fitted using the following Gompertz-Makeham *GM* (*r* = 0, *s = 1, 2, 3*) curves:

$$GM(0, 1) = e^{\beta_1}, \qquad GM(0, 2) = e^{\beta_1+\beta_2 x}, \quad GM(0, 3) = e^{\beta_1+\beta_2 x+\beta_3 x^2}.$$

The general *GM* (*r*, *s*) formula is given by Forfar *et al.* (pp. 20, 1988) for the family of parametric polynomial curves and is detailed in Appendix 12.11. We only considered *s* <= 3, as we found that for *s* > 3 the higher polynomial curves provided no noticeable improvement in overall fit. Similarly, for *r = 1*, we found that the *GM* (*1*, *s*) provided a similar fit to *GM* (*0*, *s*).

On substituting for m_x^{jk}, E_x^{jk} at each age exact *x*, we performed maximum likelihood estimation to determine the parameters α_i and β_j for the above range of *GM* (*r*, *s*) models.

4.9.2 Model Selection Criteria

On performing the graduation we have a wide range of possible fitted curves. To determine an adequate fit we shall use the "Likelihood Ratio (LR) Test" (pp. 471, McCullagh and Nelder, 1989) to compare the adequacy of the fit of each *GM(0, s)* curve as we increase the number of parameters *s* from 1 to 5.

From the previous section on log likelihood maximisation, we can determine the likelihood ratio test statistic

$$D = -2\,[\ln(L_1) - \ln(L_2)],$$

where L_1 and L_2 are maximum log-likelihoods assuming different *GM(0, s)* curves, where L_1 has fewer parameters than L_2.

Our criteria for determining the number of parameters in our final "best-fit" curve is based on whether the increase in *D* on adding an additional parameter was significant and that we should reject L_1. This was determined by whether the increase in *D* exceeded the 5% tail of a chi-square distribution with 1 degree of freedom.

Examples of the above *D* statistic, for unit step increases in the number of parameters for the *GM(0, s)* curves (including claims for "all conditions" > £2,000), are shown in the following Table 14.

Table 14: The likelihood ratio *D*-test statistic comparison with χ^2 on 1 df to determine a suitable GM(0,*s*) model.

Likelihood Ratio Test (including claims for "all conditions" > £2000)	Healthy to 1st Incident (*HA*)			1st Incident to Withdrawal (*AW*)		
	D-Test statistic	p-value	Conclusion	D-Test statistic	p-value	Conclusion
GM (0,2) vs GM (0,1)	1,596.3		Reject GM(0,1)	18.5	0.000	Reject GM(0,1)
GM (0,3) vs GM (0,2)	657.7	0.000	Reject GM(0,2)	13.6	0.000	Reject GM(0,2)
GM (0,4) vs GM (0,3)	**1.9**	**0.168**	**Accept GM(0,3)**	**0.3**	**0.557**	**Accept GM(0,3)**

Likelihood Ratio Test	1st Incident to Any 2nd Incident (AB^{Any})			1st Incident to the Same 2nd Incident (AB^{Same})		
	D-Test statistic	p-value	Conclusion	D-Test statistic	p-value	Conclusion
GM (0,2) vs GM (0,1)	**2.8**	**0.093**	**Accept GM(0,1)**	10.7	0.001	Reject GM(0,1)
GM (0,3) vs GM (0,2)	0.9	0.350	Accept GM(0,2)	**0.7**	**0.393**	**Accept GM(0,2)**
GM (0,4) vs GM (0,3)	2.1	0.147	Accept GM(0,3)	1.4	0.232	Accept GM(0,3)

In the above Table 14 we find that there was a significant improvement in fit on increasing from curve *GM(0,2)* to *GM(0,3)* for the healthy to 1st incident transition (*HA*) and withdrawal after 1st incident (*AW*). Similarly, *GM(0,1)* is acceptable for the 1st incident to any 2nd incident (AB^{Any}), or *GM(0, 2)* for the same 2nd incident (AB^{same}).

In addition, to ensure that the final choice of the *GM(0, s)* curve statistic *D* looks reasonable, we have also calculated the Bayes Information Criterion (BIC, Schwarz 1978) and the Akaike Information Criterion (AIC)[4] in the following Table 15.

[4] Select likelihood L_3 with minimum BIC $= -2 \ln(L_3) + k \ln(n)$, or likelihood L_4 with minimum AIC $= 2n - 2[\ln(L_4)]$ for parameters n and degrees of freedom k.

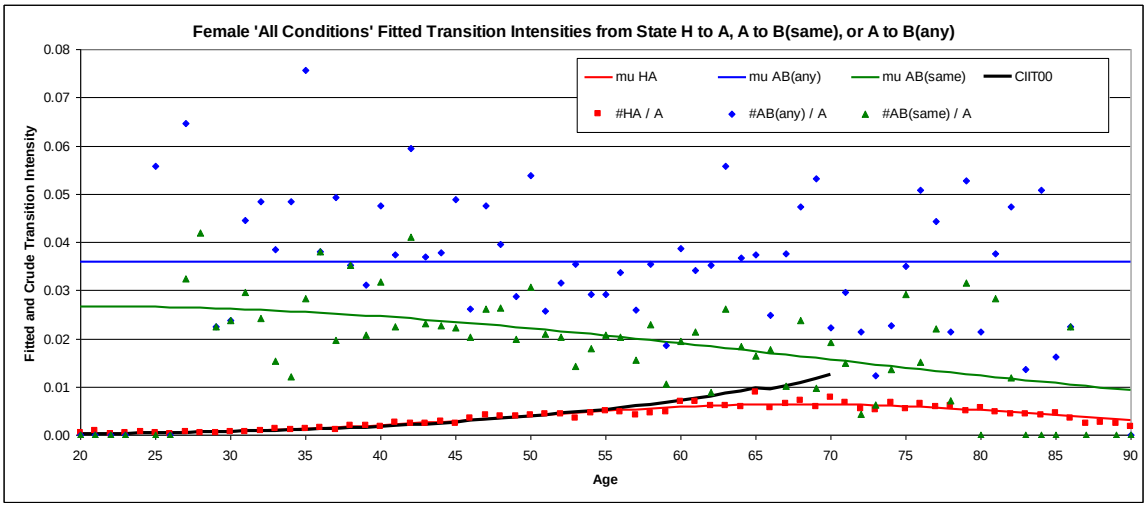
Table 15: The Bayes Information Criterion (BIC) and the Akaike Information Criterion (AIC) test statistics for an increasing number of parameters in each likelihood function.

Likelihood GM (0,s)	HA		AW		AB^{Any}		AB^{Same}	
	BIC	AIC	BIC	AIC	AIC	AIC	BIC	AIC
GM (0,1)	-28,491	-28,643	-1,393	-1,536	**-1,117**	**-1,269**	-126	-278
GM (0,2)	-30,092	-30,239	-1,416	-1,554	-1,124	-1,272	**-141**	**-289**
GM (0,3)	***-30,754***	***-30,897***	***-1,434***	***-1,568***	***-1,129***	***-1,273***	***-146***	***-290***
GM (0,4)	-30,760	-30,899	-1,438	-1,568	-1,136	-1,275	-152	-291
GM (0,5)	-30,765	-30,900	-1,442	-1,568	-1,140	-1,275	-156	-291

In Table 15 we have highlighted in bold blue our previous choice under the likelihood ratio test statistic which is approximately consistent with the minimum BIC or minimum AIC test statistic for transitions *HA* and *AW*. (Increasing to *GM(0,4)* or *GM(0,5)* only changes the last significant number slightly).

For the other transition AB^{Any} or AB^{same}, there is little difference between the *GM(0,1)* and *GM(0,3)*, or the *GM(0,2)* and *GM(0,3)* curves when considering the minimum BIC or minimum AIC test statistic. However, when fitting breast cancer only there is a difference, so for consistency between fitting curves to different conditions we assumed *GM(0,3)* throughout, even when *GM(0,1)* provides an adequate fit. In practice, the corresponding fitted transition intensity curves are practically identical, with a flat *GM(0,3)* blue curve for AB^{Any} in the following Figure 5.

Figure 5: **The fitted *GM(0,3)* transition rates for the 1st or 2nd incident, compared to the corresponding crude transition rates, and the CIIT00 1st incidence.**



From Figure 5 we note a reasonable graduation for the 1st transition rate *HA* is possible due to sufficient data. We have kept the feature of a fall off in 1st incidence rate after age 65 to allow an adequate fit with the data. An alternative view would be to follow the CIIT00 curve of increasing incidence on the assumption that we have inadequate data and should use the external insured experience instead.

However, the choice of the graduation curve is difficult for the 2nd transition rate AB^{Any} due to heterogeneity and lack of data causing high volatility, with a horizontal line (shown in blue) the only likely option. If we restrict the 2nd incident to strictly the same condition then we have the sloping curve (shown in green) possibly because the effect of the 1st condition (at young to middle age) has worn off, so less likely to undergo the same treatment again (at the oldest ages).

The standard set of goodness-of-fit tests for the above final choices for each of the transitions *HA*, AB^{Any} and AB^{Same} was undertaken in Appendix 12.12. These were all acceptable, except for outliers at a few particular ages, e.g. age 65, which needed to be removed for an acceptable χ^2 statistical test (as discussed in Appendix 12.12.2 and 12.12.3).

Individual standardised deviation normal plots were also undertaken in Appendix 12.12, where no significant issues arose with this choice of *GM(0,3)* curve for each transition. Although transitions to the death state can be fitted with a *GM(0,2)* curve, we shall consider instead an alternative method in section 4.10 because of data credibility.

All the transitions from the 2nd incident state *B* to the individual state *W*, provided an adequate fit with the *GM(0,2)* parameterisation, as discussed in Appendix 12.12.4.

4.9.3 The Fitted 1st Incidence Rate for the Main conditions

The resulting 'best' fit curves for the main conditions are shown in the following Figure 6, and for the prevalent cancers in Figure 7.

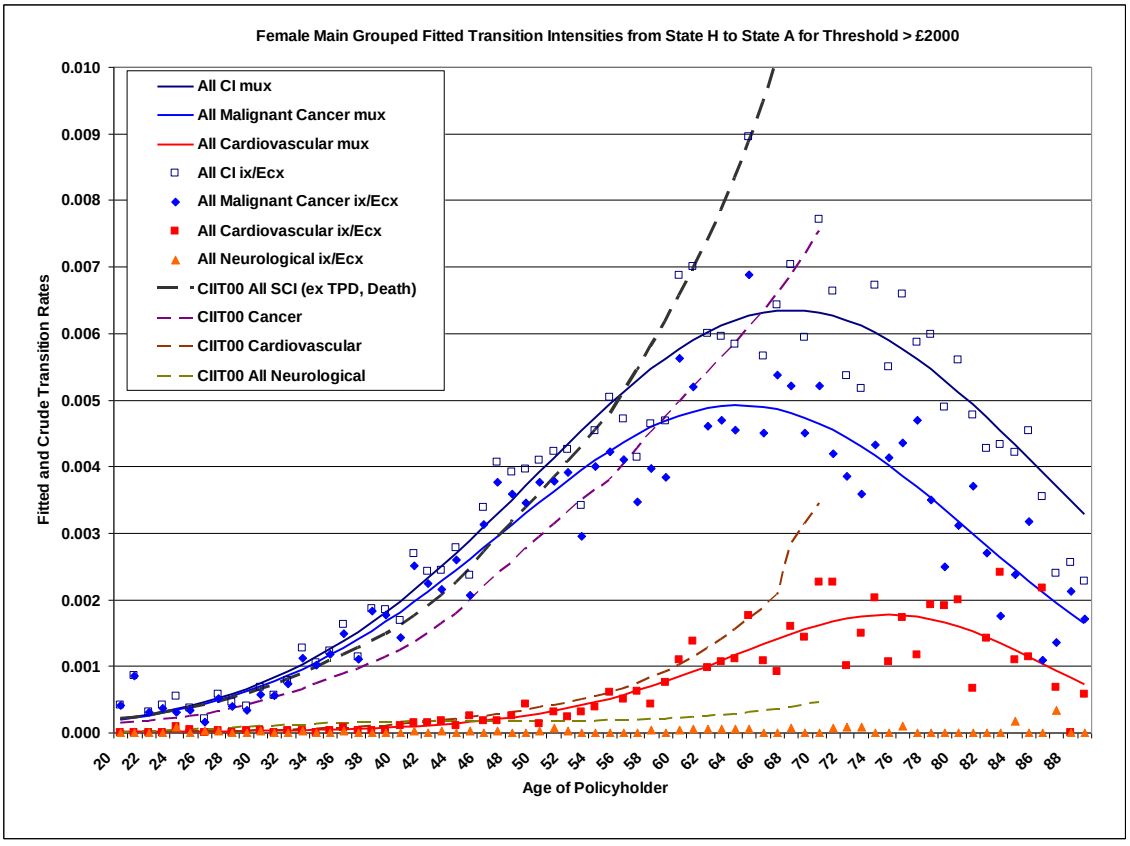


Figure 6: The female fitted 1st incidence transition intensities for all the conditions, all malignant cancer, and all cardiovascular grouped conditions, compared with the corresponding developed crude rates and the FNS CIIT00 incidence rates.

From Figure 6, our "best-fit" malignant cancer (blue) curve fits reasonably well to the developed crude incidence data shown by the blue diamonds. For ages below 59, we note a slightly higher incidence rate for our blue malignant cancer curve compared to the purple female non-smoker CIIT00 (pp.67, Brett & DuToit 2006) broken curve (as a result of the choice for our claim acceptance threshold of £2,000).

After age 59 our blue incidence rate curve levels off and begins to decrease, while the CIIT00 table continues to increase in magnitude. Provided we only look at policyholders up to age 65, then on balance we should be more conservative than the CIIT00 table.

The converse is true for the combined cardio-vascular conditions, where our fitted red cardio-vascular incidence rate curve is below the brown CIIT00 broken curve. As discussed previously we are probably a little light on the number of cardiovascular incidents.

The overall, combined fitted black curve for all our main CI conditions (after developing the claims) are more conservative than the corresponding CIIT00 SACI curve (excluding TPD and death) from ages 20 to 56. After age 56, our data suggests that the incidence is levelling off and even decreasing, resulting in a more optimistic incidence rate.

However, the exposure beyond age 56 is relatively small, resulting in an exposure weighted incidence rate from ages 20 to 69 of around 6% greater than the corresponding CIIT00 value for cancer, and 8% for all the conditions provided in the data.

This 8% additional incidence is a reasonable margin to allow for any missing neurological and accidental claims in our data, which the CIIT00 SACI experience suggests would be expected to be around this percentage of the total incidence.

4.9.4 Fitted 1st Incidence Rate for Malignant Cancer Individual Conditions

Similarly, we can graduate using the family of *GM(r,s)* polynomial curves for the main breast, skin, colon and ovarian malignant cancer conditions and compare them with the ONS population incidence rate curves, as shown in the following Figure 7.

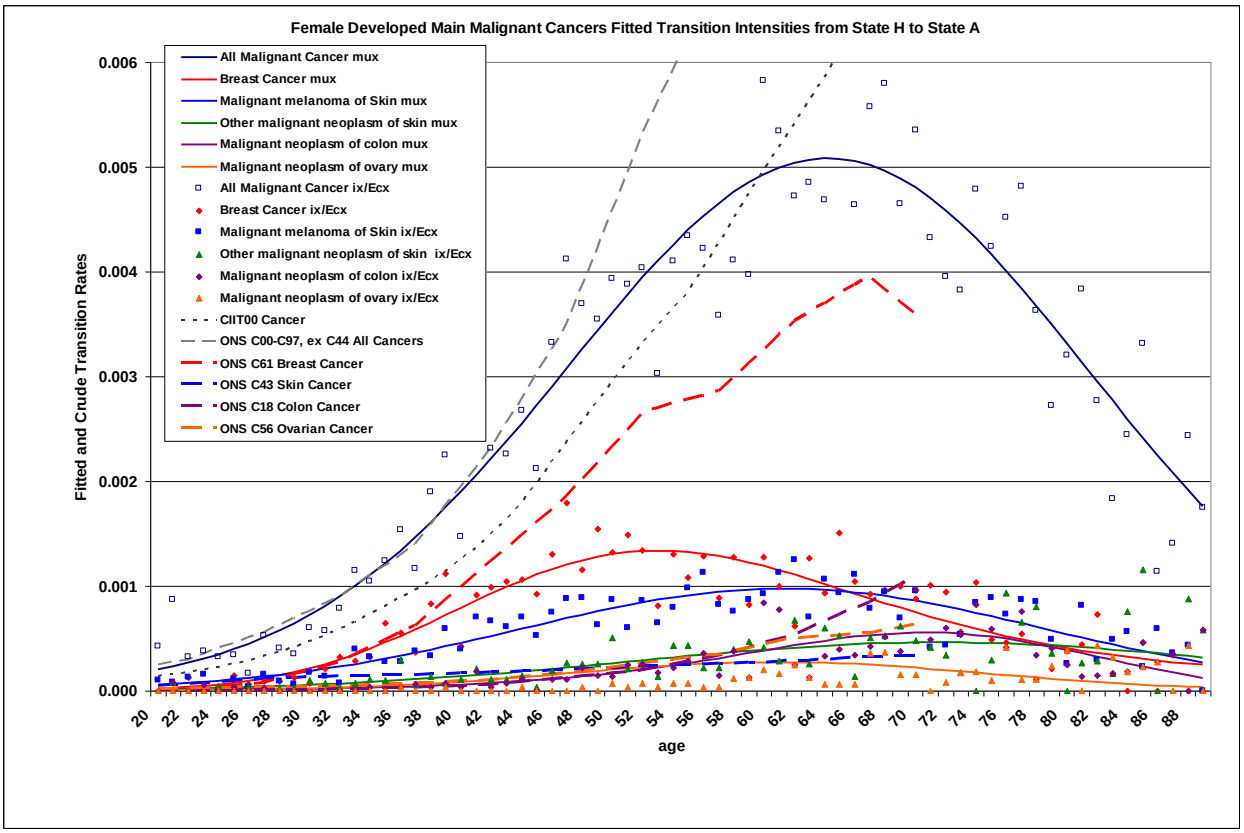


Figure 7: The female fitted 1st incidence transition intensities for the main individual malignant cancer conditions compared with the corresponding developed crude rates and the ONS cancer registration incidence rates.

From Figure 7 above, for our choice of threshold and developed claims the "All malignant" cancer (dark blue) curve provides a similar incidence rate to the ONS population cancer incidence rate below age 40 (broken grey curve). We also note that the insured FNS CIIT00 stand-alone cancer (dotted) curve continues to increase beyond age 65, whereas our data and fitted curve indicates a decrease. We shall assume that our curve

is more appropriate for our product rather than trying to extrapolate our data in order to follow the direction of the CIIT00 curve.

In Appendix 12.12, a more formal Chi-square test for goodness of fit fails due to the outliers at age 21 and 65, causing large standardised deviations. On removing these two points, the standardised deviations become more normally distributed with an acceptable Chi-square test statistic.

As we shall only be considering 10-year term CI policies, with an oldest inception age of 60, the rapid decrease in incidence after age 70 will not affect the cash flow calculations. However, we have decided to include the oldest ages from 70 to 89 as this gives a better fit to our 'humped' curve.

As the malignant cancer looks reasonable we calculated the individual probabilities for each transition between states and age using the method discussed in Appendix 12.14, and shown by column 5 in Table 57 and Table 58 (Appendix 12.14.6).

In order that we can consider looking at individual exclusions for particular cancer treatments (as required for our *example 3* discussed in the introduction) we discuss our fitted breast cancer and skin cancer curves shown above in Figure 7.

4.9.4.1 **Breast Cancer Crude Incidence Rate**

From Figure 7 we see that the crude breast cancer rate (red curve) becomes increasingly lower than the ONS population incidence rate above age 37. Our lower insured incidence rate may be explainable by:

- The insurance providing access to earlier detection and prevention, reducing the incidence of expensive treatments.

- The insured population are generally from higher socio-economic groups, which are more likely to have healthier lifestyles with regard to smoking, alcohol and diet choices.

- The variability of our small insured breast cancer claimant population with an arbitrary claims threshold, making comparison difficult with a large general population.

Our incidence rate for breast cancer does not look too unreasonable peaking at 12 per 10,000 for ages 47 to 52 where we would expect most incidences, before decreasing to approximately 8 per 10,000 until age 69.

As we have no other alternative comparable insured table, we continued with this incidence rate and calculated the corresponding probabilities as shown by column 5 in Table 59 and Table 60 (Appendix 12.14.7).

4.9.4.2 **Skin Cancer Crude Incidence Rate**

For skin cancer (shown by the blue curve in Figure 7), we obtained a far higher incidence rate of 50 to 80 per 10,000, as age increases from 40 to 59, compared to the ONS cancer increase rate increasing to 25 per 10,000 over this age interval (broken blue curve). This is unusual, as our insured population would be expected to more informed about the dangers of skin cancer.

However, our higher insured incidence rate may be explainable by:

- Greater insured population affluence means that they may be able to take more sunny holidays throughout the year.

- There may be a greater degree of adverse selection present, with a new policy taken out after noticing say, new skin moles/blemishes, which may take several years before becoming cancerous.

- The ONS C43 data may possibly be under-reporting the true extend of malignant skin cancer (with up to 23% reported in Yorkshire and Northern regions by Gavin and Walsh (pp.152, 2005)).

- There is a large potential overlap of our paid claims falling outside the criteria of C43 and within C44 – non-malignant skin cancer, especially if both are covered within a PMI policy then there is no strict need to accurately classify. Under-reporting of C44 is also a large problem as discussed in the English Cancer Statistics Registrations (pp.14, 2007).

As the above is problematic, we shall not consider any examples including (or excluding) only skin cancer. Although we have calculated the corresponding probabilities in column 5 of Table 61 and Table 62 (Appendix 12.14.8) to allow further investigations if required.

4.10 Mortality Incidence Rate

4.10.1 Crude Mortality Incidence Rate

We do not have information on the deaths of healthy policyholders, so we are unable to determine the overall mortality rate. However, we do have information on any claimant deaths after the 1st treatment until the current date, allowing us to determine the number of deaths, exposure and crude mortality rates post 1st incidence for all the malignant cancer, cardiovascular and all conditions in the following Table 16.

Table 16: The crude mortality rate (i/E) given that the 1st incident was any of the cancers, any of the cardiovascular conditions, or any of the conditions.

	post 1st All Malignant Cancer Incident			post 1st Cardio-vascular Incident			Post 1st All Condition Incident		
Age Group	Number of Deaths i	Exposure E	Crude Death Rate i/E	Number of Deaths	Exposure E	Crude Death Rate i/E	Number of Deaths	Exposure E	Crude Death Rate i/E
20-24	0	119	-	-	7	-	0	133	-
25-29	1	174	0.006	-	8	-	1	200	0.005
30-34	3	402	0.008	-	19	-	3	446	0.007
35-39	12	673	0.019	-	18	-	12	701	0.018
40-44	18	989	0.018	-	60	-	18	1,093	0.016
45-49	25	1,653	0.015	-	135	-	25	1,821	0.014
50-54	32	1,810	0.018	1	120	0.012	34	1,992	0.017
55-59	40	1,753	0.023	1	257	0.004	42	2,080	0.020
60-64	47	1,330	0.035	3	396	0.008	50	1,800	0.028
65-69	47	1,129	0.041	5	337	0.015	52	1,504	0.034
70-74	51	770	0.066	6	372	0.016	58	1,198	0.048
75-79	42	482	0.088	9	212	0.043	51	739	0.069
80-84	19	256	0.073	15	168	0.090	35	463	0.075
85-89	6	76	0.085	2	42	0.048	8	126	0.067
20-89	**343**	**11,617**	**0.030**	**43**	**2,151**	**0.020**	**389**	**14,297**	**0.027**

Note: The exact total exposure time E is the number of policyholder years post 1st incident (before the 2nd incident, death or withdrawal).

As a rough reality check the above Table 16 indicates a far higher mortality rate for malignant cancer between ages 20 and 70, than implied from the ONS 5 year cancer survival statistics (Walters *et al.* 2009). This is shown in the following Figure 8, on comparing with the fitted mortality transition intensities for the main conditions (Table 50 and Table 51 in Appendix 12.12.6).

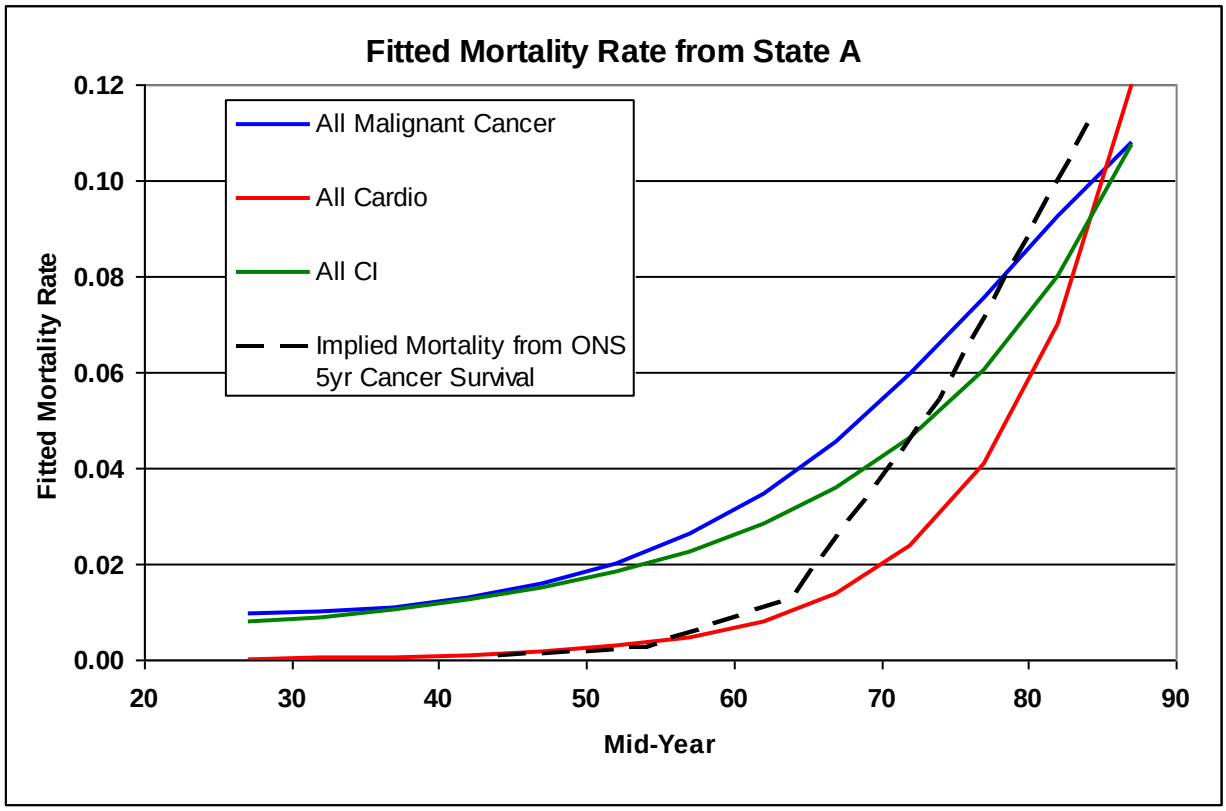


Figure 8: Fitted mortality transition intensities conditional on the 1st incident condition equal to any cancer, any cardiovascular, or any conditions, compared with the corresponding ONS 5 year cancer survival statistics.

The higher mortality rate observed for our curves in Figure 8 is partly because we are including mainly the short-term higher mortality rate following the date of the qualifying event, but not the medium-long term durations since surgery with lower mortality rate beyond our 1 to 7-year time span after the qualifying event.

In addition, a healthy policyholder who undergoes a qualifying event, and then succumbs to mortality within a year, should be recorded as a death from a healthy state, if we are

using integer probabilities in our calculation. In undertaking the previous calculations, these deaths are actually included within the mortality rate after the 1st treatment.

To obtain a more credible mortality incidence rate we would need a longer time span and timing rules for differentiating between a healthy death and a post 1st treatment death.

As this is not possible, we shall consider the following alternative more credible method to determine the long term expected mortality rate post treatment using industry tables.

4.10.2 Dash-Grimshaw Mortality Method

4.10.2.1 **Mortality after 1st Incident**

The client's PMI claimant experience was found not to be credible for determining the incidence of death required in our ACI product after the 1st incident. Therefore, we have used the Dash-Grimshaw method below to add the total deaths not due to CI causes onto our previously calculated stand-alone incidence rates, when we required accelerated incidence rates.

The Dash-Grimshaw method required the calculation of the total "additional deaths"

$(1-\Sigma\, k_x^i)\, q_x$ due to non-CI causes.

Where k_x^i = the proportion of deaths due to CI condition i for our insured population,

Σ = summation over the CI conditions,

q_x = the initial rate of mortality for the insured population (we shall use the standard CMI table TFN00).

The k_x^i for our small insured population are not credible, so we need to find individual k_x^i for a larger insured population. However, no such standard insured tables exist, so we have assumed that the same proportion of deaths for each CI condition holds as provided

in the general population CIBT02 tables of Robjohns *et al*. (pp. 189, 2006), which we shall denote by $k_x^{i\ \mathrm{CIBT02}}$.

Thus the mortality due to condition i is calculated as $q_x\ k_x^{i\ \mathrm{CIBT02}}$. On summing over all the CI conditions the total mortality is given by $q_x\ \Sigma_{\mathrm{All}\ i}\ k_x^{i\ \mathrm{CIBT02}}$.

We shall assume that if only a selection of CI conditions results in a first incident benefit payment, then we will still have a death benefit from the remaining 'other' CI conditions, with probability equal to $q_x\ \ \Sigma_{Other\ i}\ k_x^{i\ \mathrm{CIBT02}}$ from the 'other' CI conditions.

A practical example and further details are shown in Table 54 (Appendix 12.13).

4.10.2.2 **Mortality after the 2nd Incident**

We have insufficient data to determine a consistently increasing mortality rate after the 2nd incident with age. However, using the previous method we do know the mortality rate after the 1st incidence (including any subsequent incidents).

So to determine the mortality rate before and after the occurrence of any 2nd incident, we shall split this post 1st mortality rate in the same proportion as the number of deaths observed from the experience before and after the 2nd incident. However, with our data this is only possible with malignant cancer.

For more detailed individual cancers, we have 1 year and 2- 5 year general population survival rates from Walters *et al* (2009), which we have assumed are similar to our insured population. We have also assumed out of convience that on average the 2nd incident takes place after 1 year since the 1st incident, so that we can use these tables to determine the proportion of deaths in years 2 to 5, relative to years 1 to 5.

For splitting the death incident rate for our total cardiovascular conditions before and after the 1st incident, we shall assume that the British Heart Foundation 1 year population flat survival rate of 62% (British Heart Foundation, 2010) is suitable across all ages.

As we have no credible data for the neurological or accident type conditions, we have just assumed the proportion of our PMI observed deaths after the 1st incident summed across all ages.

Finally, as above, if we are only interested in a selection of CI conditions, then we would only be interested in the probability split of mortality for those conditions before and after the 1st incident. For the 'other' conditions there is no need to split the mortality in such a way as no benefit is payable on the 1st incident.

The above assumptions are not critical for determining realistic premiums, as for our age range from 30 to 60 the majority of benefit payments will be for the 1st or 2nd incident rather than death. Even if we decrease the proportion payable on the 1st incident, say to 50%, then the probability of a further 2nd incident for the remaining benefit payment, multiplied by the probability of the 1st incident, will still be greater than the probability of a death benefit from our original healthy state.

4.11 Withdrawals

From the original 10 years of data around 12% of the policies were no longer still in force because of withdrawal, as opposed to a claim or death, so we assumed a 12% withdrawal rate for our healthy lives.

For the withdrawals after the 1st incident we have the actual number of withdrawals, exposure post 1st incident and crude withdrawal rates, as shown in the following Table 17.

Table 17: The crude withdrawal rate (i/E), given that the 1st incident was either breast cancer, skin cancer, any of the cancers, any of the cardiovascular conditions, or any of the conditions.

	post 1st Breast Cancer Incident			post 1st Skin Cancer Incident			post 1st All Malignant Cancer Incident			post 1st Cardio-vascular Incident			post 1st All Conditions Incident		
Age Group	Number of Withdrawals	Exposure	Crude Withdrawal Rate	Number of Withdrawals	Exposure	Crude Withdrawal Rate	Number of Withdrawals	Exposure	Crude Withdrawal Rate	Number of Withdrawals	Exposure	Crude Withdrawal Rate	Number of Withdrawals	Exposure	Crude Withdrawal Rate
20-24	2	17	0.119	1	16	0.061	9	119	0.076	-	7	-	9	133	0.068
25-29	4	60	0.066	-	25	-	6	174	0.035	1	8	0.131	8	200	0.040
30-34	3	132	0.023	1	88	0.011	15	402	0.037	1	19	0.052	18	446	0.040
35-39	11	303	0.036	-	115	-	16	673	0.024	2	18	0.113	20	701	0.029
40-44	9	473	0.019	6	176	0.034	30	989	0.030	5	60	0.083	39	1,093	0.036
45-49	24	839	0.029	10	271	0.037	57	1,653	0.034	4	135	0.030	64	1,821	0.035
50-54	25	766	0.033	9	289	0.031	76	1,810	0.042	8	120	0.067	90	1,992	0.045
55-59	9	597	0.015	11	335	0.033	57	1,753	0.033	18	257	0.070	78	2,080	0.037
60-64	10	362	0.028	6	197	0.031	40	1,330	0.030	17	396	0.043	61	1,800	0.034
65-69	14	354	0.040	3	150	0.020	47	1,129	0.042	16	337	0.048	64	1,504	0.043
70-74	9	211	0.043	2	96	0.021	47	770	0.061	21	372	0.056	69	1,198	0.058
75-79	1	55	0.018	6	91	0.066	31	482	0.064	13	212	0.061	50	739	0.068
80-84	3	44	0.068	1	33	0.030	22	256	0.086	9	168	0.053	36	463	0.078
85-89	-	12	-	1	5	0.186	5	76	0.066	6	42	0.142	12	126	0.095
20-89	**124**	**4,225**	**0.029**	**57**	**1,888**	**0.030**	**458**	**11,617**	**0.039**	**121**	**2,151**	**0.056**	**618**	**14,297**	**0.043**

Note: The exact total exposure time E is the number of policyholder years post 1st incident (before the 2nd incident, death or withdrawal).

From Table 17 the overall CI “all conditions” withdrawal rate and the cancer withdrawal rates are not too dissimilar, so we assumed that the withdrawal rate for a particular condition was the same as the overall CI “all conditions” rate at a particular age with the fitting and curve testing undertaken in Appendix 12.12.4.

This assumption is conservative for cardiovascular conditions, with the withdrawal rates in the above table tending to be higher. Although the low numbers of withdrawals makes it difficult to be confident in splitting the withdrawal rates into any finer divisions by type of condition or cancer.

Similarly, for withdrawals after the 2nd incident (any condition or strictly the same), we have just assumed the combined CI rate, which had a lower, nearly flat fitted incidence rate across all ages compared to the fitted 1st incidence rate.

5 Extended CI Models

5.1 General Buy-back Model

We shall introduce a new "buy-back" model which extends the standard ACI model to allow the healthy policyholder to pay an additional premium at inception that provides automatic reinstatement of the ACI coverage after a claim free period, should any of the qualifying CI conditions be satisfied.

The additional premium should be far less for a healthy policyholder (which we shall denote by state *H*) than for a policyholder applying for reinstatement after the 1st qualifying condition (denoted by a 1st post incident state *A*) has occurred. This is because a far smaller proportion of policyholders in state *H* are ever likely to claim for a 2nd qualifying condition (which we have denoted by a 2nd post incident state *B*) compared to policyholders already in state *A*.

We can denote the possible policyholder states by extending the multi-model CI framework of Dash and Grimshaw (pp.163, 1990) to include our state *B* as shown in Figure 9 below.

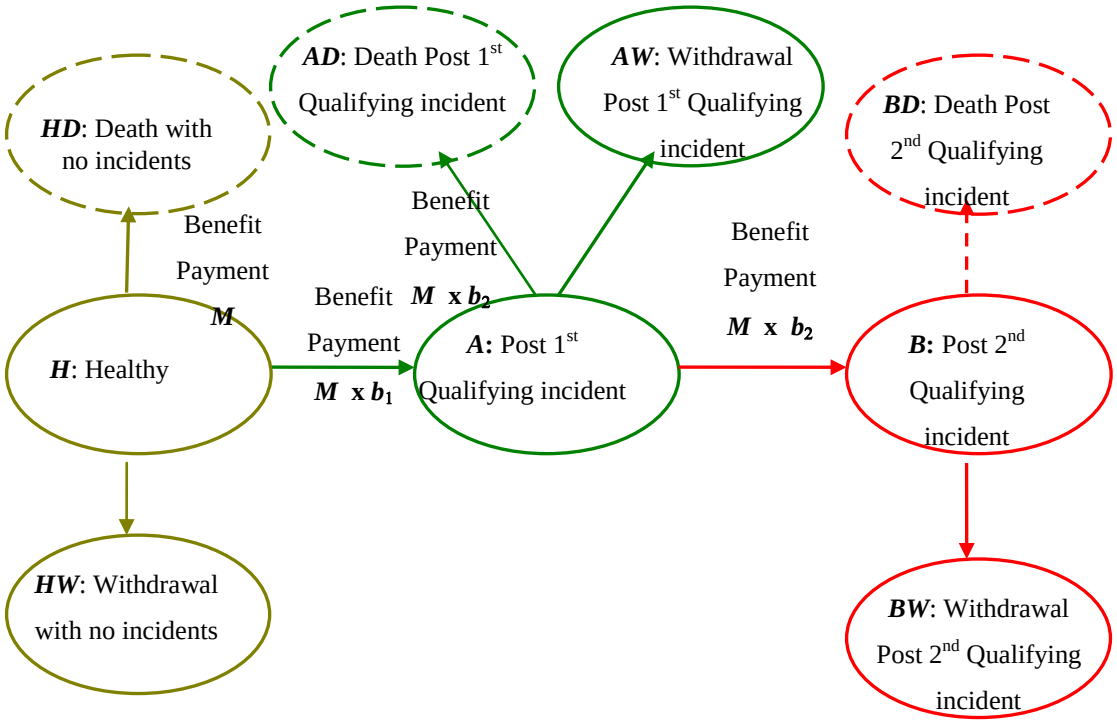


Figure 9: Our extended accelerated critical illness model showing the usual healthy state *H* and post 1st incident state *A* in green, and introducing a 2nd incident state *B* in red. For completeness, the corresponding absorbing death states *HD*, *AD*, *BD* (dotted lines) and for the withdrawal states *HW*, *AW* and *BW* are also shown.

Figure 9 shows all the possible transitions for a policyholder out of the healthy state *H*, post 1st incident state *A*, and post 2nd incident state *B*. As discussed below, for our *example 1* we shall set $b_1 = 0.5$ and $b_2 = 0.5$.

Choice of Relative Size of Benefit Reinstatement

Our interest is in those transitions that lead to a benefit payment following satisfaction of either the 1st or 2nd qualifying CI condition. In addition, for an ACI product we are also interested in payments on death from any state.

We have split the benefit payment amount £*M* into a:

- 1st payment of £*M* x b_1 , where $0 \leq b_1 \leq 1$
- 2nd payment of £*M* x b_2, where $b_2 = 1 - b_1$.

The choice of b_2 is so that the policyholder has always received a total accumulated benefit payment of £M on the 2nd incident or death (assuming one of these occurs within the policy term).

By altering the proportion b_1 we can obtain a wide range of possible cases for our general buy-back model. Specifically:

1) Setting $b_1 = 1$, we obtain the "standard" ACI model per unit of benefit (as shown by the green circles in Figure 1 only).

2) Setting $b_1 < 1$, we obtain a reinstatement (as shown by the additional red circles in Figure 1) where we have the following two possibilities:

   - On setting $b_1 > 0.5$, a partial reinstatement of benefit is provided, with any 2nd benefit payout lower than the 1st benefit payout. For example, if the insurer wishes to exercise caution by limiting the relative size of 2nd benefit payouts in case the assumptions regarding the 2nd incidence rate turn out to be too optimistic.

   - Conversely, setting $b_1 < 0.5$, then the insurer is potentially paying a higher 2nd benefit payout compared to the 1st benefit payout. Including a delay is reasonable if a 2nd incident is likely to be far more traumatic for the policyholder than the 1st incident, thus aligning the size of benefit more to the policyholders needs.

3) Setting $b_1 = 0.5$, we obtain a complete reinstatement or full "buy-back" with any 1st and 2nd benefit payments equal. In our actual calculations we have needed to deduct half the benefit payable from a healthy state on death in order to obtain the same magnitude of 50% benefit payment throughout. We shall refer to this particular choice of b_1 as our *example 1* (as discussed in the introduction).

4) Finally, on setting $b_1 = 0$, we obtained the extreme case of an unusual delayed ACI model, as it provides CI coverage to an initially healthy policyholder, but only on the 2nd qualifying incident.

For $0 \leq b_1 \leq 1$ in our multi-state model shown in Figure 9, a benefit is payable either on death, or the 1st or 2nd qualifying incident. The resulting expected cash flows are now discussed in section 5.2.

5.2 Expected Cash flows

5.2.1 Standard Stand-Alone Critical Illness (SACI) Model

5.2.1.1 Expected Cash flow from State *H* CF_t^H

For the standard stand-alone critical illness (SACI) model the expected cash flow at the end of the t^{th} policy year, per policyholder in state H at the start of the t^{th} policy year, is given by

$$^{SACI}CF_t^H = \pi_{t-1}v^{-1} - M\ v^{-0.5}\left(p_{y+t-1,\tau}^{H\ A} + p_{y+t-1,\tau}^{H\ AD}\right).$$

Where we have made the following assumptions:

- Age y last birthday at the start of the policy term of say 10 years.
- An annual premium π_{t-1} payable at the start of the year, in relation to a one-off benefit payment M.
- A constant discount factor v = (1 + discount interest rate) $^{-1}$.

  Fitted probability estimates $p_{y+t-1,\tau}^{H\ A}$ for the 1st incident, incorporating a survival period equal to τ (discussed below) after entry to state A.
- Fitted probability estimates $p_{y+t-1,\tau}^{H\ AD}$ for the same post 1st incident benefit calculation, but in this case the policyholder has died by the end of the year after the survival period.

- A single *n*-year policy term for a life aged *y* at time $t = 0$.

These fitted probability estimates are calculated by taking the fitted estimates for the transition probabilities in Table 48 and Table 49 (Appendix 12.12.5), and then substituting into the formulas shown in Appendix 12.14. The resulting probability estimates shown in Table 55 and Table 56 are then used to determine the numerical cash flow values using the formula in this section.

As standard for a SACI product, a survival period τ was incorporated into the above transition probabilities (full details in Appendix 12.15) to allow for no benefit payment following say up to 30 days post 1st treatment date. We shall distinguish this slightly reduced probability from the corresponding probabilities with no survival period (as in the accelerated models) using the postfix τ.

For the SACI model there are no expected cash flows from state *A* or state *B*, because no further premiums are required or benefits payable, so the expected cash flow ${}^{SACI}CF_t^A = 0$ and ${}^{SACI}CF_t^B = 0$.

5.2.2 Standard Accelerated Critical Illness (ACI) Model

5.2.2.1 **Expected Cash flow from State *H*** CF_t^H

To obtain the corresponding expected cash flow for the standard accelerated model just requires additional probabilities of death directly from state *H*, or indirectly via state *A*, in the above SACI model cash flow expression.

Thus for the standard accelerated critical illness (ACI) model, the cash flow at the end of the t^{th} policy year, per policyholder in state *H* at the start of the t^{th} policy year, is given by ${}^{ACI}CF_t^H = \pi_{t-1}v^{-1} - M\,v^{-0.5}\left(p_{y+t-1}^{H\,D} + p_{y+t-1}^{H\,A} + p_{y+t-1}^{H\,AD}\right)$.

We have assumed the same assumptions for the SACI model above, but with no survival period τ required.

Similar to the SACI model, there are no expected cash flows from state *A* or state *B* for the ACI model, because no further benefits are payable or premiums received. So we shall set the corresponding expected cash flows ${}^{ACI}CF_t^A = 0$, and ${}^{ACI}CF_t^B = 0$.

5.2.3 Extended Stand-Alone Critical Illness (ESACI) Model

5.2.3.1 Expected Cash flow from State *H* CF_t^H

For our extended stand-alone critical illness (ESACI) model we require an additional term compared to the SACI model for entering state *B* from state *H* (via state *A*) within a 1 year time period. Thus the extended cash flow at the end of the t^{th} policy year, per policyholder in state *H* at the start of the t^{th} policy year, is given by

$${}^{ESACI}CF_t^H = \pi_{t-1}v^{-1} - M\left[b_1 v^{-0.5}\left(p_{y+t-1,\tau}^{HA} + p_{y+t-1,\tau}^{HAD}\right) + v^{-0.5}\left(p_{y+t-1,\tau}^{HB} + p_{y+t-1,\tau}^{HBD}\right)\right].$$

In addition to the above SACI assumptions we also require:

- A proportion of unit benefit payment b_1, $0 \le b_1 \le 1$, payable on average mid-way through the year for the 1st incident. In our *example 1* (the full buy-back model) we shall assume $b_1 = 0.5$.
- A remaining proportion of unit benefit payment $b_2 = 1 - b_1$, payable on average mid-way through the year for the 2nd incident. If we have both incidents within 1 year, then for simplicity a total proportion of 1 is payable on average mid-way through the year.
- Fitted probability estimates $p_{y+t-1,\tau}^{HB}$ for the 2nd incident, incorporating a survival period equal to τ after entry to state *B* from intermediary state *A* (all transitions between states within 1 year).

- Fitted probability estimates $p^{H\,BD}_{y+t-1,\tau}$ for the same post 2nd incident benefit calculation as in the previous probability, but in this case the policyholder has died by the end of the year after the survival period.
- A claim free interval of 180 days between state *A* and state *B* for the same condition, or 30 days for all the other conditions.

5.2.3.2 **Expected Cash flows from State *A*** CF_t^A

For our ESACI model we have the expected cash flow at the end of the t^{th} year, per policyholder in state *A* at the start of the t^{th} year, given by

$$^{ESACI}CF_t^A = z_1\pi_{t-1}v^{-1} - M\,b_2 v^{-0.5}\left(p^{AB}_{y+t-1,\tau} + p^{A\,BD}_{y+t-1,\tau}\right).$$

This assumed in addition to the above assumptions:

- A single annual premium $z_1\ \pi_{t\text{-}1,}\ 0 \le z_1 \le 1$, payable at the start of the year. This allows a proportional reduction in premium after the 1st incident to reflect a proportional reduction in benefit payable, say $z_1 = b_2 / (b_1 + b_2) = b_2$.
- Fitted probability estimates $p^{AB}_{y+t-1,\tau}$ for the occurrence of the 2nd incident, while incorporating the survival period τ.
- Fitted probability estimates $p^{A\,BD}_{y+t-1,\tau}$ identical to the previous probability, but in this case the policyholder has died by the end of the year after the survival period.

For the ESACI model there are no expected cash flows from state *B* because no further benefits are payable, so we have set the expected cash flow $^{ESACI}CF_t^B = 0$.

5.2.4 Extended Accelerated Critical Illness (EACI) Model

5.2.4.1 **Expected Cash flow from State *H*** CF_t^H

Similarly, for our split benefit extended accelerated critical illness (EACI) model we have

$$^{EACI}CF_t^H = \pi_{t-1}v^{-1} - v^{-0.5}M\left[\left(p_{y+t-1}^{H\,D} + p_{y+t-1}^{H\,AD} + p_{y+t-1}^{H\,BD}\right) + \lambda_1 b_1 p_{y+t-1}^{H\,A} + \left(\lambda_1 b_1 + \lambda_2 b_2\right)p_{y+t-1}^{H\,B}\right].$$

In the above expression we have added parameters λ_1 ($0 \le \lambda_1 \le 1$) and λ_2 ($0 \le \lambda_2 \le 1$) corresponding to an arbitrary proportion of the benefit payment made on the 1st and 2nd incident respectively, with the remainder on death. So that as in the previous models (where λ_1=1 and λ_2=1) the total benefit is always equal to *M* if death occurs at any time within the policy term.

The rationale is to show that the formula can be easily extended to allow automatic full "buy-back" of the death benefit after both the 1st and the 2nd incidents (within the policy term). For example, if $b_1 = b_2 = 0.5$ and $\lambda_1 = 1$, then the death benefit payment between the 1st and 2nd incidents M ((1 - λ_1) $b_1 + b_2$) is the same as the 1st incident benefit payment $M\ b_1\ \lambda_1$. In addition, if $\lambda_2 = 0.5$, then the death benefit payment after the 2nd incident given by $M\ b_2$ (1 - λ_2), is the same as the 2nd incident benefit payment $M\ b_2\ \lambda_2$.

5.2.4.2 **Expected Cash flows from State *A*** CF_t^A

For our EACI model we need to add the probabilities of death from state *A* (directly or indirectly through state *B*) to the cash flow expression in the ESACI model above. After the 1st incident benefit payment in state *A* of $M\,\lambda_1 b_1$, the remaining benefit proportion payable on death is equal to (1 - λ_1) $b_1 + b_2$.

Thus the cash flow, per policyholder in state *A* at the end of the t^{th} year, is given by

$$^{EACI}CF_t^A = z_1\pi_{t-1}v^{-1} - v^{-0.5}M\left[\left((1-\lambda_1)b_1 + b_2\right)\left(p_{y+t-1}^{A\,D} + p_{y+t-1}^{A\,BD}\right) + \lambda_2 b_2 p_{y+t-1}^{A\,B}\right].$$

Where we have assumed only a proportion λ_2 of the 2nd benefit b_2 is payable on the 2nd incident.

5.2.4.3 **Expected Cash flow from State *B*** CF_t^B

For all our models there are no cash flows from state *B* except if we choose $\lambda_2 < 1$ in our EACI model. In which case there is then an expected death benefit following the 2nd incident, with an expected cash flow at the end of the year, per policyholder in state *B* at the start of the t^{th} year, given by

$$^{EACI}CF_t^B = z_2\,\pi_{t-1}v^{-1} - M(1-\lambda_2)\,b_2 v^{-0.5}\,p_{y+t-1}^{BD}.$$

This assumed in addition to the above assumptions:

- A single annual premium $z_2\ \pi_{t-1}$, where $0 \le z_2 \le 1$, payable at the start of the year. This allows a proportional reduction in premium after the 2nd incident to reflect the same proportional reduction in benefit payable, say $z_1 = (1 - \lambda_2)\ b_2 / (b_1 + b_2)$. This is reasonable as if $\lambda_2 = 1$ (or near 1) then we would expect no (or very little) further premium.

5.3 Extended CI Emerging Cost EC_t^H

The above cash flows CF_t^H, CF_t^A and CF_t^B assume that the policyholder is in state *H*, *A*, or *B* at the start of time *t*, respectively. To determine the expected cash flow at time *t* for a policyholder in state *H* at time 0 (the "emerging cost"), we need to multiply by the respective probabilities to obtain

$$EC_t^H = {}_{t-1}p_y^{HH}\ CF_t^H + {}_{t-1}p_y^{HA}\ CF_t^A + {}_{t-1}p_y^{HB}\ CF_t^B.$$

Where we have dropped the superscript denoting the model, as each has the same generic form (provided certain cash flows are set equal to 0 where necessary).

If we discount by *v*, say equal to 5%, and sum over all future years, *n* say =10 years, then we have the total discounted emerging cost (TDEC) = $\sum_{t=1}^{n} EC_t^H v^t$, which we can use to compare between the models at a particular entry age.

For example consider a healthy female aged 40 at time t = 0, with a 10-year term EACI policy for a premium of £100 per benefit M = £10,000 covering all the CI conditions. Then as an alternative to paying a proportion of the benefit b_1 on the 1st incident, we can also split this benefit so that only λ_1 (M x b_1) is payable on the 1st incident with the remainder (1-λ_1) (M x b_1) payable on death (within 10-years). Similarly, only λ_2 (M x b_2) is payable on the 2nd incident, with the remainder added to any outstanding benefits on subsequent death in order that a total benefit of M has always potentially been paid (within the policy term). To reduce the number of parameters we shall assume λ_2 = say λ_1 throughout this dissertation.

Thus we can vary both the proportion $b_1$of the total benefit M payable on the 1st incident relative to the 2nd incident, and the proportion accelerated forward λ_1 at each incident, as shown in the following Figure 10.

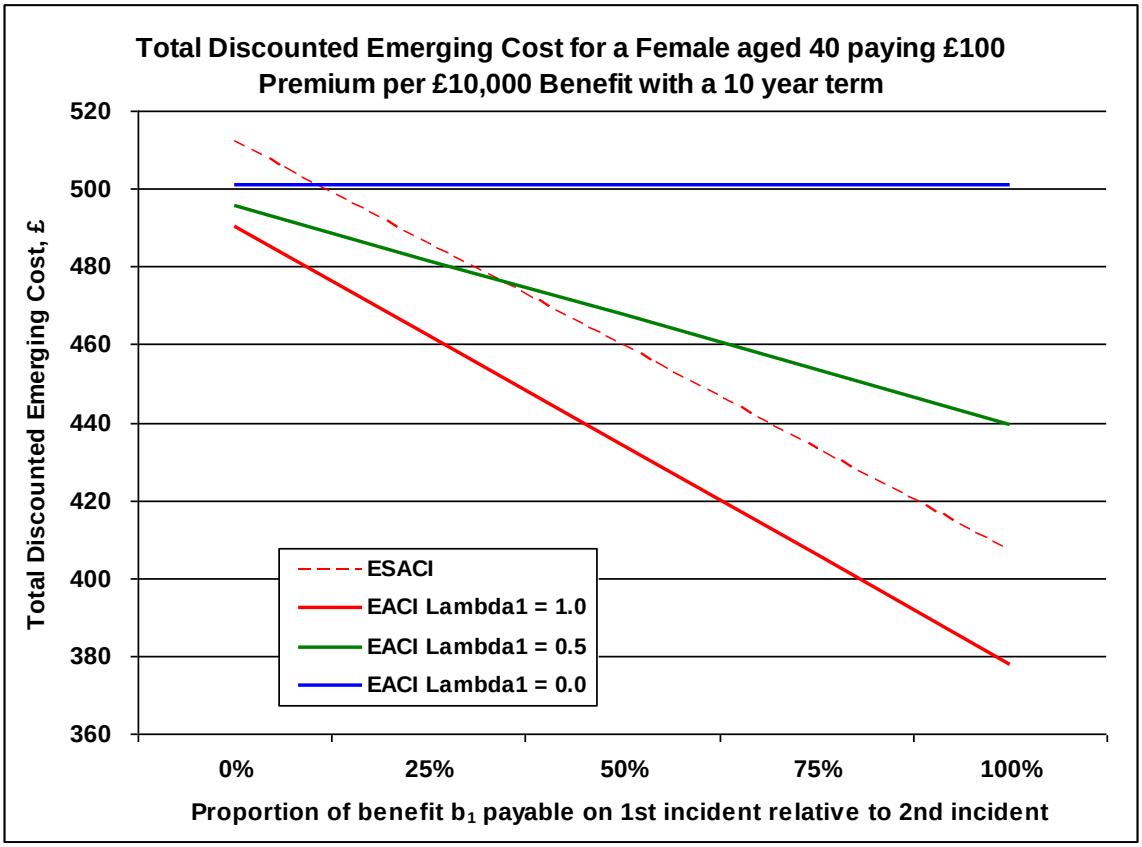


Figure 10: The Total Discounted Emerging Cost (TDEC) for increasing proportion b_1 of the total benefit M payable on the 1st incident for selected proportion accelerated forward λ_1 on each incident.

In Figure 10, the blue curve shows the TDEC for the extreme case of all the benefit $b_1 M$ payable on death, i.e. a term only policy. The red curve corresponds to all the benefit payable on the 1st or 2nd incidents. Finally, the green curve shows the mid-point TDEC value for only half the benefit payable on the 1st and 2nd incidents, with the reminder on death. The lines are straight as the TDEC is a linearly decreasing function of b_1 (for each fixed λ_1), with the emerging cost from state *H* the main component. This emerging cost decreases as b_1 increases as the formula deducts the expected benefit payment for the 1st incident (which is proportional to b_1) from the fixed annual premium of £100.

For a fixed proportion b_1, as more of the 1st benefit is accelerated forward by increasing λ_1 from 0.0 to 0.5 (blue to green curve) then from 0.5 to 1.0 (green to red curve), we obtained a decrease in the TDEC, as there is a far higher expected probability that a 40 year old policyholder will have a 1st incident than die within the next 10 years. On increasing the 1st incident b_1, the decrease in TDEC become greater as the magnitude of the 1st benefit payment increases.

For comparison, we have shown the extended stand alone "all conditions" model with no deaths by the parallel dotted line to indicate that the effect of mortality on the TDC is far smaller than the effect of changing b_1 or λ_1 at approximately £100 for a female aged 40. For our future models we shall keep $\lambda_1 = 1$, as our interest lies in determining a full "buy-back" premium which only requires altering b_1 (and not λ_1) in Chapter 7.

However, to determine a realistic "buy-back" premium, we need to satisfy a reasonable profit criterion. So we need to determine formula for the calculation of reserves and profits in section 6.7 and section 6.8. To save repetition of formula, we shall first consider in Chapter 6 our 'restricted' models, as the required reserving and profit formula will then just be special cases of the corresponding formula for these more general models.

6 Our Restricted ACI Models

6.1 Restricted Basic ACI (RBACI) Model

We consider the following example of an unhealthy female policyholder. By "unhealthy" we mean that she has had a previous minor health complaint that would be considered to increase the risk of a payment from their CI policy, e.g. slight angina, but have not had a previous full qualifying CI condition.

This unhealthy life understands that such a pre-existing minor health complaint means that she is at a higher risk of claiming for a related CI condition, e.g. any cardiovascular conditions.

However, she feels that she should not be refused CI outright, but should be offered a similar product which provides coverage for the remaining CI conditions, which are unrelated to her minor health complaint.

Before we can determine such a "restricted" relative premium, we first need to consider the transitions for healthy (or unhealthy) policyholders to either:

- The conditions within the qualifying state *A*.

- Those other conditions with no qualifying benefit payment, which we have denoted by state A^{other}.

We have extended the standard ACI multi-state model to include state A^{Other} and all additional states, as shown in blue in Figure 11 below.

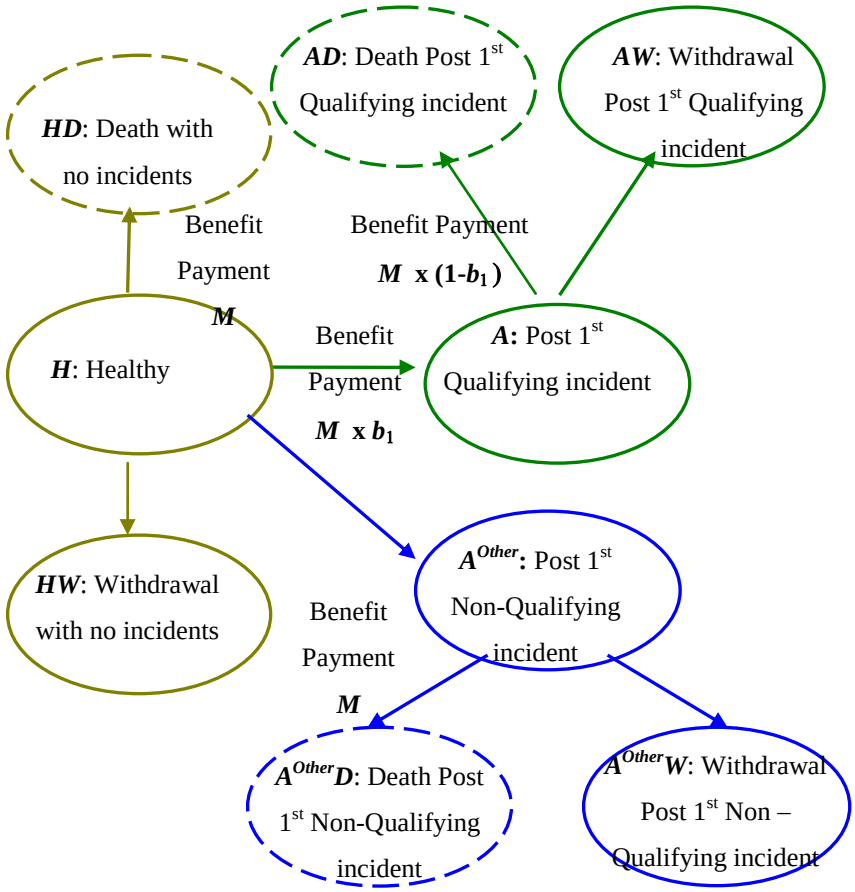


Figure 11: Our Restricted Basic Accelerated Critical Illness (RBACI) model, showing the usual healthy (state *H*) and post 1st qualifying conditions (state *A*) drawn in green, with a new post 1st non-qualifying condition (state A^{other}) in blue. For completeness, the corresponding absorbing death states *HD, AD,* $A^{other}D$*, BD* (dotted lines) are shown for the ACI model only, and for the withdrawal states *HW, AW,* $A^{other}W$ and *BW* are also shown.

The problem with our restricted basic model above is that it ignores the possibility of an initially healthy or unhealthy policyholder subsequently satisfying one of the non-qualifying conditions as an intermediate step before satisfying one of the qualifying conditions.

In our example, this would correspond to our unhealthy policyholder succumbing unsurprisingly to a heart attack after purchasing the non-cardiovascular CI policy. Although no heart attack payment was made, they then subsequently developed a cancer at a far younger age than a typical healthy policyholder.

We therefore need to consider whether the incidence of a non-qualifying condition to a qualifying condition is far higher than the incidence of a qualifying condition from the healthy state. If this is the case, then our restricted basic model above would under-estimate the required premium.

6.2 Restricted Standard ACI (RACI) Model

Therefore, for the insurer to charge an adequate premium, we need to include the possibility of a transition from state A^{Other} to say a new state *B*, where a full benefit payment occurs only when we have strictly the same qualifying conditions as for the 1st treatment state *A*.

This is shown by adding the red circles in order to obtain our restricted standard ACI model in the following Figure 12.

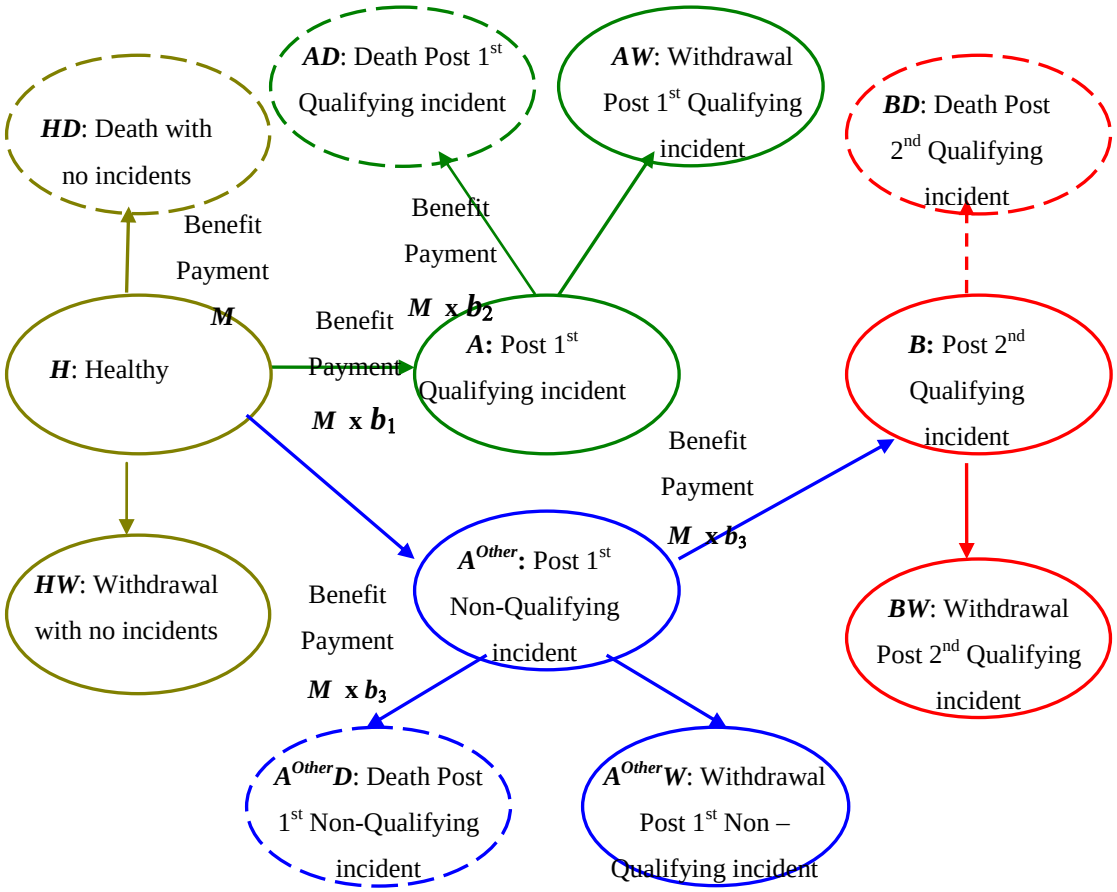


Figure 12: Our restricted standard accelerated critical illness (RACI) model, showing in addition to the previous RBACI model, a 2nd treatment state *B* in red for strictly the same qualifying conditions as in state *A*. For completeness, the additional absorbing death state *BD* (dotted red lines) is shown for the ACI model only, and the withdrawal state *BW* is also shown.

Love and Ryan (2007) have considered a similar model (with all the $b_i = 1$ throughout); however, they considered a transition from state A^{other} to state A, rather than introducing a new state B.

6.3 Restricted Extended "buy-back" Model (REACI)

However, by including an additional state *B*, we can extend the above model further to allow a partial benefit payment on the 1st treatment, with the remainder on the 2nd treatment (as previously undertaken in section 5.1), to obtain a restricted extended "buy-back" model as shown in the following Figure 13.

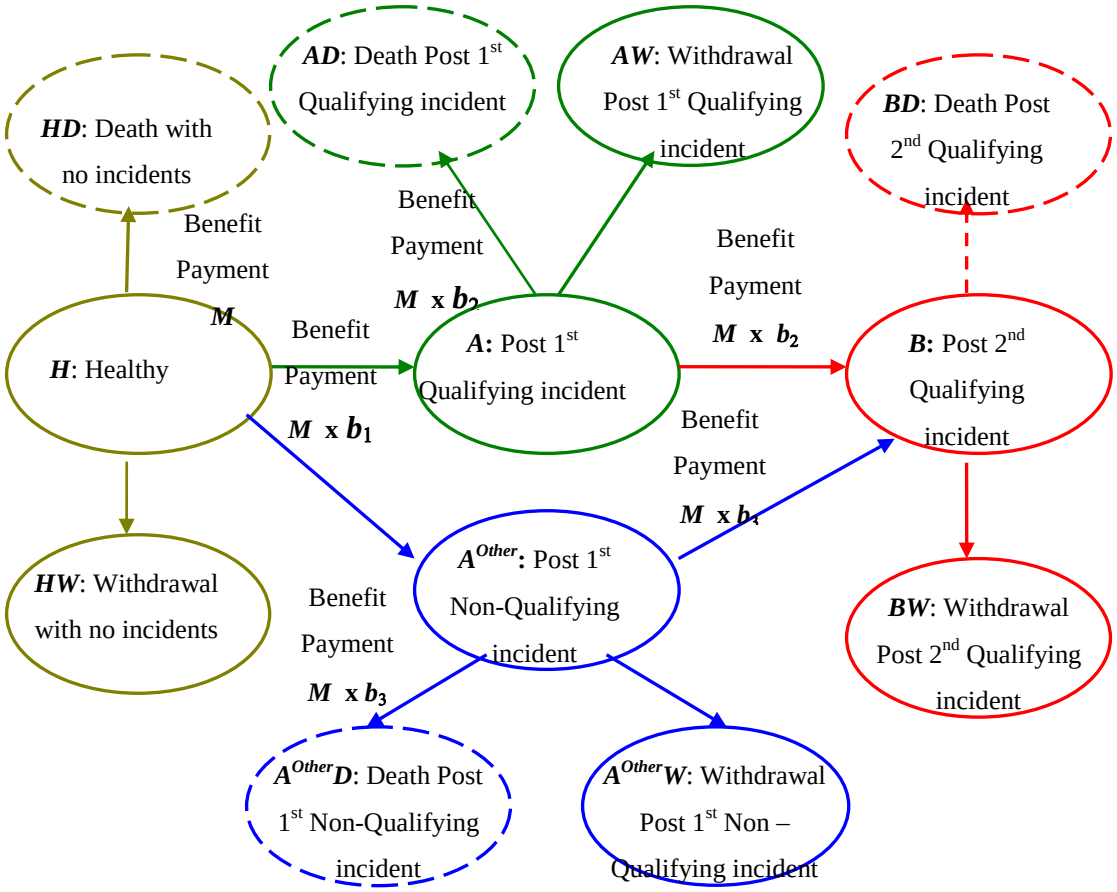


Figure 13: Our restricted extended accelerated critical illness (REACI) model, showing in addition to the previous RACI model, a transition from the1st treatment state *A* to the 2nd treatment state *B*.

Our previous restricted basic model in Figure 11 and standard model in Figure 12 are special cases of the above model in Figure 13, where we need to set the benefit payment equal to 0 for the transition from state *A* to state *B* for both models, and state A^{Other} to state *B* for the basic model only. As discussed below, for our *example 2* and *3*, we shall set $b_1 = 0.5$, $b_2 = 0.5$ and $b_3 = 1$.

We shall now consider in section 6.4 the full set of accelerated cash flows for our restricted extended (REACI) model and the restricted standard model (RACI), together with the corresponding cash flows for the stand-alone models (RESACI and RSACI).

6.4 Restricted Expected Cash flows

6.4.1 Restricted Stand-Alone CI model (RSACI)

Although there is no benefit payment on state A^{Other} for the RSACI model (with all the same formulas as in sections 5.2.1), we will still need to recalculate our "restricted" expected cash flows as we will have a reduced 1st incidence probability on restricting the qualifying conditions.

6.4.2 Restricted Accelerated CI model (RACI)

For our new restricted accelerated CI model (RACI) we will need to include the death benefit payable from state A^{Other}, requiring an additional probability ${}_{y+t-1}p^{H\,A^{Other}D}$ to be estimated in the following state *H* cash flow

$${}^{RACI}CF_t^{H} = \pi_{t-1}v^{-1} - M\,v^{-0.5}\left({}_{y+t-1}p^{H\,D} + {}_{y+t-1}p^{H\,A} + {}_{y+t-1}p^{H\,AD} + {}_{y+t-1}p^{H\,A^{Other}D}\right).$$

Note that the estimate for the probability ${}_{y+t-1}p^{H\,AD}$ will decrease in order that the total probability of death has remained unchanged after the 1st incident (i.e. will be regardless of whether death is after a qualifying condition or not).

As no further premiums are required or benefits payable from state *A*, state A^{Other}, or state *B*, we have the corresponding expected cash flows ${}^{RACI}CF_t^{A} = 0$, ${}^{RACI}CF_t^{A^{Other}} = 0$ and ${}^{RACI}CF_t^{B} = 0$.

6.4.3 Restricted Extended Stand-Alone CI model (RESACI)

6.4.3.1 **Restricted Expected Stand-Alone Cash flow from state *H*** CF_t^H

For our new restricted extended stand-alone critical illness (RESACI) model, we now require an additional term for entering state *B* from state A^{other}. The restricted extended cash flow is thus given by

$$
\begin{aligned}
{}^{RESACI}CF_t^H \quad &= \pi_{t-1}v^{-1} - M\Big[b_1 v^{-0.5}\left(p_{y+t-1,\tau}^{H\,A} + p_{y+t-1,\tau}^{H\,AD}\right) + v^{-0.5}\left(p_{y+t-1,\tau}^{H\,B} + p_{y+t-1,\tau}^{H\,BD}\right) \\
&\quad + b_3 v^{-0.5}\, p_{y+t-1}^{H\,A^{other}B}\Big].
\end{aligned}
$$

Note: we cannot just add the numerical value of the last term onto the calculated value for ${}^{ESACI}CF_t^H$ in section 5.2.3.1 above as the probabilities will now all be smaller after restricting state *A* and state *B* to a sub-set of the qualifying conditions.

In addition, to the same assumptions as shown before for ${}^{ESACI}CF_t^H$ in section 5.2, we also require:

- Fitted probability estimates $p_{y+t-1}^{H\,A^{other}B}$ for the 2nd incident after entry to state *B* from state A^{other} (no survival period is required as there is no benefit payable on entering state A^{other}).

- A proportion of benefit payable b_3 ($0 \le b_3 \le 1$) on average mid-way through the year on entry to state *B* from a non-qualifying state A^{other}. In our *example 2* and *3* we shall set this equal to 1, in order that the total benefit payable to date on entering state *B* is the same regardless of whether the claimant entered from a qualifying or a non-qualifying state.

- An interval of 30 days between state A^{other} and state *B*. This is less onerous than the 180 days we have chosen from state *A* to state *B*, but felt to be more reasonable from the policyholders viewpoint as no benefit was payable on entering state A^{other}. As for traditional SACI the 30 days is to distinguish from

a death benefit, as well as to try and differentiate from directly moving from state *H* to state *B*, via state *A* rather than via state A^{other}.

The probabilities are fitted using GM(0,*s*) models as before, with numerical estimates shown in Table 57 to Table 64, for selected restricted conditions to be discussed in Chapter 7.

6.4.3.2 **Restricted Expected Cash flow from State *A*** CF_t^A

The formula for the expected cash flows from state *A* remain unchanged from ${}^{\text{ESACI}}CF_t^A$ in sections 5.2.3.2, as there are no transitions from state *A* to state A^{other}, or vice versa.

6.4.3.3 **Restricted Expected Cash flow from State A^{Other}** $CF_t^{A^{Other}}$

For our RESACI model we have the expected cash flow at the end of the t^{th} year, per policyholder in state A^{other} at the start of the t^{th} year, given by

$${}^{\text{RESACI}}CF_t^{A^{Other}} = z_3\,\pi_{t-1}v^{-1} - M\,b_3\,v^{-0.5}\left(p_{y+t-1,\tau}^{A^{Other}\,B} + p_{y+t-1,\tau}^{A^{Other}\,BD}\right).$$

This assumes in addition to the above assumptions:

- An annual premium $z_3\ \pi_{t\text{-}1,}\ 0 \le z_3 \le 1$, payable at the start of each year. We have assumed that the premium is in proportion to the benefit proportion $b_{3.}$ We shall keep the whole single annual premium payable at the start of the year equal to $z_3 = 1$, because no benefit has being paid to-date. Although we could increase the premiums to reflect the greater risk of a subsequent incident or death, or reduce the premium because the insured has a greater need for the premium payments to meet changes in financial circumstances following the 1st incident.

- A fitted probability estimate $p_{y+t-1,\tau}^{A^{Other}\,B}$ for the occurrence of the 2nd incident, while incorporating the survival period τ.

- A fitted probability estimate $p_{y+t-1,\tau}^{A^{Other}\,BD}$ for the same post 2nd incident benefit calculation, but in this case the policyholder has died by the end of the year after the survival period.

6.4.4 Restricted Extended Accelerated CI model (REACI)

6.4.4.1 Restricted Expected Accelerated Cash flow from state *H* CF_t^H

The previous RESACI model provides no death benefit. To obtain the corresponding expected cash flow for the restricted extended ACI model, we just require additional probabilities of 2nd incidence or death from state *H* via state A^{other} in the expression for ${}^{EACI}CF_t^H$ shown in section 5.2.4.1. This is given by

$$
\begin{aligned}
{}^{REACI}CF_t^H = \pi_{t-1}v^{-1} - v^{-0.5}M\Big[\Big(&p_{y+t-1}^{H\,D} + p_{y+t-1}^{H\,AD} + p_{y+t-1}^{H\,A^{Other}D} + p_{y+t-1}^{H\,BD}\Big) + \lambda_1 b_1 p_{y+t-1}^{H\,A} \\
&+ (\lambda_1 b_1 + \lambda_2 b_2) p_{y+t-1}^{H\,AB} + \lambda_3 b_3 p_{y+t-1}^{H\,A^{Other}B}\Big].
\end{aligned}
$$

In this expression we have added a further parameter $\lambda_3\,(0 \le \lambda_3 \le 1)$, corresponding to an arbitrary proportion of the benefit payment made on the 2nd incident state *B* from state A^{other}, with the remainder on death. In our models we shall set λ_3 equal to 1, to be consistent with those other policyholders with intermediate state *A*, who would now have just received their outstanding benefit.

6.4.4.2 Restricted Expected Cash flow from state *A* CF_t^A

The formula for the expected cash flows from state *A* remain unchanged from ${}^{EACI}CF_t^A$ in section 5.2.4.2, as there are no transitions from state *A* to state A^{other}, or vice versa.

6.4.4.3 Restricted Expected Cash flow from state A^{Other} $CF_t^{A^{Other}}$

Similarly, for our REACI model we need to add the probability of death from state A^{Other}.

The cash flow per policyholder in state A^{Other} at the end of the t^{th} year is given by

$${}^{\text{REACI}}CF_t^{A^{Other}} = z_3\pi_{t-1}v^{-1} - v^{-0.5}M\,b_3\left[\left(p_{y+t-1}^{A^{Other}\,D} + p_{y+t-1}^{A^{Other}\,BD}\right) + \lambda_3 p_{y+t-1}^{A^{Other}\,B}\right],$$

where we have assumed only a proportion λ_3 of the benefit b_3 is payable on the 2nd incident. In our models we shall set λ_3 equal to 1.

6.4.4.4 **Restricted Expected Cash flow from state *B*** CF_t^B

For all our models there are no cash flows from state *B* in our REACI model, except if we choose $\lambda_2 < 1$ or $\lambda_3 < 1$. In which case there is then an expected death benefit following the 2nd incident, with an expected cash flow at the end of the year per policyholder in state *B*, at the start of the t^{th} year, given by

$${}^{\text{REACI}}CF_t^B = z_2\,\pi_{t-1}v^{-1} - M\left[\left(1-\lambda_2\right)b_2 + \left(1-\lambda_3\right)b_3\right]v^{-0.5}\,p_{y+t-1}^{BD}.$$

Assuming:

- A single annual premium $z_2\ \pi_{t-1}$, where $0 \le z_2 \le 1$, payable at the start of the year. This allows a proportional reduction in premium after the 2nd incident to reflect the same proportional reduction in benefit payable, say $z_1 = \left(1-\lambda_2\right)b_2 + \left(1-\lambda_3\right)b_3$. This is reasonable, as if $\lambda_2 = 1$ and $\lambda_3 = 1$ (or both near 1), then we would expect no (or very little) further premium.

For simplicity in our worked examples we shall assume $\lambda_2 = 1$ and $\lambda_3 = 1$, i.e. ${}^{\text{REACI}}CF_t^B = 0$, as no future benefits are payable after entering state *B*.

6.5 Restricted Extended Critical Illness Emerging Cost EC_t^H

The above cash flows CF_t^H , CF_t^A , $CF_t^{A^{Other}}$ and CF_t^B assume that the policyholder is in state *H, A,* A^{Other} or *B* at the start of time *t,* respectively. To determine the expected cash flow at time *t* for a policyholder in state *H* at time 0 (the "emerging cost"), we need to multiply by the respective probabilities

$$EC_t^H = {}_{t-1}p_y^{H\,H}\, CF_t^H + {}_{t-1}p_y^{H\,A}\, CF_t^A + {}_{t-1}p_y^{H\,B}\, CF_t^B + {}_{t-1}p_y^{H\,A^{Other}}\, CF_t^{A^{Other}} .$$

Where we have dropped the superscript denoting the model, as each has the same generic form (provided certain cash flows are set equal to 0 where necessary). A special case with ${}_{t-1}p_y^{H\,A^{Other}} = 0$ and $CF_t^{A^{Other}} = 0$ results in the general form for the unrestricted buy-back model from section 5.3.

On discounting at a say 5% discount rate, and summing over $t = 1$ to 10 we can determine the total discounted emerging cost , TDEC = $\sum_{t=1}^{10} EC_t^H v^t$. This is shown in the following Figure 14 for a female paying £100 premium in order to receive a 10-year £10,000 cancer only benefit at sample ages from 20 to 60.

We have assumed our restricted extended stand-alone (RESACI) or accelerated (REACI) models, with increasing proportion of benefit payable b_1 on the 1st incident.

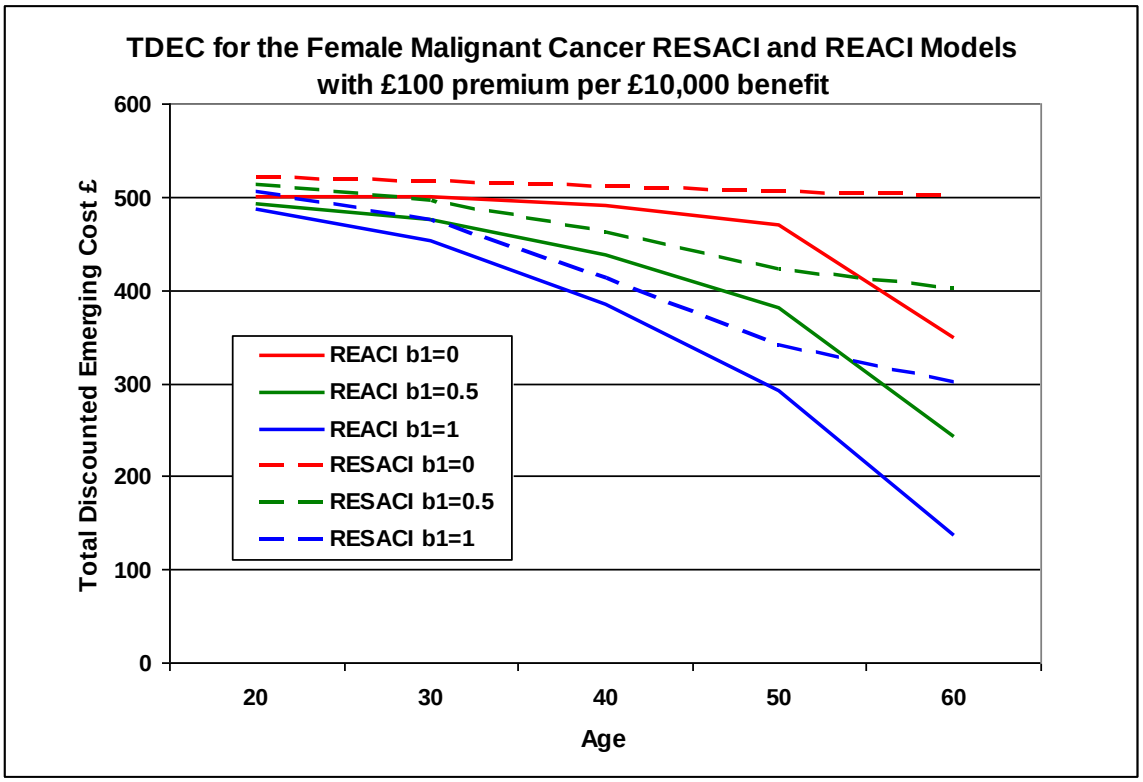


Figure 14: The TDEC resulting from a £100 annual premium payable over a 10-year term, in order to receive a £10,000 malignant cancer benefit for the REACI and RESACI models.

From Figure 14, we note that for each of the curves (fixed b_1) the older the age the lower the TDEC. This is because of a greater expected benefit payment as the 1st and 2nd incidence rate increases. In addition, for each of the REACI solid line curves, where a mortality benefit is payable, the TDEC is lower than the corresponding RESACI dotted line curve (with no mortality benefit payable). This difference increases with age as the mortality incidence rate increases.

Alternatively, for an increasing b_1 (red to blue curve) we note that as the proportion of the benefit payable on the 1st incident increases, the TDEC decreases by a larger amount at the older ages. Essentially, we are increasing the magnitude of the benefit amount discussed in the previous paragraph.

6.6 The Equivalence Premium for the Total Discounted Restricted Emerging Cost (TDEC)

The above TDEC is dependent on the premium and benefit amounts chosen. Alternatively, if we assume that the total discounted value of all future expected premiums are sufficient to meet all future expected benefits, i.e. TDEC = 0. Then we can determine the required fixed annual premium π per unit of total benefit M for a particular model.

For example, we found the premiums per £10,000 of benefit for a 10-year female malignant cancer only REACI and RESACI product, which provided a TDEC = 0 in the following Figure 15.

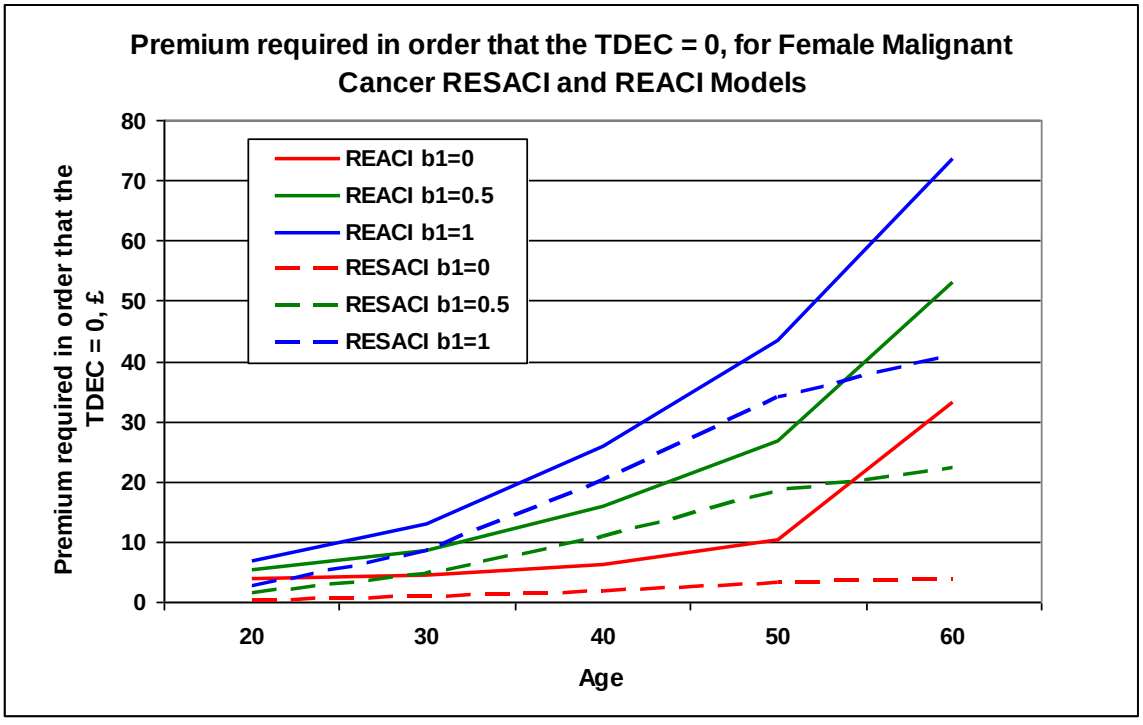


Figure 15: The premiums per £10,000 of benefit for a 10-year female malignant cancer only REACI and RESACI products with increasing b_1, which provided a TDEC = 0.

From Figure 15 we note that the premium required for a TDEC = 0 increases more steeply with increasing age (for a fixed b_1) as the expected 1st and 2nd incidence rates increase with age for the RESACI (dotted lines) and REACI (solid lines) models. In

addition, for the REACI model the gradient is far steeper due to the inclusion of death benefits, with mortality increasing with age.

The probability for a 1st incident is higher than for a 2nd incident, which are then each weighted by b_1 and 1- b_1 respectively, resulting in a relatively large expected benefit on the 1st incident compared to the 2nd incident, which is then magnified even further on increasing b_1 resulting in the rapid increase in premium on moving from one curve to the next.

The rapid jump in annual premium required for policies starting at the older ages may not be acceptable, and in practice the age mix of the business would need to be considered.

The above premiums for a TDEC = 0 assumed that no lapses occur, whereas it may be financially more beneficial to certain policyholders to lapse early rather than pay the full term of premiums if the outstanding expected benefit payments are lower than the expected future premiums after discounting.

To prevent a loss to the life office on this or any other event, we need to put aside reserves in the early years of the policy which can then be utilised in the later years. We shall calculate retrospective reserves equal to the discounted expected future benefit payments less the discounted expected future premiums in the next section 6.7.

6.7 The Restricted Extended Critical Illness Prospective Reserves

We only need to consider the prospective reserves for the RESACI and REACI models, as the reserves for all the other models are just simpler cases, as discussed below.

6.7.1 Healthy State *H* Prospective Reserves ${}_tV_y^H$

For our RESACI model, the end of year *t* prospective reserve, for a policyholder aged *y* and in state *H* at the start of year *t*, is given by

$$
\begin{aligned}
{}^{RESACI}{}_tV_y^H \quad = \quad & \sum_{u=0}^{n-t-1} v^{u+0.5}\, {}_up_{y+t}^{HH} M\Big[b_1\left(p_{y+t+u,\tau}^{HA} + p_{y+t+u,\tau}^{HAD}\right) + \left(p_{y+t+u,\tau}^{HB} + p_{y+t+u,\tau}^{HBD}\right) \\
& + b_3 p_{y+t+u}^{HA^{other}B}\Big] - \sum_{u=0}^{n-t-1} \pi_{u+t} v^u\, {}_up_{y+t}^{HH} \text{ , for a } n \text{ year term.}
\end{aligned}
$$

In practice to determine the RESACI reserves, we can use a generalisation of the recursive relationship (pp.61, Gerber 1995), to obtain

$$
\begin{aligned}
{}^{RESACI}{}_tV_y^H \quad = \; & v^{0.5} M\Big[b_1\left(p_{y+t,\tau}^{HA} + p_{y+t,\tau}^{HAD}\right) + \left(p_{y+t,\tau}^{HB} + p_{y+t,\tau}^{HBD}\right) + b_3 p_{y+t+u}^{HA^{other}B}\Big] \\
& + v\, p_{y+t}^{HH}\; {}^{RESACI}{}_{t+1}V_y^H - \pi_t ,
\end{aligned}
$$

starting with an initial value at $t = 0$, ${}^{RESACI}{}_0V_y^H = 0$.

The ESACI model would be missing the 3rd term and the traditional SACI model would be missing the 2nd and 3rd terms, with $b_1 = 1$.

We can extend these easily for our REACI model by requiring the full benefit payable on death from state *H*, and generalising to only allow a partial benefit payment on the 1st or 2nd incidence.

$$
\begin{aligned}
{}^{REACI}{}_tV_y^H \quad = \; & \sum_{u=0}^{n-t-1} v^{u+0.5}\, {}_up_{y+t}^{HH} M\Big[\, p_{y+t+u}^{HD} + p_{y+t+u}^{HAD} + p_{y+t+u}^{HA^{Other}D} + p_{y+t+u}^{HBD}
\end{aligned}
$$

$$+\lambda_1 b_1 p^{H\,A}_{y+t+u} + (\lambda_1 b_1 + \lambda_2 b_2) p^{H\,B}_{y+t+u} + \lambda_3 b_3 p^{H\,A^{Other}B}_{y+t+u}\Big] - \sum_{u=0}^{n-t-1} \pi_{u+t} v^{u}{}_{u} p^{H\,H}_{y+t} \,.$$

As above, we can use a recursive relationship to obtain the ${}^{REACI}_{t}V^{H}_{y}$ reserve.

6.7.2 Post 1st Incident, State *A* Prospective Reserves ${}_{t}V^{A}_{y}$

The RESACI and REACI models also require an end of year *t* reserve for a policyholder in state *A* at the start of year *t*. These prospective reserves are given by:

$${}^{RESACI}_{t}V^{A}_{y} = b_2 M \sum_{u=0}^{n-t-1} v^{u+0.5}{}_{u} p^{AA}_{y+t} \left(p^{A\,B}_{y+t+u,\tau} + p^{A\,BD}_{y+t+u,\tau} \right) - z_1 \sum_{u=0}^{n-t-1} \pi_{u+t} v^{u}{}_{u} p^{AA}_{y+t} ,$$

$${}^{REACI}_{t}V^{A}_{y} = M \sum_{u=0}^{n-t-1} v^{u+0.5}{}_{u} p^{AA}_{y+t} \Big[\big((1-\lambda_1) b_1 + b_2 \big) \big(p^{A\,D}_{y+t+u} + p^{A\,BD}_{y+t+u} \big) + \lambda_2 b_2 p^{A\,B}_{y+t+u} \Big]$$
$$- z_1 \sum_{u=0}^{n-t-1} \pi_{u+t} v^{u}{}_{u} p^{AA}_{y+t} .$$

Whereas before, we can use the recursive relationship to obtain

$${}^{RESACI}_{t}V^{A}_{y} = v^{0.5} M \Big[b_2{}_{u} p^{AA}_{y+t} \left(p^{A\,B}_{y+t+u,\tau} + p^{A\,BD}_{y+t+u,\tau} \right) \Big] + v\, p^{AA}_{y+t}\ {}^{RESACI}_{t+1}V^{A}_{y} - z_1 \pi_t \ ,$$

starting with ${}^{RESACI}_{0}V^{A}_{y} = 0$. Similarly, for the ${}^{REACI}_{t}V^{A}_{y}$ reserve.

The reserves for the ESACI and EACI models have the same formula, but will have different fitted values for the probabilities. The standard SACI and ACI models have no reserves for a policyholder in state *A*, as no further benefit is payable.

6.7.3 Post 1st Incident, State A^{Other} Prospective Reserves ${}_{t}V^{A^{Other}}_{y}$

The RESACI and REACI models also require an end of year *t* reserve for a policyholder in state *A* at the start of year *t*. These prospective reserves are given by:

$$
\begin{aligned}
{}^{RESACI}{}_{t}V_{y}^{A^{Other}} &= b_3 M \sum_{u=0}^{n-t-1} v^{u+0.5}{}_{u}p_{y+t}^{A^{Other}\,A^{Other}} \left(p_{y+t+u,\tau}^{A^{Other}\,B} + p_{y+t+u,\tau}^{A^{Other}\,BD} \right) \\
&\quad - z_3 \sum_{u=0}^{n-t-1} \pi_{u+t} v^{u}{}_{u}p_{y+t}^{A^{Other}\,A^{Other}},
\end{aligned}
$$

$$
\begin{aligned}
{}^{REACI}{}_{t}V_{y}^{A^{Other}} &= M \sum_{u=0}^{n-t-1} v^{u+0.5}{}_{u}p_{y+t}^{A^{Other}\,A^{Other}} b_3 \left[\left(p_{y+t+u}^{A^{Other}\,D} + p_{y+t+u}^{A^{Other}\,BD} \right) + \lambda_3 p_{y+t+u}^{A^{Other}\,B} \right] \\
&\quad - z_3 \sum_{u=0}^{n-t-1} \pi_{u+t} v^{u}{}_{u}p_{y+t}^{A^{Other}\,A^{Other}}.
\end{aligned}
$$

Whereas before, we can use the recursive relationship to obtain

$$
{}^{RESACI}{}_{t}V_{y}^{A^{Other}} = v^{0.5} M \left[b_3 {}_{u}p_{y+t}^{A^{Other}\,A^{Other}} \left(p_{y+t+u,\tau}^{A^{Other}\,B} + p_{y+t+u,\tau}^{A^{Other}\,BD} \right) \right] + v\, p_{y+t}^{A^{Other}\,A^{Other}}\ {}^{RESACI}{}_{t+1}V_{y}^{A^{Other}} - z_3 \pi_t ,
$$

starting with ${}^{RESACI}{}_{0}V_{y}^{A^{Other}} = 0$. Similarly, for the ${}^{REACI}{}_{t}V_{y}^{A^{Other}}$ reserve.

6.7.4 Post 2nd Incident, State *B* Prospective Reserves ${}_{t}V_{y}^{B}$

Finally, for the restricted extended accelerated models with either $\lambda_2 < 1$ or $\lambda_3 < 1$, we also require an end of year *t* reserve for a policyholder in state *B* at the start of year *t*, in order to provide the remaining death benefit after 2nd incident. This is given by

$$
{}^{REACI}{}_{t}V_{y}^{B} = \left[\left(1-\lambda_2\right) b_2 + \left(1-\lambda_3\right) b_3 \right] M \sum_{u=0}^{n-t-1} v^{u+0.5}{}_{u}p_{y+t}^{BB}\ p_{y+t+u}^{BD} - z_2 \sum_{u=0}^{n-t-1} \pi_{u+t} v^{u}{}_{u}p_{y+t}^{BB}.
$$

The corresponding recursive relationship is provided by

$$
{}^{REACI}{}_{t}V_{y}^{B} = v^{0.5} M \left[\left(1-\lambda_2\right) b_2 + \left(1-\lambda_3\right) b_3 \right] {}_{u}p_{y+t}^{BB}\ p_{y+t+u}^{BD} + v\, p_{y+t}^{BB}\ {}^{REACI}{}_{t+1}V_{y}^{B} - z_2 \pi_t ,
$$

starting with ${}^{REACI}{}_{0}V_{y}^{B} = 0$.

The reserves for the ESACI and EACI models have the same formula (with $b_3 = 0$), but will have different fitted values for the probabilities. The standard SACI and ACI models have no reserves for a policyholder in state *B*, as no further benefit is payable.

We shall now discuss how these reserves are added to the previous cash flows from section 6.4, to determine the profit vector and profit margin in the next sections 6.8 and 6.9.

6.8 The Actuarial Profit Vector

We only need to consider the profit vector for the RESACI and REACI models, as all the profit vectors for the other models are just simpler cases as discussed below.

6.8.1 Profit Vector for Policyholder in State *H*, PRO_t^H

To ensure solvency of the life office, the profit available for distribution to shareholders in the standard ACI model is equal to the cash flow CF_t^H plus the reserve at the start of the year ${}_{t-1}V_y^H$, less the reserve ${}_tV_y^H$ for those policyholders still in state *H* at the end of the year. For our RESACI and REACI models we also need to deduct the new reserve ${}_tV_y^A$ (and ${}_tV_y^B$ for the REACI model when $\lambda_2 < 1$ or $\lambda_3 < 1$) for those policyholders who have moved to state *A* (or state *B*) during the year.

For our restricted extended models, the "profit vector" is given by

$$PRO_t^H = CF_t^H + {}_{t-1}V_y^H v^{-1} - p_{y+t-1}^{H\,H}\,{}_tV_y^H - p_{y+t-1}^{H\,A}\,{}_tV_y^A - p_{y+t-1}^{H\,A^{Other}}\,{}_tV_y^{A^{Other}} - p_{y+t-1}^{H\,B}\,{}_tV_y^B,$$

Where

${}_tV_y^{A^{Other}} = 0$ for all the unrestricted extended, SACI and ACI models,

${}_tV_y^A = 0$ for the SACI and ACI models,

${}_tV_y^B = 0$ for all the models, except when $\lambda_2 < 1$ or $\lambda_3 < 1$ in the REACI model and $\lambda_2 < 1$ in the EACI model.

These conditions also hold for the following profit vectors PRO_t^A, $PRO_t^{A^{Other}}$ and PRO_t^B in the cash flows for our extended models. These profit vectors will always be equal to 0 for the traditional SACI and ACI models.

6.8.2 Profit Vector for Policyholder in State *A*, PRO_t^A

Similarly, for a policyholder in state *A* at the start of year *t*, the profit vector at the end of the t^{th} year is equal to the cash flow CF_t^A, plus the reserve at the start of the year ${}_{t-1}V_y^A$, less the reserve ${}_tV_y^A$ for those policyholders still in state *A* at the end of the year, and less the new reserve ${}_tV_y^B$ for those policyholders who have moved to state *B* during the year.

For our extended models this "profit vector" is given by

$$PRO_t^A = CF_t^A + {}_{t-1}V_y^A v^{-1} - p_{y+t-1}^{AA}\,{}_tV_y^A - p_{y+t-1}^{AB}\,{}_tV_y^B .$$

6.8.3 Profit Vector for Policyholder in State A^{Other}, $PRO_t^{A^{Other}}$

By symmetry, for our restricted extended models the profit vector at the end of year *t* for a policyholder in state A^{Other} at the start of year *t* is given by

$$PRO_t^{A^{Other}} = CF_t^{A^{Other}} + {}_{t-1}V_y^{A^{Other}} v^{-1} - p_{y+t-1}^{AA}\,{}_tV_y^{A^{Other}} - p_{y+t-1}^{A^{Other}\,B}\,{}_tV_y^B .$$

Otherwise, for our non-restricted extended models assume $PRO_t^{A^{Other}} = 0$ in the profit signature formula below.

6.8.4 Profit Vector for Policyholder in State *B*, PRO_t^B

Finally, for our EACI model (when $\lambda_2 < 1$ only), and REACI model (when $\lambda_2 < 1$ or $\lambda_3 < 1$ only) we will also have a profit vector for those policyholders already in state *B* at the start of the t^{th} year given by

$$PRO_t^B = CF_t^B + {}_{t-1}V_y^B v^{-1} - p_{y+t-1}^{BB}\,{}_tV_y^B .$$

6.8.5 Extended Accelerated Critical Illness Profit Signature σ_t

The above profit vectors assume that the policyholder is either in state *H*, state *A*, (state A^{Other}), or state *B* at the start of year *t*.

To calculate the profit for those policyholders who were originally all in state *H* at time *t* = 0, i.e. the "profit signature", we need to multiply the previous profit vectors by the probability of staying in state *H*, or moving to state *A*, (state A^{Other}) or state *B* by time *t* – 1, respectively.

For our models this is given by

$$\begin{aligned}\sigma_t &= \sigma_t^H + \sigma_t^A + \sigma_t^{A^{Other}} + \sigma_t^B \\ &= {}_{t-1}p_y^{H\,H}\ PRO_t^H + {}_{t-1}p_y^{H\,A}\ PRO_t^A + {}_{t-1}p_y^{H\,A^{Other}}\ PRO_t^{A^{Other}} + {}_{t-1}p_y^{H\,B}\ PRO_t^B .\end{aligned}$$

Intuitively, this required that the healthy policyholder aged *y* (at time 0), to either have remained in state *H* until time *t* -1, or already changed to state *A*, (state A^{Other}) or state *B* before time *t* -1.

On discounting the profit signature for each year *t*, and summing over all years *t* = 1,…,*n*, we can obtain the total expected discounted profit signature, TEPS = $\sum_{t=1}^{n} \sigma_t v^t$.

In our previous female malignant cancer example (annual premium of £100 per £10,000 of benefit over a *n* = 10-year term), the TEPS for the REACI and RESACI models are shown in the following Figure 16.

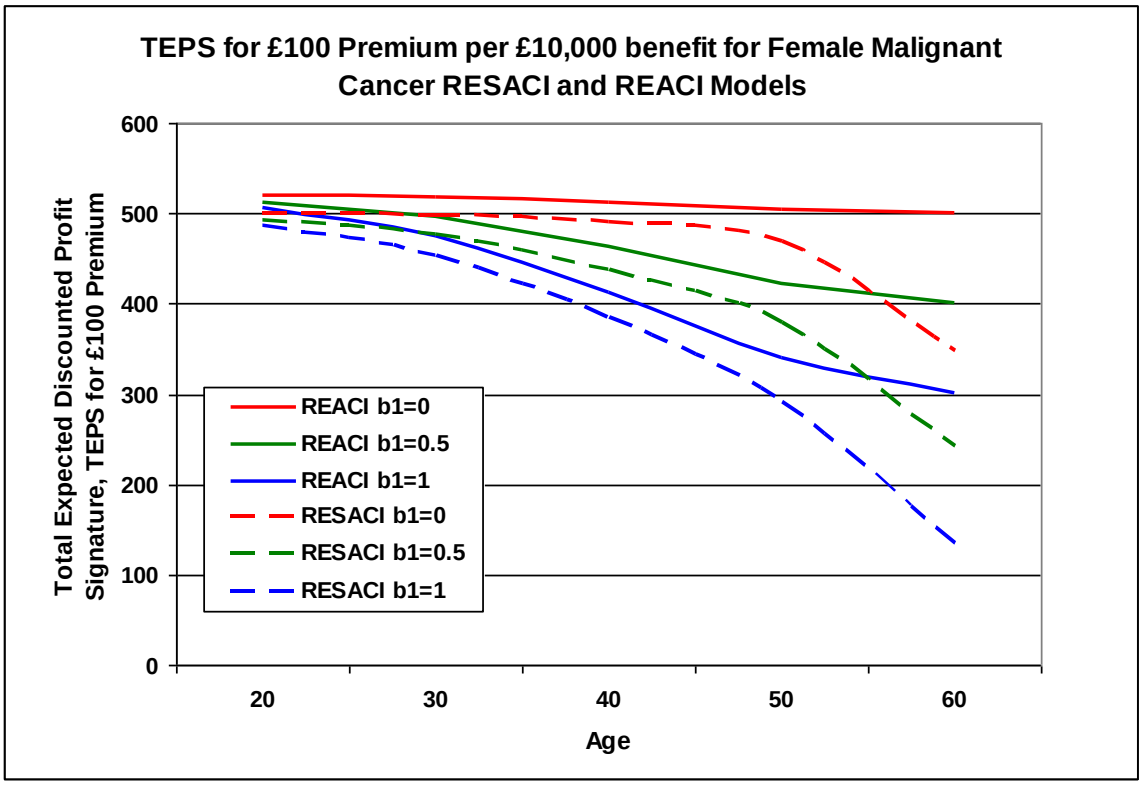


Figure 16: The total expected discounted profit signature (TEPS) for a fixed £100 annual premium over 10 years, for the REACI and RESACI models with increasing proportion b_1 from 0 to 1.

Figure 16 shows a steadily decreasing TEPS with increasing age (for a particular proportion b_1 payable on the 1st incident) as the expected 1st and 2nd incidence rates increase for the RESACI model (dotted lines). In addition, for the REACI model (solid lines) the gradient is far steeper with increasing age, because of the inclusion of increasing mortality with age. At each fixed age, the value of the TEPS occurs at a lower level when the proportion b_1 payable on the 1st incident is higher (from the red to blue curve) as a larger proportion of the total benefit payment is brought forward.

6.9 The Discounted Profit Margin (PM)

On dividing the previous total expected profit signature by the corresponding discounted total premium for our restricted models, we obtain the following discounted profit margin

$$DPM = \frac{\sum_{t=1}^{n} \sigma_t v^t}{\sum_{t=1}^{n} \pi_{t-1} v^{t-1} \left({}_{t-1}p_y^{H\,H} + z_1\ {}_{t-1}p_y^{H\,A} + z_2\ {}_{t-1}p_y^{H\,B} + z_3\ {}_{t-1}p_y^{H\,A^{Other}} \right)}.$$

Where the proportions z_1, z_2 and z_3 of the annual premium payable in state *A*, state *B* and state A^{Other} have been set equal to the outstanding proportion of the original benefit payable.

For our models, z_1, z_2 and $z_3 = 0$ for the SACI and ACI models,

$z_2 > 0$ only for the EACI model when $\lambda_2 < 1$ or
the REACI model when $\lambda_2 < 1$ or $\lambda_3 < 1$,

$z_3 > 0$ only for the RESACI and REACI models.

For our female malignant cancer stand-alone 10-year term policy, we compared the size of the discounted profit margin (DPM) for both our standard RSACI (b_1 = 1) and extended RESACI (b_1 = 0.5) models at four different fixed annual premium levels (£50, £100, £150, £200) as shown in Figure 17 below.

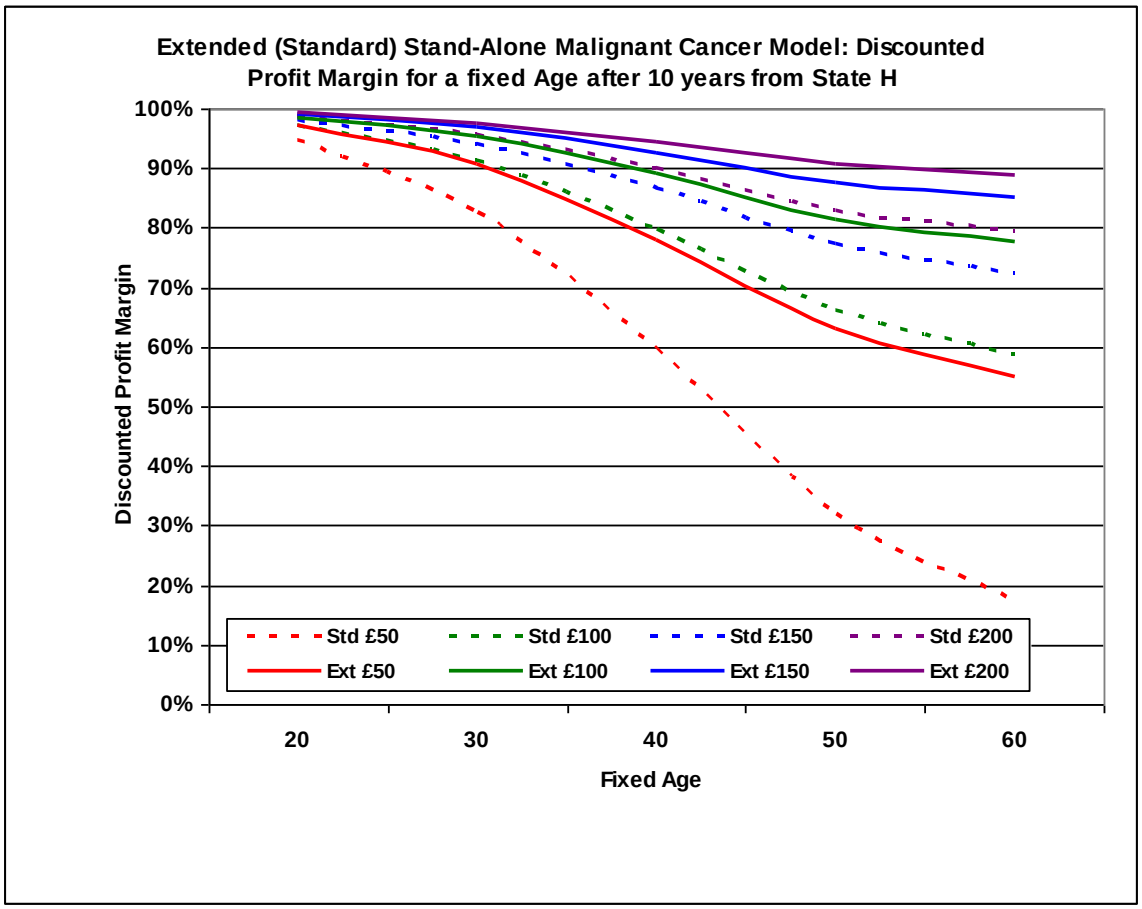


Figure 17: The discounted profit margin (DPM) against increasing age for each premium separately, assuming the RSACI and RESACI malignant cancer models.

In Figure 17 each curve shows a steady decrease in profit margin with increasing age because of increased morbidity. At any age and premium amount, the profit margin for our RESACI model (solid curve) is higher than the RSACI (dotted curve) model, because we are delaying half the payment to the 2nd incident (which may not occur within the 10-year time span) reducing the DPM numerator, while now collecting an additional 50% of the premiums between the 1st and 2nd incidents resulting in an increase in the DPM denominator.

The same conclusions hold for our RACI and REACI accelerated models, in the following Figure 18.

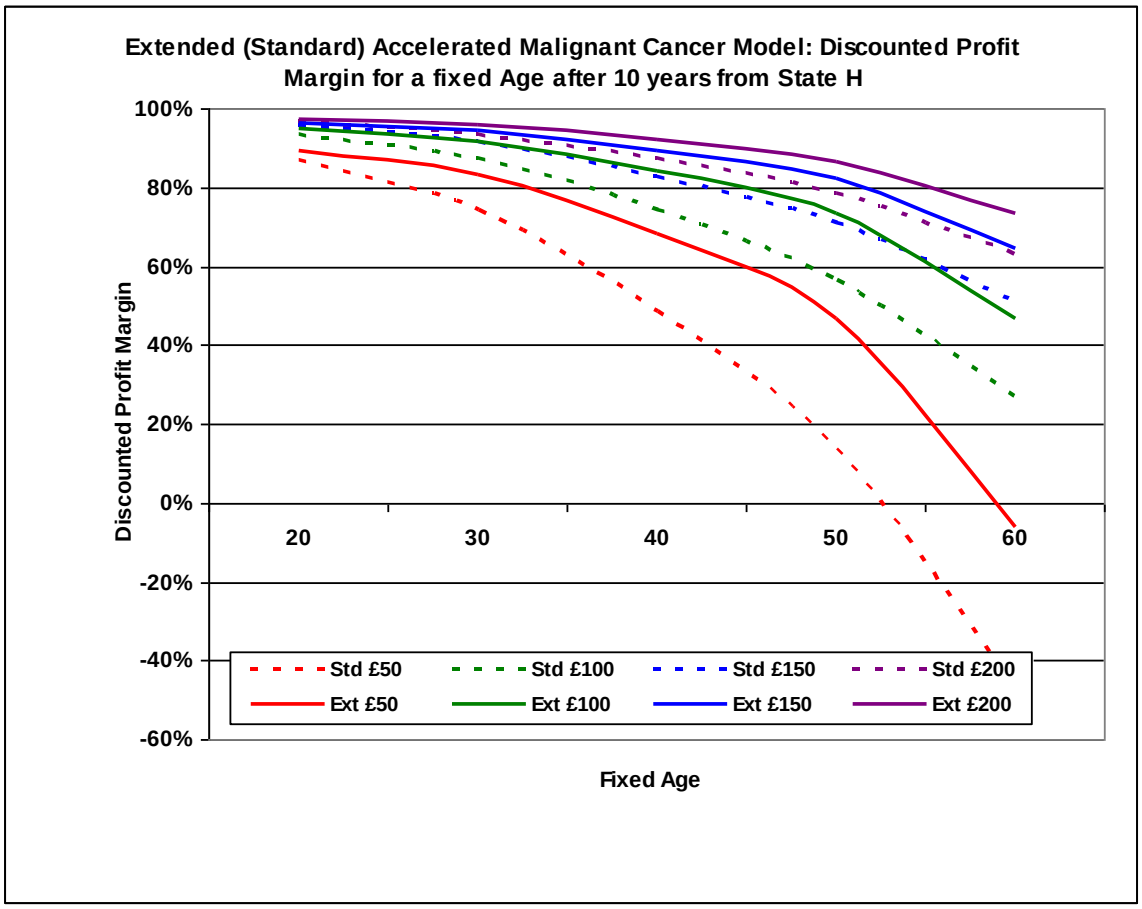


Figure 18: The discounted profit margin (DPM) against increasing age for each premium separately, assuming the RACI and REACI malignant cancer models.

In Figure 18 the profit margin is further decreased at all ages and premium amounts compared to Figure 17, because of the addition of the expected mortality benefits which increase with age. This decreases the numerator of the DPM resulting in a lower DPM, because we only have a slight reduction in the expected premium of the denominator compared to the profit margin in Figure 17.

For both Figure 17 and Figure 18, increasing the premium by a set £50 (to move onto the neighbouring curve) results in a more dramatic improvement in the DPM as the age increases. This is because as age increases the expected benefits increase dramatically resulting in the numerator of the DPM becoming increasingly smaller with age. So any fixed increase in premium will have a far more dramatic effect on the small numerator

than the already fairly large denominator, resulting in a greater proportional increase in the DPM than at a younger age.

On comparing the two figures we find that a £50 increase in premium is more dramatic for the stand-alone models than for the accelerated models. This is because for the accelerated models the expected benefits in the numerator of the DPM is higher than for the stand-alone models, so the additional fixed premium will have less impact on the DPM ratio.

Alternatively, and more usefully for each model, we can plot the DPM against increasing premium for each fixed age in the following Figure 19 and Figure 20.

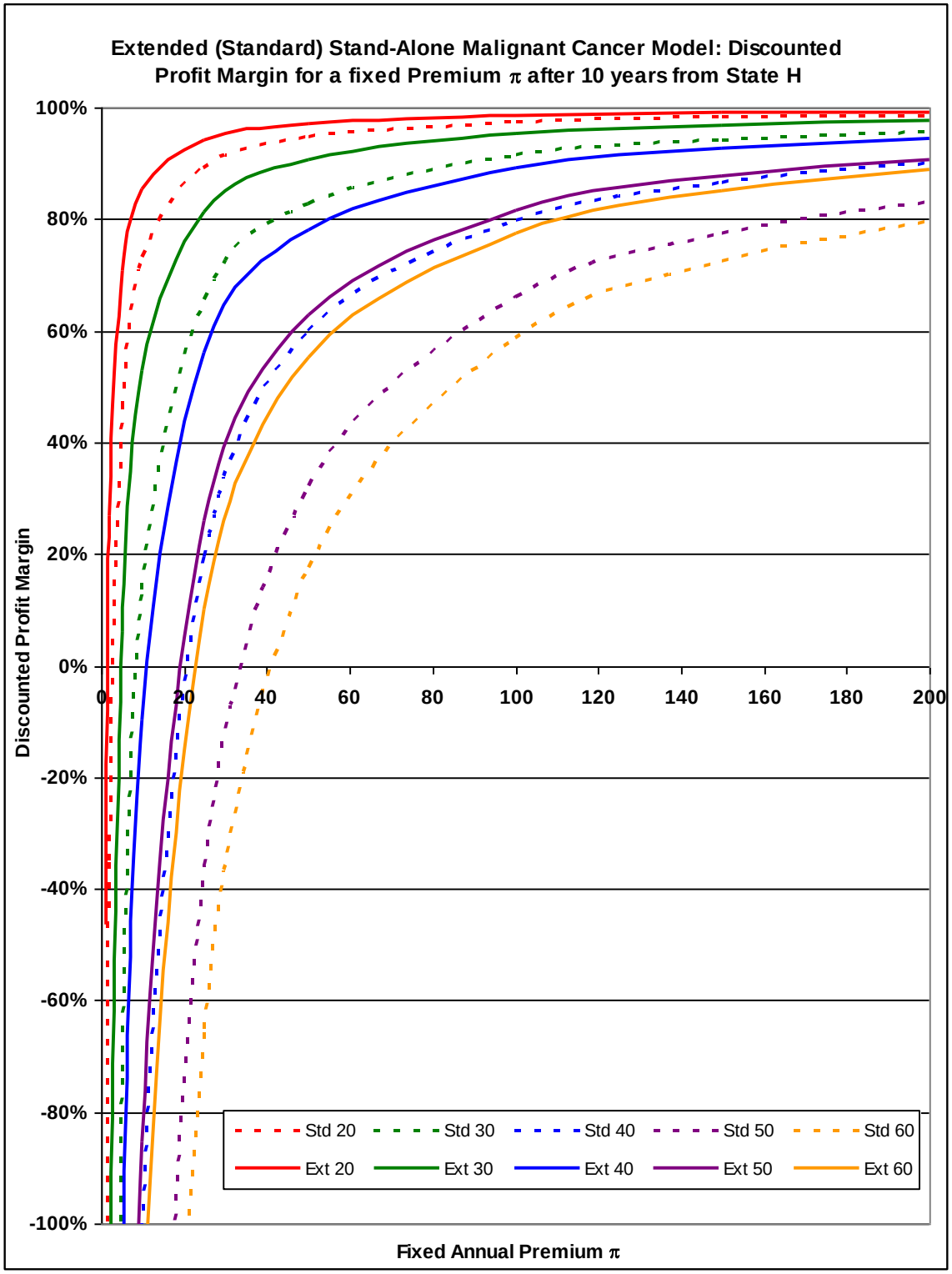


Figure 19: The discounted profit margin (DPM) against increasing premium for each age curve separately, assuming the standard and extended stand-alone malignant cancer restricted models RSACI and RESACI.

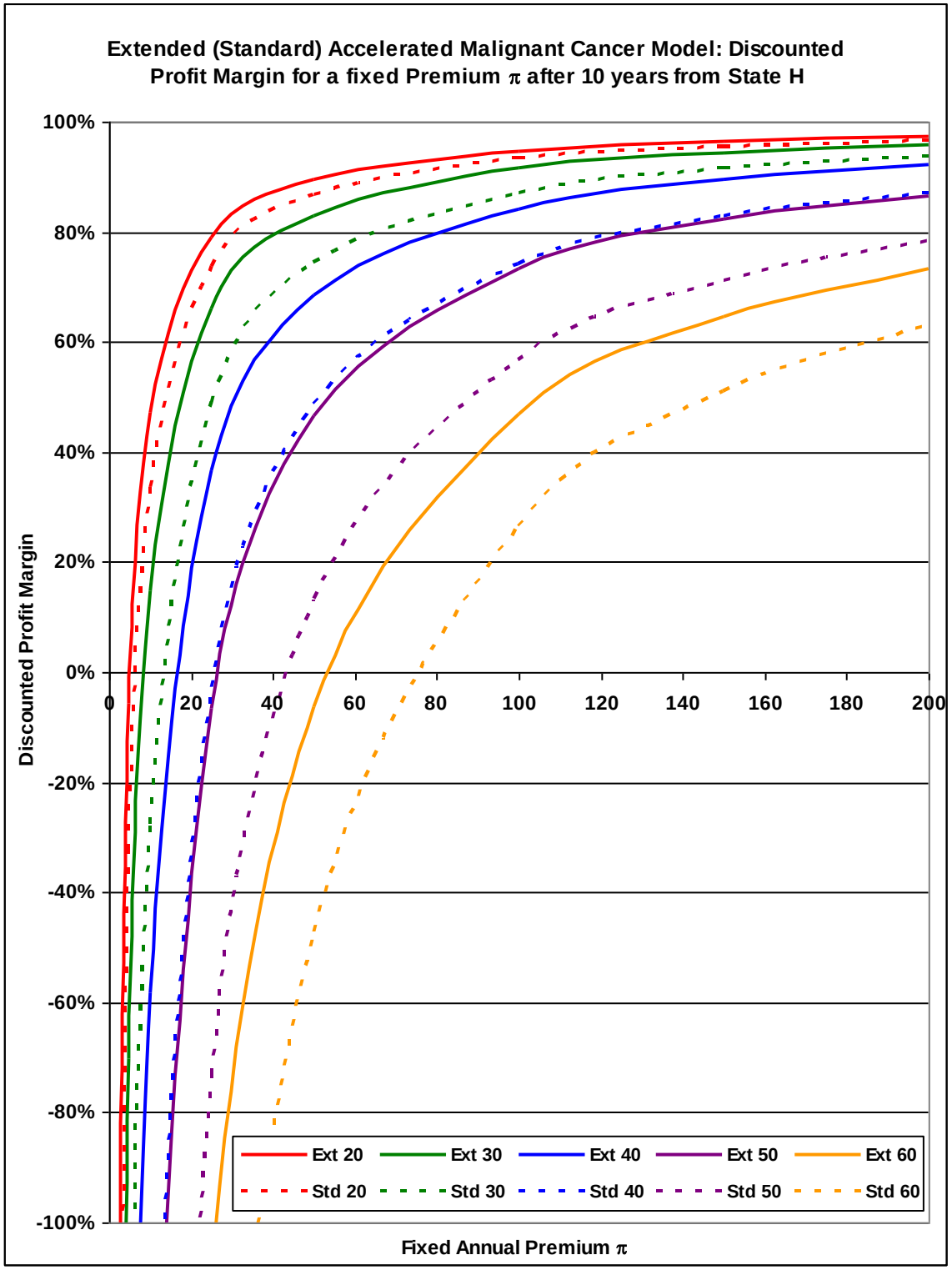


Figure 20: The discounted profit margin (DPM) against increasing premium for each age curve separately, assuming the standard and extended accelerated malignant cancer restricted models RACI and REACI.

For both Figure 19 and Figure 20 at ages below 20, we need very little annual expected premium to obtain a very high DPM, due to very low expected benefits payable in the next 10 years. As age increases the additional premium required for the same increase in positive DPM becomes more onerous as the age curves become more concave. This is because the expected benefit rapidly increases with a higher probability of a 1st and 2nd incident with increasing age. The inclusion of death benefits in Figure 20 results in a higher annual expected premium at all ages for a particular DPM.

In both Figure 19 and Figure 20 the annual premium is higher for the standard RSACI and RACI models (dotted lines) than the extended RESACI and REACI models (solid lines), because of the payment of a full benefit ($b_1 = 1$) on the 1st incident rather than only half the benefit ($b_1 = 0.5$). This difference in premiums increases rapidly with age as the expected benefit payable increases with age.

We shall now consider in the following Chapter 7 the reverse question of more concern to the insurer of what is the required premium for a fixed DPM, as this is how the policyholder will compare our different models in practice.

7 Restricted Extended Model Examples

We shall now apply the previous theory to calculate the required additional female premium required for a buy-back critical illness 10-year policy, while maintaining the same profit criteria of say a 20% discounted profit margin throughout all the following *examples 1* to *4* from the introduction.

7.1 Stand-Alone All Conditions Buy-Back Model

For the 'all conditions' model shown in the previous Figure 19, we can read off the required premium at a particular discounted profit margin (DPM) for a particular age and model. For example, rows 3 and 5 of the following Table 18 for the stand-alone full "buy-back" ($b_1 = 0.5$) and standard ($b_1 = 1.0$) models are consistent with the values on the *x*-axis of the above Figure 19 solid and broken lines when the *y*-axis DPM is equal to 20%.

Table 18: The required premium for a 20% profit margin for the stand-alone RESACI model with a benefit amount of £10,000 and proportion b_1 payable on the 1st incident within 10 years.

Step	Benefit Proportion b_1 on 1st Incident	Premium £ at Age 20	30	40	50	60
	0 (Deferred)	0.3	1.0	2.3	4.0	4.9
	0.25	1.1	3.5	8.3	14.7	19.3
a	**0.5 (Buy-Back)**	1.9	6.1	14.4	25.4	33.8
	0.75	2.7	8.6	20.4	36.2	48.5
b	**1 (Standard SACI)**	3.5	11.2	26.5	47.1	**63.4**
c = 2 x a - b	**Stand-Alone 'All Conditions' Buy-Back Option Premium**	0.3	1.0	2.2	3.7	4.2
c / b	**Buy-back Option Premium as a % of SACI Premium**	7%	8%	8%	8%	7%

Table 18 illustrates that the premium for the standard model increases more rapidly than the "buy-back" and "deferred" models, reaching a higher value of £63.4 at age 60, as a higher proportion of the benefit is payable on the 1st incident. In addition, because of the

timing delay in paying the remaining benefit, this may not even occur before the end of the 10 year policy term.

On doubling the buy-back premium to allow the same unit standard benefit at both the 1st and 2nd incident, we can compare with the standard stand-alone model on the final row to obtain the buy-back premium option. This option increases from £0.3 at age 20, to £4.2 at age 60, as the probability of the 2nd incidence increases rapidly with increasing age. However, as a % of the standard SACI premium the option premium remains fairly steady at around 8% between ages 20 and 60.

As well as these premium observations for a fixed model or fixed age, the following Figure 21 shows more clearly the increase in premium for both increasing b_1 and increasing age.

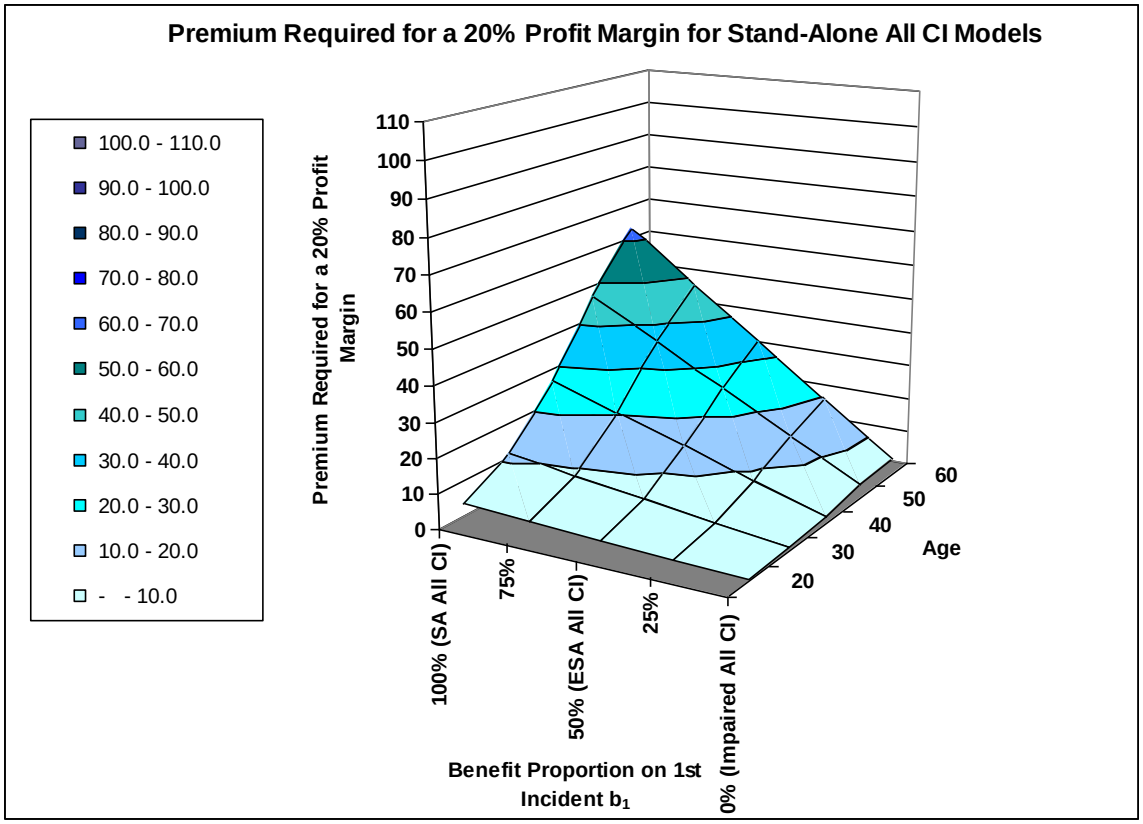


Figure 21: Our stand-alone cancer model RESACI, showing the increase in annual premium for a 20% profit margin, as both age increases and benefit proportion b_1 increases.

On allowing both the age and b_1 dimensions to change, we can traverse along a particular coloured line in Figure 21, while keeping the premium level constant. Thus by changing the relative size of the proportion b_1 payable upon satisfaction of the first qualifying condition enables us to offer all the policyholders the same level premium regardless of their age. For example, the upper border of the grey coloured strip corresponds to a premium of £20, which on increasing from ages 40 to 60, corresponds to a value of b_1 decreasing from 75% to 30%.

7.2 Accelerated All Conditions Buy-Back Model (*Example 1*)

We can repeat the above for the accelerated all conditions buy-back model (our *example 1*), provided we also deduct the implied premium due to deaths from the healthy state, i.e. non-CI conditions, as shown in the following Table 19.

Table 19: The required premium for a 20% profit margin for the accelerated REACI model with a benefit amount of £10,000 and proportion b_1 payable on the 1st incident within 10 years.

Step	Benefit Size £*M*	Female 'All Conditions' Model	Premium for a 20% Profit Margin £ 20	30	40	50	60
a	100%	SA b_1 = 1, Figure 19, Table 18	3.5	11.2	26.5	47.1	63.4
b	100%	ACI b_1 = 1, Figure 20	8.5	16.4	33.6	59.1	104.4
c = b - a		Deaths	4.9	5.2	7.1	12.1	41.0
d		% of deaths due to non-CI	78%	69%	57%	47%	37%
e = c x d		Deaths due to non-CI '1 - Σ k_x'	3.86	3.61	4.05	5.62	15.30
f	50%	Extended b_1 = 0.5 REACI All Conditions	6.7	10.9	20.5	35.8	72.5
g = 2 x f - e	100%	Buy-back Premium	9.5	18.1	36.9	65.9	129.8
h = g - b	100%	Accelerated All Conditions Buy-Back Premium Option	1.1	1.7	3.3	6.8	25.4
i = h / b	100%	Buy-back Option as a % of ACI	12%	10%	10%	11%	24%

The accelerated buy-back premium option increases far more rapidly than the previous stand-alone premium option with increasing age due to the addition of mortality after the 1st and 2nd incident, which increases rapidly with age. As a % of the standard ACI premium, the buy-back option premium remains fairly steady at around 11% between ages 20 and 50, before rapidly increasing to 24% at age 60. The reason being is a near doubling of the buy-back premium from ages 50 to 60, as shown in the following Figure 22.

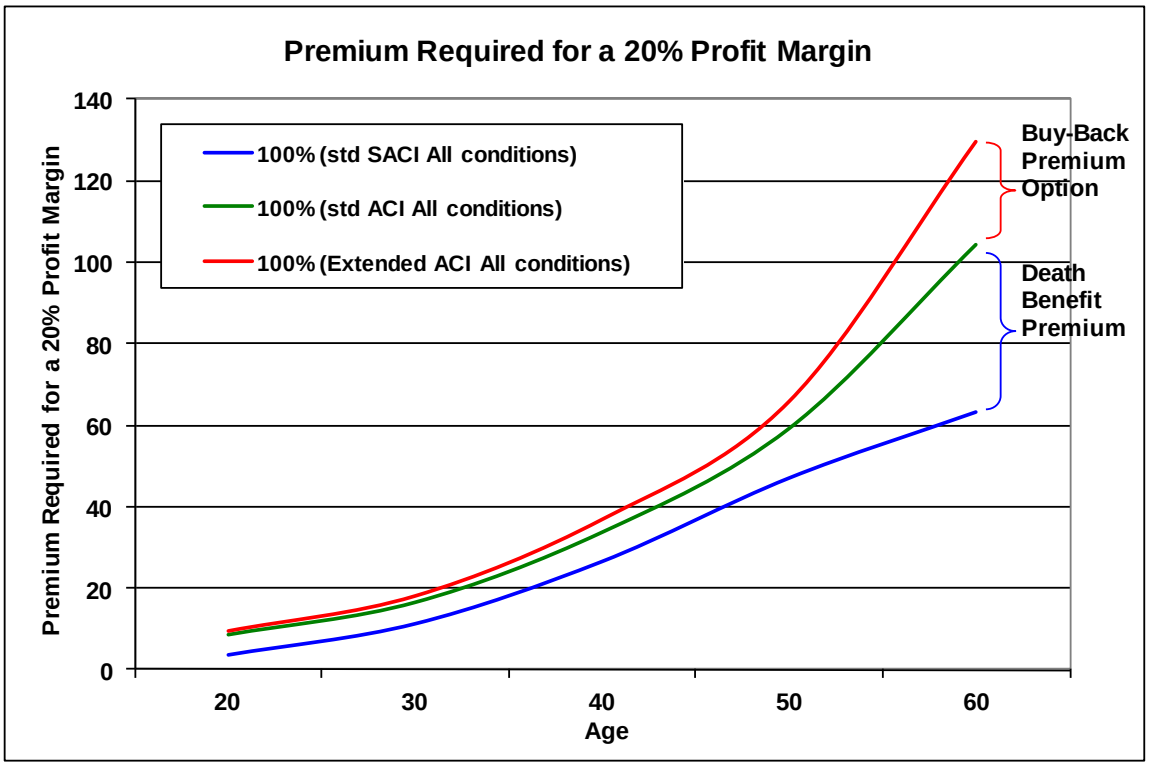


Figure 22: The premium required for a 20% profit margin for an accelerated model with buy-back (*example 1*), compared to the corresponding standard stand-alone or accelerated models.

7.3 Accelerated Cancer Buy-Back Model (*Example 2*)

Alternatively, we can consider a benefit payable on cancer only in our accelerated REACI model in Figure 13. We shall denote this by our *example 2*, when a full reinstatement of the original cancer only benefit coverage is provided. The required premiums for a 20% profit margin for the following special cases of this REACI model are shown in the following Table 20.

Table 20: The required premiums at each age for a 20% profit margin for the special cases of our accelerated cancer only REACI model, with increasing benefit proportion b_1 on the 1st incident.

	Benefit Payment on Malignant Cancer Only			Premium Required for a 20% Profit Margin £				
Step (used below)	**Cancer Only Model**	**b_1 (b_2=1-b_1,b_3=1)**	**Transitions with a Benefit Payment**	**Age**				
				20	**30**	**40**	**50**	**60**
	Basic (no deaths)		$H \rightarrow A^{cancer\ (ex\ deaths)}$	2.7	9.7	23.7	40.7	49.5
	Basic (inc Deaths)		$H \rightarrow A^{cancer}$	3.2	10.9	27.0	47.2	72.7
a	**Std Stand-Alone RSACI**	**b_1 = 1**	$H \rightarrow A^{cancer(ex\ deaths)}$, $A^{non\text{-}cancer(ex\ deaths)} \rightarrow B^{cancer(ex\ deaths)}$	3.4	10.8	25.2	42.6	51.9
b	**Std Accelerated RACI**	**b_1 = 1**	$H \rightarrow A^{cancer}$, $A^{non\text{-}cancer} \rightarrow B^{cancer}$	8.3	16.0	32.1	54.2	91.9
	REACI - 33% buy-back	b_1=0.75	$H \rightarrow A^{cancer}$, $A^{cancer} \rightarrow B^{cancer}$, $A^{non\text{-}cancer} \rightarrow B^{cancer}$	7.4	13.3	25.9	43.7	79.1
f	**REACI - 100% buy-back**	**b_1=0.5**		6.6	10.6	19.8	33.3	66.5
	REACI - 300% buy-back	b_1=0.25		5.8	8.0	13.6	23.0	53.9
	REACI Deferred	**b_1=0**	$A^{cancer} \rightarrow B^{cancer}$, $A^{non\text{-}cancer} \rightarrow B^{cancer}$	4.9	5.3	7.5	12.8	41.4

On comparing the difference in the premium for the standard RACI model (row 4) with the basic (inc deaths) model (row 2) in Table 20, we note that on introducing the

possibility of cancer from non-cancer conditions, we require an increase in premium of £5.1 at age 20, to £19.2 at age 60.

The same pattern of increasing premium with age and proportion b_1 is also observed for the accelerated REACI model, with a far steeper increasing gradient with age as the underlying mortality increases (as shown in the following Figure 23).

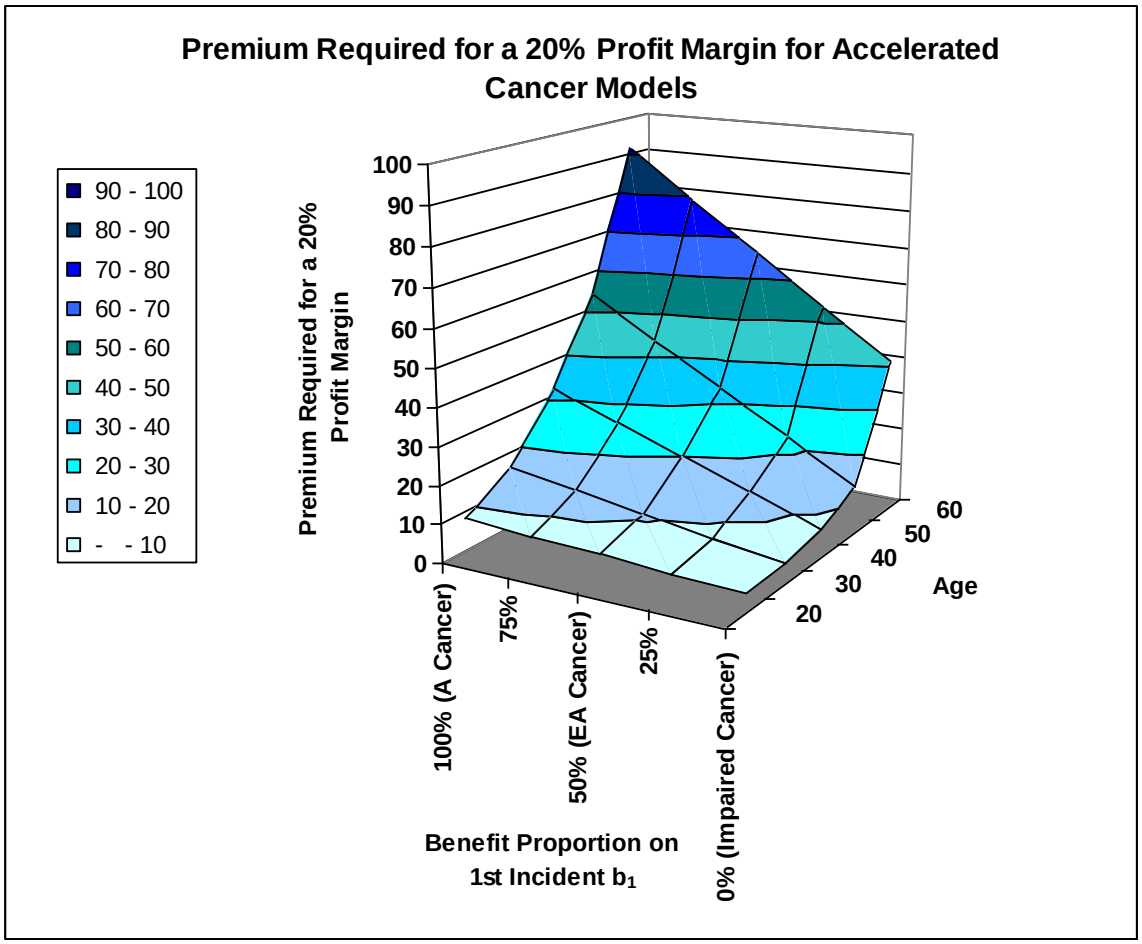


Figure 23: Our accelerated REACI cancer model showing the increase in annual premium for a 20% profit margin, as both age increases and benefit proportion b_1 increases.

As for the previous RESACI model the surface contours of Figure 23 allow us to determine what proportion of the 1st benefit b_1 could be accelerated and still satisfy the required 20% profit margin if a fixed premium was required for all ages.

At a particular profit margin, if we increase the premium payable then we will have a corresponding proportional increase in the benefit paid. This means that we can increase the premium payable in all our previous extended stand-alone "buy-back" models in the required proportion in order to provide a corresponding unit benefit. This premium per unit benefit can then be compared with the standard model providing a unit benefit to determine the additional cost of the buy-back option for a required % buy-back.

However, for the extended accelerated models if we double the benefit (when $b_1 = 0.5$), to allow a unit benefit payable on the 1st and 2nd incidents, we would also have doubled the benefit payable from the healthy state to death. As we only require a unit benefit we need to undertake an additional calculation to deduct the premium for deaths due to non-cancer from the doubling of the corresponding accelerated model premium. As we do not have any mortality data for policyholders from the healthy state, we shall use the same method as discussed in section 4.10.2, to determine the proportion of deaths from the non-cancer states '1 - k_x'. Then multiply by the mortality premium, i.e. the difference in the premium for the standard stand-alone and accelerated single benefit models.

These steps are shown in the following **Table 21** for our female cancer policyholder looking for the required premium option on a 100% buy-back of £10,000 benefit, which provides a 20% profit margin.

Table 21: The calculation of the 100% buy-back option premiums required for the REACI female cancer model (with £10,000 benefit) in order to provide a 20% profit margin.

Step	Benefit Size £M	Female Cancer Model	Premium for a 20% Profit Margin £ 20	30	40	50	60
a	100%	SA Cancer RSACI	3.4	10.8	25.2	42.6	51.9
b	100%	A Cancer RACI	8.3	16.0	32.1	54.2	91.9
c = b - a		Deaths	4.9	5.1	7.0	11.6	40.1
d		% of deaths due to non-Cancer	83%	67%	55%	46%	53%
e = c x d		Deaths due to non-Cancer '1-k_x'	4.0	3.4	3.9	5.4	21.2
f	50%	Extended b_1 = 0.5 REACI Cancer	6.6	10.6	19.8	33.3	66.5
g = 2 x f - e	100%	Buy-back premium	9.2	17.9	35.7	61.3	111.7
h = g - b	100%	100% Buy-back Option premium	0.9	1.9	3.6	7.1	19.8
i = h / b	100%	Buy-back Option as a % of RACI	11.1%	12.0%	11.1%	13.1%	21.5%

The first three steps ‘a’ to ‘c’ in **Table 21** determine the premium required for the death benefit from the difference in the ‘RSACI cancer’ and ‘RACI cancer’ models. A proportion k_x of the deaths will be due to cancer and the other ‘1 - k_x’ of deaths will be due to non-cancer. So we will need to deduct the corresponding non-cancer death premium in step ‘e’ from our 100% ‘REACI cancer’ premium (2 x step ‘f’) in step ‘g’, in order that we still only pay 100% benefit on death from the healthy state rather than 200%.

Finally, on deducting the original ‘RACI cancer’ premium in step ‘b’ from the buy-back premium in step ‘g’ the buy-back option premium can be determined in step ‘h’. This can be seen graphically in Figure 24 below as the difference between the red buy-back premium curve and the blue standard accelerated cancer curve.

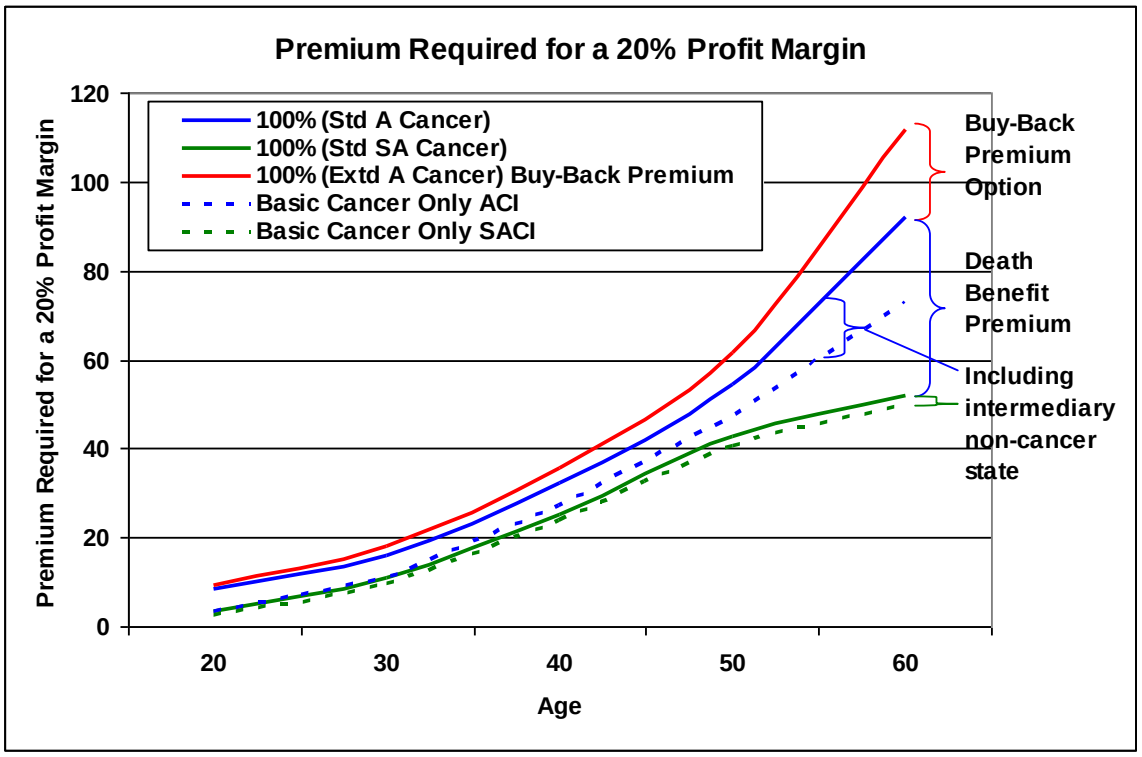


Figure 24: The premium required for a 20% profit margin for either an accelerated with buy-back (*example 2*), standard accelerated or stand-alone cancer buy-back, compared to the corresponding cases for a basic cancer only model with no intermediary non-cancer state in the model.

From Figure 24 the difference in the red and blue curves (step 'h' in **Table 21**) shows that the 'buy-back' premium increases from £0.9 at age 20 to £19.8 at age 60. This will be discussed further when we compare with other models in Chapter 8. Similarly, the difference between the green standard stand-alone cancer curve and the standard accelerated cancer curve indicates that the premium amount required to pay for the 'death benefit' of £4.9 at age 20, to £40.0 at age 60, is still relatively more expensive than the 'buy-back' premium.

If we had just considered the basic cancer model (which ignores transitions from the intermediary non-cancer state to the cancer state) then we would have obtained the dotted curves corresponding to the respective standard model with the same colour. The difference between the dotted and solid lines is equal to the increase in premium to pay for the inclusion of a qualifying benefit payable, after a non-qualifying benefit. This

difference is greater for the accelerated cancer model than the stand-alone cancer model, because we are also including a higher incidence of deaths from the non-qualifying state, whereas the basic accelerated cancer model would continue to assume the standard healthy mortality rate for policyholders in the non-qualifying state. As mortality increases more with age, so this difference increases more with age.

In the last row of **Table 21** above the buy-back premium as a % of our standard accelerated RACI cancer model premium increases from 11.1% at age 20, to 21.5% at age 60.

For simplicity, some insurers prefer to offer a flat premium increase across all ages, say 12%. However, it should be kept in mind that our table of buy-back premium increases rapidly with ages above 50 resulting in a potential change in policyholder mix towards the oldest ages.

One possibility in ordr to allow a flat option premium at all ages would be to reduce the benefit reinstated as age increases. However, this would require only providing approximately 40% of the benefit payable at age 60.

7.4 Cancer (Excluding Breast Cancer) Model (*Example 3*)

In a practical critical illness underwriting situation, the underwriter may wish to exclude certain components of a CI qualifying condition, rather than the whole CI condition as this may provide too little benefit coverage. For example, if the policyholder has had a family history of breast cancer, but they are themselves healthy, then the policyholder may be offered the aforementioned cancer only product excluding breast cancer. We shall denote this by our *example 3*, when a full reinstatement of the original cancer (excluding breast) benefit coverage is provided.

We can easily re-use the same special cases of the REACI models above, by including breast cancer with the other conditions in our state A^{Other}, obtaining the following Table 22 of premiums required for a 20% profit margin.

Table 22: The required premium at each age for a 20% profit margin for the special cases of our accelerated cancer only (excluding breast) REACI model, with increasing benefit proportion b_1 on the 1st incident.

	Benefit Payment on Malignant Cancer (Excluding breast Only			Premium Required for a 20% Profit Margin £				
Step (used below)	Cancer (Excluding breast) Only	b_1 (b_2=1-b_1,b_3=1)	Transitions with a Benefit Payment	Age 20	30	40	50	60
	Basic (no deaths)		$H \rightarrow A^{cancer\ (ex\ death,\ ex\ breasts)}$	2.2	6.3	14.1	27.7	39.1
	Basic (inc Deaths)		$H \rightarrow A^{cancer\ (ex\ breast)}$	2.7	7.2	16.5	33.0	61.3
a	Std Stand-Alone RSACI	$b_1 = 1$	$H \rightarrow A^{cancer(ex\ deaths,\ ex\ breast)}$, $A^{non\text{-}cancer(ex\ deaths,\ inc\ breast)} \rightarrow B^{cancer(ex\ deaths,\ ex\ breast)}$	2.8	7.1	15.3	29.1	40.9
b	Std Accelerated RACI	$b_1 = 1$	$H \rightarrow A^{cancer(ex\ breast)}$, $A^{non\text{-}cancer(inc\ breast)} \rightarrow B^{cancer(ex\ breast)}$	7.6	11.8	21.0	39.5	80.2
	REACI - 33% buy-	b_1=0.75	$H \rightarrow A^{cancer(ex\ breast)}$, $A^{cancer(ex\ breast)} \rightarrow B^{cancer(ex\ breast)}$, $A^{non\text{-}cancer(inc\ breast)} \rightarrow B^{cancer(ex\ breast)}$	2.5	6.1	13.6	27.1	53.0
f	REACI - 100% buy-	b_1=0.5		1.8	4.3	9.8	19.7	42.7
	REACI - 300% buy-	b_1=0.25		1.1	2.6	5.9	12.5	32.5
	REACI Deferred	b_1=0	$A^{cancer(ex\ breast)} \rightarrow B^{cancer(ex\ breast)}$, $A^{non\text{-}cancer(inc\ breast)} \rightarrow B^{cancer(ex\ breast)}$	0.4	0.8	2.1	5.2	22.3

On comparing the difference in the premium for the standard RACI model in row 4 with the basic model in row 2 of Table 22, we note that on introducing the possibility of cancer (ex breast) from the non-cancer (inc breast) conditions we require an additional premium of £4.9 at age 20, to £18.9 at age 60.

This increase is slightly less than in the previous cancer only comparison, because we do not have to pay out on breast cancer, although this is offset by a far higher 2nd incidence of cancer (ex breast cancer) following a 1st incidence of breast cancer, than just for the cardiovascular, neurological and other non-cancer conditions present in the previous model. So as before, the basic model (which ignores transitions from the intermediary non-qualifying states) would indicate an insufficient premium.

In Figure 25 the same pattern of increasing premium with age and proportion b_1 is observed as for the previous REACI cancer only model; except that the value is less at each coordinate due to no payments on incidents of breast cancer.

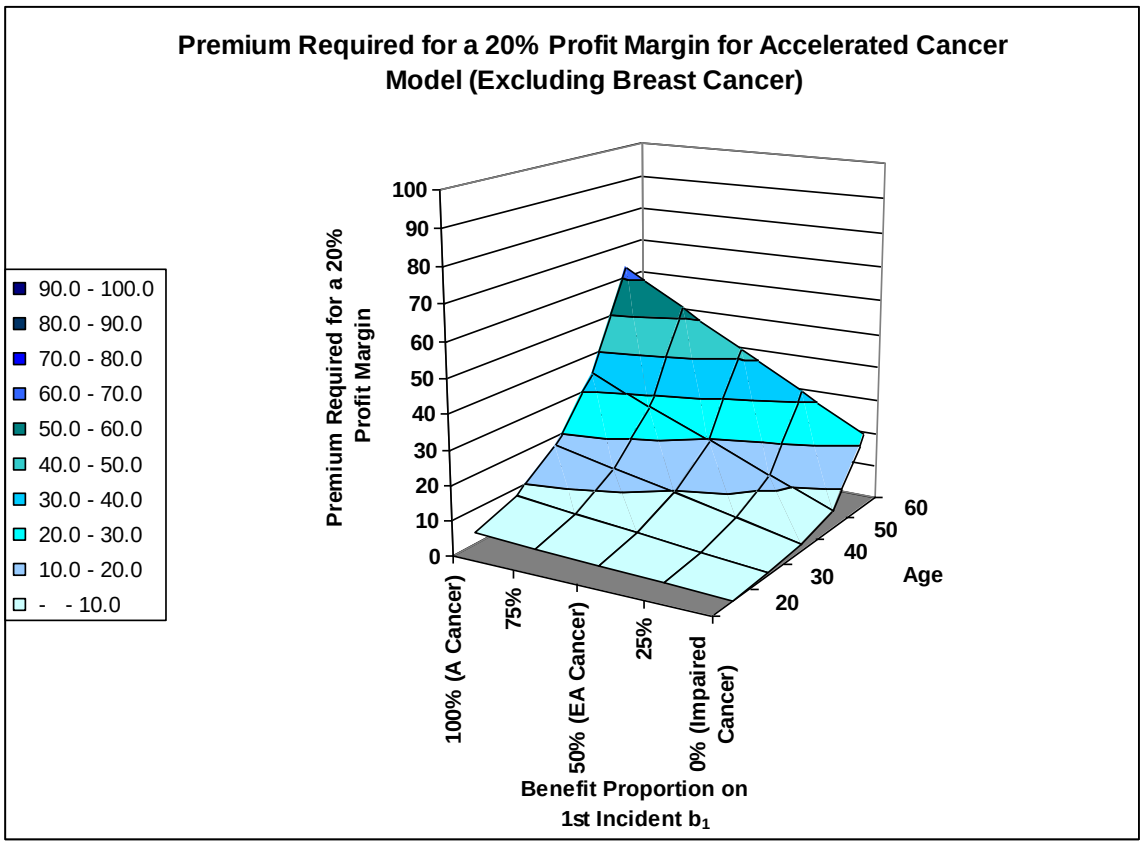


Figure 25: Our accelerated REACI cancer (excluding breast) model showing the increase in annual premium for a 20% profit margin, as both age increases and benefit proportion b_1 increases.

As in the previous REACI cancer only model, we can increase the premium proportionally in order to provide a unit benefit on the 1st incident. Then after making a slight adjustment for the doubling of deaths from healthy policyholders, we compare the

resulting premium per unit of benefit with the standard model to determine the additional cost of the buy-back option in the following Table 23.

Table 23: The calculation of the 100% buy-back option premiums required for the REACI female cancer (excluding breast) model (with £10,000 benefit) in order to provide a 20% profit margin.

Step	Benefit Size £M	Female Cancer (Excluding breast) Model	Premium for a 20% Profit Margin £ 20	30	40	50	60
a	100%	SA Cancer (ex breast) RSACI	2.8	7.1	15.3	29.1	40.9
b	100%	A Cancer (ex breast) RACI	7.6	11.8	21.0	39.5	80.2
c = b - a		Deaths	4.8	4.7	5.8	10.3	39.3
d		% of deaths due to non-Cancer (ex breast)	86%	79%	74%	64%	59%
e = c x d		Deaths due to non-Cancer (ex breast) '1-k_x'	4.1	3.7	4.3	6.6	23.3
f	50%	Extended b_1 = 0.5 REACI Cancer	6.2	8.3	13.4	24.9	59.6
g = 2 x f - e	100%	(ex breast) Buy-back premium	8.3	12.8	22.5	43.1	95.8
h = g - b	100%	100% Buy-back Option (ex breast) premium	0.7	1.0	1.5	3.6	15.6
i = h / b	100%	Buy-back Option as a % of RACI	9.2%	8.5%	7.1%	9.1%	19.5%

The cancer (excluding breast) curves corresponding to steps ‘a’, ‘b’ and ‘g’ in

Table 23 are shown in the following Figure 26 by the solid curves, together with the dotted curves for the corresponding basic model with no ‘non-cancer, except breast cancer’ intermediary state.

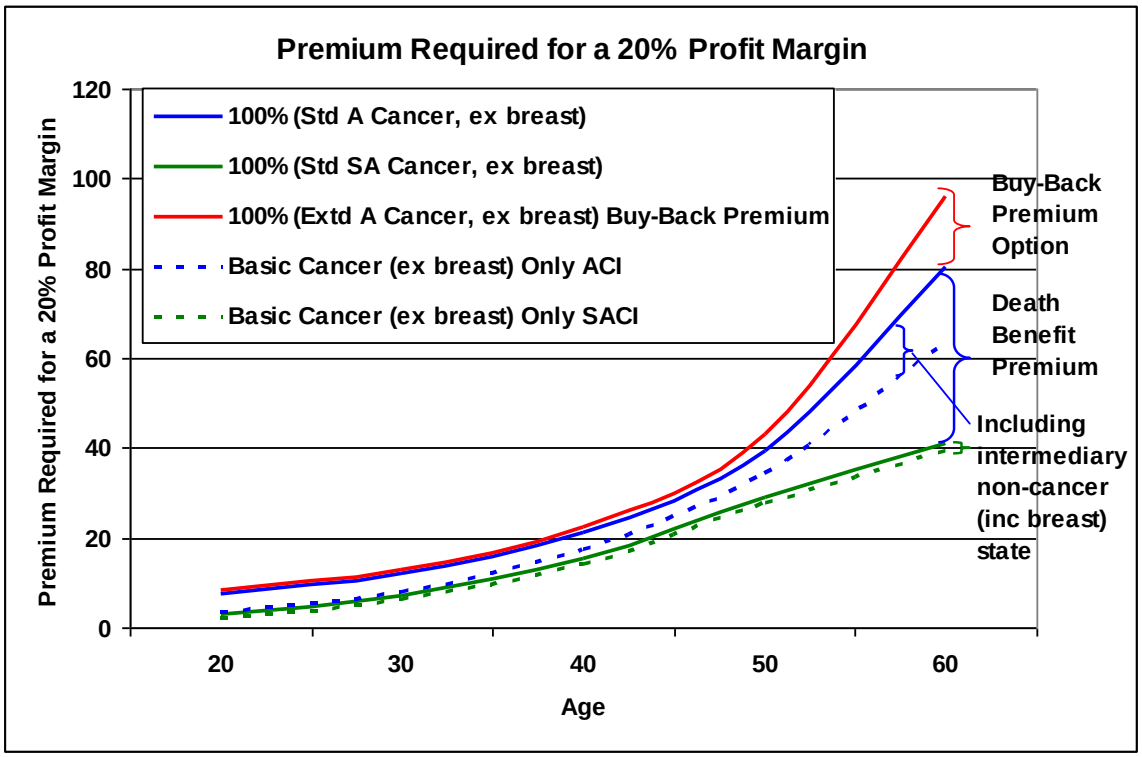


Figure 26: The premium required for a 20% profit margin for either an accelerated with buy-back (*example 3*), standard accelerated or stand-alone cancer (excluding breast), compared to the corresponding cases for a basic cancer only model with no intermediary non-cancer state in the model.

As previously, the difference between the blue and red curves in Figure 26 allows us to determine the premium for the buy-back option excluding breast cancer as shown by 'step h' in Table 23. This buy-back premium option as a % of the standard accelerated cancer premium increases from 9.2% at age 20, to 19.5% at age 60, which is slightly cheaper than when we included all the cancers above (11.1% at age 20, to 22.5% at age 60).

A decrease in the buy-back premium option is expected as over half the incidence for female cancer is due to breast cancer. However, there is an increase in policyholders falling into the intermediary non-qualifying state (which now includes breast cancer), increasing the 2nd incidence rate of non-breast cancer conditions which will increase the incidence . Therefore, in this extreme example of excluding breast cancer, we need to be careful to ensure that we include such intermediary states. As such intermediary states are

ignored in the basic buy-back model this leads to a greater under-estimation of the correct premium as age increases. Further comparison of this buy-back premium option with the previous examples will be discussed further in Chapter 8 below.

7.5 Cardio-Vascular Model (*Example 4*)

Alternatively, we can consider a cardio-vascular model instead of the previous cancer model, which we shall denote by our *example 4* when a full reinstatement of the original cardio-vascular benefit coverage is provided. The following premiums for a 20% profit margin are required in Table 24 below for the various extended models.

Table 24: The required premiums at each age for a 20% profit margin for the special cases of our cardio-vascular only RACI model, with increasing benefit proportion b_1 on the 1st incident.

	Benefit Payment on Cardio-vascular Only			Premium Required for a 20% Profit Margin £				
Step (used below)	Cardio-vascular Only Model	b_1 (b_2=1-b_1,b_3=1)	Transitions with a Benefit Payment	Age 20	30	40	50	60
	Basic (no deaths)		$H \rightarrow A^{cardio}$ *(ex deaths)*	0.3	1.0	2.8	6.9	14.0
	Basic (inc Deaths)		$H \rightarrow A^{cardio}$	0.4	0.8	2.7	8.0	31.2
a	Std Stand-Alone RSACI	$b_1 = 1$	$H \rightarrow A^{cardio}$ *(ex deaths)*, $A^{non\text{-}cardio} \rightarrow B^{cardio}$ *(ex deaths)*	0.3	1.0	2.8	6.9	14.0
b	Std Accelerated	$b_1 = 1$	$H \rightarrow A^{cardio}$, $A^{non\text{-}cardio} \rightarrow B^{cardio}$	0.4	0.8	2.8	8.2	32.0
	REACI - 33% buy-back	b_1=0.75	$H \rightarrow A^{cardio}$, $A^{cardio} \rightarrow B^{cardio}$, $A^{non\text{-}cardio} \rightarrow B^{cardio}$, $H \rightarrow A^{cardio}$ *(ex deaths)*	0.3	0.7	2.5	7.1	29.2
f	REACI - 100% buy-back	b_1=0.5		0.3	0.6	2.1	6.0	26.4
	REACI - 300% buy-back	b_1=0.25		0.3	0.5	1.8	4.8	23.6
	REACI Deferred	b_1=0	$H \rightarrow A^{cardio}$	0.2	0.4	1.5	3.7	20.7

On comparing the difference in premium for the standard accelerated cardio-vascular model with the corresponding simplified model in Table 24, we note that there is only a slight increase in premium at the oldest age of £0.8, indicating little secondary cardiovascular incidence after non-cardiovascular primary incidence. So a simpler model ignoring other conditions would provide approximately the same premiums at ages below 50. At the youngest age 20 there is hardly any difference in premium between whether part of the benefit is delayed or paid up front, as the 1st incidence rate is relatively low.

Delaying the benefit is far more important as age increases, with a larger decrease in premium, compared to paying all the benefit up-front on the 1st incidence. However, this effect is secondary to the rapidly increasing premium after age 40, because of the increasing cardiovascular 2nd incidence and mortality, as shown in the following Figure 27.

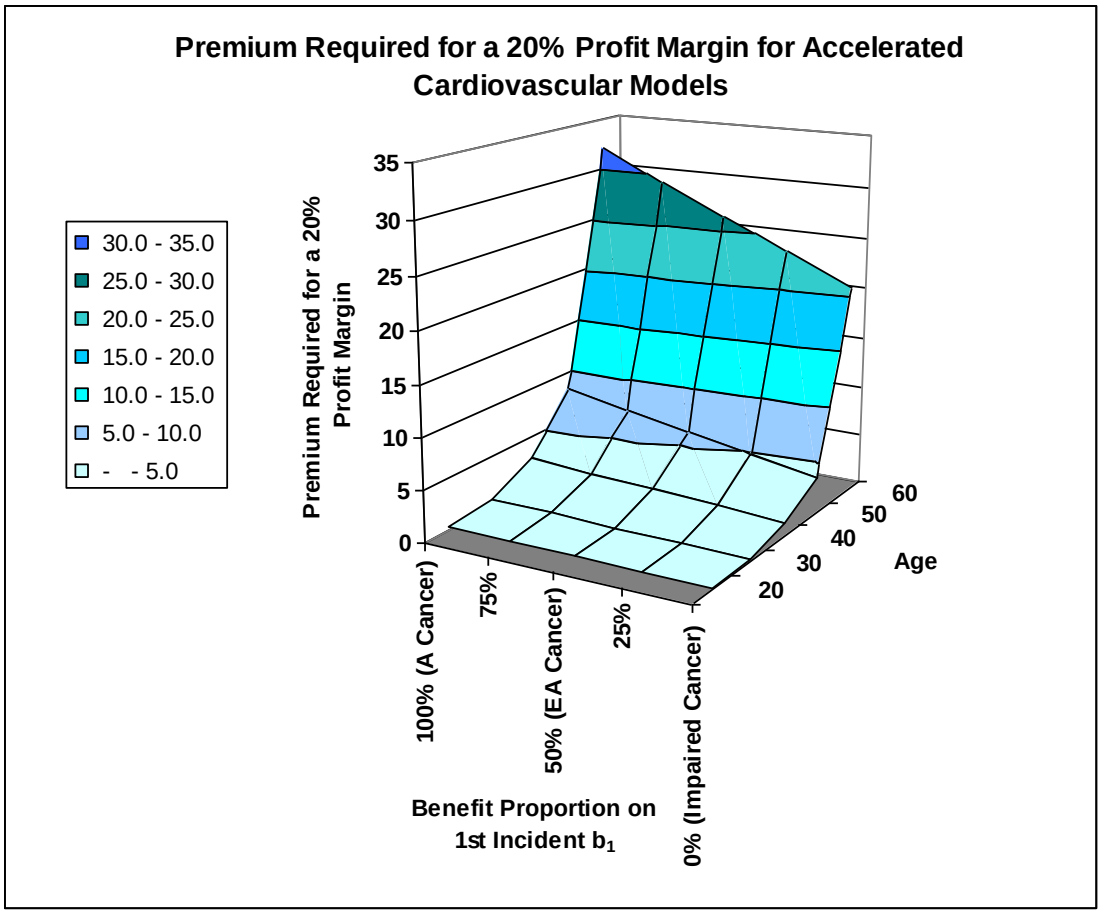


Figure 27: Our accelerated REACI cardiovascular model showing the increase in annual premium for a 20% profit margin, as both age increases and benefit proportion b_1 increases.

Overall, the above Figure 27 indicates that we only need to be concerned with the premium required for the cardiovascular benefit reinstatement at ages 50 and over for any choice of benefit reinstatement percentage. This is shown for the buy-back premium (b_1 = 0.5) in the following Table 25 and Figure 28.

Table 25: The calculation of the 100% buy-back option premiums required for the REACI cardio-vascular model (with £10,000 benefit) in order to provide a 20% Profit Margin.

Step	Benefit Size £*M*	Female Cardiovascular Model	Premium for a 20% Profit Margin £ 20	30	40	50	60
a	100%	SA Cardiovascular RSACI	0.2	0.4	1.4	4.6	11.6
b	100%	A Cardiovascular RACI	4.8	4.7	6.5	13.7	49.6
c = b - a		Deaths	4.6	4.3	5.1	9.1	38.0
d		% of deaths due to non-Cardiovascular (Robjohns *et al* 2006)	97%	94%	91%	91%	87%
e = c x d		Deaths due to non-Cardiovascular '1-k_x'	4.5	4.1	4.6	8.2	33.0
f	50%	Extended b_1 = 0.5 REACI Cardiovascular	4.7	4.5	5.8	11.3	43.5
g = 2 x f - e	100%	Buy-back premium	4.9	5.0	6.9	14.3	54.0
h = g - b	100%	100% Buy-back Option premium	0.1	0.2	0.4	0.6	4.4
i = h / b	100%	Buy-back Option as a % of RACI	3%	5%	6%	4%	9%

From 'step g' in Table 25, the buy-back cardiovascular premium shown in red increases rapidly from £4.9 at age 20, to £54.0 at age 60, as the incidence of cardiovascular diseases and mortality increases with age.

On deducting the premium for the standard accelerated cardiovascular model (shown in blue) we still have a rapidly increasing buy-back premium option from £0.1 at age 20, to £4.4 at age 60 in 'step h'. This is because the secondary incidence of cardiovascular

disease begins to increase rapidly after age 50. This difference is shown in the following Figure 28 on comparing the difference between the red and blue curves.

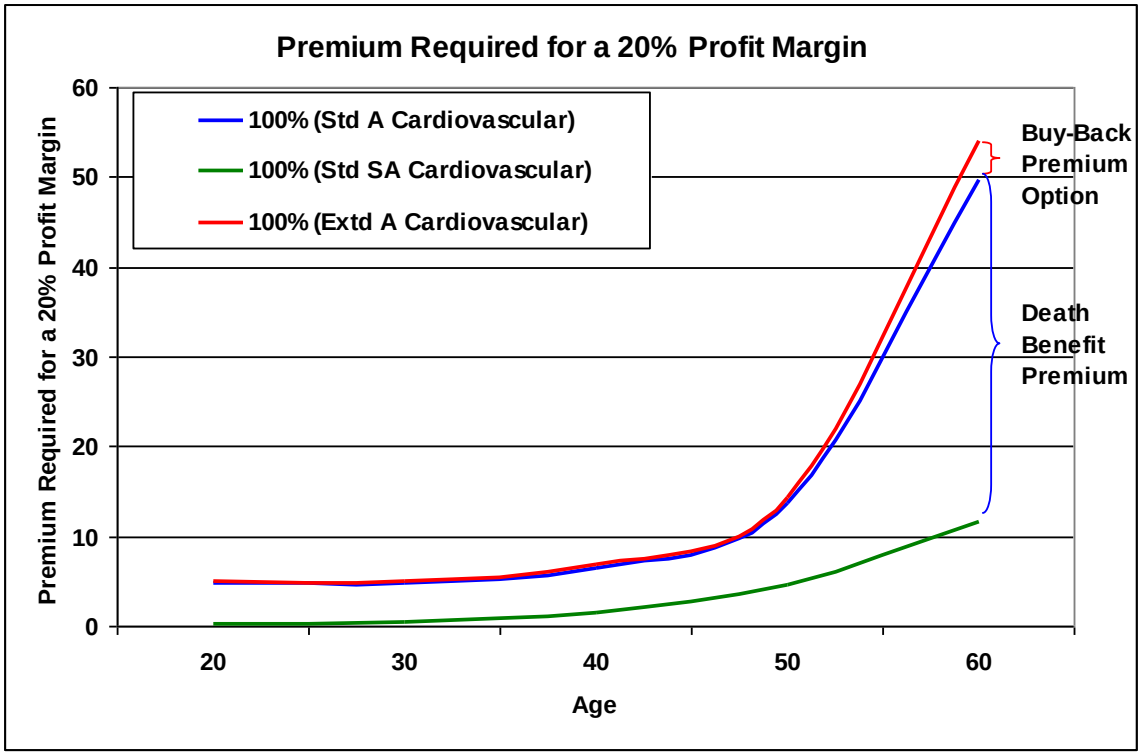


Figure 28: The premium required for a 20% profit margin for either an accelerated with buy-back (*example 4*), standard accelerated or stand-alone cardiovascular model.

Further comparison of this buy-back premium option with the previous buy-back cancer and all condition options will be discussed in the following Chapter 8.

In Figure 28 the magnitude of the death benefit (shown by the difference in the blue and green curve) increases rapidly from £4.6 at age 20, to £38.0 at age 60. This is the same as in the cancer only, and cancer (excluding breast) models shown by 'step c' in **Table 21** and Table 23. This is to be expected, as we are paying death benefits from both the qualifying and non-qualifying states, as well as the healthy state, so we would expect the same implied death premium regardless of what conditions are actually included in the qualifying state.

7.6 Individual Condition Models are not Additive

As an aside, we could continue in the above fashion determining individual premiums for a neurological, accident only etc. model. However, we cannot add the premiums we require together in a "menu" style to determine a "tailored" product. This is because the total premium will exceed the corresponding premium for a standard ACI product as shown by the heights of the bar-charts in Figure 29 below.

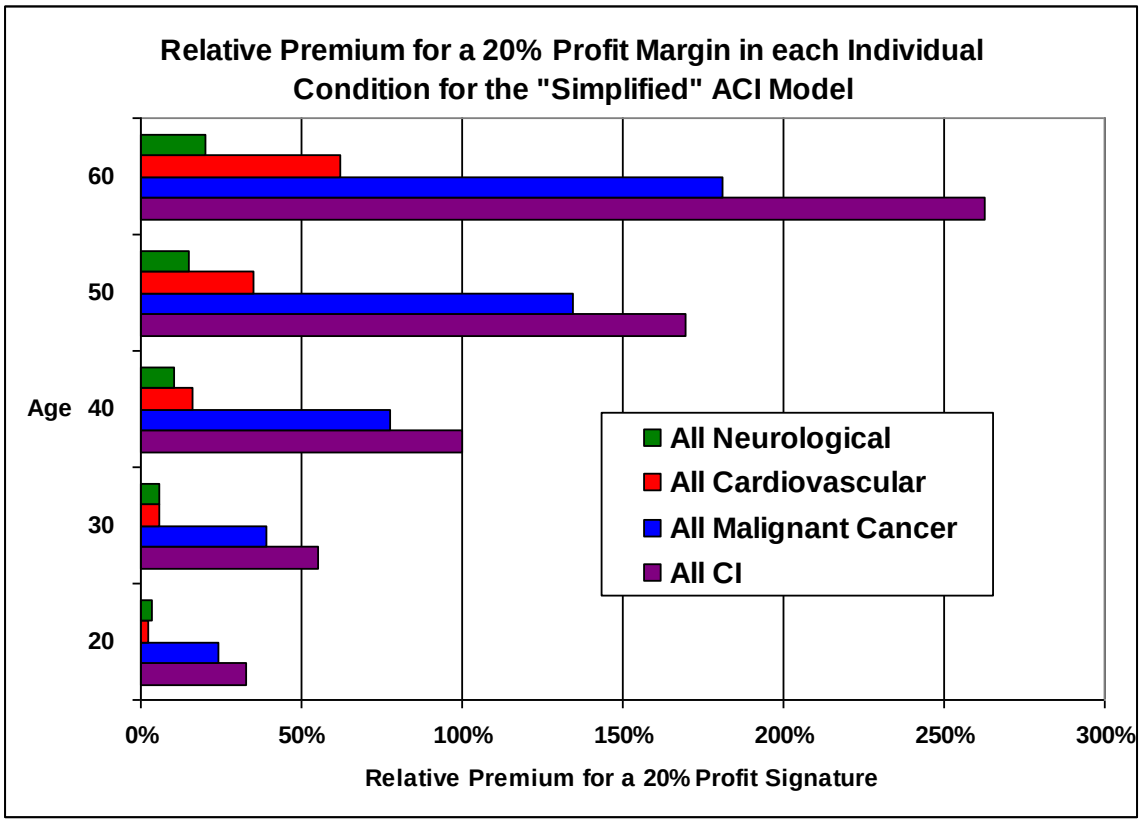


Figure 29: The relative premium required for a 20% profit margin for individual cancer, cardiovascular, neurological and other models, compared to the standard ACI model. Premiums relative to a 40 year old female with a standard ACI only product costing £100.

The reason for this is that upon summing these premiums over the individual conditions the following repeated counting of incidence rates will occur:

- Each condition will become included as one of the "other condition" when it is not the qualifying condition.

- Each individual condition includes “deaths” from both non-qualifying and qualifying conditions.

In practice, this repeated counting can be avoided provided all the selected “menu” qualifying conditions are included at the start within our state *A*, and not added afterwards.

8 Comparison of our Examples

We have summarised the above full 100% buy-back premiums for our four different examples in the following Table 26 and Figure 30.

Table 26: The buy-back option premium required for a 20% profit margin for our four RACI models based on a different set of qualifying conditions.

Example	Qualifying Conditions in RACI model	Full 100% "Buy-Back" premium at Age				
		20	30	40	50	60
1	All Critical Illness	1.1	1.7	3.3	6.8	25.4
2	Cancer Buy-Back	0.9	1.9	3.6	7.1	19.8
3	Cancer Buy-Back (ex breast)	0.7	1.0	1.5	3.6	15.6
4	Cardiovascular	0.1	0.2	0.4	0.6	4.4

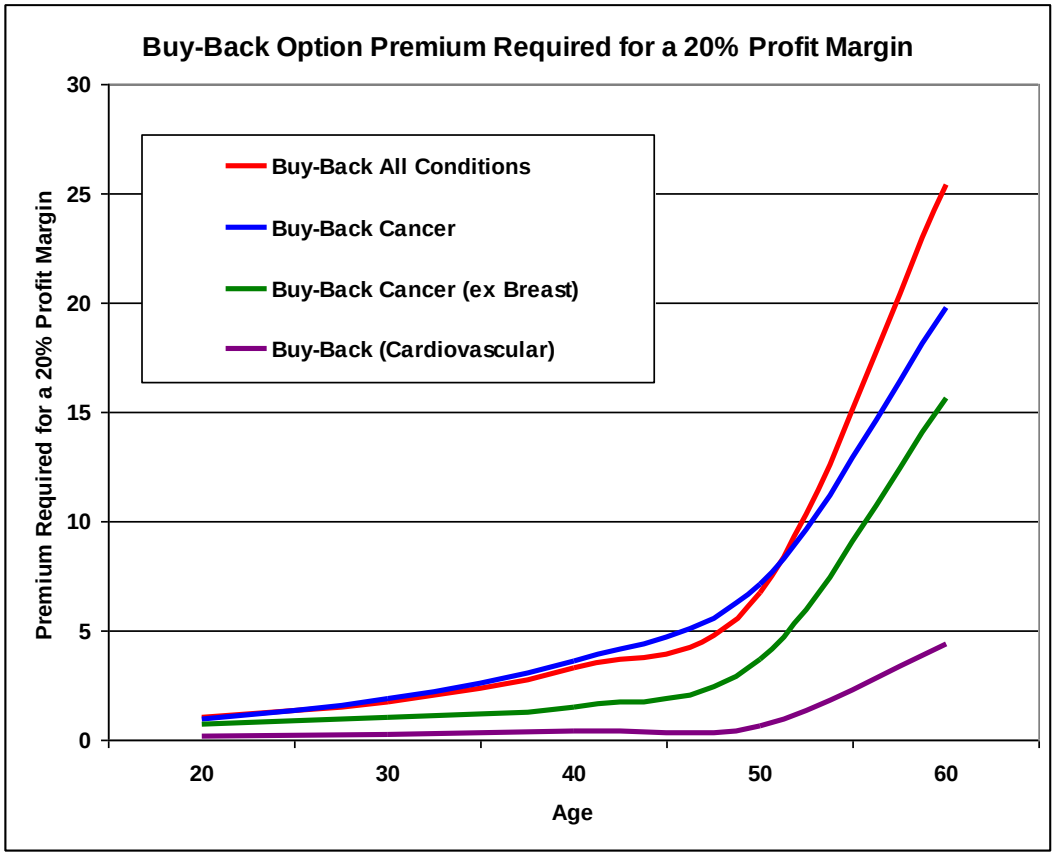


Figure 30: The buy-back option premium required for a 20% profit margin for our four RACI models based on a different set of qualifying conditions.

From Table 26 and Figure 30, we note that the full buy-back option increases rapidly after age 50 for all our models.

We note that the buy-back relative premium option for cancer (blue curve) follows the premium for the "all conditions" (red curve) fairly closely from age 20 to age 50, as our data is predominately cancer until this age. After age 50, the cardio-vascular and neurological conditions become increasingly more important resulting in the higher premium for the "all conditions" curve.

The cancer buy-back option premium blue curve is slightly higher between ages 30 and 50, because the 2nd cancer incidence rate (relative to the 1st cancer incidence exposure) in this age range is higher than for the 2nd 'all conditions' incidence rate (relative to the 'all conditions' 1st incidence in the exposure).

After age 50, the 2nd incidence for cardiovascular diseases increases more rapidly, together with increasing incidence for neurological and other conditions results in the steepening of the "all conditions" curve and the option premium becoming rapidly more expensive than the cancer only premium.

When we compare the blue cancer curve with the green cancer (excluding breast) curve we note an increasing difference in premium from approximately £0.2 at age 20, to £3.5 at age 40. This is consistent with our expectation of an incidence in breast cancer over this age range. From age 50 to age 60, the green and blue curves rapidly increase at about the same rate, consistent with a fairly constant 2nd incidence of breast cancer over this age range.

To compare the above premium option amounts more easily, we have divided by the accelerated premium for the corresponding model with no buy-back option in the following Table 27.

Table 27: The buy-back premiums as a % of the corresponding accelerated (with no buy-back) model premium.

Example	Model	Age				
		20	30	40	50	60
1	All Conditions	12%	10%	10%	11%	24%
2	Cancer Only	11%	12%	11%	13%	21%
3	Cancer Only (excluding breast cancer)	9%	8%	7%	9%	20%
4	Cardiovascular	3%	5%	6%	4%	9%

Table 27 indicates that an additional buy-back option premium of approximately 10% to 12% (as age increases from 20 to 50) would need to the added to the underlying standard "all conditions" accelerated model, i.e. the current practice of a flat premium loading across all ages does not look unreasonable. However, after age 50, the buy-back premium option rapidly increases as the 2nd incidence and mortality rapidly increase with age.

Similarly, for the other *examples*, where a flat premium between ages 20 and 50 is reasonable, before a rapid increase. Considering, the additional restrictions in qualifying conditions, we may have expected a larger reduction in buy-back premium option relative to the corresponding standard accelerated model in each case. However, the cost of benefit payments via the intermediary non-qualifying state offsets this reduction.

Overall, this narrow range in relatively low buy-back premium is likely to be acceptable to the policyholder. So there is not much incentive to reduce the benefit coverage in order to reduce the buy-back option premium for healthy policyholders. However, for unhealthy lives who are excluded from the standard healthy *example 1* product, the possibility of a buy-back option which is not more expensive than that paid by healthy policyholders may be appealing, albeit with a reduced benefit coverage.

We note that all these values are sensitive to the set of assumptions that we have made in section 1.1. In particular, increasing the threshold level of the PMI data above £2,000 (see section 4.2), or a longer claim free period following the 1st incident (see section 4.8.2) would reduce the buy-back premium option even further.

9 Conclusions

This dissertation has utilised PMI data in a multi-state modelling framework to demonstrate the practical calculation of the additional option premium required at the start of the policy in order to purchase a buy-back of full benefit coverage, should a critical illness qualifying condition occur (*example 1*).

In addition, we have presented a new model restricting the qualifying benefit payments to certain conditions, e.g. cancer only model (*example 2*), cardiovascular only model (*example 4*), or cancer (excluding breast) (*example 3*) only model to allow a simpler buy-back model, or allow particular exclusions for 'unhealthy' policyholders. However, we have demonstrated that to ensure correct premiums are charged, we still need to allow the non-qualifying conditions to act as an intermediary state before a full payment on a subsequent qualifying condition (or death). This has been incorporated into our previous buy-back model by extending the modelling framework.

All the *examples* indicate a steady increase in the buy-back premium option with age (at start of policy) from 20 to 50, before accelerating rapidly from ages 50 to 60. This buy-back option premium is fairly flat when compared to the premium for the corresponding standard accelerated model with no option, at around 10% between ages 20 and 50, before increasing to around 20% at age 60.

For the more restrictive qualifying benefit *example*s only a slightly lower buy-back option premium is required. A larger discount may be expected as the benefit coverage is dramatically reduced, but this is offset by the cost of benefit payments via the intermediary non-qualifying state. So based on our analysis all currently healthy policyholders should consider a buy-back product that provides the full range of CI qualifying conditions. For unhealthy policyholders (with restrictions imposed) the buy-back option is still relatively inexpensive compared to the corresponding standard accelerated model (with no buy-back option) which they may be excluded from purchasing.

We have satisfied our aim in the introduction to determine a reasonably priced option premium for both healthy and unhealthy policyholders which would be far cheaper than purchasing a new CI product (with possible restrictions) from the market after the first incident.

10 Further Work

The above dissertation has illustrated how PMI data could potentially be used to price accelerated buy-back critical illness in a new multi-state framework. Further work would be needed to repeat the above for males, but this was not undertaken as only a different dataset rather than any new methodology.

Although, our aim has being to illustrate a buy-back for an accelerated critical illness model, further data or alternative sources would be required to fully include adequately all the typical CI conditions shown in Table 28 (Appendix 12.1). Therefore, in practical pricing, a first step would be a cancer only buy-back product, with possible exclusions, until we are comfortable with the new methodology.

Further work would also be needed to review the appropriateness of all the assumptions made in section 1.1. In particular, the appropriateness of underwriting definitions and severity levels between PMI and CI business with further adjustments made for differences.

Our 2nd incidence rates are likely to be conservative because of only 10 years of data for a new book of business, whereas a longer time-span would reduce the magnitude of the 2nd incidence rate as we would have more time post 1st treatment to offset the initially high 2nd incidence rate. Alternatively, as we are looking at a growing book of business we presumably have younger, healthy policyholders rather than a mature book, which would offset this.

Although we have calibrated the threshold level for the PMI claims at £2,000, a larger dataset would also provide more confidence and allow comparisons with higher threshold levels. In addition, we would be able to apply more of the restrictions currently undertaken in the market (see section 3.4) to determine if the pricing was adequate.

Alternative methods are available which model directly the interaction between different conditions explicitly. For example, Lauer *et al* (pp.7, 2003) discuss how heart attack and stroke are strongly correlated, with a significant probability of 2nd incidence of one following the other. For this reason, we have kept all the cardiovascular conditions as a single condition. However, between different conditions, any correlations are indirectly included in the model through the 1st to 2nd incidence rates derived from the data. A more explicit structured approach would require considerably more data to allow us to calibrate these interactions.

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12 Appendix

12.1 Critical Illness Conditions

Table 28: The individual conditions in a typical critical illness product

Our Grouping	Individual Conditions
Malignant Cancer	Cancer Benign brain tumour
All Cardiovascular	Heart Attack Stroke Heart Valve Replacement or Repair Coronary Artery Bypass Balloon angioplasty Aorta Graft Pulmonary artery surgery
Neurological	Alzheimer's disease Pre-Senile Dementia Motor neurone disease Multiple Sclerosis Parkinson's disease
Accident	Blindness Loss of hearing Loss of speech
Other	Aplastic anemia Bacterial Meningitis Cardiomyopathy Chronic liver disease Coma Creutzfeldt-Jakob disease Degenerative brain disease Encephalitis HIV/AIDS Kidney Failure Liver failure Loss of hands or feet Loss of independence Major Organ Transplant Paralysis/Paraplegia Respiratory Failure Rheumatoid arthritis Systemic lupus erythematosus Terminal Illness Third-degree burns Traumatic head injury

12.2 The Time Interval In-between 1st and 2nd Incidents

This 2nd incident will have a very high probability of occurring after the 1st incident if it is just a continuation of a planned series of hospital treatment episodes. For example, a time break of 1 to 3 months may be too short for a typical cancer treatment, whereas 1 to 2 years may be too long a break with no benefit coverage provided. So to separate two incidents we have assumed an arbitrary time-break of ≥ 180 days between the end date of one treatment and the start date of another treatment for the same condition.

For example, in Figure 31 below the end date of the 1st treatment to the start date of the 2nd treatment is only 96 days. So as the time interval is less than this 180 days assumption, they will be considered the same 1st incident with the end date equal to the end date of the 2nd treatment. This is then compared to the start date of the 3rd treatment. Only if this time interval is greater than 180 days (as in the example here) will the 3rd treatment be considered as our 2nd incident; otherwise, we would combine with the previous two treatments and repeat the same process for the 4th treatment.

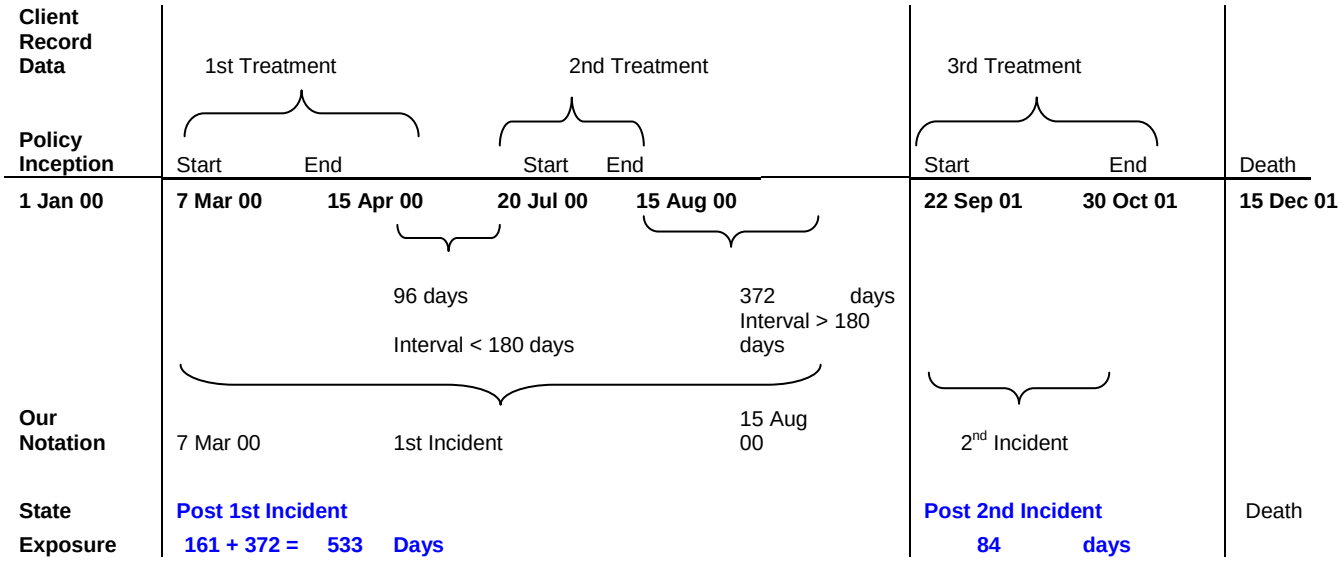

Figure 31: Example of the combination of two treatments into a single incident as the interval between them is less than our chosen 180 days (for different conditions).

12.3 The Client's PMI Claims

Table 29 shows the number of PMI paid claims for the 1st incident of each condition shown, subject to a minimum paid amount of £2,000 for inclusion.

Table 29: The PMI paid 1st incidents by five-yearly age ranges for each condition shown, subject to a minimum paid amount of £2,000.

1st incident	Age Range	20-	25-	30-	35-	40-	45-	50-	55-	60-	65-	70-	75-	80-	85-	20-89
	Exposure	*80.0*	*154.7*	*143.1*	*176.4*	*140.5*	*137.8*	*143.6*	*133.3*	*86.3*	*71.7*	*59.4*	*46.9*	*34.3*	*15.1*	*1,423.0*
Malignant Cancer	Breast	4	16	34	88	121	175	176	140	86	75	51	16	12	3	**997**
	Melanoma of skin	7	14	31	53	83	98	104	118	85	61	37	35	16	5	**747**
	Other skin	2	3	11	19	19	27	44	45	37	32	17	28	9	8	**301**
	Ovarian	0	0	7	12	15	16	24	26	28	26	9	5	1	0	**169**
	Colon	2	2	1	6	12	16	29	34	41	29	36	23	6	5	**242**
	Bladder	0	0	0	2	1	1	8	10	14	14	7	9	9	3	**78**
	Lung	0	0	1	3	3	17	12	10	16	19	11	15	5	1	**113**
	Stomach	0	0	0	1	3	2	6	15	3	10	4	3	3	0	**50**
	Colo-rectal	0	0	0	0	3	6	4	12	9	13	7	5	5	0	**64**
	Pancreatic	0	0	0	1	1	3	8	10	7	11	9	1	2	0	**53**
	Kidney & urinary	0	1	0	0	2	7	10	9	13	6	2	5	2	0	**57**
	Cervix uteri	3	2	9	5	6	4	7	8	2	2	1	1	0	0	**50**
	Body of uterus	0	0	1	1	0	6	6	4	3	6	1	2	0	1	**31**
	Brain	1	2	3	2	6	9	5	9	10	9	1	0	0	0	**57**
	Other Malignant	15	15	17	25	32	54	86	74	75	69	60	34	26	4	**586**
	All Malignant Cancer	**34**	**55**	**115**	**218**	**307**	**441**	**529**	**524**	**429**	**382**	**253**	**182**	**96**	**30**	**3595**
	Benign Brain Tumour	**2**	**0**	**2**	**1**	**6**	**3**	**9**	**9**	**3**	**1**	**3**	**3**	**0**	**0**	**42**
Cardiovascular	Heart Attack	0	0	0	3	6	14	17	26	17	15	13	12	11	5	**139**
	Heart Valve	1	0	0	1	1	3	4	6	14	14	8	12	5	1	**70**
	Aorta Graft	1	1	2	0	2	2	4	9	9	13	14	13	1	0	**71**
	By-Pass	0	0	0	1	5	9	8	28	44	36	36	14	7	0	**188**
	Stroke	0	2	1	1	5	8	7	8	13	19	37	21	28	10	**160**
	All Cardiovascular	**2**	**3**	**3**	**6**	**19**	**36**	**40**	**77**	**97**	**97**	**108**	**72**	**52**	**16**	**628**
Neurological	Parkinson's	0	0	0	0	0	0	1	0	1	2	3	1	1	1	**10**
	Multiple Sclerosis	2	2	2	1	2	2	1	1	4	0	0	0	0	0	**17**
	Motor Neurone	0	0	0	0	0	0	2	0	0	0	0	0	0	0	**2**
	All Neurological	**2**	**2**	**2**	**1**	**2**	**2**	**4**	**1**	**5**	**2**	**3**	**1**	**1**	**1**	**29**
Accidental	Deafness	**0**	**2**	**0**	**1**	**2**	**3**	**3**	**3**	**3**	**1**	**1**	**1**	**0**	**0**	**20**
	Blindness	**0**	**1**	**2**	**0**	**1**	**2**	**4**	**5**	**13**	**7**	**9**	**12**	**12**	**3**	**71**
All Conditions		**40**	**63**	**124**	**227**	**337**	**487**	**589**	**619**	**550**	**490**	**377**	**271**	**161**	**50**	**4385**

12.4 Example of our Paid Claim Development

For an example of the calculation to determine a developed claim, consider a paid claim on say 1st Oct 2007, which happened to be 90 days before our valuation date of 31st Dec 2007. Assuming the latest possible date of diagnosis is used, then there would be 90 days or a "% diagnosed to settled" of 49% (from the Diagnosed to settled payment patterns shown in Table 30, Brett and DuTolt pp. 30, 2007) to divide our 1st claim by to find the total expected paid claims, which is approximately equal to 2. At the other extreme, the date of diagnosis could of occurred after the policy inception/last renewal date on 1st Jan 2007, with a % diagnosed to settled" of 91%, as shown in the following Figure 32.

Client Record Data	Range for Date of Diagnosis				
	Earliest Policy Inception/ Renewal			Latest Claim Paid	Valuation Date
Date	1 Jan 07			1 Oct 07	31 Dec 07
Number of Days before Valuation Date	365	228 (average of 90 and 365 days)	140 (corresponding to the average of 49% and 91%)	90	0
% Diagnosed to Settled using Table 3	91%	80%	70%	49%	

Figure 32: Example of the combination of the calculation of the average % to diagnosied setted value, and the corresponding number of days before the valuation date.

On taking the average "% diagnosed to settled" value of **70%** provides 1.4x the increase in the current paid claims at 140 days before the valuation date. This is more conservative than using the average number of days between these extreme dates of 228 days, and a corresponding "% diagnosed to settled" value of 80%.

Similarly, the above applies for determining the development of the 2nd paid claim, from the extreme possible dates for the 2nd date of diagnosis starting just after the 1st incident paid date to the 2nd incident paid date.

On applying this development to our 1st incident paid counts shown in Table 29 above, we obtained the following Table 31 below.

12.5 The Client's PMI Developed Claim Counts

Table 31 indicates the number of PMI developed paid 1st incidents for each condition shown, subject to a minimum paid amount of £2,000 for inclusion.

Table 31: The developed PMI paid 1st incidents by five-yearly age ranges for each condition shown, subject to a minimum paid amount of £2,000.

1st incident	Age Range	20-	25-	30-	35-	40-	45-	50-	55-	60-	65-	70-	75-	80-	85-	20-89
	Exposure	***80.0***	***154.7***	***143.1***	***176.4***	***140.5***	***137.8***	***143.6***	***133.3***	***86.3***	***71.7***	***59.4***	***46.9***	***34.3***	***15.1***	***1,394.4***
Malignant	**Breast**	4.1	16.4	34.8	104.0	124.7	185.3	180.2	143.7	88.9	78.6	52.8	17.6	12.6	3.1	**1,046.7**
Cancer	**Melanoma of skin**	7.2	14.4	31.7	55.3	86.5	101.5	108.6	122.3	87.6	64.4	37.9	36.3	16.5	5.3	**775.6**
	Other skin	2.1	3.1	11.2	19.9	19.6	28.0	45.4	46.3	38.1	33.0	17.4	28.6	9.2	8.2	**310.2**
	Ovarian	-	-	7.1	12.4	15.4	19.5	24.9	26.6	28.8	31.9	9.3	5.1	1.0	-	**182.2**
	Colon	2.0	2.0	1.0	6.2	12.3	16.5	29.8	35.2	42.5	29.7	40.8	23.9	6.1	5.1	**253.2**
	Bladder	-	-	-	2.0	1.0	1.0	8.2	10.2	14.3	14.4	7.1	9.2	9.2	3.1	**79.8**
	Lung	-	-	1.0	3.1	3.1	17.7	12.3	10.5	16.5	19.5	11.8	15.5	5.1	1.3	**117.5**
	Stomach	-	-	-	1.0	3.1	2.0	6.2	15.5	3.1	10.2	4.1	3.1	3.1	-	**51.2**
	Colo-rectal	-	-	-	-	3.1	6.2	4.1	12.4	9.3	13.3	7.1	5.1	5.1	-	**65.6**
	Pancreatic	-	-	-	1.0	1.0	3.1	8.2	10.3	7.2	11.3	9.3	1.0	2.2	-	**54.6**
	Kidney & urinary	-	1.0	-	-	2.0	7.1	10.4	9.2	13.6	6.1	2.0	5.2	2.0	-	**58.9**
	Cervix uteri	3.1	2.1	10.1	5.1	6.1	4.1	7.1	8.2	2.0	2.0	1.0	1.0	-	-	**52.0**
	Body of uterus	-	-	1.1	1.0	-	6.4	6.1	4.2	3.1	6.2	1.0	2.0	-	1.0	**32.2**
	Brain	1.0	2.0	3.1	2.1	6.2	9.3	5.1	9.3	10.4	9.3	1.0	-	-	-	**58.8**
	Other Malignant	15.4	15.4	17.4	25.6	33.3	55.3	88.5	75.8	76.9	70.9	62.1	35.1	26.8	4.7	**603.1**
	All Malignant Cancer	**34.9**	**56.5**	**118.6**	**238.8**	**317.3**	**463.0**	**545.0**	**539.8**	**442.5**	**401.1**	**265.0**	**188.7**	**99.0**	**31.7**	**3,741.7**
	Benign Brain Tumour	2.0	-	2.1	1.0	6.1	3.1	9.2	9.2	3.1	1.0	3.1	3.1	-	-	**43.0**
Cardiovascular	**Heart Attack**	-	-	-	3.1	6.1	14.3	17.4	26.7	17.4	15.4	13.3	12.3	11.4	5.2	**142.5**
	Heart Valve	1.0	-	-	1.0	1.0	3.0	4.1	6.1	14.4	14.3	8.2	12.3	5.2	1.0	**71.7**
	Aorta Graft	1.0	1.1	2.0	-	2.1	2.0	4.1	9.2	9.2	13.4	14.3	13.3	1.0	-	**72.8**
	By-Pass	-	-	-	1.0	5.1	9.3	8.2	28.6	45.1	36.8	36.8	14.3	7.2	-	**192.4**
	Stroke	-	2.0	1.0	1.0	5.1	8.2	7.2	8.2	13.3	19.4	37.8	21.8	28.6	10.2	**163.9**
	All Cardiovascular	**2.0**	**3.1**	**3.1**	**6.1**	**19.4**	**36.9**	**41.0**	**78.8**	**99.3**	**99.3**	**110.4**	**74.0**	**53.3**	**16.5**	**643.4**
Neurological	**Parkinson's**	-	-	-	-	-	-	1.0	-	1.0	2.0	3.1	1.0	1.0	1.0	**10.3**
	Multiple Sclerosis	2.1	2.1	2.0	1.0	2.1	2.0	1.0	1.0	4.1	-	-	-	-	-	**17.5**
	Motor Neurone	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	**2.0**
	All Neurological	**2.1**	**2.1**	**2.0**	**1.0**	**2.1**	**2.0**	**4.1**	**1.0**	**5.1**	**2.0**	**3.1**	**1.0**	**1.0**	**1.0**	**29.8**
Accidental	**Deafness**	**-**	**2.0**	**-**	**1.0**	**2.1**	**3.1**	**3.1**	**3.1**	**3.1**	**1.0**	**1.0**	**1.0**	**-**	**-**	**20.4**
	Blindness	**-**	**1.0**	**2.0**	**-**	**1.0**	**2.0**	**4.1**	**5.3**	**13.3**	**7.1**	**9.2**	**12.3**	**12.9**	**3.1**	**73.5**
All Conditions		**41.1**	**64.8**	**127.8**	**248.0**	**348.0**	**510.1**	**606.4**	**637.1**	**566.3**	**511.6**	**391.8**	**280.1**	**166.3**	**52.3**	**4,551.7**

Table 32 indicates the number of PMI developed paid claim incidents for **any** 2nd condition from the 1st condition shown (subject to a minimum paid amount of £2,000 for inclusion).

Table 32: The developed paid claim incidents for any 2nd condition from the 1st condition shown below.

1st incident	Age Range	20-	25-	30-	35-	40-	45-	50-	55-	60-	65-	70-	75-	80-	85-	20-89
	Exposure	*Varies by 1st condition*														
Malignant	**Breast**	-	-	2.0	12.3	12.3	20.9	17.7	12.5	6.1	4.4	4.1	-	-	-	92.3
Cancer	**Melanoma of skin**	-	3.2	6.3	2.0	8.3	9.4	3.1	9.5	2.1	4.4	-	3.2	2.1	-	53.7
	Other skin	-	-	-	-	2.4	2.0	3.1	1.0	-	1.0	2.1	-	-	-	11.7
	Ovarian	-	-	-	1.0	1.0	1.0	2.1	1.0	2.1	2.1	-	1.1	-	-	11.4
	Colon	-	-	-	1.0	1.1	5.1	3.1	6.2	3.1	2.1	1.0	4.2	-	-	26.7
	Bladder	-	-	-	1.1	-	-	4.1	2.0	3.1	1.0	1.0	3.1	1.0	1.0	17.4
	Lung	-	-	-	-	-	-	-	-	2.0	-	-	1.1	-	-	3.1
	Stomach	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	1.0
	Colo-rectal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pancreatic	-	-	-	-	-	-	1.0	1.0	-	2.1	-	-	-	-	4.1
	Kidney & urinary	-	-	-	-	-	-	-	-	1.1	1.0	-	-	-	-	2.1
	Cervix uteri	-	-	-	1.0	-	-	-	-	-	-	-	-	-	-	1.0
	Body of uterus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Brain	-	1.0	-	-	-	-	-	-	2.1	-	-	-	-	-	3.1
	Other Malignant	2.0	1.0	1.0	2.1	5.2	2.1	7.2	5.2	6.3	5.1	4.3	1.0	1.0	-	43.7
	All Malignant Cancer	**2.0**	**5.2**	**9.4**	**20.5**	**30.2**	**40.6**	**41.4**	**39.5**	**27.9**	**23.2**	**12.5**	**13.6**	**4.1**	**1.0**	**271.4**
	Benign Brain Tumour	**1.0**	**-**	**-**	**-**	**-**	**-**	**1.0**	**-**	**1.1**	**-**	**-**	**-**	**-**	**-**	**3.2**
Cardiovascular	**Heart Attack**	-	-	-	-	1.0	1.0	-	-	1.0	-	2.0	-	-	-	5.1
	Heart Valve	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Aorta Graft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	By-Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Stroke	-	-	-	-	-	1.0	-	-	-	1.0	1.0	2.0	-	-	5.1
	All Cardiovascular	**-**	**-**	**-**	**-**	**1.0**	**2.0**	**-**	**-**	**1.0**	**1.0**	**3.1**	**2.0**	**-**	**-**	**10.2**
Neurological	**Parkinson's**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
	Multiple Sclerosis	**-**	**-**	**-**	**-**	**-**	**-**	**1.0**	**-**	**2.1**	**1.1**	**-**	**-**	**-**	**1.0**	**5.3**
	Motor Neurone	-	-	-	-	-	-	-	-	1.1	-	-	-	-	-	1.1
	All Neurological	-	-	-	-	-	1.0	-	-	2.0	-	-	-	-	-	3.1
Accidental	**Deafness**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Blindness	**-**	**-**	**-**	**-**	**-**	**1.0**	**-**	**-**	**3.1**	**-**	**-**	**-**	**-**	**-**	**4.1**
All Conditions		**3.1**	**5.2**	**9.4**	**20.5**	**31.3**	**43.7**	**43.5**	**39.5**	**35.3**	**25.3**	**15.5**	**15.7**	**4.1**	**2.1**	**294.3**

Table 33 indicates the number of PMI developed paid claim incidents for the **same** 2nd condition from the 1st condition shown (subject to a minimum paid amount of £2,000 for inclusion).

Table 33: The developed paid claim incidents for the same 2nd condition from the 1st condition shown below.

1st incident	Age Range	20-	25-	30-	35-	40-	45-	50-	55-	60-	65-	70-	75-	80-	85-	20-89
	Exposure	*Varies by 1st condition*														
Malignant Cancer	**Breast**	-	3.4	8.7	21.2	17.4	34.6	25.2	21.0	14.4	5.1	4.1	1.0	1.0	2.1	159.3
	Melanoma of skin	-	1.0	7.4	6.2	13.4	12.6	5.3	11.6	9.7	7.7	2.1	9.8	3.1	-	89.9
	Other skin	-	1.0	1.1	1.1	2.4	1.0	5.2	3.1	2.1	6.2	3.1	1.0	-	1.0	28.3
	Ovarian	-	-	-	1.0	1.0	2.0	2.1	2.1	2.1	6.4	-	2.1	1.0	-	19.8
	Colon	-	-	-	3.1	1.1	5.1	6.2	6.2	5.1	5.2	3.1	4.2	2.1	-	41.3
	Bladder	-	-	-	1.1	-	-	4.1	2.0	4.1	1.0	2.1	4.1	2.0	1.0	21.5
	Lung	-	-	-	-	1.3	2.0	1.0	-	5.2	-	-	1.1	1.1	-	11.7
	Stomach	-	-	-	-	-	-	1.0	2.1	-	1.0	-	2.0	-	-	6.2
	Colo-rectal	-	-	-	-	1.0	1.0	-	1.0	3.1	4.2	1.0	-	-	-	11.4
	Pancreatic	-	-	-	-	-	-	-	-	-	2.1	-	-	-	-	2.1
	Kidney & urinary	-	-	-	-	-	-	-	-	1.1	1.0	-	-	-	-	2.1
	Cervix uteri	-	-	-	1.0	-	-	1.0	1.0	-	-	1.0	-	-	-	4.1
	Body of uterus	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-	1.0
	Brain	-	1.0	-	-	1.0	-	1.0	-	5.1	-	-	-	-	-	8.2
	Other Malignant	2.0	2.0	2.1	3.1	8.3	9.4	15.4	8.3	12.5	10.4	4.1	6.3	3.1	-	87.0
	All Malignant Cancer	**2.0**	**8.5**	**19.3**	**37.7**	**46.9**	**68.8**	**67.6**	**58.5**	**64.5**	**50.3**	**20.6**	**31.6**	**13.4**	**4.1**	**493.9**
	Benign Brain Tumour	**1.0**	**-**	**-**	**-**	**-**	**-**	**1.0**	**-**	**1.1**	**-**	**-**	**-**	**-**	**-**	**3.2**
Cardiovascular	**Heart Attack**	-	-	-	-	1.0	1.0	1.0	1.0	4.1	1.0	2.0	1.1	1.0	-	13.3
	Heart Valve	-	-	-	-	-	-	2.1	1.0	-	1.0	-	-	-	-	4.1
	Aorta Graft	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-	1.0
	By-Pass	-	-	-	-	1.0	-	-	2.0	1.0	2.1	1.0	-	1.0	-	8.2
	Stroke	-	1.0	-	-	-	1.0	-	-	-	4.1	1.0	2.0	-	-	9.2
	All Cardiovascular	**-**	**1.0**	**-**	**-**	**2.0**	**2.0**	**3.1**	**4.1**	**5.1**	**8.2**	**5.1**	**3.1**	**2.1**	**-**	**35.9**
Neurological	**Parkinson's**	**-**	**1.0**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1.0**	**-**	**-**	**2.0**
	Multiple Sclerosis	**-**	**-**	**-**	**-**	**-**	**-**	**1.0**	**-**	**3.2**	**3.1**	**2.0**	**-**	**-**	**1.0**	**10.4**
	Motor Neurone	-	-	-	-	-	-	-	-	1.1	-	-	-	-	-	1.1
	All Neurological	-	-	-	-	-	1.0	-	-	2.0	-	-	-	-	-	3.1
Accidental	**Deafness**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Blindness	**-**	**-**	**-**	**-**	**-**	**1.0**	**-**	**-**	**3.1**	**-**	**-**	**-**	**-**	**-**	**4.1**
All Conditions		**3.1**	**10.6**	**19.3**	**37.7**	**48.9**	**71.9**	**72.7**	**62.6**	**77.0**	**61.7**	**27.8**	**35.7**	**15.5**	**5.2**	**549.5**

12.6 Exposure Calculation

From 2002 to 2007, the PMI insurer has provided us with the actual exposures for the number of female PMI policyholders incepting since 2002 in 5-yearly age intervals, as shown in the following Table 34.

Table 34: The actual female exposure from 2002 to 2007 in each age interval.

Female	2002	2003	2004	2005	2006	2007
Under 20	5,599	6,027	6,911	7,218	7,246	7,669
20-24	7,363	6,671	6,204	5,292	4,538	4,544
25-29	11,889	12,377	12,993	12,768	12,180	12,426
30-34	11,382	12,155	13,695	13,805	14,261	14,463
35-39	11,849	12,562	13,736	14,005	14,374	14,650
40-44	11,428	12,233	13,899	14,620	15,090	15,959
45-49	11,209	12,026	13,383	13,899	14,676	15,607
50-54	11,985	12,135	13,242	13,588	14,071	14,670
55-59	10,601	11,673	13,006	13,680	14,087	14,328
60-64	7,178	7,740	8,934	9,717	10,940	12,687
65-69	5,931	6,284	6,932	7,304	7,626	8,184
70-74	4,798	5,214	5,586	5,770	6,089	6,442
75-79	3,933	4,113	4,302	4,649	4,918	5,203
80-84	2,541	3,070	3,479	3,539	3,704	3,753
85-89	1,270	1,376	1,446	1,667	1,918	2,089
90+	476	562	606	699	744	831
Total Female	**119,432**	**126,218**	**138,354**	**142,220**	**146,462**	**153,505**
Female % of Total*	**44.0%**	**44.5%**	**44.4%**	**43.9%**	**44.4%**	**44.7%**

*when comparing with column 6 in Table 35 below.

However, from the start of the 1st policy underwritten in 1994 to 2001 we only have the total number of new joiners in each year and estimated withdrawals, as shown in Table 35 and Table 36 below.

Table 35: The estimated combined male and female exposure from 1994 to 2001, based on the actual number of new joiners in each calendar year and the estimated lapse rates.

Calendar	Actual New	Actual New	Estimated Total	Total	Actual
1994	62,719	62,719	-	**62,719**	
1995	70,941	133,660	12,544	**121,116**	
1996	77,399	211,059	34,258	**176,801**	
1997	57,298	268,357	64,222	**204,135**	
1998	60,886	329,243	96,491	**232,752**	
1999	45,904	375,147	131,816	**243,331**	
2000	47,804	422,951	166,310	**256,641**	
2001	49,079	472,030	201,305	**270,725**	
2002	54,383	526,413	237,264	289,149	271,707
2003	47,868	574,281	275,248	299,033	283,847
2004	46,879	621,160	313,586	307,574	311,488
2005	45,081	666,241	352,413	313,828	323,667
2006	45,164	711,405	391,426	319,979	330,031
2007	50,596	762,001	430,620	331,381	343,667

Table 36: The historical combined male and female lapse rates from the insurer's PMI data.

Years	Estimated
1	20.0%
2	15.0%
3	14.0%
4	13.0%
5	11.0%
6	9.5%
7	9.3%
8	9.3%
9	9.0%
10	9.0%
11	8.8%
12	8.8%
13	8.0%
14	7.3%

We note from the final column of Table 35 that there is a slight discrepancy between our total estimate population and the actual population from 2002 to 2007, but generally within 5%. So we only need to make a slight proportional adjustment to the exposure at each age interval to make the totals match.

From Table 34 we extrapolated the trend in the proportion of exposure in each 5-yearly age interval backwards from 2007 to 2002 to the earliest year 1994, obtaining the following Table 37.

Table 37: The extrapolated relative male and female exposures from 1994 to 2001, using trends deduced from the actual exposure after 2002 in each age interval.

Female	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
< 20	4.3%	4.3%	4.4%	4.4%	4.5%	4.5%	4.6%	4.6%	4.7%	4.8%	5.0%	5.1%	4.9%	5.0%
20-24	8.3%	8.2%	8.1%	8.0%	7.7%	7.4%	7.1%	6.8%	6.2%	5.3%	4.5%	3.7%	3.1%	3.0%
25-29	14.8%	14.2%	13.6%	12.9%	12.4%	11.8%	11.3%	10.6%	10.0%	9.8%	9.4%	9.0%	8.3%	8.1%
30-34	9.8%	9.8%	9.8%	9.8%	9.7%	9.7%	9.7%	9.6%	9.5%	9.6%	9.9%	9.7%	9.7%	9.4%
35-39	10.6%	10.5%	10.4%	10.4%	10.3%	10.2%	10.2%	10.0%	9.9%	10.0%	9.9%	9.8%	9.8%	9.5%
40-44	8.2%	8.4%	8.5%	8.7%	8.8%	9.0%	9.2%	9.4%	9.6%	9.7%	10.0%	10.3%	10.3%	10.4%
45-49	8.3%	8.4%	8.5%	8.7%	8.8%	9.0%	9.1%	9.2%	9.4%	9.5%	9.7%	9.8%	10.0%	10.2%
50-54	10.1%	10.1%	10.0%	10.0%	9.9%	9.8%	9.8%	9.9%	10.0%	9.6%	9.6%	9.6%	9.6%	9.6%
55-59	8.3%	8.4%	8.5%	8.6%	8.7%	8.8%	8.9%	8.9%	8.9%	9.2%	9.4%	9.6%	9.6%	9.3%
60-64	3.4%	3.7%	3.9%	4.2%	4.5%	4.8%	5.1%	5.5%	6.0%	6.1%	6.5%	6.8%	7.5%	8.3%
65-69	4.3%	4.4%	4.5%	4.5%	4.6%	4.7%	4.8%	4.9%	5.0%	5.0%	5.0%	5.1%	5.2%	5.3%
70-74	3.9%	3.9%	4.0%	4.0%	4.0%	4.0%	4.1%	4.0%	4.0%	4.1%	4.0%	4.1%	4.2%	4.2%
75-79	2.9%	3.0%	3.0%	3.0%	3.1%	3.1%	3.1%	3.2%	3.3%	3.3%	3.1%	3.3%	3.4%	3.4%
80-84	2.1%	2.1%	2.1%	2.2%	2.2%	2.3%	2.3%	2.2%	2.1%	2.4%	2.5%	2.5%	2.5%	2.4%
85-89	0.6%	0.7%	0.7%	0.8%	0.8%	0.9%	0.9%	1.0%	1.1%	1.1%	1.0%	1.2%	1.3%	1.4%
90+									0.4%	0.4%	0.4%	0.5%	0.5%	0.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Assuming the female % remains at 44% of all policyholders for the earlier years, we populated the above Table 37 using the totals from the final two columns of Table 35 and obtained the following exposure Table 38.

Table 38: The estimated female exposure from 1994 to 2001 based on trends deduced from the actual exposure after 2002 in each age interval.

Female	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	1994-2007 (after deductions for HA or HD)
20-24	2,256	4,139	5,724	6,242	6,761	6,697	6,670	7,006	7,363	6,671	6,204	5,292	4,538	4,544	**79,995**
25-29	3,892	7,192	10,027	11,032	12,037	12,018	12,079	12,003	11,889	12,377	12,993	12,768	12,180	12,426	**154,680**
30-34	2,576	4,963	7,229	8,328	9,474	9,883	10,400	10,878	11,382	12,155	13,695	13,805	14,261	14,463	**143,068**
35-39	2,772	5,318	7,711	8,843	10,015	10,400	10,895	11,360	11,849	12,562	13,736	14,005	14,374	14,650	**176,395**
40-44	2,151	4,233	6,295	7,401	8,599	9,158	9,836	10,602	11,428	12,233	13,899	14,620	15,090	15,959	**140,525**
45-49	2,170	4,257	6,312	7,401	8,574	9,105	9,752	10,454	11,209	12,026	13,383	13,899	14,676	15,607	**137,763**
50-54	2,655	5,098	7,399	8,493	9,628	10,008	10,494	11,213	11,985	12,135	13,242	13,588	14,071	14,670	**143,562**
55-59	2,168	4,239	6,266	7,324	8,457	8,952	9,558	10,064	10,601	11,673	13,006	13,680	14,087	14,328	**133,347**
60-64	900	1,862	2,898	3,555	4,341	4,840	5,422	6,260	7,178	7,740	8,934	9,717	10,940	12,687	**86,285**
65-69	1,134	2,224	3,298	3,867	4,480	4,758	5,096	5,498	5,931	6,284	6,932	7,304	7,626	8,184	**71,670**
70-74	1,025	1,992	2,925	3,398	3,898	4,100	4,351	4,568	4,798	5,214	5,586	5,770	6,089	6,442	**59,416**
75-79	767	1,499	2,214	2,587	2,986	3,159	3,372	3,642	3,933	4,113	4,302	4,649	4,918	5,203	**46,884**
80-84	543	1,068	1,588	1,865	2,166	2,305	2,474	2,509	2,541	3,070	3,479	3,539	3,704	3,753	**34,335**
85-89	165	340	527	645	784	871	974	1,115	1,270	1,376	1,446	1,667	1,918	2,089	**15,112**
20-89	**25,174**	**48,424**	**70,413**	**80,981**	**92,201**	**96,254**	**101,372**	**107,171**	**113,357**	**119,629**	**130,837**	**134,303**	**138,472**	**145,005**	**1,394,427**

To determine the total exposure in state *H* from Table 38, we noted that the exposure in a particular year can also be reduced because of decrements caused by the first incidence *A* or deaths *D*. Thus while assuming uniform decrements across the year we deducted half the number of transitions from state *H* to state *A*, or state *H* to state *D*. This total exposure in state *H* is shown in the last column.

12.7 The Crude 1st Incidence Rate

On dividing the developed 1st paid counts for a particular condition in Table 32 (Appendix 12.5) by the corresponding exposure across all years 1994-07 (last column in Table 38), we have the following Table 39 of crude 1st incidence rates from the healthy state for the condition shown.

Table 39: The female crude developed 1st incidence rates (x10,000) from the healthy state for the condition shown.

1st incident	Age Range	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	20-89
Malignant	**Breast**	0.5	1.1	2.4	5.9	8.9	13.5	12.6	10.8	10.3	11.0	8.9	3.8	3.7	2.0	7.4
	Melanoma of skin	0.9	0.9	2.2	3.1	6.2	7.4	7.6	9.2	10.2	9.0	6.4	7.7	4.8	3.5	5.5
	Other skin	0.3	0.2	0.8	1.1	1.4	2.0	3.2	3.5	4.4	4.6	2.9	6.1	2.7	5.4	2.2
	Ovarian	-	-	0.5	0.7	1.1	1.4	1.7	2.0	3.3	4.5	1.6	1.1	0.3	-	1.3
	Colon	0.3	0.1	0.1	0.4	0.9	1.2	2.1	2.6	4.9	4.1	6.9	5.1	1.8	3.4	1.8
	Bladder	-	-	-	0.1	0.1	0.1	0.6	0.8	1.7	2.0	1.2	2.0	2.7	2.0	0.6
	Lung	-	-	0.1	0.2	0.2	1.3	0.9	0.8	1.9	2.7	2.0	3.3	1.5	0.9	0.8
	Stomach	-	-	-	0.1	0.2	0.1	0.4	1.2	0.4	1.4	0.7	0.7	0.9	-	0.4
	Colo-rectal	-	-	-	-	0.2	0.4	0.3	0.9	1.1	1.9	1.2	1.1	1.5	-	0.5
	Pancreatic	-	-	-	0.1	0.1	0.2	0.6	0.8	0.8	1.6	1.6	0.2	0.6	-	0.4
	Kidney & urinary	-	0.1	-	-	0.1	0.5	0.7	0.7	1.6	0.9	0.3	1.1	0.6	-	0.4
	Cervix uteri	0.4	0.1	0.7	0.3	0.4	0.3	0.5	0.6	0.2	0.3	0.2	0.2	-	-	0.4
	Body of uterus	-	-	0.1	0.1	-	0.5	0.4	0.3	0.4	0.9	0.2	0.4	-	0.7	0.2
	Brain	0.1	0.1	0.2	0.1	0.4	0.7	0.4	0.7	1.2	1.3	0.2	-	-	-	0.4
	Other Malignant	1.9	1.0	1.2	1.5	2.4	4.0	6.2	5.7	8.9	9.9	10.5	7.5	7.8	3.1	4.2
	All Malignant Cancer	**4.4**	**3.7**	**8.3**	**13.5**	**22.6**	**33.6**	**38.0**	**40.5**	**51.3**	**56.0**	**44.6**	**40.2**	**28.8**	**21.0**	**26.3**
	Benign Brain Tumour	**0.3**	**-**	**0.1**	**0.1**	**0.4**	**0.2**	**0.6**	**0.7**	**0.4**	**0.1**	**0.5**	**0.7**	**-**	**-**	**-**
Cardiovascular	**Heart Attack**	-	-	-	0.2	0.4	1.0	1.2	2.0	2.0	2.1	2.2	2.6	3.3	3.5	6.2
	Heart Valve	0.1	0.1	0.1	-	0.1	0.1	0.3	0.7	1.1	1.9	2.4	2.8	0.3	-	-
	Aorta Graft	0.1	-	-	0.1	0.1	0.2	0.3	0.5	1.7	2.0	1.4	2.6	1.5	0.7	0.2
	By-Pass	-	-	-	0.1	0.4	0.7	0.6	2.1	5.2	5.1	6.2	3.0	2.1	-	-
	Stroke	-	0.1	0.1	0.1	0.4	0.6	0.5	0.6	1.5	2.7	6.4	4.7	8.3	6.8	1.5
	All Cardiovascular	**0.3**	**0.2**	**0.2**	**0.3**	**1.4**	**2.7**	**2.9**	**5.9**	**11.5**	**13.9**	**18.6**	**15.8**	**15.5**	**10.9**	**34.3**
Neurological	**Parkinson's**	-	-	-	-	-	-	0.1	-	0.1	0.3	0.5	0.2	0.3	0.7	0.5
	Multiple Sclerosis	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	-	-	-	-	-	0.5
	Motor Neurone	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	1.4
	All Neurological	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.3**	**0.1**	**0.6**	**0.3**	**0.5**	**0.2**	**0.3**	**0.7**	**4.5**
Accidental	**Deafness**	**-**	**0.1**	**-**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.4**	**0.1**	**0.2**	**0.2**	**-**	**-**	**0.3**
	Blindness	**-**	**0.1**	**0.1**	**-**	**0.1**	**0.1**	**0.3**	**0.4**	**1.5**	**1.0**	**1.5**	**2.6**	**3.8**	**2.0**	**1.0**
All Conditions		**5.1**	**4.2**	**8.9**	**14.1**	**24.8**	**37.0**	**42.2**	**47.8**	**65.6**	**71.4**	**65.9**	**59.7**	**48.4**	**34.6**	**0.1**

12.8 The Exposure after the 1st Incident

In the following Table 40 we have calculated the exposure in policy years from the date of the 1st incident condition shown to either the 2nd incident (any condition), death, withdrawal or the end of our data period (31st Dec 2007).

Table 40: The female exposure in policy years post 1st incident condition shown to either the 2nd incident (*any* condition), death, withdrawal or end of period.

1st incident	Age Range	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	20-89
Malignant	**Breast**	16.8	60.3	131.8	303.0	472.9	839.2	765.8	596.7	361.6	354.0	211.2	55.2	44.4	12.4	4,225.1
	Melanoma of skin	16.3	25.0	87.8	115.1	176.0	271.2	289.0	334.8	196.6	150.0	96.5	90.8	33.3	5.4	1,887.8
	Other skin	1.9	4.7	45.2	52.3	60.1	85.3	114.7	157.5	154.7	88.3	60.3	86.0	28.7	25.0	964.8
	Ovarian	-	-	26.7	19.6	72.9	41.8	86.5	78.3	94.0	47.4	13.7	9.7	2.3	-	492.8
	Colon	7.0	10.4	2.4	17.1	31.5	55.6	81.1	127.1	121.2	77.6	89.0	51.2	18.2	20.3	709.6
	Bladder	-	-	-	11.2	2.2	4.4	20.9	41.7	48.4	40.3	25.0	20.9	20.5	3.1	238.4
	Lung	-	-	0.3	13.5	8.2	29.9	16.3	23.2	23.9	27.5	21.9	31.2	5.1	0.3	201.2
	Stomach	-	-	-	3.6	7.7	4.7	30.5	36.9	10.3	29.0	13.9	1.8	8.9	-	147.1
	Colo-rectal	-	-	-	-	9.2	14.8	6.9	40.4	34.3	39.6	37.7	22.6	15.5	-	221.1
	Pancreatic	-	-	-	1.8	0.1	1.6	15.8	17.1	6.1	14.9	15.8	0.0	1.0	-	74.3
	Kidney & urinary	-	1.9	-	-	5.2	41.6	14.9	27.7	26.3	25.6	12.9	19.7	6.9	-	182.8
	Cervix uteri	21.0	11.4	35.9	30.4	39.6	29.8	48.8	22.8	5.6	9.5	0.7	9.3	-	-	264.8
	Body of uterus	-	-	1.0	6.4	-	8.2	20.0	9.8	6.6	16.4	1.6	11.4	-	1.1	82.5
	Brain	4.4	3.5	13.1	3.6	18.2	37.1	19.4	18.6	11.3	7.7	11.7	-	-	-	148.5
	Other Malignant	51.2	56.3	58.0	96.0	85.5	188.1	279.8	220.7	229.1	201.4	158.1	72.4	70.7	8.2	1,775.5
	All Malignant Cancer	**118.7**	**173.5**	**402.1**	**673.5**	**989.3**	**1,653.4**	**1,810.1**	**1,753.3**	**1,330.0**	**1,129.3**	**770.1**	**482.1**	**255.6**	**75.8**	**11,616.6**
	Benign Brain Tumour	**5.4**	**-**	**7.9**	**0.2**	**25.0**	**4.2**	**21.5**	**37.1**	**8.0**	**0.2**	**11.5**	**13.1**	**-**	**-**	**134.1**
Cardiovascular	**Heart Attack**	-	-	-	6.6	17.6	56.3	42.8	70.2	53.8	44.0	27.1	43.6	28.3	8.9	399.3
	Heart Valve	1.8	-	8.1	-	2.1	10.6	11.6	20.4	45.9	34.5	52.7	27.6	2.5	-	217.9
	Aorta Graft	4.8	-	-	1.3	3.0	23.1	11.8	19.9	54.9	40.2	30.6	45.7	22.8	3.0	261.1
	By-Pass	-	-	-	8.9	22.0	25.9	24.9	109.5	202.6	151.2	142.8	56.6	30.4	-	774.8
	Stroke	-	7.6	11.3	0.7	15.2	19.7	28.6	37.3	38.9	66.8	118.8	38.2	84.5	30.5	498.2
	All Cardiovascular	**6.6**	**7.6**	**19.4**	**17.6**	**60.0**	**135.5**	**119.7**	**257.4**	**396.1**	**336.7**	**372.0**	**211.8**	**168.4**	**42.3**	**2,151.3**
Neurological	**Parkinson's**	**-**	**9.0**	**-**	**1.3**	**10.5**	**15.2**	**5.2**	**16.6**	**3.7**	**10.5**	**6.1**	**2.1**	**-**	**-**	**80.1**
	Multiple Sclerosis	**-**	**0.3**	**6.1**	**-**	**3.2**	**5.6**	**18.8**	**4.4**	**41.8**	**24.2**	**27.3**	**25.1**	**35.8**	**5.8**	**198.5**
	Motor Neurone	-	-	-	-	-	-	4.3	-	9.8	3.1	11.1	4.8	3.6	2.1	38.8
	All Neurological	2.2	9.4	10.6	8.8	4.6	7.5	8.6	11.4	10.5	-	-	-	-	-	73.5
Accidental	**Deafness**	-	-	-	-	-	-	4.0	-	-	-	-	-	-	-	4.0
	Blindness	**2.2**	**9.4**	**10.6**	**8.8**	**4.6**	**7.5**	**17.0**	**11.4**	**20.3**	**3.1**	**11.1**	**4.8**	**3.6**	**2.1**	**116.4**
All Conditions		**212.1**	**326.5**	**849.5**	**1,420.4**	**2,048.6**	**2,792.4**	**2,463.7**	**2,226.3**	**1,953.5**	**1,631.8**	**1,266.4**	**746.2**	**475.8**	**127.9**	**18,541.0**

Similarly, in the following Table 41 we have calculated the exposure in policy years from the date of the 1st incident condition shown to either the 2nd incident (same condition), death, withdrawal or the end of our data period (31st Dec 2007).

Table 41: The female exposure in policy years post 1st incident condition shown to either the 2nd incident (*same* condition), death, withdrawal or end of our data period.

1st incident	Age Range	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	20-89
Malignant	**Breast**	16.8	60.3	131.8	303.0	472.9	839.2	765.8	596.7	361.6	354.0	211.2	55.2	44.4	12.4	4,225.1
	Melanoma of skin	16.3	25.0	87.8	115.1	176.0	271.2	289.0	334.8	196.6	150.0	96.5	90.8	33.3	5.4	1,887.8
	Other skin	1.9	4.7	45.2	52.3	60.1	85.3	114.7	157.5	154.7	88.3	60.3	86.0	28.7	25.0	964.8
	Ovarian	-	-	26.7	19.6	72.9	41.8	86.5	78.3	94.0	47.4	13.7	9.7	2.3	-	492.8
	Colon	7.0	10.4	2.4	17.1	31.5	55.6	81.1	127.1	121.2	77.6	89.0	51.2	18.2	20.3	709.6
	Bladder	-	-	-	11.2	2.2	4.4	20.9	41.7	48.4	40.3	25.0	20.9	20.5	3.1	238.4
	Lung	-	-	0.3	13.5	8.2	29.9	16.3	23.2	23.9	27.5	21.9	31.2	5.1	0.3	201.2
	Stomach	-	-	-	3.6	7.7	4.7	30.5	36.9	10.3	29.0	13.9	1.8	8.9	-	147.1
	Colo-rectal	-	-	-	-	9.2	14.8	6.9	40.4	34.3	39.6	37.7	22.6	15.5	-	221.1
	Pancreatic	-	-	-	1.8	0.1	1.6	15.8	17.1	6.1	14.9	15.8	0.0	1.0	-	74.3
	Kidney & urinary	-	1.9	-	-	5.2	41.6	14.9	27.7	26.3	25.6	12.9	19.7	6.9	-	182.8
	Cervix uteri	21.0	11.4	35.9	30.4	39.6	29.8	48.8	22.8	5.6	9.5	0.7	9.3	-	-	264.8
	Body of uterus	-	-	1.0	6.4	-	8.2	20.0	9.8	6.6	16.4	1.6	11.4	-	1.1	82.5
	Brain	4.4	3.5	13.1	3.6	18.2	37.1	19.4	18.6	11.3	7.7	11.7	-	-	-	148.5
	Other Malignant	51.2	56.3	58.0	96.0	85.5	188.1	279.8	220.7	229.1	201.4	158.1	72.4	70.7	8.2	1,775.5
	All Malignant Cancer	**118.7**	**173.5**	**402.1**	**673.5**	**989.3**	**1,653.4**	**1,810.1**	**1,753.3**	**1,330.0**	**1,129.3**	**770.1**	**482.1**	**255.6**	**75.8**	**11,616.6**
	Benign Brain Tumour	**5.4**	**-**	**7.9**	**0.2**	**25.0**	**4.2**	**21.5**	**37.1**	**8.0**	**0.2**	**11.5**	**13.1**	**-**	**-**	**134.1**
Cardiovascular	**Heart Attack**	-	-	-	6.6	17.6	56.3	42.8	70.2	53.8	44.0	27.1	43.6	28.3	8.9	399.3
	Heart Valve	1.8	-	8.1	-	2.1	10.6	11.6	20.4	45.9	34.5	52.7	27.6	2.5	-	217.9
	Aorta Graft	4.8	-	-	1.3	3.0	23.1	11.8	19.9	54.9	40.2	30.6	45.7	22.8	3.0	261.1
	By-Pass	-	-	-	8.9	22.0	25.9	24.9	109.5	202.6	151.2	142.8	56.6	30.4	-	774.8
	Stroke	-	7.6	11.3	0.7	15.2	19.7	28.6	37.3	38.9	66.8	118.8	38.2	84.5	30.5	498.2
	All Cardiovascular	**6.6**	**7.6**	**19.4**	**17.6**	**60.0**	**135.5**	**119.7**	**257.4**	**396.1**	**336.7**	**372.0**	**211.8**	**168.4**	**42.3**	**2,151.3**
Neurological	**Parkinson's**	**-**	**9.0**	**-**	**1.3**	**10.5**	**15.2**	**5.2**	**16.6**	**3.7**	**10.5**	**6.1**	**2.1**	**-**	**-**	**80.1**
	Multiple Sclerosis	**-**	**0.3**	**6.1**	**-**	**3.2**	**5.6**	**18.8**	**4.4**	**41.8**	**24.2**	**27.3**	**25.1**	**35.8**	**5.8**	**198.5**
	Motor Neurone	-	-	-	-	-	-	4.3	-	9.8	3.1	11.1	4.8	3.6	2.1	38.8
	All Neurological	2.2	9.4	10.6	8.8	4.6	7.5	8.6	11.4	10.5	-	-	-	-	-	73.5
Accidental	**Deafness**	-	-	-	-	-	-	4.0	-	-	-	-	-	-	-	4.0
	Blindness	**2.2**	**9.4**	**10.6**	**8.8**	**4.6**	**7.5**	**17.0**	**11.4**	**20.3**	**3.1**	**11.1**	**4.8**	**3.6**	**2.1**	**116.4**
All Conditions		**212.1**	**326.5**	**849.5**	**1,420.4**	**2,048.6**	**2,792.4**	**2,463.7**	**2,226.3**	**1,953.5**	**1,631.8**	**1,266.4**	**746.2**	**475.8**	**127.9**	**18,541.0**

12.9 The Crude 2nd Incidence Rate

On dividing the developed 2nd paid counts (Table 32, Appendix 12.5) for any subsequent condition by the corresponding exposure above in Table 40 (Appendix 12.8), we have the following Table 42 of crude 2nd incidence rates following the particular 1st incident condition shown.

Table 42: The female crude developed 2nd incidence rates (x10,000) for any condition from the individual or grouped 1st incident condition shown.

1st incident	Age Range	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	20-89
Malignant	**Breast**	-	564	662	699	368	412	330	352	399	145	194	187	229	1,677	377
	Melanoma of skin	-	409	848	539	760	463	183	347	493	514	219	1,077	940	-	476
	Other skin	-	2,192	234	205	399	120	449	196	133	704	514	119	-	419	293
	Ovarian	-	-	-	1,797	334	918	770	488	424	673	345	812	1,130	-	582
	Colon	-	-	-	1,797	334	918	770	488	424	673	345	812	1,130	-	582
	Bladder	-	-	-	948	-	-	1,962	490	842	257	825	1,961	997	3,347	903
	Lung	-	-	-	-	1,617	683	629	-	2,185	-	-	343	2,083	-	583
	Stomach	-	-	-	-	-	-	335	563	-	353	-	11,347	-	-	419
	Colo-rectal	-	-	-	-	1,118	690	-	255	909	1,050	271	-	-	-	514
	Pancreatic	-	-	-	-	-	-	-	-	-	1,386	-	-	-	-	278
	Kidney & urinary	-	-	-	-	-	-	-	-	411	401	-	-	-	-	115
	Cervix uteri	-	-	-	336	-	-	213	450	-	-	13,953	-	-	-	155
	Body of uterus	-	-	-	-	-	1,246	-	-	-	-	-	-	-	-	123
	Brain	-	2,944	-	-	574	-	540	-	4,475	-	-	-	-	-	551
	Other Malignant	399	363	356	322	965	500	550	377	545	515	262	866	434	-	490
	All Malignant	**172**	**491**	**480**	**560**	**474**	**416**	**373**	**334**	**485**	**446**	**268**	**655**	**524**	**547**	**425**
	Benign Brain	**1,888**	**-**	**-**	**-**	**-**	**-**	**480**	**-**	**1,432**	**-**	**-**	**-**	**-**	**-**	**238**
Cardiovascular	**Heart Attack**	-	-	-	-	581	181	238	145	765	233	753	241	362	-	334
	Heart Valve	-	-	-	-	-	-	1,768	501	-	296	-	-	-	-	188
	Aorta Graft	-	-	-	-	-	-	-	-	-	-	334	-	-	-	39
	By-Pass	-	-	-	-	462	-	-	186	50	137	72	-	340	-	106
	Stroke	-	1,340	-	-	-	520	-	-	-	612	86	534	-	-	185
	All	**-**	**1,340**	**-**	**-**	**341**	**150**	**257**	**159**	**130**	**244**	**137**	**146**	**122**	**-**	**167**
Neurological	**Parkinson's**	**-**	**1,138**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**4,833**	**-**	**-**	**255**
	Multiple Sclerosis	**-**	**-**	**-**	**-**	**-**	**-**	**544**	**-**	**754**	**1,299**	**748**	**-**	**-**	**1,791**	**524**
	Motor Neurone	-	-	-	-	-	-	-	-	1,098	-	-	-	-	-	276
	All Neurological	-	-	-	-	-	1,352	-	-	1,944	-	-	-	-	-	416
Accidental	**Deafness**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Blindness	**-**	**-**	**-**	**-**	**-**	**1,352**	**-**	**-**	**1,537**	**-**	**-**	**-**	**-**	**-**	**355**
All Conditions		**231**	**529**	**432**	**537**	**448**	**395**	**365**	**301**	**428**	**410**	**232**	**483**	**334**	**411**	**384**

Alternatively, we can restrict the data to only include 2nd paid claims where the condition corresponds exactly to the same condition as in the 1st paid claim. On dividing by the corresponding exposure for that condition post 1st incident (Table 32, Appendix 12.5), we have the subsequent crude central incidence rate Table 43.

Table 43: The female crude developed 2nd incidence rate (x10,000) for the same individual or grouped 1st incident condition shown.

1st incident	Age Range	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	20-89
Malignant	**Breast**	-	-	155	406	260	249	232	209	169	124	194	-	-	-	219
	Melanoma of skin	-	1,273	721	178	469	348	109	283	108	292	-	356	624	-	285
	Other skin	-	-	-	-	399	239	271	65	-	115	344	-	-	-	121
	Ovarian	-	-	-	519	140	244	238	133	221	442	-	1,104	-	-	231
	Colon	-	-	-	597	334	918	379	488	253	265	115	812	-	-	377
	Bladder	-	-	-	948	-	-	1,962	490	631	257	408	1,472	499	3,347	731
	Lung	-	-	-	-	-	-	-	-	858	-	-	343	-	-	155
	Stomach	-	-	-	-	-	-	-	277	-	-	-	-	-	-	69
	Colo-rectal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pancreatic	-	-	-	-	-	-	647	599	-	1,387	-	-	-	-	553
	Kidney & urinary	-	-	-	-	-	-	-	-	411	401	-	-	-	-	115
	Cervix uteri	-	-	-	336	-	-	-	-	-	-	-	-	-	-	39
	Body of uterus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Brain	-	2,944	-	-	-	-	-	-	1,814	-	-	-	-	-	207
	Other Malignant	399	181	179	215	610	114	256	237	274	255	270	142	145	-	246
	All Malignant	**172**	**301**	**234**	**305**	**306**	**246**	**229**	**225**	**210**	**206**	**162**	**283**	**161**	**135**	**234**
	Benign Brain	**1,888**	**-**	**-**	**-**	**-**	**-**	**480**	**-**	**1,432**	**-**	**-**	**-**	**-**	**-**	**238**
Cardiovascular	**Heart Attack**	-	-	-	-	581	181	-	-	195	-	753	-	-	-	129
	Heart Valve	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Aorta Graft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	By-Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Stroke	-	-	-	-	-	520	-	-	-	153	86	534	-	-	103
	All	**-**	**-**	**-**	**-**	**171**	**150**	**-**	**-**	**26**	**30**	**82**	**96**	**-**	**-**	**48**
Neurological	**Parkinson's**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
	Multiple Sclerosis	**-**	**-**	**-**	**-**	**-**	**-**	**544**	**-**	**509**	**453**	**-**	**-**	**-**	**1,791**	**266**
	Motor Neurone	-	-	-	-	-	-	-	-	1,098	-	-	-	-	-	276
	All Neurological	-	-	-	-	-	1,352	-	-	1,944	-	-	-	-	-	416
Accidental	**Deafness**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Blindness	**-**	**-**	**-**	**-**	**-**	**1,352**	**-**	**-**	**1,537**	**-**	**-**	**-**	**-**	**-**	**355**
All Conditions		**231**	**262**	**211**	**293**	**286**	**240**	**218**	**190**	**196**	**168**	**130**	**212**	**89**	**163**	**206**

12.10 Duration Since the Policy Inception and After the 1st Incident

The following Table 44 shows the number of developed 1st incident paid claims and corresponding 1st incidence rate for malignant cancer (ex BBT) from the policy inception, assuming no waiting period after the 1st incident.

Table 44: The female malignant cancer (ex BBT) paid 1st incident claims (> £2,000), exposure and crude central incidence rate at each duration since the policy inception.

Age	Number of Developed Paid Claims within Duration (years)								
Interval	0 - 0.25	0.25 - 1	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5+	All
20-29	15	10	25	12	7	11	3	24	**82**
30-39	68	51	119	37	31	20	26	79	**312**
40-49	127	105	232	107	90	64	59	163	**715**
50-59	173	136	309	148	136	117	78	219	**1,007**
60-69	128	117	245	114	92	90	67	167	**775**
70-79	56	87	143	70	40	38	40	84	**415**
80-89	22	22	44	23	23	9	8	18	**125**
20-89	**589**	**528**	**1,117**	**511**	**419**	**349**	**283**	**754**	**3,431**
Age	**Exposure at Duration (policy years)**								
Interval	**0 - 0.25**	**0.25 - 1**	**0 - 1**	**1 - 2**	**2 - 3**	**3 - 4**	**4 - 5**	**5+**	**All**
20-29	55,938	43,707	35,598	29,151	24,044	70,185	258,623	55,938	**43,707**
30-39	63,042	48,089	38,236	30,645	24,745	68,987	273,745	63,042	**48,089**
40-49	58,180	43,833	34,518	27,395	21,918	59,489	245,332	58,180	**43,833**
50-59	59,443	45,163	35,794	28,591	23,037	63,594	255,622	59,443	**45,163**
60-69	31,846	23,577	18,334	14,403	11,411	30,011	129,583	31,846	**23,577**
70-79	22,734	17,209	13,614	10,870	8,765	24,042	97,234	22,734	**17,209**
80-89	10,153	7,610	5,952	4,701	3,743	10,063	42,222	10,153	**7,610**
20-89	301,335	229,189	**182,046**	**145,755**	**117,664**	**326,371**	**1,302,360**	**301,335**	**229,189**
Age	**Incidence Rate (Number of Developed Paid Claims / Exposure) at Duration**								
Interval	**0 - 0.25**	**0.25 - 1**	**0 - 1**	**1 - 2**	**2 - 3**	**3 - 4**	**4 - 5**	**5+**	**All**
20-29	2.3	0.4	4.5	2.7	2.0	3.8	1.2	3.4	**3.2**
30-39	10.2	2.2	18.9	7.7	8.1	6.5	10.5	11.5	**11.4**
40-49	19.1	4.5	39.9	24.4	26.1	23.4	26.9	27.4	**29.1**
50-59	26.0	5.8	52.0	32.8	38.0	40.9	33.9	34.4	**39.4**
60-69	19.2	5.0	76.9	48.4	50.2	62.5	58.7	55.6	**59.8**
70-79	8.4	3.7	62.9	40.7	29.4	35.0	45.6	34.9	**42.7**
80-89	3.3	0.9	43.3	30.2	38.6	19.1	21.4	17.9	**29.6**
20-89	**88.4**	**22.5**	**37.1**	**22.3**	**23.0**	**23.9**	**24.1**	**23.1**	**26.3**

The following Table 45 shows the number of 2nd incident paid claims and corresponding 2nd incidence rate for malignant cancer (ex BBT) from the 1st incident exposure, assuming no waiting period after the 2nd incidence.

Table 45: The female malignant cancer (ex BBT) number of developed paid 2nd incidence claims (> £2,000), exposure and crude incidence rate at each duration since the end date of any 1st incident.

	Number of Developed Paid Claims within Duration (years)								
Age Interval	0 - 0.5	0.5 - 1	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5+	All
20-29	4	5	9	2	0	0	0	0	11
30-39	19	21	40	10	2	2	2	5	61
40-49	44	49	93	20	7	4	0	9	133
50-59	48	60	108	20	3	6	0	18	155
60-69	49	40	89	14	7	2	2	10	124
70-79	13	26	39	9	4	2	1	1	56
80-89	6	4	10	4	3	0	0	2	19
20-89	**183**	**205**	**388**	**79**	**26**	**16**	**5**	**45**	**559**
	Exposure at Duration (policy years)								
Age Interval	0 - 0.5	0.5 - 1	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5+	All
20-29	56	49	105	79	56	41	33	240	**554**
30-39	222	200	422	346	277	222	164	882	**2,313**
40-49	418	386	804	671	549	450	352	2,056	**4,883**
50-59	454	416	870	706	578	441	327	1,804	**4,727**
60-69	360	325	685	551	431	318	224	1,457	**3,667**
70-79	195	179	375	306	244	181	113	819	**2,038**
80-89	45	42	87	73	52	31	21	359	**622**
20-89	**1,750**	**1,598**	**3,348**	**2,733**	**2,187**	**1,684**	**1,234**	**7,617**	**18,802**
	Incidence Rate per 10,000 (Number of Developed Paid Claims / Exposure) at Duration								
Age Interval	0 - 0.5	0.5 - 1	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5+	All
20-29	717	1,020	858	253	-	-	-	-	**199**
30-39	855	1,050	948	289	72	90	122	57	**264**
40-49	1,052	1,269	1,156	298	127	89	-	44	**272**
50-59	1,058	1,441	1,241	283	52	136	-	100	**328**
60-69	1,363	1,230	1,300	254	162	63	89	69	**338**
70-79	666	1,450	1,041	294	164	110	89	12	**275**
80-89	1,337	955	1,152	545	581	-	-	56	**306**
20-89	**1,046**	**1,283**	**1,159**	**289**	**119**	**95**	**41**	**59**	**297**

From Table 45 we note that approximately 70% of all the paid claims occur within 1 year's duration from the end date of the 1st incident of any condition, with a significant drop off in the number of paid malignant cancer claims after one year's duration from 388 to 79. As the exposure does not decrease as dramatically, we obtained a corresponding drop in the incidence rate from 0.12 to 0.03 after 1 year's duration.

This would indicate having a one year waiting period to reduce the incidence rate of the 2nd condition to a considerably lower level, as undertaken by the current CI "Buy-back" providers mentioned in section 3.4 However, a policyholder under-going a 2nd incident may feel that a one year waiting period is artificially too long in order to prevent a "buy-back" benefit payment from ever occurring in most genuine cases leading to resentment. Whereas our aim is to provide the policyholder with a product which costs a little more premium, but has a fair chance of providing the expected benefit.

From Table 45 we note that of those paid claims within the 1st year, approximately half occur within the 1st six months, and the number of incidents remains fairly uniform across each of the 1st half yearly intervals in the 1st year. So if we assume a waiting period of half a year's duration then we would reduce the number of incidents in the 1st year's duration and the corresponding incidence rate by approximately half. However, the policyholder may still question why they are paying premiums for six months with no coverage (as we intend to keep the proportion of premium payable proportional to the proportion of outstanding benefit)?

We noted from the data that around half the 2nd incidents are for exactly the same individual condition type within the 1st six months. So we would only increase the pervious incidence rate by approximately a half if we require 180 days waiting period for exactly the same individual condition, but allowed a more generous benefit structure to the policyholder with only 30 days waiting period for any other condition.

The choice of 30 days is to exclude as much as possible those claims which follow immediately after the 1st claim, where the cause of the other condition is directly related to the 1st condition. The 30 days also matches the usual 30 days waiting period for a SACI product so would not appear unusual to the policyholder.

On implementing these two different sets of waiting periods to the paid claim count data in Table 45, we have the following Table 46.

Table 46: The female malignant cancer (ex BBT) paid 2nd incident claim counts (> £2,000), exposure and crude central incidence rate at each duration since the end date of any 1st incident, with a 180-day (30-day) moratorium for the same (any) condition.

	Number of Developed Paid Claims within Duration (years)								
Age Interval	**0 - 0.5**	**0.5 - 1**	**0 - 1**	**1 - 2**	**2 - 3**	**3 - 4**	**4 - 5**	**5+**	**All**
20-29	3	5	8	2	0	0	0	0	10
30-39	8	21	29	10	2	2	2	3	48
40-49	23	51	74	22	7	4	0	3	110
50-59	22	62	84	17	3	6	0	10	120
60-69	32	42	74	13	7	2	2	9	107
70-79	6	24	30	9	4	3	0	0	46
80-89	4	4	8	4	3	0	0	2	17
20-89	**98**	**209**	**307**	**77**	**26**	**17**	**5**	**26**	**458**
	Exposure at Duration (policy years)								
Age Interval	**0 - 0.5**	**0.5 - 1**	**0 - 1**	**1 - 2**	**2 - 3**	**3 - 4**	**4 - 5**	**5+**	**All**
20-29	64	54	117	83	56	42	33	223	**554**
30-39	254	226	480	379	292	230	170	816	**2,367**
40-49	484	438	922	737	578	467	362	1,925	**4,990**
50-59	522	473	995	778	615	458	337	1,668	**4,851**
60-69	414	370	784	603	456	330	230	1,343	**3,746**
70-79	215	196	411	328	257	188	118	780	**2,082**
80-89	57	50	107	81	52	31	21	332	**625**
20-89	**2,010**	**1,808**	**3,818**	**2,988**	**2,307**	**1,747**	**1,269**	**7,087**	**19,216**
	Incidence Rate (Number of Developed Paid Claims / Exposure) at Duration								
Age Interval	**0 - 0.5**	**0.5 - 1**	**0 - 1**	**1 - 2**	**2 - 3**	**3 - 4**	**4 - 5**	**5+**	**All**
20-29	472	930	682	240	-	-	-	-	**180**
30-39	315	929	604	264	68	87	118	37	**203**
40-49	475	1,165	803	299	121	86	-	16	**220**
50-59	421	1,311	844	219	49	131	-	60	**247**
60-69	773	1,135	944	215	154	61	87	67	**286**
70-79	279	1,222	729	274	155	160	-	-	**221**
80-89	702	792	744	494	572	-	-	60	**272**
20-89	**487**	**1,156**	**804**	**258**	**113**	**97**	**39**	**37**	**238**

Comparing the paid count data after the addition of our waiting period in Table 46, to the original values in Table 45, we note that the incidence rate reduces at all durations because of fewer claims, plus a longer exposure post 1st incident while waiting for a longer time interval before the 2nd incident, withdrawal or death.

The above is one possibility for the choice of post 1st incident waiting period, which still leaves us in total with 75% of the original paid counts. Our models can easily be adapted to consider removing any required % of the paid claims, but we shall not consider this further.

For both Table 45 and Table 46, although we have a trend in incidence rate by duration, we do not have sufficient data to determine credible select incidence rates by age, so we shall just consider the aggregate incidence rate by age across all durations.

12.11 Maximum Likelihood Estimation

To determine the underlying smooth curve of transitions rates through our crude incidence rates, let i_x denote the number of transitions or incidents from state j to state k, where $j = H, A, B,$ and $k = A, B, D, W,$ at age x (as provided above in section 12.5). Note: we have dropped the j, k superscripts for i_x (and the following m_x) for ease of notation, as the states will remain fixed in the remaining discussion.

Assume i_x has a Poisson distribution, $i_x \sim$ Poisson(m_x), with mean $m_x = E_x^j \, \mu_x^{jk}$,

where E_x^j = Total 'central exposed-to-risk' or waiting time in state j,

μ_x^{jk} = Force of mortality from state j to k,

m_x = The number of transitions from state j to k.

To determine a smooth form for the number of transitions m_x, we shall assume the Gompertz-Makeham *GM* (r,s) (Forfar *et al.* pp. 20, 1988), family of curves given by

$$GM(r,s) = \sum_{i=1}^{r} \alpha_i x^{i-1} + e^{\sum_{j=1}^{s} \beta_j x^{j-1}} \quad ,$$

to provide a smooth function for $\log \mu_x^{jk}$ when $r = 0$, or $\log(\mu_x^{jk} - \alpha_1)$ when $r = 1$.

These curves are parameterised using one to five unknown parameters, which we now need to estimate from the observed i_x. The method of maximum likelihood estimation provides one possible technique.

Assuming we have n observations for i_x at the midpoint age $x_1, \ldots, x_n$, within each of the n say 5-yearly age intervals. Then the Poisson likelihood across all of these ages is given by

$$l(i;m) = \prod_{x_1,\ldots x_n} m_x^{\,i_x} e^{-m_x} \, .$$

with the corresponding Poisson log-likelihood given by

$$l_c = \log(l(i;m)) \propto \sum_{x_1,\ldots,x_n} \left[-m_x + i_x \log(m_x) \right],$$

Substituting in the parametric form of $m_x = E_x^j \mu_x^{jk}$, based on a particular *GM* (*r*,*s*) choice of the curve μ_x^{jk}, we can solve numerically to find the parameter estimates which provide the maximum log-likelihood *L*.

12.12 Individual Model Goodness-of-Fit Tests

The 'best-fitting' curve for each transition from section 4.9 underwent the standard statistical tests (discussed on pp.92, Coughlan *et al* 2007), with the results shown below in Table 47.

Table 47 : Female Goodness-of-fit tests for selected *GM*(0,2) and *GM*(0,3) transitions from ages 20 to 89.

Test Statistics	HA	AW	AB^{any}	AB^{same}	$B^{any}W$	$B^{same}W$
Likelihood Ratio 'best-fitting' curve		**GM(0,3)**	**GM(0,3)**	**GM(0,3)**	**GM(0,2)**	**GM(0,2)**
1. Chi-Square Test						
Test Statistic	138	83	97	58	62	64
95% point of Chi-Square	87	84	87	87	86	86
Degrees of Freedom	67	64	67	67	66	66
p-value	0.000	0.053	0.009	0.773	0.611	0.549
Conclusion	**Reject**	**Accept**	**Reject**	**Accept**	**Accept**	**Accept**
2. Individual Standardised Deviance Test (IDST)						
Expect 11 in interval (∞ ,-1]	**16**	10	11	5	6	5
Expect 25 in interval (-1 ,0)	22	28	25	35	32	37
Expect 25 in interval [0,1)	16	13	20	22	15	8
Expect 11 in interval [1, ∞)	**17**	14	15	9	11	8
Conclusion	**Reject**	**Accept**	**Accept**	**Reject**	**Reject**	**Reject**
3. Signs Test						
Number of Positive Signs	33	27	35	31	26	16
Number of Positive Signs	38	38	37	41	38	42
Binomial(n,0.5) cumulative probability	0.32	0	0.45	0.14	0.08	0.00
Conclusion	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**	**Reject**
4. Runs Test						
Expected Number of Runs, mu	36.3	32.6	37.0	36.3	31.9	24.2
Number of Positive Signs	17.3	15.1	17.7	17.1	14.6	9.0
Number of observed Runs	33.0	32.0	41.0	43.0	24.0	22.0
Test Statistic ~ N(0,1)	-0.8	-0.1	1.0	1.6	-2.1	-0.7
Conclusion	**Accept**	**Accept**	**Accept**	**Accept**	**Reject**	**Accept**
5. Kolmogorov-Smirnov (KS) Test						
Test Statistic	0.0007	0.0009	0.0008	0.0009	0.0034	0.0067
Conclusion	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**
6. Serial Correlation (SC) Test						
1-step Correlation	0.1	0.1	0.0	-0.2	0.2	-0.0
Test Statistic ~ N(0,1)	1.0	0.9	0.2	-1.8	1.3	-0.0
Conclusion	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**	**Accept**

Note: We have used a 95% confidence interval to determine whether to accept or reject the following hypothesis:

***H_0*:** The observed critical illness incidence counts i_x (for each age x from 20 to 89) are a possible realisation from the underlying distribution with expected counts E_x from the standard *GM*(0,s) curve.

The following are more detailed commentary on the main features of Table 47 concentrating on the Chi-squared test and individual standardised deviance test (ISDT), as the other tests were nearly always adequate.

12.12.1 Transition from Healthy to 1st Incident (*HA*)

For transitions from the healthy state to the 1st incident, the Chi-squared test statistic of 138 is considerably larger than the 95% point of the Chi-squared distribution corresponding to 87 (on 67 degrees of freedom) assuming a GM(0,3) model from ages 20 to 89. This is because of anomalies in the data, as indicated by 16 and 17 extreme standard deviations less than -1, or greater than +1, compared to the 11 expected. The individual ordered residuals are shown against the normal scores in Figure 32.

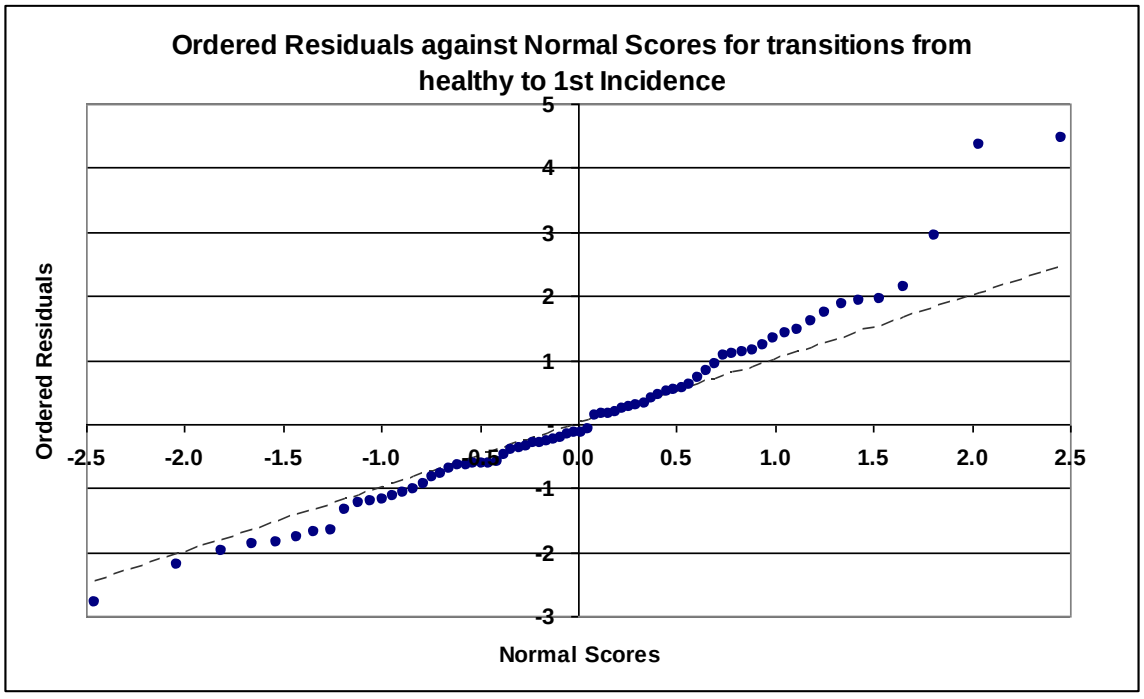

Figure 32: Fitted *GM*(0,3) ordered residuals against normal scores for the 1st incidence rate from the healthy state for females aged 20 to 89.

From Figure 32, we note that the largest positive deviation is at age 65, where the actual developed number of paid incidents increases from 93 at age 64, to143 at age 65, before decreasing to 86 at age 66.

This is possibly due to health checks undertaken by individuals just prior to retirement as any company provided medical coverage ceases revealing 'hidden' conditions, which would of probably only come to light at an older age. The 2nd largest positive outlier exists at ages 21, but this could just be volatility in the data at such young ages.

A plot of residuals against fitted values shows a random pattern with no expanding fan-shaped pattern, suggesting no strong heteroscedasticity.

Increasing the parameterisation of the model provided no improvement in overall fit to account for these outliers. Even so, all the other tests where acceptable indicating that the overall shape of the *GM*(0,3) curve is fitting approximately evenly above and below the actual data and providing a reasonable match, even though statistically a few outliers are problematic. On removing these outliers, the curve provided an adequate Chi-square fit.

12.12.2 Transition from the 1st to 2nd Incident for Any Condition (AB^{any})

The Chi-square test is only just not significant at the 1% level (*p*-value = 0.009) for the *GM* (0,3) model fit for transitions from the 1st incident to any 2nd incident. Again this is due to an outlier at age 35 with a standardised residual of 4.8, as shown in the following Figure 33.

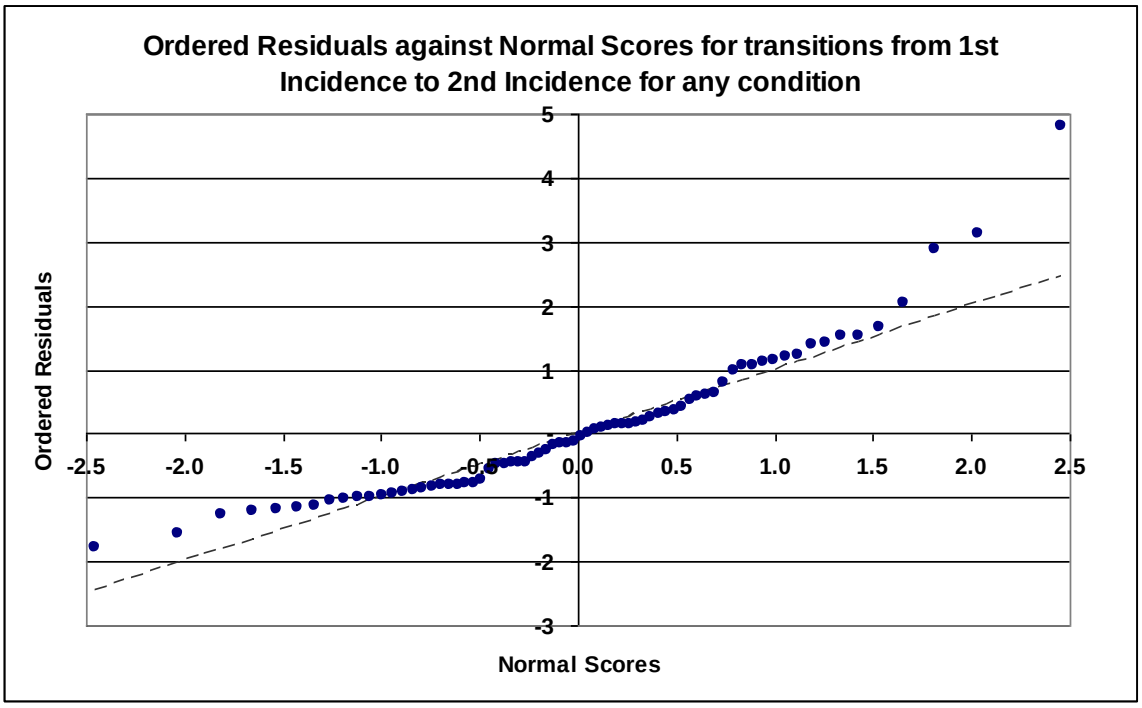

Figure 33: Fitted *GM*(0,3) ordered residuals against normal scores for the 2nd incidence rate from any condition after the 1st incident for females aged 20 to 89.

A separate plot of residuals against fitted values shows a slight increase in positive residuals with increasing age suggesting possible heteroscedasticity. This is not surprising as we are looking at a much more limited dataset than for the 1st incident, with lots of different distinct possibilities for the 1st and 2nd condition, resulting in increased heterogeneity than for the transition from healthy to 1st incident.

12.12.3 Transition from the 1st to 2nd Incident for the Same Condition (AB^{same})

When we consider the same 2nd condition as the 1st condition, we obtain possibly too small a Chi-square statistic with too few observations in the tails, which failed the requirement of around 11 observations greater than 1 or less than -1 in the individual standardised deviance test (ISDT).

From the individual ordered residuals in the following Figure 34, we noted that there are possibly too few extreme negative residuals.

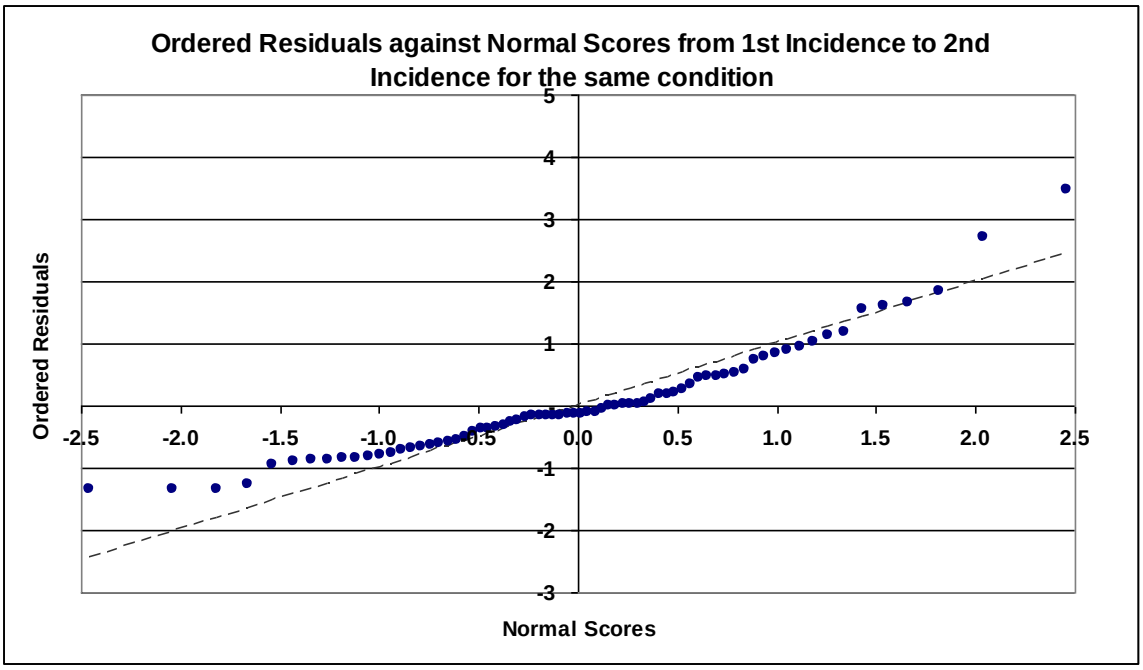

Figure 34: Fitted *GM*(0,3) ordered residuals against normal scores for the 2nd incidence rate from the same condition after the 1st incident for females aged 20 to 89.

If we change from the *GM*(0,3) to the *GM*(0,1) or *GM*(0,2) model then we still obtain an acceptable ISDT, with all the other tests still adequate. This indicates that there is insufficient date to differentiate by age for the 2nd incidence rate, and we can assume a constant incidence rate if we desire. For convenience and consistency with the other transitions, we shall just assume the *GM*(0,3) curve as the fitted parameterisation leads to practically the same shape as the *GM*(0,1) curve.

12.12.4 Transition from State *A* or State *B* to the Withdrawal State *W*

The Chi-square test statistic for the withdrawal transitions from state *A* (*AW*) is just acceptable with a *p*-value of 0.053, and an acceptable individual standardised deviance test (ISDT). For transitions from state *B*, the ISDT is not acceptable, with not enough extreme negative observations.

As a reality check from the following Figure 35 we noted that the withdrawal data is fairly volatile making the final choice of curve difficult.

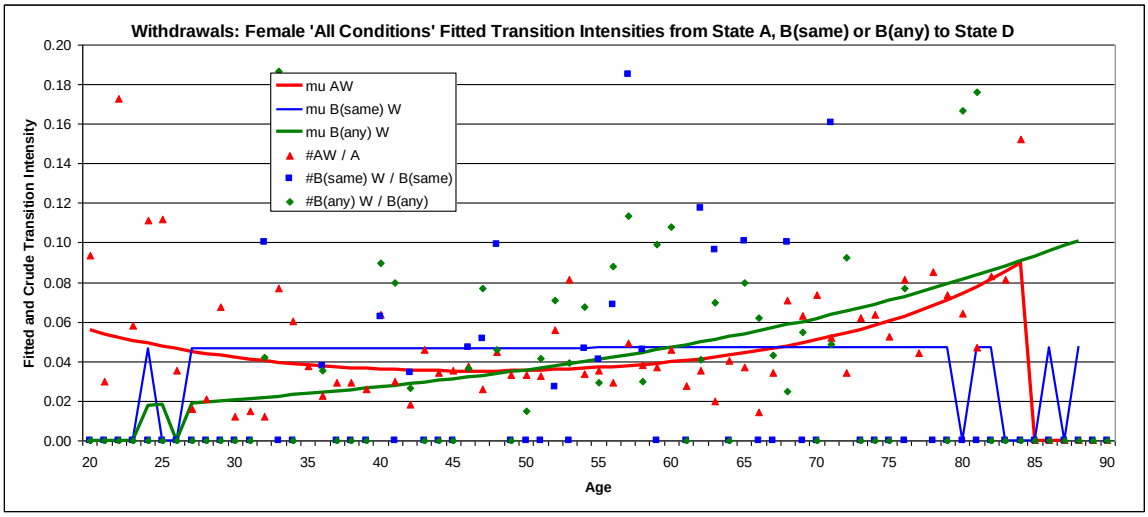

Figure 35: Fitted *GM*(0,2) transition rates for the 1st or 2nd withdrawal from state *A* or state *B*, compared to the corresponding crude transition rates.

From Figure 35 after the 1st incident, we can possibly detect a decrease in the withdrawal rate at the youngest ages from age 20 to 40, before increasing from ages 60 to 80 (shown by the red curve). The withdrawal following a claim may possibly be because the PMI policyholders have reviewable contracts, resulting in the subsequent premium increase felt to be unaffordable or offer poor value for money, especially if re-rated at an older age.

For withdrawal after the 2nd incident, the incidence is probably flat given the limited data (blue curve) or possibly gently sloping upwards for strictly the same condition (shown by

the green curve). As there are no subsequent benefit payments, the final choice is not that critical to the premium calculation (apart from a 2nd order effect in determining the probability of moving from state *A* to state *B*).

Finally, even though our curves are suspect they seem to produce reasonable lower transition intensities of 4% for withdrawal after the 1st incident, and 2% to 5% after the 2nd incident (for ages 20 to 60), compared to the client provided withdrawal rate of 12% from the healthy state.

12.12.5 Fitted Transition Intensities from the Healthy State *H* to the 1st Incident State *A*

The following Table 48 and Table 49 show the healthy to 1st incident transition intensities per 10,000 for the prominent cancers and the main grouped CI conditions.

Table 48: Fitted transition Intensities (x10,000) from the healthy state to the 1st Incident for the prominent cancers, all the malignant cancers, all the cardiovascular, and all the combined CI conditions for ages 20 to 49.

Model	*GM(0,4)*	*GM(0,3)*	*GM(0,3)*	*GM(0,3)*	*GM(0,4)*	Difference	*GM(0,4)*	*GM(0,4)*	Difference	*GM(0,3)*
Age	Breast Cancer	Malignant melanoma of Skin	Other malignant neoplasm of skin	Malignant neoplasm of ovary and other uterine adnexa	Malignant neoplasm of colon	Other Cancer	All Malignant Cancer	All Cardio vascular	Neurological / Accidental	All Combined CI
20	0.20	0.56	0.18	0.03	0.10	0.93	1.99	0.12	0.04	2.16
21	0.27	0.64	0.20	0.04	0.10	1.05	2.30	0.13	0.06	2.48
22	0.35	0.73	0.23	0.05	0.11	1.17	2.64	0.14	0.07	2.85
23	0.46	0.83	0.26	0.06	0.11	1.30	3.03	0.15	0.09	3.26
24	0.59	0.94	0.29	0.07	0.12	1.44	3.46	0.16	0.11	3.72
25	0.75	1.07	0.32	0.09	0.13	1.57	3.94	0.17	0.12	4.24
26	0.95	1.20	0.36	0.11	0.14	1.71	4.47	0.19	0.14	4.80
27	1.18	1.35	0.40	0.13	0.16	1.84	5.06	0.20	0.17	5.43
28	1.45	1.52	0.45	0.15	0.17	1.97	5.71	0.22	0.19	6.12
29	1.76	1.69	0.50	0.18	0.19	2.10	6.42	0.25	0.21	6.89
30	2.12	1.88	0.56	0.21	0.20	2.23	7.20	0.27	0.24	7.72
31	2.52	2.09	0.61	0.25	0.22	2.35	8.05	0.30	0.27	8.62
32	2.97	2.31	0.68	0.30	0.25	2.47	8.97	0.34	0.31	9.61
33	3.47	2.54	0.75	0.34	0.27	2.59	9.96	0.37	0.34	10.68
34	4.01	2.79	0.82	0.40	0.30	2.71	11.02	0.42	0.38	11.83
35	4.59	3.05	0.90	0.46	0.33	2.83	12.16	0.47	0.43	13.06
36	5.20	3.33	0.98	0.52	0.37	2.97	13.38	0.53	0.48	14.38
37	5.85	3.62	1.07	0.60	0.41	3.12	14.66	0.59	0.53	15.79
38	6.52	3.92	1.16	0.68	0.46	3.29	16.03	0.67	0.58	17.28
39	7.20	4.23	1.26	0.76	0.51	3.49	17.46	0.76	0.65	18.86
40	7.89	4.55	1.36	0.85	0.57	3.73	18.95	0.86	0.71	20.52
41	8.58	4.88	1.47	0.95	0.64	4.00	20.51	0.97	0.78	22.27
42	9.25	5.21	1.58	1.05	0.71	4.32	22.13	1.10	0.86	24.09
43	9.89	5.55	1.70	1.16	0.79	4.69	23.79	1.24	0.94	25.98
44	10.50	5.90	1.82	1.28	0.88	5.12	25.50	1.41	1.03	27.93
45	11.07	6.24	1.94	1.39	0.98	5.61	27.24	1.60	1.12	29.95
46	11.59	6.58	2.07	1.51	1.09	6.16	29.00	1.81	1.21	32.01
47	12.05	6.91	2.20	1.63	1.22	6.76	30.78	2.04	1.30	34.12
48	12.45	7.24	2.33	1.75	1.35	7.43	32.55	2.31	1.40	36.26
49	12.78	7.56	2.47	1.87	1.49	8.15	34.32	2.61	1.49	38.42

Table 49: Fitted transition Intensities (x10,000) from the healthy state to the 1st Incident for the prominent cancers, all the malignant cancers, all the cardiovascular, and all the combined CI conditions for ages 50 to 89.

Model	*GM(0,4)*	*GM(0,3)*	*GM(0,3)*	*GM(0,3)*	*GM(0,4)*	Difference	*GM(0,4)*	*GM(0,4)*	Difference	*GM(0,3)*
Age	Breast Cancer	Malignant melanoma of Skin	Other malignant neoplasm of skin	Malignant neoplasm of ovary and other uterine adnexa	Malignant neoplasm of colon	Other Cancer	All Malignant Cancer	All Cardio vascular	Neurologic al /Accidental	All Combined CI
50	13.03	7.86	2.61	1.99	1.65	8.92	36.06	2.94	1.58	40.58
51	13.22	8.15	2.74	2.10	1.82	9.73	37.77	3.31	1.66	42.75
52	13.33	8.43	2.88	2.21	2.01	10.57	39.43	3.72	1.74	44.89
53	13.36	8.68	3.02	2.31	2.20	11.44	41.02	4.17	1.81	47.00
54	13.33	8.91	3.16	2.41	2.41	12.32	42.53	4.67	1.86	49.07
55	13.23	9.11	3.29	2.49	2.63	13.21	43.96	5.21	1.90	51.07
56	13.07	9.29	3.42	2.56	2.86	14.08	45.28	5.79	1.93	53.00
57	12.85	9.44	3.55	2.62	3.09	14.92	46.48	6.43	1.93	54.84
58	12.57	9.56	3.68	2.67	3.34	15.73	47.56	7.10	1.91	56.58
59	12.26	9.65	3.80	2.71	3.58	16.50	48.50	7.82	1.88	58.19
60	11.90	9.71	3.91	2.73	3.83	17.20	49.29	8.58	1.82	59.68
61	11.51	9.74	4.02	2.73	4.08	17.84	49.92	9.37	1.73	61.02
62	11.10	9.73	4.12	2.72	4.32	18.40	50.39	10.19	1.63	62.21
63	10.66	9.69	4.21	2.70	4.55	18.88	50.69	11.03	1.51	63.24
64	10.21	9.62	4.30	2.66	4.77	19.26	50.82	11.89	1.38	64.09
65	9.76	9.52	4.37	2.61	4.97	19.56	50.78	12.74	1.24	64.76
66	9.29	9.39	4.44	2.55	5.14	19.76	50.57	13.58	1.10	65.25
67	8.83	9.22	4.49	2.47	5.29	19.87	50.18	14.39	0.97	65.54
68	8.38	9.03	4.54	2.39	5.41	19.89	49.63	15.17	0.85	65.64
69	7.93	8.82	4.57	2.29	5.50	19.81	48.92	15.88	0.75	65.55
70	7.49	8.58	4.60	2.19	5.54	19.65	48.05	16.53	0.69	65.26
71	7.07	8.32	4.61	2.08	5.55	19.41	47.03	17.08	0.67	64.79
72	6.66	8.04	4.61	1.97	5.52	19.09	45.88	17.53	0.71	64.12
73	6.27	7.74	4.60	1.85	5.44	18.70	44.60	17.87	0.81	63.28
74	5.89	7.43	4.58	1.73	5.32	18.25	43.21	18.08	0.97	62.26
75	5.54	7.11	4.55	1.61	5.16	17.75	41.71	18.15	1.21	61.07
76	5.20	6.78	4.50	1.49	4.97	17.19	40.13	18.08	1.53	59.74
77	4.89	6.44	4.45	1.37	4.74	16.58	38.47	17.86	1.93	58.25
78	4.59	6.10	4.38	1.25	4.48	15.94	36.75	17.50	2.39	56.64
79	4.31	5.76	4.31	1.14	4.20	15.27	34.99	16.99	2.93	54.91
80	4.05	5.42	4.23	1.03	3.89	14.57	33.19	16.36	3.53	53.07
81	3.81	5.08	4.14	0.93	3.58	13.84	31.38	15.60	4.17	51.15
82	3.59	4.75	4.04	0.83	3.25	13.10	29.56	14.74	4.85	49.15
83	3.38	4.42	3.93	0.74	2.93	12.34	27.75	13.79	5.54	47.08
84	3.19	4.10	3.82	0.66	2.61	11.57	25.96	12.78	6.24	44.97
85	3.02	3.79	3.70	0.58	2.30	10.80	24.19	11.72	6.92	42.83
86	2.86	3.50	3.58	0.51	2.01	10.02	22.47	10.64	7.56	40.67
87	2.71	3.22	3.45	0.44	1.73	9.24	20.80	9.55	8.16	38.50
88	2.58	2.94	3.32	0.39	1.48	8.48	19.18	8.48	8.68	36.34
89	2.46	2.69	3.18	0.33	1.24	7.72	17.62	7.45	9.13	34.21
20-89	7.81	5.51	1.98	1.31	1.53	7.59	25.73	3.30	0.94	29.97

12.12.6 Fitted Transition Intensities from the 1st Incident State *A* to the 2nd Incident State *B* for the Same Individual Condition

The following Table 50 and Table 51 show the 1st to 2nd incident transition intensities per 10,000, for the prominent cancers and the main grouped CI conditions, for the same individual condition on the 2nd incident.

Table 50: Fitted transition Intensities (x10,000) from the 1st Incident to the 2nd Incident for the same condition for prominent cancers, all the malignant cancer, all the cardiovascular, and all the CI conditions combined for ages 20 to 49.

Model	*GM(0,4)*	*GM(0,3)*	*GM(0,1)*	*GM(0,2)*	*GM(0,1)*		*GM(0,1)*	*GM(0,1)*		*GM(0,3)*
Age	Breast Cancer	Malignant melanoma of Skin	Other malignant neoplasm of skin	Malignant neoplasm of ovary and other uterine adnexa	Malignant neoplasm of colon		All Malignant Cancer	All Cardio vascular		All CI
20	218.52	1,238.91	120.95	231.17	376.94		233.52	47.59		274.48
21	218.52	1,146.69	120.95	231.17	376.94		233.52	47.59		274.62
22	218.52	1,063.15	120.95	231.17	376.94		233.52	47.59		274.64
23	218.52	987.39	120.95	231.17	376.94		233.52	47.59		274.53
24	218.52	918.59	120.95	231.17	376.94		233.52	47.59		274.30
25	218.52	856.05	120.95	231.17	376.94		233.52	47.59		273.95
26	218.52	799.14	120.95	231.17	376.94		233.52	47.59		273.47
27	218.52	747.29	120.95	231.17	376.94		233.52	47.59		272.88
28	218.52	700.00	120.95	231.17	376.94		233.52	47.59		272.16
29	218.52	656.83	120.95	231.17	376.94		233.52	47.59		271.32
30	218.52	617.38	120.95	231.17	376.94		233.52	47.59		270.37
31	218.52	581.28	120.95	231.17	376.94		233.52	47.59		269.30
32	218.52	548.24	120.95	231.17	376.94		233.52	47.59		268.11
33	218.52	517.96	120.95	231.17	376.94		233.52	47.59		266.81
34	218.52	490.20	120.95	231.17	376.94		233.52	47.59		265.39
35	218.52	464.71	120.95	231.17	376.94		233.52	47.59		263.86
36	218.52	441.31	120.95	231.17	376.94		233.52	47.59		262.23
37	218.52	419.80	120.95	231.17	376.94		233.52	47.59		260.49
38	218.52	400.02	120.95	231.17	376.94		233.52	47.59		258.64
39	218.52	381.83	120.95	231.17	376.94		233.52	47.59		256.69
40	218.52	365.09	120.95	231.17	376.94		233.52	47.59		254.65
41	218.52	349.69	120.95	231.17	376.94		233.52	47.59		252.50
42	218.52	335.50	120.95	231.17	376.94		233.52	47.59		250.26
43	218.52	322.45	120.95	231.17	376.94		233.52	47.59		247.93
44	218.52	310.43	120.95	231.17	376.94		233.52	47.59		245.52
45	218.52	299.37	120.95	231.17	376.94		233.52	47.59		243.01
46	218.52	289.20	120.95	231.17	376.94		233.52	47.59		240.43
47	218.52	279.86	120.95	231.17	376.94		233.52	47.59		237.76
48	218.52	271.28	120.95	231.17	376.94		233.52	47.59		235.02
49	218.52	263.42	120.95	231.17	376.94		233.52	47.59		232.21

Table 51: Fitted transition Intensities (x10,000) from the 1st Incident to the 2nd Incident for the same condition for prominent cancers, all the malignant cancer, all the cardiovascular, and all the CI conditions combined for ages 50 to 89.

Model	*GM(0,4)*	*GM(0,3)*	*GM(0,1)*	*GM(0,2)*	*GM(0,1)*		*GM(0,1)*	*GM(0,1)*		*GM(0,3)*
Age	**Breast Cancer**	**Malignant melanoma of Skin**	**Other malignant neoplasm of skin**	**Malignant neoplasm of ovary and other uterine adnexa**	**Malignant neoplasm of colon**		**All Malignant Cancer**	**All Cardio vascular**		**All CI**
50	218.52	256.22	120.95	231.17	376.94		233.52	47.59		229.33
51	218.52	249.64	120.95	231.17	376.94		233.52	47.59		226.38
52	218.52	243.65	120.95	231.17	376.94		233.52	47.59		223.37
53	218.52	238.21	120.95	231.17	376.94		233.52	47.59		220.30
54	218.52	233.30	120.95	231.17	376.94		233.52	47.59		217.18
55	218.52	228.87	120.95	231.17	376.94		233.52	47.59		214.00
56	218.52	224.91	120.95	231.17	376.94		233.52	47.59		210.78
57	218.52	221.40	120.95	231.17	376.94		233.52	47.59		207.51
58	218.52	218.32	120.95	231.17	376.94		233.52	47.59		204.20
59	218.52	215.65	120.95	231.17	376.94		233.52	47.59		200.85
60	218.52	213.38	120.95	231.17	376.94		233.52	47.59		197.47
61	218.52	211.50	120.95	231.17	376.94		233.52	47.59		194.06
62	218.52	209.99	120.95	231.17	376.94		233.52	47.59		190.63
63	218.52	208.84	120.95	231.17	376.94		233.52	47.59		187.17
64	218.52	208.06	120.95	231.17	376.94		233.52	47.59		183.69
65	218.52	207.64	120.95	231.17	376.94		233.52	47.59		180.19
66	218.52	207.58	120.95	231.17	376.94		233.52	47.59		176.69
67	218.52	207.86	120.95	231.17	376.94		233.52	47.59		173.17
68	218.52	208.51	120.95	231.17	376.94		233.52	47.59		169.64
69	218.52	209.52	120.95	231.17	376.94		233.52	47.59		166.12
70	218.52	210.89	120.95	231.17	376.94		233.52	47.59		162.59
71	218.52	212.64	120.95	231.17	376.94		233.52	47.59		159.07
72	218.52	214.76	120.95	231.17	376.94		233.52	47.59		155.56
73	218.52	217.28	120.95	231.17	376.94		233.52	47.59		152.05
74	218.52	220.21	120.95	231.17	376.94		233.52	47.59		148.56
75	218.52	223.56	120.95	231.17	376.94		233.52	47.59		145.08
76	218.52	227.34	120.95	231.17	376.94		233.52	47.59		141.62
77	218.52	231.59	120.95	231.17	376.94		233.52	47.59		138.18
78	218.52	236.32	120.95	231.17	376.94		233.52	47.59		134.76
79	218.52	241.56	120.95	231.17	376.94		233.52	47.59		131.37
80	218.52	247.34	120.95	231.17	376.94		233.52	47.59		128.01
81	218.52	253.70	120.95	231.17	376.94		233.52	47.59		124.67
82	218.52	260.66	120.95	231.17	376.94		233.52	47.59		121.37
83	218.52	268.27	120.95	231.17	376.94		233.52	47.59		118.11
84	218.52	276.58	120.95	231.17	376.94		233.52	47.59		114.88
85	218.52	285.63	120.95	231.17	376.94		233.52	47.59		111.69
86	218.52	295.48	120.95	231.17	376.94		233.52	47.59		108.53
87	218.52	306.20	120.95	231.17	376.94		233.52	47.59		105.42
88	218.52	317.85	120.95	231.17	376.94		233.52	47.59		102.36
89	218.52	330.51	120.95	231.17	376.94		233.52	47.59		99.34

12.12.7 Fitted Transition Intensities from the 1st Incident to the 2nd Incident for any Individual Condition

The following Table 52 and Table 53 show the 1st to 2nd transition intensities per 10,000 for the prominent cancers and main grouped CI conditions, for any individual condition on the 2nd incident.

Table 52: Fitted transition Intensities (x10,000) from the 1st Incident to the 2nd Incident for any condition for the prominent cancers, all the malignant cancers, all the cardiovascular and all the combined CI conditions for ages 20 to 49.

Model	*GM(0,4)*	*GM(0,3)*	*GM(0,1)*	*GM(0,2)*	*GM(0,1)*		*GM(0,1)*	*GM(0,1)*		*GM(0,3)*
Age	**Breast Cancer**	**Malignant melanoma of Skin**	**Other malignant neoplasm of skin**	**Malignant neoplasm of ovary and other uterine adnexa**	**Malignant neoplasm of colon**		**All Malignant Cancer**	**All Cardio vascular**		**All CI**
20	348.24	1,144.38	292.94	36.00	582.04		424.97	166.69		424.97
21	381.73	1,078.96	292.94	38.40	582.04		424.97	166.69		424.97
22	414.65	1,019.04	292.94	40.98	582.04		424.97	166.69		424.97
23	446.44	964.09	292.94	43.72	582.04		424.97	166.69		352.97
24	476.62	913.68	292.94	46.65	582.04		424.97	166.69		287.45
25	504.68	867.39	292.94	49.77	582.04		424.97	166.69		424.97
26	530.21	824.87	292.94	53.10	582.04		424.97	166.69		421.30
27	552.84	785.78	292.94	56.66	582.04		424.97	166.69		351.65
28	572.29	749.82	292.94	60.45	582.04		424.97	166.69		374.66
29	588.33	716.74	292.94	64.50	582.04		424.97	166.69		360.41
30	600.85	686.30	292.94	68.81	582.04		424.97	166.69		368.94
31	609.79	658.29	292.94	73.42	582.04		424.97	166.69		424.97
32	615.19	632.50	292.94	78.34	582.04		424.97	166.69		413.68
33	617.13	608.77	292.94	83.58	582.04		424.97	166.69		355.57
34	615.79	586.93	292.94	89.17	582.04		424.97	166.69		414.93
35	611.38	566.85	292.94	95.14	582.04		424.97	166.69		416.16
36	604.15	548.40	292.94	101.51	582.04		424.97	166.69		387.03
37	594.39	531.47	292.94	108.31	582.04		424.97	166.69		421.54
38	582.42	515.94	292.94	115.56	582.04		424.97	166.69		423.56
39	568.55	501.72	292.94	123.30	582.04		424.97	166.69		412.45
40	553.11	488.74	292.94	131.55	582.04		424.97	166.69		370.53
41	536.42	476.91	292.94	140.36	582.04		424.97	166.69		404.74
42	518.77	466.17	292.94	149.76	582.04		424.97	166.69		409.02
43	500.45	456.45	292.94	159.78	582.04		424.97	166.69		380.05
44	481.74	447.71	292.94	170.48	582.04		424.97	166.69		393.11
45	462.87	439.89	292.94	181.89	582.04		424.97	166.69		380.98
46	444.05	432.94	292.94	194.07	582.04		424.97	166.69		401.09
47	425.48	426.84	292.94	207.06	582.04		424.97	166.69		400.62
48	407.32	421.55	292.94	220.92	582.04		424.97	166.69		401.36
49	389.70	417.04	292.94	235.71	582.04		424.97	166.69		399.62

Table 53: Fitted transition Intensities (x10,000) from the 1st Incident to the 2nd Incident for any condition for the prominent cancers, all the malignant cancers, all the cardiovascular and all the combined CI conditions for ages 50 to 89.

Model	*GM(0,4)*	*GM(0,3)*	*GM(0,1)*	*GM(0,2)*	*GM(0,1)*		*GM(0,1)*	*GM(0,1)*		*GM(0,3)*
Age	**Breast Cancer**	**Malignant melanoma of Skin**	**Other malignant neoplasm of skin**	**Malignant neoplasm of ovary and other uterine adnexa**	**Malignant neoplasm of colon**		**All Malignant Cancer**	**All Cardio vascular**		**All CI**
50	372.75	413.29	292.94	251.49	582.04		424.97	166.69		389.85
51	356.54	410.28	292.94	268.33	582.04		424.97	166.69		395.49
52	341.17	407.99	292.94	286.29	582.04		424.97	166.69		402.70
53	326.68	406.40	292.94	305.46	582.04		424.97	166.69		395.08
54	313.12	405.53	292.94	325.91	582.04		424.97	166.69		396.35
55	300.51	405.34	292.94	347.73	582.04		424.97	166.69		371.18
56	288.88	405.86	292.94	371.01	582.04		424.97	166.69		389.44
57	278.24	407.08	292.94	395.84	582.04		424.97	166.69		374.83
58	268.60	409.00	292.94	422.34	582.04		424.97	166.69		368.87
59	259.96	411.63	292.94	450.62	582.04		424.97	166.69		390.55
60	252.33	415.00	292.94	480.78	582.04		424.97	166.69		356.35
61	245.71	419.11	292.94	512.97	582.04		424.97	166.69		341.70
62	240.10	423.99	292.94	547.31	582.04		424.97	166.69		352.76
63	235.53	429.67	292.94	583.95	582.04		424.97	166.69		360.08
64	232.01	436.17	292.94	623.05	582.04		424.97	166.69		344.58
65	229.56	443.53	292.94	664.76	582.04		424.97	166.69		346.97
66	228.24	451.79	292.94	709.26	582.04		424.97	166.69		359.34
67	228.08	460.99	292.94	756.74	582.04		424.97	166.69		387.96
68	229.16	471.20	292.94	807.41	582.04		424.97	166.69		341.09
69	231.57	482.45	292.94	861.46	582.04		424.97	166.69		349.06
70	235.43	494.82	292.94	919.13	582.04		424.97	166.69		324.70
71	240.88	508.39	292.94	980.66	582.04		424.97	166.69		322.14
72	248.11	523.22	292.94	1,046.32	582.04		424.97	166.69		324.05
73	257.36	539.41	292.94	1,116.36	582.04		424.97	166.69		337.95
74	268.91	557.06	292.94	1,191.10	582.04		424.97	166.69		319.90
75	283.14	576.28	292.94	1,270.84	582.04		424.97	166.69		350.08
76	300.50	597.19	292.94	1,355.92	582.04		424.97	166.69		317.74
77	321.57	619.91	292.94	1,446.69	582.04		424.97	166.69		362.79
78	347.08	644.61	292.94	1,543.54	582.04		424.97	166.69		288.44
79	377.98	671.45	292.94	1,646.88	582.04		424.97	166.69		295.07
80	415.43	700.60	292.94	1,757.13	582.04		424.97	166.69		275.69
81	460.97	732.28	292.94	1,874.76	582.04		424.97	166.69		336.22
82	516.56	766.70	292.94	2,000.27	582.04		424.97	166.69		323.21
83	584.78	804.13	292.94	2,134.18	582.04		424.97	166.69		231.01
84	668.99	844.83	292.94	2,277.06	582.04		424.97	166.69		306.21
85	773.63	889.12	292.94	2,429.50	582.04		424.97	166.69		364.75
86	904.64	937.34	292.94	2,592.15	582.04		424.97	166.69		222.80
87	1,069.99	989.87	292.94	2,765.68	582.04		424.97	166.69		307.97
88	1,280.54	1,047.15	292.94	2,950.84	582.04		424.97	166.69		379.05
89	1,551.12	1,109.64	292.94	3,148.39	582.04		424.97	166.69		403.66

From Table 52 and Table 53 we note that we have only being able to fit a shape to the breast cancer, malignant skin cancer and ovarian cancer for an identical 2nd incidence rate. For the other cancers and cardiovascular only a constant rate is achievable, suggesting that more data is needed if we wish to model using these particular individual conditions. Although the 'all malignant cancer' crude central incidence rate begins to increase rapidly after age 80, before age 80 the addition of the other conditions with no trend in claims incidence results in no overall clear trend. Therefore the flat incidence rate is the best that we can propose for the 20-69 age range that we are interested in.

12.13 Deaths

As discussed in section 4.10.2, we shall use the Dash-Grimshaw method for calculating the probability of death from either the healthy state or post the 1st or 2nd incident. The following Table 54 shows the steps for calculating the probability of death post 1st incident, where we shall consider our most complicated *example 4* of a cancer only (excluding breast) model as the other *examples 1* to *3* will just miss out some of the steps.

Table 54: Calculation of the probability of death post 1st or 2nd incident using population mortality tables and proportion of deaths due to a particular condition.

Probability	Notation	Mortality Rate (per 10,000) or Proportion	Age 40	50	60	70	80
	q_x	TF00 mortality rate	8.2	19.6	60.6	193.3	576.1
	k^{All}	CIBT02 proportion of CI deaths	55%	58%	59%	61%	63%
p_x^{HD}	q_x (1-k^{All})	Non-CI mortality rate	3.7	8.3	25.0	75.9	214.8
	k^{cancer}	CIBT02 proportion of cancer deaths	41%	52%	52%	40%	24%
	b^{cancer}	ONS proportion of breast cancer deaths relative to cancer deaths	37%	30%	22%	14%	13%
p_x^{CD}	$M = q_x k^{cancer}$ X (1-b^{cancer})	Cancer (ex breast) mortality rate	2.1	7.1	24.8	66.3	117.6
	s	ONS Cancer proportion of 1year survivors	70%	65%	61%	56%	51%
p_x^{AD}	M (1 –s)	Post 1st to 2nd Incident mortality rate	0.6	2.5	9.8	29.3	57.4
p_x^{BD}	M s	Post 2nd Incident mortality rate	1.5	4.6	15.0	37.0	60.2
$p^{A^{Other}D}$	k^{All} q_x - M	Other CI mortality rate	2.4	4.3	10.9	51.1	243.7

The steps shown in the above Table 54 are starting from the standard CMI TF00 insured mortality table of initial ultimate mortality rates q_x for age x. We then combined with the

proportion of deaths k^{All} due to CI from the CIBT02 population table to determine the probability of death from a healthy state p_x^{HD} using the formula q_x (1 - k^{All}), while assuming that there are the same proportion of deaths in the insured population as the general population.

Similarly, if we need the cancer (excluding breast cancer) mortality rate then using the ONS population proportions for cancer deaths, and those cancer deaths which are due to breast cancer, we can determine the probability of death after cancer incidence (excluding breast cancer) p_x^{CD} (where state *C* is equal to state *A* and state *B* combined, i.e. the standard single tiered model).

From the ONS cancer survival statistics we can determine the proportion of 1 year survivors allowing us to split the post cancer mortality rate into post 1st to 2nd, and post 2nd mortality rates to determine p_x^{AD} and p_x^{BD}.

For our restricted models, if we calculate p_x^{AD} for only some of the conditions as qualifying for a benefit payment, then we can determine the probability of death from the remaining conditions $p_x^{A^{Other}D}$ by noting that the total probability of death from $p_x^{A^{All\ Conditions}D}$ remains unchanged. This is in order that the sum of the death probabilities from all the states still equals one. Note: $p_x^{A^{Other}D}$ will equal 0 when we include all the conditions, i.e. $p_x^{CD} = q_x\, k^{\text{All}}$.

As we have an estimate for p_x^{jD} we can now calculate μ_x^{jD} on re-arranging the formula in Appendix 12.14, for *j* = *H*, *A* or *B*. By using the fitted estimates for the transition probabilities $\mu_x^{jk} = m_x^{jk} / E_x^{j}$, from state *j* = *H*, *A* or *B* to state *k* = *A*, *B* or *W*, from the above Table 54, we can now calculate the remaining non-mortality probabilities using all the formula in Appendix 12.14.

12.14 Calculation of Transition Probabilities

12.14.1 Kolmogorov Forward Differential Equations

To determine the transition probabilities from the transition intensities we applied the Kolmogorov forward differential equations (Haberman and Pitacco, pp.17, 1999)

$$\frac{d}{dt}\,{}_t p_y^{ij} = \sum_{k=H,A,B;\,k\neq j} {}_t p_y^{ik}\,\mu_{y+t}^{kj} \quad - \quad {}_t p_y^{ij} \sum_{k=H,A,B;\,k\neq j} {}_t p_y^{jk}\,\mu_{y+t}^{jk}\,.$$

Where on substituting for our *i* equal to states *H, A* and *B*, and *j* equal to states *H, A, B, D* and *W* (where *j* is the same or a later state than *i*) we have the following list of expressions.

$$\frac{d}{dt}\,{}_t p_y^{HH} = -{}_t p_y^{HH}(\mu_{y+t}^{HD} + \mu_{y+t}^{HW} + \mu_{y+t}^{HA}) \;\Rightarrow\; {}_t p_y^{HH} = \exp\left[-\int_{u=0}^{t}\left(\mu_{y+u}^{HD} + \mu_{y+u}^{HW} + \mu_{y+u}^{HA}\right)du\right],$$

$$\frac{d}{dt}\,{}_t p_y^{HD} = {}_t p_y^{HH}\,\mu_{y+t}^{HD} \qquad \Rightarrow \qquad {}_t p_y^{HD} = \int_{u=0}^{t} {}_u p_y^{HH}\,\mu_{y+u}^{HD}\,du\,,$$

$$\frac{d}{dt}\,{}_t p_y^{HW} = {}_t p_y^{HH}\,\mu_{y+t}^{HW} \qquad \Rightarrow \qquad {}_t p_y^{HW} = \int_{u=0}^{t} {}_u p_y^{HH}\,\mu_{y+u}^{HW}\,du\,,$$

$$\frac{d}{dt}\,{}_t p_y^{AA} = -{}_t p_y^{AA}\left(\mu_{y+t}^{AD} + \mu_{y+t}^{AW} + \mu_{y+t}^{AB}\right) \;\Rightarrow\; {}_t p_y^{AA} = \exp\left[-\int_{u=0}^{t}\left(\mu_{y+u}^{AD} + \mu_{y+u}^{AW} + \mu_{y+u}^{AB}\right)du\right],$$

$$\frac{d}{dt}\,{}_t p_y^{AD} = {}_t p_y^{AA}\,\mu_{y+t}^{AD} \qquad \Rightarrow \qquad {}_t p_y^{AD} = \int_{u=0}^{t} {}_u p_y^{AA}\,\mu_{y+u}^{AD}\,du\,,$$

$$\frac{d}{dt}\,{}_t p_y^{AW} = {}_t p_y^{AA}\,\mu_{y+t}^{AW} \qquad \Rightarrow \qquad {}_t p_y^{AW} = \int_{u=0}^{t} {}_u p_y^{AA}\,\mu_{y+u}^{AW}\,du\,,$$

$$\frac{d}{dt}\,{}_t p_y^{BB} = -{}_t p_y^{BB}\left(\mu_{y+t}^{BD} + \mu_{y+t}^{BW}\right) \qquad \Rightarrow \qquad {}_t p_y^{BB} = \exp\left[-\int_{u=0}^{t}\left(\mu_{y+u}^{BD} + \mu_{y+u}^{BW}\right)du\right],$$

$$\frac{d}{dt}\,{}_t p_y^{BD} = {}_t p_y^{BB}\,\mu_{y+t}^{BD} \qquad \Rightarrow \qquad {}_t p_y^{BD} = \int_{u=0}^{t} {}_u p_y^{BB}\,\mu_{y+u}^{BD}\,du\,,$$

$$\frac{d}{dt}{}_t p_y^{BW} = {}_t p_y^{BB}\mu_{y+t}^{BW} \qquad \Rightarrow \qquad {}_t p_y^{BW} = \int_{u=0}^{t} {}_u p_y^{BB}\mu_{y+u}^{BW}\, du\,.$$

The following transitions required the integrated form of Kolmogorov's equation:

$$\frac{d}{dt}{}_t p_y^{HA} = {}_t p_y^{HH}\mu_{y+t}^{HA} - {}_t p_y^{HA}\left(\mu_{y+t}^{AD} + \mu_{y+t}^{AW} + \mu_{y+t}^{AB}\right) \Rightarrow \quad {}_t p_y^{HA} = \int_{u=0}^{t} {}_u p_y^{HH}\mu_{y+u\,t-u}^{HA}\, p_{y+u}^{AA}\, du\,,$$

$$\frac{d}{dt}{}_t p_y^{HB} = {}_t p_y^{HA}\mu_{y+t}^{AB} - {}_t p_y^{HB}\left(\mu_{y+t}^{BD} + \mu_{y+t}^{BW}\right) \qquad \Rightarrow \qquad {}_t p_y^{HB} = \int_{u=0}^{t} {}_u p_y^{HA}\mu_{y+u\,t-u}^{AB}\, p_{y+u}^{BB}\, du\,,$$

$$\frac{d}{dt}{}_t p_y^{AB} = {}_t p_y^{AA}\mu_{y+t}^{AB} - {}_t p_y^{AB}\left(\mu_{y+t}^{BD} + \mu_{y+t}^{BW}\right) \qquad \Rightarrow \qquad {}_t p_y^{AB} = \int_{u=0}^{t} {}_u p_y^{AA}\mu_{y+u\,t-u}^{AB}\, p_{y+u}^{BB}\, du\,.$$

On substituting the above ${}_t p_y^{HA}$, ${}_t p_y^{HB}$, ${}_t p_y^{AB}$, we obtain the following differential two step-transitions to state *D* within 1 time period:

$$\frac{d}{dt}{}_t p_y^{HAD} = {}_t p_y^{HA}\left(\mu_{y+t}^{AD} + \mu_{y+t}^{AW}\right) \qquad \Rightarrow \qquad {}_t p_y^{HAD} = \int_{u=0}^{t} {}_u p_y^{HA}\left(\mu_{y+u}^{AD} + \mu_{y+u}^{AW}\right) du\,,$$

$$\frac{d}{dt}{}_t p_y^{HBD} = {}_t p_y^{HB}\left(\mu_{y+t}^{BD} + \mu_{y+t}^{BW}\right) \qquad \Rightarrow \qquad {}_t p_y^{HBD} = \int_{u=0}^{t} {}_u p_y^{HB}\left(\mu_{y+u}^{BD} + \mu_{y+u}^{BW}\right) du\,,$$

$$\frac{d}{dt}{}_t p_y^{ABD} = {}_t p_y^{AB}\left(\mu_{y+t}^{BD} + \mu_{y+t}^{BW}\right) \qquad \Rightarrow \qquad {}_t p_y^{ABD} = \int_{u=0}^{t} {}_u p_y^{AB}\left(\mu_{y+u}^{BD} + \mu_{y+u}^{BW}\right) du\,.$$

Similarly, it is not necessary to explicitly list the corresponding two step-transitions to state *W* as identical to above, with states *D* and *W* interchanged in the notation.

12.14.2 Transition Probabilities from State *B*

To solve these integrals, we shall assume a constant transition rate over each integer age :

$\mu_{y+u}^{jk} = \mu_y^{jk}$ for $0 \le u \le 1$, and $j = H, A, B$ and $k = A, B, D, W$, $k \ge j$.

For $0 \le u < v \le 1$, we have the following simplifications for state *B*:

$$ {}_v p_y^{BB} = \exp\left[-\int_{u=0}^{v} \left(\mu_y^{BD} + \mu_y^{BW} \right) du \right] = e^{-v\left(\mu_y^{BD} + \mu_y^{BW}\right)}, $$

$$ {}_v p_y^{BD} = \int_{u=0}^{v} {}_u p_y^{BB} \mu_y^{BD} \, du = \mu_y^{BD} \int_{u=0}^{v} e^{-u\left(\mu_y^{BD} + \mu_y^{BW}\right)} du = \frac{\mu_y^{BD}}{\mu_y^{BD} + \mu_y^{BW}} \left[1 - e^{-v\left(\mu_y^{BD} + \mu_y^{BW}\right)} \right]. $$

12.14.3 Transition Probabilities from State *A*

Similarly, for current state *A*:

$$ {}_v p_y^{AA} = \exp\left[-\int_{u=0}^{v} \left(\mu_y^{AD} + \mu_y^{AW} + \mu_y^{AB} \right) du \right] = e^{-v\left(\mu_y^{AD} + \mu_y^{AW} + \mu_y^{AB}\right)}, $$

$$ {}_v p_y^{AD} = \int_{u=0}^{v} {}_u p_y^{AA} \mu_y^{AD} \, du = \mu_y^{AD} \int_{u=0}^{v} e^{-u\left(\mu_y^{AD} + \mu_y^{AW} + \mu_y^{AB}\right)} du $$

$$ = \frac{\mu_y^{AD}}{\mu_y^{AD} + \mu_y^{AW} + \mu_y^{AB}} \left[1 - e^{-v\left(\mu_y^{AD} + \mu_y^{AW} + \mu_y^{AB}\right)} \right]. $$

When $v = 1$, we can use the numerical values for, p_y^{AD}, p_y^{BD} from the previous Appendix 12.13 to re-arrange the equations above in order to determine the required μ_y^{AD}, μ_y^{BD} in the expressions above and below.

Substituting for ${}_v p_y^{AA}$ and ${}_v p_y^{BB}$, we obtain the following expression

$$
\begin{aligned}
{}_v p_y^{AB} &= \int_{u=0}^{v} {}_u p_y^{AA} \mu_y^{AB} \frac{{}_v p_y^{BB}}{{}_u p_y^{BB}}\, du \\
&= \mu_y^{AB} e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)} \int_{u=0}^{v} e^{-u\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}\right)}\, du \\
&= \frac{\mu_y^{AB}\, e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)}\left[1-e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}\right)}\right]}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}} \\
&= \frac{\mu_y^{AB}\left[e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)}-e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)}\right]}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}}.
\end{aligned}
$$

This probability ${}_v p_y^{AB}$ can be substituted to solve the following expression

$$
\begin{aligned}
{}_v p_y^{ABD} &= \int_{u=0}^{v} {}_u p_y^{AB} \mu_y^{BD}\, du \\
&= \frac{\mu_y^{AB}\mu_y^{BD}}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}} \int_{u=0}^{v} e^{-u\left(\mu_y^{BD}+\mu_y^{BW}\right)}-e^{-u\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)} du \\
&= \frac{\mu_y^{AB}\mu_y^{BD}}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}} \left[\frac{1-e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)}}{\mu_y^{BD}+\mu_y^{BW}}-\frac{1-e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)}}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}}\right].
\end{aligned}
$$

12.14.4 Transition Probabilities from State *H*

Finally, for state *H*:

$$
{}_v p_y^{HH} = \exp\left[-\int_{u=0}^{v}\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right) du\right] = e^{-v\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)},
$$

$$
\begin{aligned}
{}_v p_y^{HD} &= \int_{u=0}^{v} {}_u p_y^{HH} \mu_y^{HD}\, du = \mu_y^{HD} \int_{u=0}^{v} e^{-u\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)}\, du \\
&= \frac{\mu_y^{HD}}{\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}}\left[1-e^{-v\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)}\right].
\end{aligned}
$$

When $v = 1$, we can use the numerical values for p_y^{HD} from the previous Appendix 12.13 to re-arrange the equation above in order to determine the required μ_y^{HD} in the expressions above and below.

Substituting for ${}_v p_y^{HH}$ and ${}_v p_y^{AA}$, we obtain the following expressions

$$
\begin{aligned}
{}_v p_y^{HA} &= \int_{u=0}^{v} {}_u p_y^{HH} \mu_y^{HA} \frac{{}_v p_y^{AA}}{{}_u p_y^{AA}} \, du \\
&= \mu_y^{HA} e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)} \int_{u=0}^{v} e^{-u\left(\mu_y^{HD}+\mu_y^{HA}-\mu_y^{AD}-\mu_y^{AW}-\mu_y^{AB}\right)} \, du \\
&= \frac{\mu_y^{HA} e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)} \left[1 - e^{-v\left(\mu_y^{HD}+\mu_y^{HA}-\mu_y^{AD}-\mu_y^{AW}-\mu_y^{AB}\right)}\right]}{\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}-\mu_y^{AD}-\mu_y^{AW}-\mu_y^{AB}} \\
&= c \left[e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)} - e^{-v\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)}\right], \\
&\text{where } c = \frac{\mu_y^{HA}}{\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}-\mu_y^{AD}-\mu_y^{AW}-\mu_y^{AB}}.
\end{aligned}
$$

This probability ${}_v p_y^{HA}$ can be substituted to solve the following expression

$$
\begin{aligned}
{}_v p_y^{HAD} &= \int_{u=0}^{v} {}_u p_y^{HA} \mu_y^{AD} \, du \\
&= c\mu_y^{AD} \int_{u=0}^{v} e^{-u\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)} - e^{-u\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)} du \\
&= c\mu_y^{AD} \left[\frac{1 - e^{\left[-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)\right]}}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}} - \frac{1 - e^{\left[-v\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)\right]}}{\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}}\right].
\end{aligned}
$$

Similarly substituting for ${}_v p_y^{HH}$ and ${}_v p_y^{AA}$, we obtain the following expression

$$
\begin{aligned}
{}_v p_y^{HB} &= \int_{u=0}^{v} {}_u p_y^{HA} \mu_y^{AB} \frac{{}_v p_y^{BB}}{{}_u p_y^{BB}}\, du \\
&= c\mu_y^{AB} e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)} \int_{u=0}^{v} \left[e^{-u\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)} - e^{-u\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)} \right] e^{-u\left(\mu_y^{BD}+\mu_y^{BW}\right)}\, du \\
&= c\mu_y^{AB} e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)} \left[\frac{1-e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}\right)}}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}} - \frac{1-e^{-v\left(\mu_y^{HD}+\mu_y^{HA}+\mu_y^{HW}-\mu_y^{BD}-\mu_y^{BW}\right)}}{\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}-\mu_y^{BD}-\mu_y^{BW}} \right] \\
&= c\mu_y^{AB} \left[\frac{e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)} - e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)}}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}} - \frac{e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)} - e^{-v\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)}}{\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}-\mu_y^{BD}-\mu_y^{BW}} \right].
\end{aligned}
$$

This probability ${}_v p_y^{HB}$ can be substituted to solve the following expression

$$
\begin{aligned}
{}_v p_y^{HBD} &= \int_{u=0}^{v} {}_u p_y^{HB} \mu_y^{BD}\, du \\
&= c\mu_y^{AB} \mu_y^{BD} \int_{u=0}^{v} \frac{e^{-u\left(\mu_y^{BD}+\mu_y^{BW}\right)} - e^{-u\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)}}{\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}} - \frac{e^{-u\left(\mu_y^{BD}+\mu_y^{BW}\right)} - e^{-u\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)}}{\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}-\mu_y^{BD}-\mu_y^{BW}}\, du \\
&= c\mu_y^{AB} \mu_y^{BD} \left[\frac{1-e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)}}{\left(\mu_y^{BD}+\mu_y^{BW}\right)\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}\right)} \right. \\
&- \frac{1-e^{-v\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)}}{\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}\right)\left(\mu_y^{AD}+\mu_y^{AW}+\mu_y^{AB}-\mu_y^{BD}-\mu_y^{BW}\right)} \\
&- \frac{1-e^{-v\left(\mu_y^{BD}+\mu_y^{BW}\right)}}{\left(\mu_y^{BD}+\mu_y^{BW}\right)\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}-\mu_y^{BD}-\mu_y^{BW}\right)} \\
&\left. - \frac{1-e^{-v\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)}}{\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}\right)\left(\mu_y^{HD}+\mu_y^{HW}+\mu_y^{HA}-\mu_y^{BD}-\mu_y^{BW}\right)} \right].
\end{aligned}
$$

Similarly, not necessary to explicitly list probabilities to state *W* as identical to state *D*, with states *D* and *W* interchanged, e.g. $_{v}p_{y}^{BW} = \frac{\mu_{y}^{BW}}{\mu_{y}^{BD}+\mu_{y}^{BW}}\left[1-e^{-v\left(\mu_{y}^{BD}+\mu_{y}^{BW}\right)}\right]$.

On substituting our fitted transition intensities from Appendix 12.12.5 to Appendix 12.12.7 into the above probability formulas, we obtain the following probability estimates for our "all CI" conditions in Table 55 and Table 56.

12.14.5 "All CI" Female Table of Transition Probabilities

Table 55: Annual probability estimates (x10,000) for the "all CI" conditions fitted transition intensities from age 20 to 49.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAD}	p_y^{HBD}	p_y^{HB}	p_y^{HAW}	p_y^{HBW}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABD}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}
20	8,845.52	3.83	1,148.66	1.91	0.00	0.06	0.02	0.00	0.00	9,238.16	0.15	537.18	219.32	0.01	5.18	9,547.49	0.66	451.85
21	8,845.22	3.85	1,148.64	2.20	0.00	0.06	0.03	0.00	0.00	9,255.67	0.16	519.45	219.53	0.01	5.18	9,547.33	0.66	452.01
22	8,844.91	3.86	1,148.62	2.52	0.00	0.07	0.03	0.00	0.00	9,271.96	0.17	502.95	219.72	0.01	5.19	9,547.15	0.68	452.17
23	8,844.58	3.83	1,148.60	2.88	0.00	0.08	0.03	0.00	0.00	9,323.94	0.19	488.54	183.00	0.01	4.32	9,546.94	0.73	452.33
24	8,844.25	3.77	1,148.58	3.30	0.00	0.08	0.02	0.00	0.00	9,381.90	0.22	475.33	139.26	0.01	3.28	9,546.70	0.81	452.49
25	8,843.74	3.84	1,148.55	3.73	0.00	0.09	0.04	0.00	0.00	9,314.34	0.22	460.02	220.21	0.01	5.20	9,546.56	0.79	452.65
26	8,843.39	3.70	1,148.53	4.23	0.00	0.10	0.05	0.00	0.00	9,328.36	0.28	447.72	218.47	0.01	5.16	9,546.25	0.94	452.81
27	8,842.85	3.70	1,148.49	4.80	0.00	0.11	0.05	0.00	0.00	9,377.14	0.30	437.13	181.14	0.01	4.28	9,546.03	1.00	452.97
28	8,842.30	3.66	1,148.46	5.40	0.00	0.12	0.06	0.00	0.00	9,374.10	0.34	426.20	194.75	0.01	4.60	9,545.79	1.08	453.13
29	8,841.70	3.60	1,148.42	6.08	0.00	0.13	0.06	0.00	0.00	9,395.93	0.39	416.63	182.72	0.01	4.32	9,545.52	1.20	453.28
30	8,841.05	3.54	1,148.38	6.82	0.00	0.15	0.07	0.00	0.00	9,401.23	0.44	407.47	186.44	0.01	4.41	9,545.23	1.33	453.44
31	8,840.22	3.59	1,148.33	7.60	0.00	0.16	0.09	0.00	0.00	9,375.00	0.47	398.38	220.91	0.02	5.22	9,545.02	1.38	453.60
32	8,839.45	3.52	1,148.28	8.48	0.00	0.18	0.10	0.00	0.00	9,390.15	0.55	390.85	213.39	0.02	5.05	9,544.70	1.54	453.76
33	8,838.59	3.46	1,148.22	9.43	0.00	0.19	0.09	0.00	0.00	9,426.72	0.62	384.42	183.88	0.02	4.35	9,544.38	1.70	453.91
34	8,837.65	3.43	1,148.16	10.43	0.00	0.21	0.12	0.00	0.00	9,400.84	0.71	377.35	215.97	0.02	5.11	9,544.05	1.88	454.07
35	8,836.52	3.51	1,148.09	11.52	0.00	0.23	0.13	0.00	0.00	9,407.32	0.77	371.53	215.26	0.02	5.10	9,543.79	1.98	454.23
36	8,835.40	3.50	1,148.02	12.69	0.00	0.25	0.14	0.00	0.00	9,426.98	0.87	366.54	200.83	0.02	4.75	9,543.44	2.17	454.39
37	8,834.20	3.51	1,147.94	13.92	0.00	0.27	0.16	0.00	0.00	9,413.34	0.98	361.47	218.99	0.03	5.19	9,543.07	2.38	454.54
38	8,832.84	3.60	1,147.86	15.23	0.00	0.29	0.18	0.00	0.00	9,416.01	1.09	357.25	220.40	0.03	5.22	9,542.73	2.57	454.70
39	8,831.58	3.52	1,147.78	16.62	0.00	0.31	0.19	0.00	0.00	9,426.98	1.22	353.70	213.02	0.03	5.05	9,542.35	2.80	454.86
40	8,830.04	3.65	1,147.68	18.10	0.00	0.34	0.19	0.00	0.00	9,450.88	1.41	350.90	192.23	0.03	4.55	9,541.85	3.14	455.01
41	8,828.53	3.69	1,147.58	19.61	0.00	0.36	0.22	0.00	0.00	9,436.98	1.61	347.88	208.55	0.04	4.94	9,541.36	3.48	455.16
42	8,826.80	3.89	1,147.47	21.20	0.00	0.39	0.24	0.00	0.00	9,436.36	1.79	345.59	211.21	0.04	5.01	9,540.92	3.76	455.32
43	8,825.09	4.01	1,147.36	22.87	0.00	0.42	0.24	0.00	0.00	9,454.20	2.03	344.11	194.99	0.04	4.63	9,540.36	4.17	455.47
44	8,823.33	4.13	1,147.25	24.57	0.00	0.45	0.27	0.00	0.00	9,447.10	2.32	342.64	203.07	0.05	4.82	9,539.75	4.63	455.62
45	8,821.49	4.28	1,147.13	26.34	0.00	0.48	0.27	0.00	0.00	9,457.11	2.65	341.93	193.66	0.05	4.60	9,539.08	5.15	455.77
46	8,819.59	4.45	1,147.01	28.12	0.00	0.51	0.31	0.00	0.00	9,444.44	3.03	341.28	206.28	0.06	4.90	9,538.34	5.74	455.92
47	8,817.63	4.65	1,146.89	29.95	0.01	0.54	0.33	0.00	0.01	9,442.87	3.47	341.28	207.39	0.07	4.93	9,537.54	6.40	456.06
48	8,815.60	4.88	1,146.76	31.82	0.01	0.58	0.35	0.00	0.01	9,443.51	3.98	341.77	205.77	0.08	4.89	9,536.65	7.15	456.21
49	8,813.66	5.01	1,146.64	33.70	0.01	0.61	0.37	0.00	0.01	9,442.70	4.62	342.69	205.04	0.09	4.88	9,535.58	8.08	456.35

Table 56: Annual probability estimates (x10,000) for the "all CI" conditions fitted transition intensities from age 50 to 79.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAD}	p_y^{HBD}	p_y^{HB}	p_y^{HAW}	p_y^{HBW}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABD}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}
50	8,811.61	5.25	1,146.51	35.59	0.01	0.65	0.38	0.00	0.01	9,443.62	5.32	344.10	202.06	0.10	4.81	9,534.45	9.07	456.49
51	8,809.44	5.61	1,146.37	37.47	0.01	0.69	0.41	0.00	0.01	9,439.69	6.09	345.89	203.37	0.11	4.84	9,533.25	10.13	456.62
52	8,807.40	5.84	1,146.24	39.34	0.01	0.73	0.44	0.00	0.01	9,432.94	7.05	348.10	206.86	0.12	4.93	9,531.82	11.42	456.75
53	8,805.13	6.34	1,146.09	41.20	0.02	0.77	0.45	0.00	0.01	9,433.18	8.07	350.92	202.87	0.13	4.83	9,530.37	12.74	456.89
54	8,802.88	6.85	1,145.95	43.01	0.02	0.81	0.47	0.00	0.01	9,427.79	9.25	354.13	203.82	0.15	4.86	9,528.73	14.25	457.01
55	8,800.58	7.46	1,145.80	44.82	0.03	0.85	0.45	0.00	0.01	9,438.06	10.61	358.13	188.55	0.16	4.49	9,526.93	15.93	457.14
56	8,798.24	8.17	1,145.65	46.51	0.03	0.90	0.49	0.00	0.01	9,422.53	12.15	362.18	198.23	0.18	4.73	9,524.94	17.80	457.25
57	8,795.79	9.06	1,145.50	48.19	0.04	0.94	0.49	0.00	0.01	9,426.16	13.88	367.12	188.16	0.19	4.49	9,522.80	19.83	457.37
58	8,793.21	10.17	1,145.33	49.76	0.04	0.99	0.50	0.00	0.01	9,419.55	15.81	372.43	187.53	0.22	4.48	9,520.48	22.04	457.48
59	8,790.49	11.51	1,145.16	51.21	0.05	1.03	0.54	0.00	0.01	9,401.17	17.98	378.08	197.79	0.25	4.73	9,517.96	24.46	457.59
60	8,787.54	13.21	1,144.97	52.64	0.06	1.08	0.49	0.00	0.01	9,415.02	20.38	384.98	175.19	0.25	4.19	9,515.26	27.05	457.69
61	8,784.25	15.38	1,144.76	53.92	0.07	1.12	0.49	0.00	0.01	9,411.95	23.00	392.18	168.59	0.26	4.03	9,512.43	29.79	457.79
62	8,780.61	18.05	1,144.53	55.03	0.08	1.17	0.52	0.00	0.01	9,394.18	25.87	399.73	175.72	0.30	4.20	9,509.42	32.70	457.88
63	8,776.71	21.14	1,144.28	56.02	0.09	1.22	0.54	0.00	0.01	9,380.65	29.09	408.06	177.61	0.33	4.25	9,506.14	35.89	457.97
64	8,772.34	24.88	1,144.00	56.89	0.10	1.27	0.52	0.00	0.01	9,376.67	32.62	417.33	168.98	0.35	4.05	9,502.66	39.29	458.05
65	8,767.69	29.08	1,143.71	57.56	0.11	1.31	0.53	0.00	0.01	9,360.77	36.62	427.11	171.02	0.39	4.10	9,498.83	43.05	458.13
66	8,738.99	59.12	1,141.87	58.00	0.09	1.36	0.55	0.00	0.01	9,352.30	29.34	437.87	175.96	0.31	4.22	9,507.82	33.67	458.51
67	8,731.09	67.16	1,141.37	58.25	0.10	1.40	0.62	0.00	0.01	9,317.29	33.00	448.87	195.76	0.38	4.70	9,504.44	36.96	458.59
68	8,722.43	76.19	1,140.82	58.47	0.12	1.45	0.52	0.00	0.01	9,331.62	37.09	461.96	165.01	0.35	3.96	9,500.76	40.57	458.67
69	8,712.76	86.50	1,140.20	58.37	0.13	1.49	0.53	0.00	0.01	9,310.59	41.60	475.18	168.20	0.39	4.04	9,496.84	44.41	458.74
70	8,701.71	98.51	1,139.49	58.12	0.14	1.53	0.49	0.00	0.01	9,305.42	46.43	489.83	154.22	0.39	3.71	9,492.80	48.39	458.81
71	8,688.86	112.66	1,138.67	57.61	0.16	1.57	0.47	0.00	0.01	9,288.08	51.46	505.28	151.13	0.41	3.64	9,488.75	52.37	458.88
72	8,673.94	129.24	1,137.71	56.85	0.17	1.60	0.48	0.00	0.01	9,261.19	56.69	521.65	156.25	0.46	3.76	9,484.73	56.31	458.95
73	8,657.01	148.18	1,136.63	55.85	0.19	1.63	0.50	0.00	0.01	9,231.20	62.27	539.17	162.92	0.52	3.93	9,480.59	60.39	459.02
74	8,637.83	169.76	1,135.40	54.69	0.20	1.65	0.45	0.00	0.01	9,217.71	68.20	558.51	151.41	0.51	3.65	9,476.33	64.58	459.08
75	8,617.00	193.32	1,134.06	53.22	0.22	1.67	0.50	0.00	0.01	9,170.92	75.01	578.28	171.03	0.62	4.13	9,471.52	69.34	459.13
76	8,594.48	218.89	1,132.62	51.66	0.23	1.69	0.42	0.00	0.01	9,162.85	82.86	600.79	149.31	0.59	3.61	9,466.06	74.77	459.17
77	8,569.96	246.80	1,131.04	49.76	0.25	1.69	0.48	0.00	0.01	9,104.73	91.77	623.33	175.19	0.75	4.24	9,459.96	80.85	459.19
78	8,543.01	277.49	1,129.31	47.87	0.27	1.70	0.35	0.00	0.01	9,113.09	101.74	649.89	131.49	0.61	3.18	9,453.31	87.49	459.20
79	8,512.38	312.28	1,127.34	45.68	0.28	1.69	0.35	0.00	0.01	9,068.58	112.28	676.55	138.55	0.69	3.36	9,446.54	94.26	459.20

Note: As a check the sum of all the probabilities for all transitions from state *H* sum to one if we include $p_y^{H\,AD}$, $p_y^{H\,AW}$ (not shown in the table). Similarly, the probabilities sum to one for all transitions from state *A* if we include $p_y^{A\,BD}$, $p_y^{A\,BW}$. The above probabilities to state *B* are for strictly the same condition as for state *A*, e.g. lung cancer, stroke, Parkinson's, blindness etc.

Similarly, if we consider splitting our developed paid claims into cancer only and other conditions when fitting our transition intensities, we obtain the following probability estimates for our "cancer" only condition below in Table 57 and Table 58.

12.14.6 "Cancer only" Female Table of Transition Probabilities

Table 57: Annual probability estimates (x10,000) for the "cancer only" condition fitted transition intensities from age 20 to 49.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAW}	p_y^{HB}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}	$p_y^{HA^{Other}}$	$p_y^{AD^{Other}}$	$p_y^{A^{Other}A^{Other}}$	$p_y^{AB^{An}}$
20	8,845.63	3.83	1,148.67	1.80	0.05	0.02	9,238.17	0.15	537.18	219.26	5.25	9,541.78	0.56	457.66	0.11	0.11	9,507.43	393.26
21	8,845.34	3.85	1,148.65	2.08	0.06	0.02	9,255.67	0.15	519.45	219.47	5.25	9,541.77	0.57	457.66	0.12	0.10	9,521.06	393.53
22	8,845.03	3.86	1,148.63	2.39	0.06	0.03	9,271.97	0.16	502.95	219.66	5.25	9,541.75	0.59	457.66	0.13	0.11	9,533.76	393.76
23	8,844.71	3.83	1,148.61	2.74	0.07	0.03	9,287.14	0.18	487.59	219.84	5.25	9,541.73	0.61	457.66	0.14	0.13	9,545.60	393.97
24	8,844.39	3.77	1,148.59	3.14	0.08	0.04	9,301.24	0.19	473.30	220.00	5.26	9,541.70	0.65	457.66	0.15	0.20	9,556.59	394.14
25	8,843.89	3.84	1,148.56	3.58	0.09	0.04	9,314.35	0.21	460.02	220.16	5.26	9,541.65	0.69	457.66	0.16	0.11	9,566.96	394.30
26	8,843.55	3.70	1,148.54	4.06	0.10	0.05	9,326.52	0.23	447.68	220.30	5.26	9,541.60	0.74	457.66	0.17	0.24	9,576.39	394.43
27	8,843.03	3.70	1,148.51	4.60	0.11	0.05	9,337.81	0.26	436.23	220.43	5.26	9,541.53	0.81	457.65	0.19	0.23	9,585.29	394.53
28	8,842.50	3.66	1,148.47	5.19	0.12	0.06	9,348.27	0.29	425.62	220.55	5.27	9,541.46	0.89	457.65	0.21	0.25	9,593.50	394.61
29	8,841.92	3.60	1,148.43	5.84	0.13	0.07	9,357.93	0.32	415.80	220.67	5.27	9,541.38	0.96	457.65	0.23	0.30	9,601.05	394.67
30	8,841.29	3.54	1,148.39	6.56	0.14	0.08	9,366.86	0.36	406.73	220.77	5.27	9,541.30	1.05	457.65	0.25	0.36	9,608.00	394.71
31	8,840.49	3.59	1,148.34	7.33	0.16	0.09	9,375.07	0.40	398.38	220.86	5.27	9,541.21	1.15	457.65	0.28	0.31	9,614.49	394.73
32	8,839.75	3.52	1,148.30	8.17	0.17	0.10	9,382.62	0.45	390.70	220.95	5.27	9,541.11	1.25	457.64	0.31	0.40	9,620.31	394.73
33	8,838.93	3.46	1,148.24	9.07	0.19	0.11	9,389.52	0.50	383.66	221.03	5.27	9,541.01	1.35	457.64	0.35	0.48	9,625.60	394.72
34	8,838.02	3.43	1,148.19	10.05	0.20	0.12	9,395.81	0.55	377.25	221.10	5.27	9,540.90	1.46	457.64	0.39	0.57	9,630.38	394.68
35	8,836.94	3.51	1,148.12	11.09	0.22	0.13	9,401.51	0.61	371.42	221.17	5.28	9,540.78	1.58	457.64	0.44	0.56	9,634.78	394.62
36	8,835.87	3.50	1,148.05	12.20	0.24	0.14	9,406.65	0.67	366.15	221.23	5.28	9,540.66	1.70	457.63	0.49	0.67	9,638.59	394.55
37	8,834.72	3.51	1,147.98	13.37	0.26	0.16	9,411.24	0.74	361.43	221.28	5.28	9,540.53	1.84	457.63	0.55	0.78	9,641.94	394.45
38	8,833.43	3.60	1,147.89	14.62	0.28	0.17	9,415.31	0.82	357.24	221.33	5.28	9,540.39	1.99	457.63	0.62	0.85	9,644.90	394.34
39	8,832.25	3.52	1,147.82	15.92	0.30	0.19	9,418.88	0.89	353.55	221.37	5.28	9,540.27	2.11	457.62	0.70	1.02	9,647.31	394.22
40	8,830.80	3.65	1,147.73	17.29	0.32	0.20	9,421.92	1.01	350.36	221.40	5.28	9,540.05	2.34	457.62	0.79	1.20	9,649.29	394.07
41	8,829.38	3.69	1,147.64	18.71	0.35	0.22	9,424.49	1.12	347.65	221.43	5.28	9,539.85	2.54	457.61	0.90	1.43	9,650.81	393.90
42	8,827.77	3.89	1,147.53	20.19	0.37	0.24	9,426.57	1.25	345.41	221.45	5.28	9,539.61	2.78	457.61	1.02	1.52	9,652.05	393.72
43	8,826.19	4.01	1,147.43	21.71	0.40	0.26	9,428.17	1.41	343.64	221.47	5.28	9,539.34	3.05	457.60	1.15	1.74	9,652.76	393.52
44	8,824.57	4.13	1,147.33	23.26	0.42	0.28	9,429.30	1.59	342.32	221.48	5.28	9,539.04	3.37	457.59	1.30	2.00	9,653.03	393.31
45	8,822.90	4.28	1,147.22	24.85	0.45	0.29	9,429.95	1.80	341.45	221.48	5.28	9,538.67	3.74	457.59	1.47	2.26	9,652.89	393.07
46	8,821.18	4.45	1,147.11	26.45	0.48	0.31	9,430.12	2.05	341.02	221.48	5.28	9,538.25	4.17	457.58	1.67	2.55	9,652.32	392.81
47	8,819.43	4.65	1,147.00	28.07	0.51	0.33	9,429.80	2.35	341.04	221.47	5.28	9,537.75	4.69	457.56	1.89	2.83	9,651.36	392.54
48	8,817.64	4.88	1,146.89	29.69	0.54	0.35	9,429.00	2.70	341.51	221.45	5.28	9,537.18	5.27	457.55	2.13	3.15	9,649.95	392.24
49	8,815.96	5.01	1,146.78	31.29	0.57	0.37	9,427.71	3.10	342.42	221.43	5.28	9,536.55	5.91	457.54	2.41	3.68	9,647.94	391.93

Table 58: Annual probability estimates (x10,000) for the "cancer only" condition fitted transition intensities from age 50 to 79.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAW}	p_y^{HB}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}	$p_y^{HA^{Other}}$	$p_y^{AD^{Other}}$	$p_y^{A^{Other}A^{Other}}$	$p_y^{AB^{Any}}$
50	8,814.20	5.25	1,146.67	32.88	0.60	0.39	9,425.91	3.55	343.78	221.40	5.28	9,535.84	6.64	457.52	2.71	4.19	9,645.53	391.59
51	8,812.36	5.61	1,146.55	34.43	0.63	0.41	9,423.61	4.06	345.60	221.36	5.28	9,535.06	7.44	457.50	3.05	4.72	9,642.68	391.24
52	8,810.68	5.84	1,146.45	35.93	0.66	0.43	9,420.79	4.63	347.88	221.32	5.28	9,534.19	8.33	457.48	3.43	5.51	9,639.14	390.86
53	8,808.81	6.34	1,146.33	37.37	0.70	0.44	9,417.44	5.27	350.63	221.27	5.28	9,533.26	9.28	457.46	3.84	6.26	9,635.22	390.46
54	8,806.99	6.85	1,146.21	38.74	0.73	0.46	9,413.54	5.99	353.86	221.21	5.28	9,532.23	10.34	457.43	4.29	7.17	9,630.68	390.04
55	8,805.17	7.46	1,146.10	40.02	0.76	0.47	9,409.05	6.81	357.59	221.15	5.28	9,531.08	11.52	457.41	4.79	8.21	9,625.55	389.59
56	8,803.34	8.17	1,145.98	41.21	0.79	0.49	9,403.95	7.73	361.82	221.07	5.27	9,529.81	12.82	457.37	5.32	9.41	9,619.80	389.12
57	8,801.44	9.06	1,145.86	42.28	0.83	0.50	9,398.23	8.76	366.58	220.99	5.27	9,528.41	14.25	457.34	5.89	10.70	9,613.46	388.62
58	8,799.46	10.17	1,145.73	43.24	0.86	0.51	9,391.86	9.90	371.89	220.90	5.27	9,526.91	15.79	457.31	6.51	12.16	9,606.44	388.09
59	8,797.37	11.51	1,145.60	44.07	0.89	0.52	9,384.85	11.13	377.75	220.79	5.27	9,525.33	17.40	457.27	7.16	13.90	9,598.63	387.54
60	8,795.09	13.21	1,145.45	44.77	0.92	0.53	9,377.12	12.50	384.21	220.68	5.27	9,523.62	19.16	457.23	7.85	15.78	9,590.12	386.96
61	8,792.49	15.38	1,145.29	45.31	0.95	0.54	9,368.73	13.91	391.28	220.57	5.27	9,521.90	20.92	457.19	8.57	17.95	9,580.74	386.35
62	8,789.57	18.05	1,145.10	45.71	0.97	0.54	9,359.61	15.42	399.00	220.44	5.26	9,520.12	22.74	457.14	9.31	20.41	9,570.49	385.71
63	8,786.41	21.14	1,144.90	45.95	1.00	0.55	9,349.68	17.08	407.40	220.30	5.26	9,518.20	24.70	457.10	10.06	23.21	9,559.27	385.04
64	8,782.79	24.88	1,144.67	46.04	1.03	0.55	9,338.93	18.85	416.50	220.15	5.26	9,516.21	26.74	457.05	10.83	26.32	9,547.09	384.34
65	8,778.88	29.08	1,144.42	45.96	1.05	0.55	9,327.24	20.82	426.36	219.99	5.26	9,514.02	28.98	457.00	11.59	29.86	9,533.78	383.60
66	8,750.90	59.12	1,142.63	45.66	1.07	0.54	9,314.55	23.03	437.00	219.81	5.25	9,511.61	31.44	456.94	12.36	8.54	9,544.04	382.82
67	8,743.71	67.16	1,142.18	45.26	1.09	0.54	9,300.71	25.55	448.48	219.62	5.25	9,508.89	34.23	456.88	13.08	10.18	9,531.08	382.00
68	8,735.72	76.19	1,141.67	44.71	1.11	0.53	9,285.82	28.25	460.84	219.41	5.25	9,506.06	37.13	456.81	13.76	12.27	9,516.84	381.15
69	8,726.68	86.50	1,141.09	44.00	1.12	0.52	9,269.84	31.12	474.15	219.19	5.24	9,503.13	40.13	456.74	14.39	14.76	9,501.34	380.25
70	8,716.18	98.51	1,140.42	43.16	1.14	0.51	9,252.80	34.05	488.46	218.95	5.24	9,500.24	43.09	456.67	14.94	17.68	9,484.51	379.31
71	8,703.80	112.66	1,139.63	42.17	1.15	0.50	9,234.79	36.89	503.85	218.71	5.24	9,497.58	45.81	456.61	15.41	21.13	9,466.17	378.33
72	8,689.26	129.24	1,138.70	41.06	1.15	0.49	9,215.64	39.74	520.38	218.45	5.23	9,495.02	48.43	456.55	15.79	24.82	9,446.56	377.30
73	8,672.62	148.18	1,137.63	39.83	1.16	0.47	9,195.32	42.55	538.14	218.19	5.23	9,492.62	50.89	456.49	16.05	29.22	9,425.16	376.23
74	8,653.60	169.76	1,136.41	38.50	1.16	0.46	9,173.70	45.37	557.20	217.90	5.22	9,490.31	53.26	456.43	16.19	34.16	9,402.06	375.12
75	8,632.81	193.32	1,135.08	37.08	1.16	0.44	9,150.41	48.48	577.64	217.60	5.22	9,487.77	55.86	456.37	16.21	40.01	9,376.81	373.94
76	8,610.21	218.89	1,133.63	35.57	1.16	0.42	9,125.48	51.78	599.58	217.27	5.21	9,485.15	58.54	456.31	16.09	47.31	9,348.82	372.72
77	8,585.48	246.80	1,132.04	34.01	1.16	0.41	9,098.77	55.27	623.12	216.93	5.21	9,482.42	61.33	456.25	15.84	56.02	9,318.04	371.43
78	8,558.19	277.49	1,130.29	32.38	1.15	0.39	9,069.94	59.20	648.37	216.55	5.20	9,479.35	64.48	456.17	15.46	65.55	9,284.96	370.07
79	8,527.10	312.28	1,128.28	30.72	1.14	0.37	9,039.70	62.69	675.49	216.16	5.20	9,476.87	67.02	456.11	14.94	76.84	9,248.55	368.66

Note: The above Table 57 and Table 58 do not show the very small probabilities for p_y^{HAD}, p_y^{HAW}, p_y^{HBD}, p_y^{HBW}, p_y^{ABD} and p_y^{ABW}, although used in the model to ensure that all the probabilities from a particular state sum to 1. All the 2nd conditions in state *B* are strictly equal to whatever the 1st condition in state *A* is equal to at the individual cancer condition level, e.g. breast cancer, lung cancer etc. The final column is the exception where state *B* can be any cancer condition as calculated using the fitted transition intensities in Appendix 12.14.2.

When we are looking at a selection of qualifying conditions, as we know the estimate for the restricted $p_y^{HA^{Selected}}$ and the $p_y^{HA^{All}}$ for all conditions (from the previous "all conditions" above) we can take the difference to determine the probability for the other condition $p_y^{HA^{Other}}$ (shown in the 4th column from the right in Table 57 and Table 58).

Similarly, for deaths we have calculated in Appendix 12.13 $p_y^{A^{All}D} = k^{All} q_y$ and $p_y^{AD^{Selected}} = k^{Selected} q_y$, where q_y = initial mortality rate and k^{All}, $k^{Selected}$ are the proportion of deaths due to all the CI conditions or the selected conditions. So as $p_y^{AD^{Other}} = (k^{All} - k^{Selected}) q_y$, we can calculate $p_y^{AD^{Other}} = p_y^{AD^{All}} - p_y^{AD^{Selected}}$, in order that the remaining deaths from $p_y^{HD} = (1- k^{All}) q_y$ remain unchanged regardless how we select which conditions qualify for a benefit payment.

Finally, we restricted our dataset to only the following conditions when calculating the transition probability estimates:

Breast cancer only	Table 59 and Table 60
Malignant melanoma of skin only	Table 61 and Table 62
Cardiovascular only	Table 63 and Table 64

12.14.7 "Breast Cancer only" Female Table of Transition Probabilities

Table 59: Annual probability estimates (x10,000) for the "Breast cancer only" condition fitted transition intensities from age 20 to 49.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAW}	p_y^{HB}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}	$p_y^{HA^{Other}}$	$p_y^{AD^{Other}}$	$p_y^{A^{Other}A^{Other}}$	$p_y^{AB^{Any}}$
20	8,847.21	3.83	1,148.77	0.18	0.01	0.00	9,252.17	0.00	537.58	205.34	4.91	9,542.29	0.04	457.67	1.75	0.77	9,506.78	323.49
21	8,847.13	3.85	1,148.77	0.24	0.01	0.00	9,269.71	0.00	519.84	205.53	4.91	9,542.28	0.04	457.67	1.98	0.77	9,520.40	354.25
22	8,847.05	3.86	1,148.76	0.32	0.01	0.00	9,286.04	0.00	503.33	205.71	4.92	9,542.28	0.05	457.67	2.22	0.80	9,533.09	384.39
23	8,846.98	3.83	1,148.76	0.42	0.01	0.00	9,301.24	0.00	487.96	205.88	4.92	9,542.27	0.06	457.67	2.49	0.85	9,544.89	413.43
24	8,846.92	3.77	1,148.75	0.54	0.01	0.01	9,315.38	0.00	473.66	206.03	4.92	9,542.26	0.07	457.67	2.78	0.96	9,555.84	440.91
25	8,846.71	3.84	1,148.74	0.69	0.02	0.01	9,328.53	0.01	460.36	206.18	4.92	9,542.25	0.08	457.67	3.08	0.92	9,566.17	466.40
26	8,846.67	3.70	1,148.74	0.86	0.02	0.01	9,340.74	0.01	448.01	206.31	4.93	9,542.24	0.09	457.67	3.41	1.12	9,575.54	489.53
27	8,846.47	3.70	1,148.72	1.07	0.02	0.01	9,352.07	0.01	436.56	206.44	4.93	9,542.22	0.11	457.67	3.76	1.18	9,584.35	509.99
28	8,846.27	3.66	1,148.71	1.32	0.03	0.01	9,362.57	0.01	425.94	206.55	4.93	9,542.18	0.15	457.67	4.13	1.26	9,592.50	527.53
29	8,846.04	3.60	1,148.70	1.60	0.04	0.02	9,372.28	0.02	416.11	206.66	4.93	9,542.14	0.19	457.67	4.52	1.37	9,599.99	541.97
30	8,845.79	3.54	1,148.68	1.93	0.04	0.02	9,381.24	0.02	407.04	206.76	4.93	9,542.09	0.25	457.67	4.93	1.50	9,606.88	553.22
31	8,845.38	3.59	1,148.65	2.30	0.05	0.03	9,389.50	0.03	398.68	206.85	4.94	9,542.03	0.31	457.67	5.37	1.52	9,613.31	561.23
32	8,845.05	3.52	1,148.63	2.71	0.06	0.03	9,397.09	0.04	391.00	206.93	4.94	9,541.96	0.38	457.66	5.84	1.67	9,619.06	566.04
33	8,844.66	3.46	1,148.61	3.16	0.06	0.04	9,404.05	0.05	383.96	207.00	4.94	9,541.89	0.45	457.66	6.33	1.83	9,624.28	567.75
34	8,844.22	3.43	1,148.58	3.66	0.07	0.04	9,410.39	0.06	377.54	207.07	4.94	9,541.81	0.53	457.66	6.86	2.00	9,628.99	566.50
35	8,843.63	3.51	1,148.54	4.19	0.08	0.05	9,416.14	0.08	371.70	207.13	4.94	9,541.73	0.61	457.66	7.42	2.06	9,633.31	562.48
36	8,843.10	3.50	1,148.51	4.75	0.09	0.05	9,421.34	0.09	366.44	207.19	4.94	9,541.63	0.71	457.66	8.03	2.24	9,637.05	555.92
37	8,842.52	3.51	1,148.47	5.34	0.10	0.06	9,425.99	0.11	361.71	207.24	4.94	9,541.53	0.82	457.65	8.68	2.44	9,640.32	547.08
38	8,841.83	3.60	1,148.43	5.95	0.11	0.07	9,430.12	0.12	357.52	207.28	4.94	9,541.45	0.90	457.65	9.39	2.64	9,643.14	536.24
39	8,841.31	3.52	1,148.40	6.58	0.12	0.07	9,433.76	0.14	353.83	207.32	4.94	9,541.39	0.96	457.65	10.16	2.92	9,645.44	523.66
40	8,840.57	3.65	1,148.35	7.21	0.13	0.08	9,436.89	0.16	350.64	207.36	4.94	9,541.27	1.08	457.65	11.00	3.31	9,647.22	509.64
41	8,839.93	3.69	1,148.31	7.83	0.14	0.09	9,439.55	0.18	347.93	207.39	4.94	9,541.17	1.19	457.65	11.91	3.72	9,648.56	494.47
42	8,839.15	3.89	1,148.26	8.45	0.15	0.09	9,441.74	0.21	345.69	207.41	4.94	9,541.04	1.31	457.64	12.90	4.03	9,649.58	478.40
43	8,838.47	4.01	1,148.22	9.04	0.16	0.10	9,443.47	0.23	343.91	207.43	4.94	9,540.95	1.41	457.64	13.98	4.56	9,649.98	461.70
44	8,837.81	4.13	1,148.17	9.60	0.17	0.11	9,444.75	0.25	342.60	207.44	4.94	9,540.84	1.52	457.64	15.14	5.18	9,649.90	444.61
45	8,837.17	4.28	1,148.13	10.12	0.18	0.11	9,445.58	0.28	341.73	207.45	4.94	9,540.72	1.65	457.63	16.39	5.87	9,649.34	427.34
46	8,836.56	4.45	1,148.09	10.59	0.19	0.12	9,445.96	0.32	341.31	207.45	4.94	9,540.58	1.79	457.63	17.73	6.66	9,648.28	410.09
47	8,835.96	4.65	1,148.06	11.01	0.20	0.12	9,445.90	0.36	341.33	207.45	4.94	9,540.41	1.96	457.63	19.16	7.56	9,646.72	393.04
48	8,835.39	4.88	1,148.02	11.38	0.21	0.13	9,445.39	0.40	341.80	207.44	4.94	9,540.23	2.15	457.62	20.67	8.58	9,644.63	376.33
49	8,834.98	5.01	1,147.99	11.67	0.21	0.13	9,444.43	0.45	342.72	207.43	4.94	9,540.04	2.35	457.62	22.27	9.89	9,641.84	360.08

Table 60: Annual probability estimates (x10,000) for the "breast cancer only" condition fitted transition intensities from age 50 to 79.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAW}	p_y^{HB}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}	$p_y^{HA^{Other}}$	$p_y^{AD^{Other}}$	$p_y^{A^{Other}A^{Other}}$	$p_y^{AB^{Any}}$
50	8,834.53	5.25	1,147.96	11.91	0.22	0.13	9,443.02	0.51	344.09	207.41	4.94	9,539.82	2.56	457.61	23.94	11.31	9,638.54	344.42
51	8,834.03	5.61	1,147.93	12.07	0.22	0.13	9,441.15	0.57	345.92	207.39	4.94	9,539.60	2.79	457.61	25.68	12.86	9,634.69	329.43
52	8,833.71	5.84	1,147.91	12.17	0.22	0.13	9,438.82	0.64	348.21	207.36	4.94	9,539.36	3.03	457.60	27.47	14.80	9,630.02	315.17
53	8,833.21	6.34	1,147.88	12.20	0.23	0.14	9,436.01	0.72	350.97	207.32	4.94	9,539.09	3.32	457.60	29.31	16.77	9,624.89	301.70
54	8,832.76	6.85	1,147.85	12.17	0.23	0.13	9,432.71	0.81	354.22	207.28	4.94	9,538.79	3.63	457.59	31.18	19.07	9,618.99	289.07
55	8,832.28	7.46	1,147.82	12.07	0.23	0.13	9,428.91	0.91	357.96	207.24	4.94	9,538.46	3.95	457.58	33.07	21.68	9,612.33	277.30
56	8,831.76	8.17	1,147.79	11.92	0.23	0.13	9,424.59	1.02	362.22	207.19	4.94	9,538.12	4.31	457.57	34.96	24.63	9,604.86	266.41
57	8,831.11	9.06	1,147.75	11.72	0.23	0.13	9,419.74	1.15	367.00	207.13	4.94	9,537.75	4.68	457.56	36.83	27.88	9,596.60	256.42
58	8,830.31	10.17	1,147.70	11.47	0.23	0.13	9,414.36	1.25	372.33	207.07	4.94	9,537.49	4.96	457.56	38.67	31.65	9,587.33	247.33
59	8,829.33	11.51	1,147.63	11.17	0.22	0.12	9,408.43	1.35	378.22	207.00	4.94	9,537.24	5.20	457.55	40.46	35.88	9,577.08	239.16
60	8,828.05	13.21	1,147.55	10.84	0.22	0.12	9,401.91	1.46	384.71	206.93	4.94	9,537.01	5.44	457.55	42.18	40.53	9,565.86	231.89
61	8,826.35	15.38	1,147.44	10.49	0.22	0.12	9,394.78	1.55	391.82	206.85	4.94	9,536.83	5.63	457.54	43.82	45.60	9,553.66	225.54
62	8,824.21	18.05	1,147.31	10.10	0.21	0.11	9,387.02	1.64	399.58	206.76	4.93	9,536.68	5.78	457.54	45.35	51.15	9,540.39	220.11
63	8,821.69	21.14	1,147.15	9.70	0.21	0.11	9,378.57	1.75	408.02	206.66	4.93	9,536.47	5.99	457.53	46.75	57.25	9,525.96	215.62
64	8,818.57	24.88	1,146.95	9.29	0.21	0.10	9,369.41	1.85	417.17	206.56	4.93	9,536.29	6.18	457.53	48.02	63.88	9,510.34	212.06
65	8,815.03	29.08	1,146.72	8.86	0.20	0.10	9,359.44	2.03	427.08	206.45	4.93	9,536.19	6.29	457.53	49.13	71.35	9,493.22	209.47
66	8,787.21	59.12	1,144.95	8.43	0.20	0.09	9,348.67	2.21	437.79	206.33	4.93	9,536.09	6.39	457.52	50.04	54.42	9,499.21	207.87
67	8,780.06	67.16	1,144.50	8.00	0.19	0.09	9,337.05	2.41	449.34	206.20	4.92	9,535.99	6.49	457.52	50.79	61.07	9,481.37	207.31
68	8,771.98	76.19	1,143.98	7.58	0.19	0.08	9,324.44	2.71	461.79	206.06	4.92	9,535.65	6.83	457.51	51.34	68.12	9,462.33	207.84
69	8,762.68	86.50	1,143.39	7.16	0.18	0.08	9,310.88	3.03	475.19	205.91	4.92	9,535.32	7.17	457.51	51.67	75.81	9,441.79	209.53
70	8,751.78	98.51	1,142.69	6.76	0.18	0.08	9,296.30	3.36	489.60	205.74	4.92	9,535.03	7.47	457.50	51.78	83.99	9,419.88	212.49
71	8,738.86	112.66	1,141.87	6.37	0.17	0.07	9,280.66	3.68	505.09	205.57	4.91	9,534.81	7.70	457.49	51.65	92.45	9,396.72	216.82
72	8,723.64	129.24	1,140.89	5.99	0.17	0.07	9,263.89	4.01	521.72	205.38	4.91	9,534.63	7.88	457.49	51.28	101.11	9,372.33	222.67
73	8,706.19	148.18	1,139.78	5.62	0.16	0.06	9,245.83	4.40	539.59	205.18	4.91	9,534.35	8.16	457.48	50.67	110.09	9,346.54	230.24
74	8,686.24	169.76	1,138.50	5.28	0.16	0.06	9,226.46	4.81	558.77	204.96	4.91	9,534.10	8.42	457.48	49.82	119.55	9,319.12	239.75
75	8,664.42	193.32	1,137.10	4.95	0.16	0.06	9,205.76	5.15	579.36	204.73	4.90	9,533.72	8.81	457.47	48.73	130.39	9,289.13	251.50
76	8,640.68	218.89	1,135.58	4.64	0.15	0.05	9,183.55	5.51	601.46	204.48	4.90	9,533.33	9.21	457.46	47.40	142.90	9,256.19	265.85
77	8,614.74	246.80	1,133.92	4.34	0.15	0.05	9,159.72	5.89	625.18	204.21	4.89	9,532.92	9.63	457.45	45.86	157.10	9,220.22	283.26
78	8,586.16	277.49	1,132.08	4.07	0.14	0.05	9,134.14	6.31	650.63	203.92	4.89	9,532.47	10.09	457.44	44.12	172.83	9,181.27	304.28
79	8,553.73	312.28	1,130.00	3.81	0.14	0.04	9,106.76	6.68	677.95	203.62	4.88	9,532.12	10.45	457.43	42.18	189.42	9,139.89	329.64

12.14.8 "Malignant Melanoma of Skin" Female Table of Transition Probabilities

Table 61: Annual probability estimates (x10,000) for the "malignant melanoma of skin" condition fitted transition intensities from age 20 to 49.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAW}	p_y^{HB}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}	$p_y^{HA^{Other}}$	$p_y^{AD^{Other}}$	$p_y^{A^{Other}A^{Other}}$	$p_y^{AB^{Any}}$
20	8,846.90	3.83	1,148.75	0.48	0.01	0.03	8,354.66	0.01	511.40	1,107.01	26.93	9,542.30	0.02	457.67	1.42	0.78	9,506.77	1,022.05
21	8,846.80	3.85	1,148.75	0.55	0.02	0.03	8,448.04	0.01	496.74	1,030.19	25.01	9,542.30	0.03	457.67	1.64	0.78	9,520.39	967.37
22	8,846.72	3.86	1,148.74	0.63	0.02	0.03	8,533.92	0.01	482.91	959.89	23.27	9,542.30	0.03	457.67	1.88	0.81	9,533.07	916.87
23	8,846.65	3.83	1,148.74	0.73	0.02	0.04	8,612.90	0.01	469.89	895.53	21.67	9,542.29	0.03	457.67	2.15	0.87	9,544.88	870.23
24	8,846.61	3.77	1,148.73	0.83	0.02	0.04	8,685.54	0.01	457.65	836.58	20.22	9,542.29	0.04	457.67	2.45	0.98	9,555.82	827.14
25	8,846.43	3.84	1,148.72	0.94	0.02	0.04	8,752.36	0.02	446.16	782.57	18.89	9,542.29	0.04	457.67	2.80	0.95	9,566.14	787.33
26	8,846.44	3.70	1,148.72	1.06	0.03	0.04	8,813.83	0.02	435.40	733.07	17.68	9,542.28	0.05	457.67	3.18	1.15	9,575.51	750.55
27	8,846.31	3.70	1,148.71	1.20	0.03	0.05	8,870.40	0.02	425.34	687.68	16.56	9,542.27	0.06	457.67	3.60	1.22	9,584.31	716.55
28	8,846.21	3.66	1,148.71	1.35	0.03	0.05	8,922.45	0.02	415.96	646.02	15.54	9,542.27	0.06	457.67	4.07	1.34	9,592.43	685.12
29	8,846.10	3.60	1,148.70	1.51	0.03	0.05	8,970.35	0.02	407.22	607.79	14.61	9,542.27	0.06	457.67	4.58	1.50	9,599.87	656.07
30	8,845.99	3.54	1,148.69	1.68	0.04	0.05	9,014.44	0.02	399.11	572.67	13.76	9,542.27	0.06	457.67	5.15	1.68	9,606.70	629.22
31	8,845.76	3.59	1,148.68	1.87	0.04	0.06	9,055.00	0.02	391.61	540.39	12.97	9,542.26	0.07	457.67	5.77	1.77	9,613.06	604.40
32	8,845.64	3.52	1,148.67	2.07	0.04	0.06	9,092.32	0.03	384.69	510.71	12.25	9,542.26	0.07	457.67	6.45	2.00	9,618.73	581.47
33	8,845.48	3.46	1,148.66	2.28	0.05	0.06	9,126.65	0.03	378.32	483.41	11.59	9,542.26	0.07	457.67	7.18	2.23	9,623.88	560.29
34	8,845.30	3.43	1,148.65	2.51	0.05	0.06	9,158.21	0.03	372.50	458.28	10.98	9,542.25	0.07	457.67	7.98	2.48	9,628.51	540.73
35	8,844.99	3.51	1,148.63	2.75	0.05	0.07	9,187.20	0.03	367.21	435.14	10.42	9,542.25	0.08	457.67	8.84	2.65	9,632.73	522.68
36	8,844.75	3.50	1,148.61	3.01	0.06	0.07	9,213.82	0.03	362.42	413.82	9.90	9,542.25	0.08	457.67	9.76	2.93	9,636.38	506.03
37	8,844.49	3.51	1,148.60	3.27	0.06	0.07	9,238.23	0.03	358.13	394.17	9.43	9,542.24	0.09	457.67	10.74	3.24	9,639.53	490.70
38	8,844.13	3.60	1,148.58	3.55	0.07	0.07	9,260.59	0.04	354.33	376.05	8.99	9,542.24	0.09	457.67	11.79	3.53	9,642.26	476.60
39	8,843.94	3.52	1,148.56	3.83	0.07	0.07	9,281.04	0.04	350.99	359.34	8.59	9,542.23	0.10	457.67	12.91	3.88	9,644.50	463.65
40	8,843.53	3.65	1,148.54	4.13	0.08	0.08	9,299.70	0.04	348.11	343.93	8.22	9,542.22	0.11	457.67	14.08	4.40	9,646.15	451.78
41	8,843.20	3.69	1,148.52	4.43	0.08	0.08	9,316.68	0.04	345.68	329.72	7.88	9,542.21	0.12	457.67	15.32	4.92	9,647.38	440.93
42	8,842.72	3.89	1,148.49	4.74	0.09	0.08	9,332.08	0.05	343.70	316.61	7.56	9,542.20	0.13	457.67	16.62	5.37	9,648.26	431.03
43	8,842.31	4.01	1,148.46	5.05	0.09	0.08	9,346.01	0.05	342.15	304.51	7.27	9,542.20	0.13	457.67	17.98	6.02	9,648.55	422.04
44	8,841.89	4.13	1,148.43	5.36	0.10	0.08	9,358.54	0.05	341.04	293.36	7.00	9,542.20	0.13	457.67	19.39	6.76	9,648.34	413.91
45	8,841.45	4.28	1,148.40	5.68	0.10	0.09	9,369.75	0.05	340.37	283.08	6.76	9,542.20	0.13	457.67	20.85	7.62	9,647.62	406.60
46	8,840.99	4.45	1,148.38	5.99	0.11	0.09	9,379.69	0.05	340.12	273.61	6.53	9,542.19	0.14	457.67	22.36	8.59	9,646.39	400.06
47	8,840.51	4.65	1,148.34	6.30	0.11	0.09	9,388.44	0.05	340.30	264.89	6.32	9,542.20	0.13	457.67	23.90	9.69	9,644.62	394.27
48	8,839.99	4.88	1,148.31	6.60	0.12	0.09	9,396.03	0.05	340.92	256.87	6.13	9,542.19	0.14	457.67	25.48	10.93	9,642.31	389.21
49	8,839.60	5.01	1,148.29	6.89	0.13	0.09	9,402.51	0.06	341.97	249.51	5.95	9,542.18	0.15	457.67	27.09	12.49	9,639.29	384.83

Table 62: Annual probability estimates (x10,000) for the "malignant melanoma of skin" condition fitted transition intensities from age 50 to 79.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAW}	p_y^{HB}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}	$p_y^{HA^{Other}}$	$p_y^{AD^{Other}}$	$p_y^{A^{Other}A^{Other}}$	$p_y^{AB^{Any}}$
50	8,839.10	5.25	1,148.26	7.17	0.13	0.09	9,407.93	0.06	343.46	242.76	5.79	9,542.18	0.15	457.67	28.71	14.17	9,635.73	381.12
51	8,838.50	5.61	1,148.22	7.44	0.14	0.09	9,412.31	0.06	345.40	236.59	5.64	9,542.17	0.16	457.67	30.35	16.00	9,631.60	378.06
52	8,838.04	5.84	1,148.19	7.69	0.14	0.10	9,415.69	0.06	347.79	230.95	5.51	9,542.17	0.16	457.67	32.00	18.25	9,626.63	375.64
53	8,837.35	6.34	1,148.14	7.92	0.15	0.10	9,418.08	0.06	350.64	225.83	5.39	9,542.16	0.17	457.67	33.64	20.57	9,621.16	373.85
54	8,836.67	6.85	1,148.10	8.13	0.15	0.10	9,419.50	0.07	353.97	221.18	5.27	9,542.15	0.18	457.67	35.26	23.25	9,614.89	372.66
55	8,835.91	7.46	1,148.05	8.32	0.16	0.10	9,419.97	0.07	357.79	216.99	5.17	9,542.14	0.20	457.67	36.87	26.27	9,607.83	372.09
56	8,835.09	8.17	1,148.00	8.48	0.16	0.10	9,419.48	0.08	362.12	213.23	5.08	9,542.13	0.21	457.67	38.44	29.67	9,599.91	372.12
57	8,834.12	9.06	1,147.94	8.62	0.17	0.10	9,418.06	0.08	366.96	209.89	5.01	9,542.12	0.22	457.67	39.97	33.41	9,591.18	372.75
58	8,832.97	10.17	1,147.87	8.72	0.17	0.10	9,415.68	0.09	372.35	206.94	4.94	9,542.09	0.24	457.67	41.44	37.51	9,581.58	373.99
59	8,831.63	11.51	1,147.78	8.80	0.18	0.10	9,412.34	0.10	378.30	204.38	4.87	9,542.06	0.27	457.67	42.86	42.06	9,571.02	375.84
60	8,829.98	13.21	1,147.68	8.85	0.18	0.10	9,408.04	0.12	384.84	202.18	4.82	9,542.03	0.31	457.67	44.20	47.01	9,559.51	378.31
61	8,827.92	15.38	1,147.54	8.87	0.19	0.10	9,402.77	0.13	391.99	200.33	4.78	9,542.00	0.34	457.66	45.45	52.31	9,547.08	381.41
62	8,825.42	18.05	1,147.38	8.86	0.19	0.09	9,396.50	0.14	399.78	198.84	4.74	9,541.96	0.38	457.66	46.60	58.05	9,533.63	385.15
63	8,822.54	21.14	1,147.20	8.82	0.19	0.09	9,389.20	0.15	408.25	197.68	4.72	9,541.94	0.40	457.66	47.64	64.44	9,518.92	389.55
64	8,819.10	24.88	1,146.98	8.75	0.19	0.09	9,380.86	0.16	417.43	196.85	4.70	9,541.92	0.42	457.66	48.57	71.34	9,503.05	394.63
65	8,815.24	29.08	1,146.74	8.65	0.20	0.09	9,371.44	0.16	427.35	196.35	4.69	9,541.90	0.44	457.66	49.35	79.07	9,485.67	400.41
66	8,787.13	59.12	1,144.95	8.51	0.20	0.09	9,360.89	0.17	438.07	196.18	4.68	9,541.88	0.46	457.66	49.96	62.38	9,491.43	406.91
67	8,779.72	67.16	1,144.47	8.36	0.20	0.09	9,349.16	0.18	449.63	196.33	4.69	9,541.86	0.48	457.66	50.44	69.30	9,473.34	414.18
68	8,771.40	76.19	1,143.94	8.18	0.20	0.09	9,336.22	0.19	462.08	196.81	4.70	9,541.83	0.51	457.66	50.74	76.96	9,453.70	422.24
69	8,761.90	86.50	1,143.34	7.97	0.20	0.09	9,322.00	0.20	475.47	197.61	4.72	9,541.80	0.54	457.66	50.86	85.28	9,432.56	431.12
70	8,750.83	98.51	1,142.63	7.74	0.20	0.08	9,306.44	0.21	489.86	198.73	4.75	9,541.78	0.56	457.66	50.79	94.05	9,410.07	440.88
71	8,737.77	112.66	1,141.80	7.49	0.20	0.08	9,289.47	0.22	505.32	200.20	4.79	9,541.77	0.57	457.66	50.51	103.04	9,386.40	451.56
72	8,722.43	129.24	1,140.82	7.23	0.20	0.08	9,271.02	0.22	521.92	202.00	4.83	9,541.75	0.59	457.66	50.03	112.19	9,361.55	463.20
73	8,704.90	148.18	1,139.70	6.95	0.20	0.08	9,250.99	0.23	539.74	204.15	4.88	9,541.72	0.62	457.66	49.33	121.81	9,335.16	475.86
74	8,684.89	169.76	1,138.42	6.65	0.20	0.07	9,229.29	0.24	558.86	206.66	4.94	9,541.69	0.65	457.66	48.43	131.89	9,307.14	489.62
75	8,663.04	193.32	1,137.02	6.35	0.20	0.07	9,205.82	0.26	579.37	209.53	5.02	9,541.66	0.68	457.66	47.31	143.41	9,276.50	504.52
76	8,639.31	218.89	1,135.50	6.04	0.20	0.07	9,180.47	0.27	601.36	212.79	5.10	9,541.63	0.72	457.66	45.98	156.64	9,242.88	520.64
77	8,613.38	246.80	1,133.83	5.72	0.19	0.07	9,153.12	0.28	624.95	216.44	5.19	9,541.59	0.75	457.66	44.47	171.58	9,206.20	538.07
78	8,584.85	277.49	1,132.00	5.40	0.19	0.07	9,123.63	0.30	650.26	220.51	5.29	9,541.55	0.80	457.65	42.76	188.13	9,166.48	556.89
79	8,552.48	312.28	1,129.92	5.08	0.19	0.06	9,091.86	0.32	677.40	225.01	5.40	9,541.51	0.84	457.65	40.89	205.39	9,124.47	577.19

12.14.9 "Cardiovascular only" Female Table of Transition Probabilities

Table 63: Annual probability estimates (x10,000) for the "cardiovascular only" condition fitted transition intensities from age 20 to 49.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAW}	p_y^{HB}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}	$p_y^{HA^{Other}}$	$p_y^{AD^{Other}}$	$p_y^{A^{Other}A^{Other}}$	$p_y^{AB^{Any}}$
20	8,847.28	3.83	1,148.78	0.11	0.00	0.00	9,411.60	0.09	542.14	45.12	1.06	9,547.99	0.14	451.86	1.82	0.58	9,506.97	158.33
21	8,847.26	3.85	1,148.77	0.12	0.00	0.00	9,429.44	0.08	524.25	45.16	1.06	9,547.84	0.14	452.02	2.10	0.60	9,520.57	158.41
22	8,847.24	3.86	1,148.77	0.13	0.00	0.00	9,446.05	0.08	507.60	45.20	1.06	9,547.68	0.13	452.18	2.42	0.64	9,533.25	158.46
23	8,847.25	3.83	1,148.77	0.13	0.00	0.00	9,461.51	0.09	492.10	45.23	1.06	9,547.51	0.15	452.34	2.78	0.68	9,545.06	158.51
24	8,847.31	3.77	1,148.78	0.15	0.00	0.00	9,475.89	0.10	477.68	45.27	1.07	9,547.34	0.16	452.50	3.18	0.78	9,556.02	158.54
25	8,847.22	3.84	1,148.77	0.16	0.00	0.00	9,489.26	0.10	464.27	45.30	1.07	9,547.17	0.17	452.66	3.62	0.74	9,566.35	158.57
26	8,847.34	3.70	1,148.78	0.17	0.00	0.00	9,501.67	0.12	451.82	45.33	1.07	9,546.99	0.19	452.82	4.11	0.92	9,575.74	158.58
27	8,847.33	3.70	1,148.78	0.19	0.00	0.00	9,513.19	0.12	440.26	45.36	1.07	9,546.82	0.20	452.98	4.66	0.98	9,584.55	158.58
28	8,847.35	3.66	1,148.78	0.21	0.00	0.00	9,523.86	0.13	429.56	45.38	1.07	9,546.64	0.21	453.15	5.26	1.07	9,592.69	158.57
29	8,847.38	3.60	1,148.78	0.23	0.01	0.00	9,533.73	0.14	419.65	45.40	1.07	9,546.46	0.23	453.31	5.91	1.21	9,600.15	158.55
30	8,847.42	3.54	1,148.78	0.25	0.01	0.00	9,542.85	0.15	410.50	45.43	1.07	9,546.29	0.25	453.47	6.63	1.37	9,607.01	158.53
31	8,847.34	3.59	1,148.78	0.28	0.01	0.00	9,551.25	0.17	402.07	45.45	1.07	9,546.11	0.27	453.63	7.42	1.42	9,613.40	158.49
32	8,847.38	3.52	1,148.78	0.31	0.01	0.00	9,558.97	0.18	394.32	45.46	1.07	9,545.93	0.29	453.79	8.26	1.62	9,619.10	158.44
33	8,847.40	3.46	1,148.78	0.34	0.01	0.00	9,566.03	0.20	387.22	45.48	1.07	9,545.74	0.31	453.95	9.18	1.82	9,624.29	158.39
34	8,847.40	3.43	1,148.78	0.39	0.01	0.00	9,572.48	0.21	380.74	45.49	1.07	9,545.56	0.34	454.11	10.16	2.04	9,628.95	158.32
35	8,847.28	3.51	1,148.78	0.43	0.01	0.00	9,578.32	0.23	374.86	45.51	1.07	9,545.36	0.37	454.27	11.22	2.15	9,633.22	158.25
36	8,847.23	3.50	1,148.77	0.49	0.01	0.00	9,583.60	0.25	369.55	45.52	1.07	9,545.17	0.40	454.43	12.34	2.39	9,636.91	158.17
37	8,847.17	3.51	1,148.77	0.55	0.01	0.00	9,588.33	0.27	364.79	45.53	1.07	9,544.98	0.44	454.59	13.53	2.65	9,640.10	158.08
38	8,847.01	3.60	1,148.76	0.62	0.01	0.00	9,592.52	0.30	360.56	45.54	1.08	9,544.76	0.49	454.75	14.79	2.87	9,642.91	157.98
39	8,847.01	3.52	1,148.76	0.70	0.01	0.00	9,596.20	0.33	356.84	45.55	1.08	9,544.56	0.53	454.91	16.11	3.15	9,645.21	157.87
40	8,846.80	3.65	1,148.74	0.79	0.01	0.00	9,599.37	0.38	353.62	45.56	1.08	9,544.32	0.61	455.07	17.49	3.56	9,646.98	157.76
41	8,846.66	3.69	1,148.74	0.89	0.02	0.00	9,602.05	0.42	350.89	45.56	1.08	9,544.10	0.68	455.23	18.93	3.99	9,648.29	157.63
42	8,846.36	3.89	1,148.72	1.01	0.02	0.00	9,604.25	0.47	348.63	45.57	1.08	9,543.85	0.76	455.39	20.42	4.32	9,649.30	157.50
43	8,846.12	4.01	1,148.70	1.15	0.02	0.00	9,606.00	0.51	346.84	45.57	1.08	9,543.63	0.82	455.55	21.96	4.87	9,649.68	157.36
44	8,845.86	4.13	1,148.69	1.30	0.02	0.00	9,607.29	0.55	345.51	45.57	1.08	9,543.41	0.89	455.71	23.53	5.51	9,649.58	157.21
45	8,845.56	4.28	1,148.67	1.47	0.03	0.00	9,608.11	0.60	344.63	45.57	1.08	9,543.17	0.96	455.87	25.14	6.24	9,648.98	157.05
46	8,845.21	4.45	1,148.64	1.67	0.03	0.00	9,608.49	0.65	344.21	45.57	1.08	9,542.93	1.04	456.03	26.76	7.08	9,647.87	156.88
47	8,844.81	4.65	1,148.62	1.88	0.03	0.00	9,608.42	0.69	344.23	45.57	1.08	9,542.71	1.11	456.19	28.40	8.08	9,646.20	156.70
48	8,844.35	4.88	1,148.59	2.13	0.04	0.01	9,607.88	0.76	344.71	45.57	1.08	9,542.44	1.22	456.34	30.03	9.15	9,644.06	156.52
49	8,843.97	5.01	1,148.57	2.41	0.04	0.01	9,606.89	0.83	345.63	45.57	1.08	9,542.17	1.33	456.50	31.65	10.54	9,641.21	156.32

Table 64: Annual probability estimates (x10,000) for the "cardiovascular only" condition fitted transition intensities from age 50 to 79.

Age	p_y^{HH}	p_y^{HD}	p_y^{HW}	p_y^{HA}	p_y^{HAW}	p_y^{HB}	p_y^{AA}	p_y^{AD}	p_y^{AW}	p_y^{AB}	p_y^{ABW}	p_y^{BB}	p_y^{BD}	p_y^{BW}	$p_y^{HA^{Other}}$	$p_y^{AD^{Other}}$	$p_y^{A^{Other}}$	$p_y^{A^{Other}}$	$p_y^{AB^{Any}}$
50	8,843.45	5.25	1,148.53	2.71	0.05	0.01	9,605.42	0.92	347.01	45.56	1.08	9,541.87	1.47	456.66	33.25	12.00	9,637.86	156.12	
51	8,842.78	5.61	1,148.49	3.05	0.06	0.01	9,603.48	1.02	348.86	45.56	1.08	9,541.55	1.63	456.82	34.82	13.57	9,633.99	155.90	
52	8,842.20	5.84	1,148.45	3.43	0.06	0.01	9,601.08	1.12	351.17	45.55	1.08	9,541.23	1.80	456.98	36.33	15.56	9,629.28	155.68	
53	8,841.34	6.34	1,148.40	3.85	0.07	0.01	9,598.18	1.24	353.95	45.54	1.08	9,540.87	1.99	457.14	37.79	17.57	9,624.11	155.44	
54	8,840.41	6.85	1,148.34	4.30	0.08	0.01	9,594.76	1.40	357.22	45.54	1.08	9,540.47	2.24	457.29	39.17	19.87	9,618.21	155.19	
55	8,839.37	7.46	1,148.27	4.80	0.09	0.01	9,590.82	1.57	361.00	45.52	1.08	9,540.03	2.52	457.45	40.46	22.45	9,611.58	154.94	
56	8,838.19	8.17	1,148.20	5.34	0.10	0.01	9,586.31	1.81	365.28	45.51	1.08	9,539.50	2.90	457.60	41.66	25.25	9,604.25	154.67	
57	8,836.79	9.06	1,148.11	5.91	0.11	0.01	9,581.23	2.08	370.10	45.50	1.08	9,538.91	3.33	457.75	42.74	28.30	9,596.19	154.39	
58	8,835.15	10.17	1,148.00	6.53	0.13	0.02	9,575.55	2.40	375.47	45.48	1.08	9,538.24	3.86	457.90	43.71	31.59	9,587.39	154.09	
59	8,833.25	11.51	1,147.88	7.19	0.14	0.02	9,569.24	2.78	381.41	45.47	1.08	9,537.48	4.47	458.05	44.54	35.18	9,577.76	153.79	
60	8,830.98	13.21	1,147.74	7.89	0.16	0.02	9,562.25	3.25	387.95	45.45	1.08	9,536.59	5.22	458.20	45.23	38.96	9,567.40	153.47	
61	8,828.25	15.38	1,147.56	8.61	0.18	0.02	9,554.51	3.86	395.11	45.43	1.08	9,535.47	6.19	458.34	45.78	42.73	9,556.47	153.13	
62	8,825.01	18.05	1,147.36	9.36	0.20	0.02	9,546.08	4.49	402.92	45.40	1.08	9,534.32	7.21	458.47	46.17	46.87	9,544.59	152.79	
63	8,821.36	21.14	1,147.13	10.12	0.22	0.02	9,536.85	5.25	411.42	45.38	1.08	9,532.96	8.43	458.61	46.41	51.30	9,531.78	152.43	
64	8,817.10	24.88	1,146.85	10.90	0.24	0.03	9,526.69	6.23	420.63	45.35	1.08	9,531.27	9.99	458.73	46.48	55.69	9,518.36	152.05	
65	8,812.40	29.08	1,146.56	11.67	0.27	0.03	9,515.66	7.31	430.60	45.32	1.08	9,529.42	11.73	458.86	46.39	60.64	9,503.69	151.65	
66	8,783.43	59.12	1,144.71	12.41	0.29	0.03	9,503.62	8.61	441.37	45.29	1.08	9,527.21	13.82	458.97	46.11	40.58	9,512.73	151.24	
67	8,775.17	67.16	1,144.18	13.14	0.31	0.03	9,490.59	10.06	452.98	45.25	1.08	9,524.78	16.14	459.08	45.70	43.77	9,498.27	150.81	
68	8,766.00	76.19	1,143.60	13.83	0.34	0.03	9,476.41	11.76	465.50	45.21	1.08	9,521.96	18.87	459.18	45.13	47.04	9,482.91	150.37	
69	8,755.68	86.50	1,142.94	14.46	0.37	0.03	9,461.03	13.71	478.96	45.17	1.08	9,518.73	22.00	459.27	44.41	50.31	9,466.67	149.90	
70	8,743.84	98.51	1,142.18	15.02	0.39	0.04	9,444.45	15.85	493.44	45.12	1.08	9,515.21	25.44	459.35	43.55	53.52	9,449.57	149.41	
71	8,730.07	112.66	1,141.30	15.50	0.42	0.04	9,426.59	18.19	509.00	45.07	1.08	9,511.38	29.20	459.42	42.54	56.44	9,431.78	148.91	
72	8,714.10	129.24	1,140.28	15.88	0.44	0.04	9,407.17	20.96	525.70	45.01	1.08	9,506.88	33.64	459.48	41.41	58.39	9,413.90	148.38	
73	8,696.01	148.18	1,139.13	16.15	0.47	0.04	9,386.33	23.93	543.63	44.95	1.08	9,502.07	38.40	459.53	40.16	60.33	9,394.91	147.83	
74	8,675.56	169.76	1,137.82	16.30	0.49	0.04	9,363.52	27.56	562.86	44.88	1.08	9,496.21	44.23	459.56	38.81	60.99	9,375.99	147.25	
75	8,653.39	193.32	1,136.40	16.32	0.51	0.04	9,338.83	31.69	583.48	44.80	1.08	9,489.58	50.85	459.57	37.36	61.81	9,355.66	146.64	
76	8,629.44	218.89	1,134.86	16.21	0.53	0.04	9,311.75	36.73	605.59	44.72	1.08	9,481.53	58.93	459.54	35.84	61.97	9,334.62	146.01	
77	8,603.42	246.80	1,133.19	15.96	0.54	0.04	9,282.58	42.26	629.30	44.63	1.08	9,472.70	67.81	459.50	34.24	62.55	9,311.72	145.34	
78	8,574.93	277.49	1,131.36	15.59	0.55	0.04	9,250.55	48.96	654.70	44.53	1.08	9,462.03	78.57	459.41	32.60	61.70	9,288.68	144.64	
79	8,542.71	312.28	1,129.29	15.08	0.56	0.04	9,216.24	56.10	681.95	44.42	1.07	9,450.68	90.02	459.30	30.91	60.42	9,264.40	143.91	

12.15 Adjustment to Transition Probabilities in Order to Satisfy Survival Period

We shall now consider how to adjust the probabilities for the stand-alone critical illness model to take account of the qualifying period, which we shall denote by τ.

12.15.1 Transition Probabilities Satisfying Survival Period from State *H* to State *A*

Consider the single step annual probability from state *H* at time k - 1 to state *A* at time *k*. If the exact time of transition to state *A* occurred before time $k - \tau$, then the qualifying period τ, would automatically be satisfied as the first possible transition to state *D* can only occur at time *k*.

Alternatively, if the transition to state *A* occurred between times $k - \tau$ and *k*, say exact time *u*, then if the policyholder moves to state *D* between times *k* and $u + \tau$, this would be before a time interval of length τ in state *A* had being completed, as shown below in Figure 36. Therefore the qualifying period condition would not be satisfied in this case.

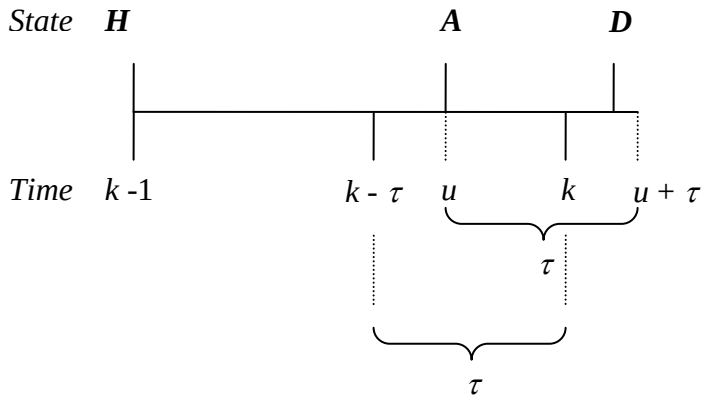

Figure 36: Example to show the timing of transitions from state *A* to state *D* within the qualifying period τ

Therefore to ensure that the qualifying period τ is also satisfied, we require the policyholder to already be in state *A* by time *k* - τ and then remain there until time *k*, with corresponding probability ${}_{\tau}p_{y+k-\tau}^{AA}$. This is the most conservative situation, as in practice the policyholder would only move onto state *D* at the earliest time *k*, and may move only just before time *k* + 1. So on average, this would occur at time *k* + 0.5. We have adopted this above conservative approach in order to show the slight effect the survival period may have on the probabilities and hence subsequent expected calculations.

The combined probability is equal to ${}_{t-\tau}p_{y}^{HA}\,{}_{\tau}p_{y+t-\tau}^{AA}$ which we shall denote by using the short-hand postfix notation τ, i.e. ${}_{t}p_{y,\tau}^{HA}$ for $t \geq \tau$.

There will be a slight over-lapping in time intervals if we use integer years for *t* and perform the usual annual probability calculations. However, this error will be fairly small for the values of τ we shall consider equal to only 30 days.

Alternatively, if $0 \leq t < \tau$, then the qualifying period is not satisfied as we have insufficient time to remain in state *A* from state *H* before the end of the time period *t*. In this case, to be sure that the survival period is satisfied, we would require the policyholder to continue remaining in state *A* for a further time period τ, with probability ${}_{\tau}p_{y+t}^{AA}$. Thus the total probability of remaining in state *A* for at least time τ in our notation is given by

$${}_{t}p_{y,\tau}^{HA} = {}_{t}p_{y}^{HA}\,{}_{\tau}p_{y+t}^{AA}, \qquad \text{for } t < \tau.$$

This expression is similar to that used by (Robjohns *et al.*, pp.85, 2006) who multiply their stand-alone critical illness incidence rate i_y by ${}_{\tau}p_{y}^{AA}$.

In practice, τ will be much smaller than *t* so we will always use the first formula. However, we will need the second formula below when calculating ${}_{v}p_{y,\tau}^{HAD}$.

In practice, the only new calculation is of the partial year probability ${}_{v}p_{y,\tau}^{HA}$, where $\tau \leq v \leq 1$, as the probabilities greater than 1 year can be found from ${}_{t}p_{y,\tau}^{HA} = {}_{t-1}p_{y}^{HA}\ {}_{v}p_{y+t-1,\tau}^{HA}$ for $t > 1$.

12.15.2 Transition Probabilities Satisfying Survival Period from State *H* to State *B*, or State *A* to State *B*

Similarly, we would require a waiting period to be satisfied after entering the 2nd incident state before the end of the time period, either from the 1st incident state

${}_{t}p_{y,\tau}^{AB} = {}_{t-\tau}p_{y}^{AB}\ {}_{\tau}p_{y+t-\tau}^{BB}$, for $t \geq \tau$,

or from the healthy state

${}_{t}p_{y,\tau}^{HB} = {}_{t-\tau}p_{y}^{HB}\ {}_{\tau}p_{y+t-\tau}^{BB}$, for $t \geq \tau$,

at the start of the time period (i.e. the 1st incident state was completely within the time period).

All of the above probabilities with a survival benefit required at the end of the time period ${}_{t}p_{y,\tau}^{HA}$, ${}_{t}p_{y,\tau}^{HB}$, ${}_{t}p_{y,\tau}^{AB}$, can be calculated from the expressions in Appendix 12.14.2 to Appendix 12.14.9.

12.15.3 Transition Probabilities Satisfying Survival Period from State *H* to State *D* (via State *A*)

For the survival period at an intermediary state, rather than the final state we need to consider the following example.

Suppose we pass from state *H* to state *D* in 1 time period, via the intermediate state *A*, then the policyholder's benefit is only paid provided they survive the qualifying period. We shall denote the corresponding probability by

$$ {}_{v}p_{y,\tau}^{H\,AD} = \int_{u=0}^{\tau} {}_{u}p_{y,\tau}^{H\,A}\,\mu_{y}^{AD}\,du + \int_{u=\tau}^{v} {}_{u}p_{y,\tau}^{H\,A}\,\mu_{y}^{AD}\,du \ , $$

where the integral needs to be split in order to use the different expressions for ${}_{t}p_{y,\tau}^{H\,A}$ depending on whether $u < \tau$ or $u > \tau$.

For the 1st integral,

$$ \int_{u=0}^{\tau} {}_{u}p_{y,\tau}^{H\,A}\,\mu_{y}^{AD}\,du = \int_{u=0}^{\tau} {}_{u}p_{y}^{H\,A}\,{}_{\tau}p_{y+u}^{AA}\,\mu_{y}^{AD}\,du = \int_{u=0}^{\tau} {}_{u}p_{y}^{H\,A}\,\frac{{}_{u+\tau}p_{y}^{AA}}{{}_{u}p_{y}^{AA}}\,\mu_{y}^{AD}\,du $$

$$ = \int_{u=0}^{\tau} {}_{u}p_{y}^{H\,A} e^{-\tau\left(\mu_{y}^{AD}+\mu_{y}^{A\,W}\right)}\mu_{y}^{AD}\,du = e^{-\tau\left(\mu_{y}^{AD}+\mu_{y}^{A\,W}\right)}\,{}_{\tau}p_{y}^{H\,AD} \ . $$

The lower limit is chosen to ensure that $u > \tau$, i.e. sufficient time available to remain in state *A*.

For the 2nd integral,

$$ \int_{u=\tau}^{v} {}_{u}p_{y,\tau}^{H\,A}\,\mu_{y}^{AD}\,du = \int_{u=\tau}^{v} {}_{u-\tau}p_{y}^{H\,A}\,{}_{\tau}p_{y+u-\tau}^{AA}\,\mu_{y}^{AD}\,du = \int_{w=0}^{v-\tau} {}_{w}p_{y}^{H\,A}\,\frac{{}_{w+\tau}p_{y}^{AA}}{{}_{w}p_{y}^{AA}}\,\mu_{y}^{AD}\,dw $$

where variable $w = u - \tau$

$$ = \int_{w=0}^{v-\tau} {}_{w}p_{y}^{H\,A} e^{-\tau\left(\mu_{y}^{AD}+\mu_{y}^{AW}\right)}\mu_{y}^{AD}\,dw = e^{-\tau\left(\mu_{y}^{AD}+\mu_{y}^{A\,W}\right)}\,{}_{v-\tau}p_{y}^{H\,AD} \ . $$

Overall, we have ${}_{v}p_{y,\tau}^{H\,AD} = e^{-\tau\left(\mu_{y}^{AD}+\mu_{y}^{A\,W}\right)}\left({}_{\tau}p_{y}^{H\,AD} + {}_{v-\tau}p_{y}^{H\,AD}\right) \le {}_{v}p_{y}^{H\,AD}$ for $v > \tau$.

This expression is as we would expect, with the probability of a policyholder exceeding the survival period decreasing as the survival period τ increases until the probability is equal to 0. At the other limit for $\tau = 0$, we obtain equality between the two probabilities on either side of the expression.

As a reality check, this will mean that a lower expected benefit is payable as τ increases (as the benefit payment is multiplied by a decreasing ${}_v p_{y,\tau}^{H\,AD}$). Alternatively, a more similar benefit is paid as τ decreases to 0, compared to if there was no survival period.

12.15.4 Transition Probabilities *HA, AB* Satisfying Survival Period

The following Table 65 shows the reduction in annual probabilities for $p_{y,\tau}^{H\,A}$ and $p_{y,\tau}^{AB}$ from identical values to $p_y^{H\,A}$ and p_y^{AB} (shown in Table 55 and Table 56) when τ = 0, all the way towards 0, as τ increase to 1 year.

Table 65: The probabilities (x10,000) for the combined "All CI" Conditions, after including a survival period τ = 0 to 180 days.

Age	$p^{HA}_{y,\tau}$				$p^{AB}_{y,\tau}$			
Y τ	**0**	**28**	**90**	**180**	**0**	**28**	**90**	**180**
20	2	2	1	1	219	203	166	112
21	2	2	2	1	220	203	166	112
22	3	2	2	1	220	203	166	112
23	3	3	2	1	183	169	138	93
24	3	3	3	2	139	129	105	71
25	4	3	3	2	220	204	166	112
26	4	4	3	2	218	202	165	111
27	5	4	4	2	181	167	137	92
28	5	5	4	3	195	180	147	99
29	6	6	5	3	183	169	138	93
30	7	6	5	4	186	172	141	95
31	8	7	6	4	221	204	167	113
32	8	8	6	4	213	197	161	109
33	9	9	7	5	184	170	139	94
34	10	10	8	5	216	200	163	110
35	12	11	9	6	215	199	163	110
36	13	12	10	7	201	186	152	102
37	14	13	11	7	219	202	165	111
38	15	14	12	8	220	204	166	112
39	17	15	13	9	213	197	161	108
40	18	17	14	9	192	178	145	98
41	20	18	15	10	209	193	157	106
42	21	20	16	11	211	195	159	107
43	23	21	17	12	195	180	147	99
44	25	23	19	13	203	188	153	103
45	26	24	20	14	194	179	146	98
46	28	26	21	15	206	191	156	105
47	30	28	23	15	207	192	156	105
48	32	29	24	16	206	190	155	105
49	34	31	26	17	205	189	155	104
50	36	33	27	18	202	187	152	103
51	37	35	28	19	203	188	153	103
52	39	36	30	20	207	191	156	105
53	41	38	31	21	203	187	153	103
54	43	40	33	22	204	188	154	104
55	45	41	34	23	189	174	142	96
56	47	43	35	24	198	183	150	101
57	48	45	37	25	188	174	142	96
58	50	46	38	26	188	173	142	95
59	51	47	39	26	198	183	149	101
60	53	49	40	27	175	162	132	89
61	54	50	41	28	169	156	127	86
62	55	51	42	28	176	162	133	89
63	56	52	43	29	178	164	134	90
64	57	53	43	29	169	156	128	86
65	58	53	44	30	171	158	129	87
66	58	54	44	30	176	163	133	90
67	58	54	44	30	196	181	148	100
68	58	54	44	30	165	152	125	84
69	58	54	44	30	168	155	127	86