Catastrophic Mortality Bonds – An Effective Hedge?

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Abstract

Life insurers are exposed to catastrophic mortality risk. Catastrophic mortality bonds are a recent market innovation that provide an alternative risk management tool to address this risk. However there is little in the way of published studies which examine their effectiveness, given that they are subject to basis risk arising from the use of country level general population mortality in their construction. By constructing a typical mortality risk portfolio and calibrating a bond for this portfolio, the hedge effectiveness of the instrument is analysed under a wide variety of circumstances. We find that on a stand-alone basis, hedge effectiveness may be too low to be acceptable to small to medium insurers. However, effectiveness of the bond increases when used in combination with surplus reinsurance and/or when pooling is used to maximise portfolio size.

Keywords

Life insurance; mortality risk management; insurance securitisation; catastrophic mortality bonds; basis risk; hedge effectiveness

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1 Introduction

Life insurers and reinsurers are exposed to the risk of future mortality uncertainty. Catastrophic mortality events pose a significant threat to the life insurance industry as they cause a sudden increase in mortality over a short period of time, which may lead to a substantial rise in claims and the potential for severe adverse financial consequences, such as breaches in regulatory solvency and capital requirements (Cox & Hu, 2004).

Although there are a range of catastrophic mortality events that may impact the life insurance industry, an influenza pandemic[1] is considered the most serious threat. The exposure to catastrophic mortality events such as influenza pandemics has been difficult for life insurers and reinsurers to manage since the probability of such events occurring in any year is low while the potential for devastating losses is high. Catastrophic mortality

[1] A pandemic is an outbreak of infectious disease that spreads throughout the world and infects a significant proportion of the human population whereas an epidemic refers to an infectious disease that spreads to people in a specific geographical region that occurs well beyond what is expected based on recent experience (Potter, 2001). According to the World Health Organisation, a pandemic can start when three conditions have been met: there is global outbreak of a disease caused by an agent that is new or long absent from the human population, the agent infects humans and is able to cause serious illness, and the agent transmits efficiently and sustainably among humans (World Health Organisation, 2011).

bonds are a recent capital market innovation that provide an alternative risk management tool to hedge against catastrophic mortality events. In contrast to the inherent credit risk associated with traditional reinsurance, they bear essentially no credit risk for sponsors (Bagus, 2007). However, catastrophic mortality bonds are not indemnity based as the payoff trigger is based on a specified mortality index, which is calculated as a weighted average of general population mortality rates (Cowley & Cummins, 2005). Consequently, the issue of basis risk arises, resulting in imperfect hedge effectiveness as the possibility exists for gains or losses in the hedged position. In particular, the sponsor is concerned that the bond payoff will be inadequate to cover the actual loss suffered (Coughlan et al., 2011).

This article quantifies the basis risk and hedge effectiveness of catastrophic mortality bonds in order to explore the level of coverage they provide for sponsors. It examines the use of catastrophic mortality bonds in hedging against additional claims arising from an influenza pandemic using a typical Australian individual fully underwritten yearly renewable term (YRT) insurance portfolio as a practical example. Interested readers may use this as a guide for application to their own specific portfolios.

Overall, we find that there is significant variation in the basis risk and hedge effectiveness of catastrophic mortality bonds. The findings suggest that catastrophic mortality bonds are a viable alternative risk management tool for large portfolio sizes, for portfolios where the distribution of sums insured is less spread, and where the life insurer's underlying exposure remains relatively stable. Hence the pooling of small to medium portfolios and/or the use of surplus reinsurance to homogenise the distribution of sums insured may be effective preparation for the effective implementation of a catastrophic mortality bond.

The remainder of this article is structured as follows. Section 2 briefly outlines the epidemiological characteristics of influenza pandemics in order to set the scene for the calibration of a bond issuance and discusses the life insurer's management of catastrophic mortality risk arising from an influenza pandemic. Section 3 provides an overview of the catastrophic mortality bond market, the key features of the bonds and concepts of basis risk and hedge effectiveness. Section 4 describes the methodology adopted for the analysis. Section 5 reports the results obtained and summarises key findings. Section 6 concludes.

2 Influenza pandemics

2.1 Epidemiological characteristics

While seasonal influenza epidemics usually occur during the autumn and winter months in temperate regions and all year round for tropical and sub-tropical regions, the emergence of influenza pandemics is not constrained by season (Nguyen-Van-Tam & Hampson, 2003) and it is reasonable to believe that influenza pandemics may appear at any time during the year.

In contrast to seasonal influenza epidemics that occur annually, influenza pandemics are rare and unpredictable events, which have occurred irregularly throughout history. To date, there is no identified chronological pattern that would allow us to predict the occurrence of future influenza pandemics (Potter, 2001). Influenza pandemics have been characterised by multiple waves of infection with varying impact occurring over two calendar years. A variety of patterns have been observed regarding duration and severity, which will be incorporated in later modelling.

2.1.1 Excess mortality rate

Evidence suggests that influenza pandemics may cause considerably higher, excess[2] mortality, but this impact is difficult to quantify because influenza may not be listed as a cause on the death certificate for many influenza related deaths (Woolnough et al., 2007). Consequently, the all-cause excess mortality and influenza- and pneumonia-specific excess mortality can be considered as the upper and lower bounds of mortality attributed to an influenza pandemic, respectively. The excess mortality rate has varied significantly among the influenza pandemics of the last 100 years, as illustrated in Table 1.

[2] The excess mortality rate is defined as the difference between the observed mortality rate and the expected baseline mortality rate in the absence of an influenza pandemic (Simonsen et al., 1997).

Table 1: Estimated excess mortality rates for the influenza pandemics of the 20th and 21st century

Name	Global excess mortality rate (per 1,000) [a]	U.S. excess mortality rate (per 1,000) [a]
1918-1919 Spanish Flu	27.60 – 55.20	4.81 – 6.50
1957-1958 Asian Flu	0.34 – 0.69	0.38 – 0.46
1968-1969 Hong Kong Flu	0.28	0.14 – 0.17
2009-2010 H1N1 Flu	Not available	0.02 – 0.14

Sources: Dauer & Serfling (1961); Glezen (1996); Simonsen et al. (1998); U.S. Census Bureau (2000, 2011a, 2011b); U.S. Department of Health & Human Services (2011); United Nations (1999); Viboud et al., (2010); World Health Organisation (2005)
[a] The excess mortality rate is calculated as the number of excess deaths divided by the average of the population over the influenza pandemic.

2.1.2 Age-specific distribution of excess mortality rates

The age-specific distribution of excess mortality rates for seasonal influenza epidemics typically has a "U" shape curve representing high mortality among infants and the elderly with comparatively low mortality rates at ages in between (Nguyen-Van-Tam & Hampson, 2003). On the other hand, the age-specific distribution of excess mortality rates for influenza pandemics has tended to affect a higher proportion of persons under 65 years of age than seasonal influenza. This is often attributed to the partial immunity that many persons over 65 years of age may have retained from exposure to similar influenza infections as children or young adults (Nguyen-Van-Tam & Hampson, 2003). The age-specific distribution of excess mortality rates for the last four influenza pandemics have exhibited either "U", "V\", or "/\" shapes and have been similar for both genders.

2.2 Catastrophic mortality risk management

2.2.1 Risk identification

For most life insurers, death benefit products constitute the majority of their risk business and as a result, they are likely to experience a significant loss[3]. This has the potential to severely impact the life insurer's results and may lead to breaches of solvency requirements.

2.2.2 Risk measurement

Life insurers assess the potential impact of influenza pandemics with risk modelling and scenario testing. Internal risk models are commonly used to assess a full range of (perceived) risks and to take into account dependencies between different risks and exposures, which can be complex. Since influenza pandemics are rare events, there is scarce data to calibrate a number of uncertain parameters required in the models. This is typically dealt with through sensitivity testing (Baumgart et al., 2007).

Several studies have examined the impact on the life insurance industry from increased mortality due to an influenza pandemic, by estimating the additional cost based on a range of deterministic scenarios derived from historical influenza pandemics[4]. It is apparent from Table 2 that a wide range of outcomes are considered possible. In general, the studies conclude that the life insurance industry can absorb the impact of a severe pandemic, but will incur significant decreases in profit and capital. It is also noted that the life reinsurance industry will be more heavily impacted since reinsurance is essentially pure mortality risk business, and that the advantage conferred by reinsurers' geographical diversification ceases to apply in the event of a pandemic (APRA, 2007; Dreyer, Kritzinger & Decker, 2007).

Table 2: Summary of assumptions and results from studies examining the potential impact of an influenza pandemic on the life insurance industry

[3] Although, of course, the actual impact of increased mortality due to an influenza pandemic will depend on the proportions of death benefit and longevity benefit products in the life insurer's portfolio (Broekhoven et al., 2006).
[4] In general, gains on the release of annuity reserves have been excluded.

Author(s)	Country	Severity [a]	General population excess mortality rate (per 1,000)	Age-specific distribution of excess mortality rate	Excess mortality rate ratio of insured versus general population (%) [b]	Influenza pandemic duration (Years)	Results: additional gross claims (AGC) or additional net claims (ANC)
APRA (2007)	Australia	Severe	1.0	Flat	100%	1	AGC: AUD 1.2 billion
Dreyer, Kritzinger & Decker (2007)	South Africa	Mild	0.40	"W"	Group life: 70%	1	AGC: ZAR 0.753 billion
		Moderate	1.40	"W"	Individual life:	1	AGC: ZAR 2.7 billion
		Severe	20.0	"W"	40% *	1	AGC: ZAR 37.6 billion
Stracke (2007)	Germany	Severe	6.4	"W"	100%	1	ANC: EUR 5.1 billion
Toole (2007)	U.S.	Moderate	0.70	"U"	57.1%	1	ANC: USD 2.8 billion
		Severe	6.5	"V\"	76.9%	1	ANC: USD 64.3 billion
Weisbart (2006)	U.S.	Moderate	1.07	"_/"	100%	1	AGC: USD 31 billion
		Severe	4.81	"U"	100%	1	AGC: USD 133 billion

[a] Severity ratings are specified by each of the authors of the study.
[b] The excess mortality rate ratio of insured versus general population reflects the potential for better mortality experience in the insured population relative to the general population in an influenza pandemic scenario.
* The excess mortality rate ratio of insured versus general population for Dreyer, Kritzinger & Decker (2007) is the same across all three scenarios, but is differentiated into group life and individual life products.

2.2.3 Risk management

Retention of catastrophic mortality risk is possible, but is unlikely to be economically efficient. Clearly, geographic diversification is not as effective as with other catastrophic mortality events since an influenza pandemic is likely to affect multiple geographical regions around the world[5]. Diversification across lines of businesses is also somewhat limited because health and general insurance business may also be affected. On the other hand, annuity business may provide a natural hedge as the value of protection and annuity liabilities move in the opposite direction in response to changes in mortality (Cox & Lin, 2007). This will depend on the age-specific distribution of excess mortality rates as life insurers primarily write protection policies to younger age groups and sell annuity policies to older age groups.

Life insurers can transfer mortality risk through reinsurance. However, this exposes the insurer to credit risk because the reinsurer may develop solvency issues due to a pandemic event causing them to default on their obligations or be slow to pay reinsurance claims (Baumgart et al., 2007; PartnerRe, 2008). An alternative is a catastrophic mortality bond, which essentially eliminates credit risk when well designed. These instruments offer several advantages and disadvantages compared to reinsurance, as discussed in the following section.

3 Catastrophic mortality bonds

3.1 Market overview

Securitisation involves the isolation of a pool of assets or rights to a set of cash flows and the repackaging of the assets or cash flows into securities that are traded in the capital markets (Cowley & Cummins, 2005). Insurance linked securities (ILS) are instruments designed to transfer insurance risk to the capital markets (Cummins & Trainar, 2009). Life securitisations have been predominantly used as a financing tool although some have facilitated risk management. On the other hand, non-life securitisations have typically been used to transfer catastrophic event risk (Ernst & Young, 2011).

The market for ILS has expanded significantly in recent years, growing at 40 to 50% per year since 1997 (Hartwig et al., 2008). To date, there have been seven public catastrophic mortality bonds transactions with a total bond issuance value of approximately USD 2.5 billion[6], though catastrophic mortality bonds represent less than 10% of the overall volume outstanding for life ILS. Despite this, the medium term outlook for catastrophic

[5] Whereas, for example, an earthquake will affect only one geographical region.
[6] Table 16 in Appendix A summarises these transactions.

mortality bonds remains positive and the market is estimated to reach USD 5 to 20 billion by 2019 (Frey, Kirova & Schmidt, 2009; Weistroffer et al., 2010).

Catastrophic mortality bonds have primarily appealed to large, globally diversified insurers and reinsurers, and have predominantly been used in developed countries. Arguably these bonds enhance the capacity of the life insurance industry to write mortality risk business by transferring catastrophic losses from the insurance industry to the capital markets (Bouriaux & MacMinn, 2009; Lin & Cox, 2007)[7].

Catastrophic mortality bonds offer several advantages over traditional reinsurance for hedging exposure to catastrophic mortality losses. They act as a form of collateralised stop-loss reinsurance[8], which essentially eliminates the credit risk exposure for sponsors (Bagus, 2007). Compared to one year coverage usually provided by stop loss reinsurance, they allow the sponsor to secure fixed cost multi-year coverage, typically ranging from three to five years, which in turn allows sponsors to spread the fixed cost of issuance over several years (Cummins, 2008). Furthermore, these bonds have the flexibility to access capital markets when required by using shelf programs[9]. This has the potential to avoid market disruptions caused by reinsurance prices and availability cycles (Cummins & Trainar, 2009).

On the other hand, several disadvantages arise with catastrophic mortality bonds. Firstly, they have significant up-front transaction costs such as legal, risk modelling, broker, rating agency and bank fees that require minimum transaction sizes for the issuance to be economical (Helfenstein & Holzheu, 2006), whereas traditional reinsurance generally has no up-front costs aside from brokerage fees (PartnerRe, 2008). Secondly, the issue of basis risk exists for catastrophic mortality bonds since the payoff trigger is index based and the actual loss suffered is unlikely to be perfectly matched by the bond payoff. This contrasts with traditional reinsurance which has no basis risk since it is indemnity based and provides full coverage for reinsured losses (Hartwig et al. 2008). Thirdly, the capital credit given by regulators and rating agencies may be reduced for catastrophic mortality bonds in comparison to traditional reinsurance (Standard & Poor's, 2008). Finally, the terms of catastrophic mortality bonds are fixed throughout the duration of coverage while traditional reinsurance can be adjusted every year allowing for short term commitment and flexibility (PartnerRe, 2008).

3.2 Key features

The basic transaction structure of catastrophic mortality bonds has remained reasonably generic over the seven public transactions[10]. Similarly, the contingent claim payoff mechanism has remained essentially the same for all transactions.

The key components of the contingent claim payoff mechanism are the principal amount, mortality index, attachment point and exhaustion point. The principal amount represents the maximum payoff that the sponsor can receive if the bond is triggered this has typically ranged from USD 50 to USD 100 million per tranche. The mortality index, attachment point and exhaustion point determine whether the bond is triggered and if so, what percentage of the principal is paid. The mortality index is defined over a two calendar year period[11] and calculated using general population mortality rates published by official public reporting sources weighted by age and gender (Rooney, 2008). The weights are specified by the sponsor to broadly reflect their exposure to an insured population and are fixed throughout the duration of the risk period[12] (Standard & Poor's, 2011). The attachment and exhaustion points are expressed as a percentage of the mortality index at issuance.

[7] Capital markets are likely to more easily absorb catastrophic losses, whereby any insured losses may be large relative to the total capitalisation of the insurance industry, but miniscule in comparison to the total volume of securities traded in the capital market.

[8] Stop loss reinsurance is a form of excess of loss reinsurance under which the reinsurer's liability commences when the aggregate claims experience on the reinsured portfolio during a specified time period exceeds a predetermined level (Carr et al., 2009).

[9] Shelf programs are structured such that all the legal, modelling, rating and other structuring costs are done for a very large bond issue. However, not all of the bond capacity is issued initially and some is left to be issued at later time when needed by the sponsor. This lowers the issuance cost for subsequent issues and reduces the time to access capital markets (Helfenstein & Holzheu, 2006).

[10] The generic structure is shown in Appendix B (Figure 12). Cowley & Cummins (2005), Bauer & Kramer (2008) and Helfenstein & Holzheu (2006) provide detailed descriptions on the functioning of these instruments for the interested reader.

[11] The mortality index is measured over a two calendar year period in order to mitigate the chance that an influenza pandemic will be cut off by the end of a measurement period.

[12] The risk period is the time period over which the catastrophic mortality bond provides coverage.

The contingent claim payoff to the sponsor, being any reduction in the principal amount, is triggered if the mortality index value exceeds the attachment point. If the mortality index does not exceed the attachment point, the full principal amount is returned to the investor at maturity. Once the attachment point is exceeded, the reduction in the principal amount increases linearly between the attachment and exhaustion point until the index exceeds the exhaustion point and the full principal is lost by the investor (Bridet, 2009). Thus far, the lowest attachment point has been 105% while the highest exhaustion point has been 150%.

The choice of an index based payoff trigger is driven by investors' demand for transparent, easy to understand and hard to manipulate triggers[13] (Weistroffer et al., 2010). Index based payoff triggers can be standardised more easily than indemnity based ones, and they reduce moral hazard because the sponsor still has an incentive to limit losses as the payoffs are based on an independent metric rather than the sponsor's actual losses. Adverse selection is also reduced because payoffs are based on publicly available data and there are few informational asymmetries to be exploited (Bouriaux & MacMinn, 2009; Helfenstein & Holzheu, 2006).

3.3 Basis risk and hedge effectiveness

Basis risk arises whenever there are differences between an underlying hedged portfolio and the associated hedging instrument. Its presence implies imperfect hedge effectiveness because there is a possibility of gains or losses in the hedged position. This does not necessarily invalidate the case for hedging because basis risk can be minimised by appropriately structuring and calibrating the hedging instrument to ensure high hedge effectiveness[14]. If the basis risk is small relative to the risk of the initial unhedged position then it is possible for the hedging strategy to be beneficial (Coughlan et al, 2011).

The issue of basis risk has been examined for several index-based ILS. In non-life, industry loss warranties, catastrophic loss index securities and catastrophe insurance linked contracts have been examined (Cummins, Lalonde & Phillips, 2004; Harrington & Niehaus, 1999; Zeng, 2000). In life, the extant literature has primarily focused on longevity linked securities (Cairns et al, 2011; Coughlan et al, 2011; Ngai & Sherris, 2011). To the authors' knowledge, there has been no published literature on the analysis of basis risk and hedge effectiveness for catastrophic mortality bonds.

In the context of catastrophic mortality bonds, basis risk could arise from differences between general and insured populations due to mismatches in age, gender, geographical location and socioeconomic class (Coughlan et al, 2011)[15]. As age, gender, country and financial exposure in the form of sum assured can be calibrated to match that of the life insurer's underlying exposure, an important determinant of basis risk is therefore associated with mismatches of socioeconomic class (Richards & Jones, 2004).

Some historical evidence suggests that the impact of underwriting and economic self-selection will continue to result in lighter mortality experience in the insured population in the event of an influenza pandemic, as compared to the general population. Mead (1919) observes that the ratio of all cause mortality claims paid to the average amount of sum insured in force was higher for industrial life policies[16] than ordinary life policies during the 1889 influenza pandemic. This is consistent with similar studies on the 1918-1919 influenza pandemic by Craig & Dublin (1919) and Little (1919). In addition, a study on the 1957-1958 and 1968-1969 influenza pandemics observes approximately 12% lower excess death rates in standard ordinary policyholders compared with age and gender matched general population (Woolnough et al., 2007). This is consistent with a study published by Metropolitan Life Insurance Company (1976).

Furthermore, basis risk remains even if similar characteristics are shared, simply because the two populations are not the same people.

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[13] An indemnity based payoff trigger is not used because investors would expect to receive a significant premium for moral hazard and adverse selection depending on the type of business covered, risk modelling credibility and the market's confidence in the sponsor's risk management procedures; investors would want to undertake more extensive due diligence of the sponsor and the securitised portfolio to better understand the insurance risk they are undertaking; and sponsors will be reluctant to disclose data on insurance portfolios since they could be of proprietary nature and their disclosure valuable to competitors (Hartwig et al, 2008; Rooney, 2008).

[14] Indeed, basis risk is inherent in most financial hedging strategies, for example, interest rate swaps.

[15] This is additional to the issue of differing overall mortality experience between general and insured populations. Insured mortality may be significantly lower than that of the general population due to the impact of underwriting and economic self-selection, with differences dependent on age, gender, smoking class, policy duration and underwriting type (Toole, 2007).

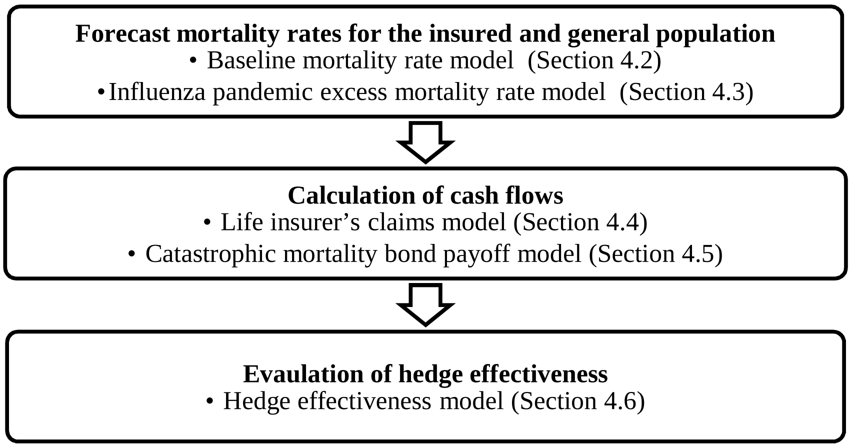
[16] Industrial life insurance is a small sum insured policy intended to cover burial expenses (Woolnough et al., 2007).

4 Methodology

4.1 Overview of framework

The framework for assessing basis risk and hedge effectiveness is adapted from Coughlan et al. (2011) and is shown in Figure 1. The life insurer's claims are determined by the insured population mortality rates while the catastrophic mortality bond payoff is determined by the general population mortality rates. The evaluation of hedge effectiveness uses simulations of the forecast mortality rates to calculate these cash flows, which are used to calculate the hedge effectiveness.

Figure 1: Framework of assessing basis risk and hedge effectiveness



Source:Modified from Coughlan et al. (2011)

4.2 Baseline mortality rate model

The baseline mortality model forecasts the baseline mortality rate for the Australian general and insured population. The baseline mortality rate is defined as the future annual mortality rates assuming that no catastrophic mortality event occurs.

4.2.1 Life tables and mortality improvements

The Australian Bureau of Statistics (ABS) 2007-2009 life tables are the basis for the Australian general population mortality. The mortality of the Australian insured population is based on the IA95-97 life tables[17] published by the Institute of Actuaries of Australia (IAAust).

Both life tables are assumed to improve by the Australian Government Actuary (AGA) 25 year mortality improvement trend to 2010, to establish the starting point for the bond. The AGA 25 year trend is chosen over the AGA 100 year trend to reflect more recent mortality changes. For projecting beyond 2010, a divergence in the rate of change in mortality rates could have an impact on hedge effectiveness. Therefore, three possible mortality improvement trends are considered for both general and insured populations: the AGA 25 year mortality improvement trends, the 100 year mortality improvement trends, and no mortality improvement.

[17] The IA95-97 life tables are based on insured mortality experience from 1995 to 1997 provided by fourteen life offices on policies with death cover only on standard lives (Chan et al., 2001).

4.3 *Influenza pandemic excess mortality rate model*

The influenza pandemic excess mortality model forecasts the excess mortality rate for the Australian general and insured population in the event that an influenza pandemic occurs. The excess mortality rate is modelled explicitly and not decomposed into the clinical attack rate and case fatality rate[18], and is modelled only as age-specific and not gender-specific. It is also modelled as additive and not multiplicative of baseline mortality, in accordance with existing studies, as this provides more severe pandemic scenarios[19].

There are two broad sources from which to develop influenza pandemic excess mortality assumptions: actual historical influenza pandemic mortality data as described in Section 2.1 and assumptions used by studies examining the potential impact of an influenza pandemic as described in Section 2.2.2. The 20th century influenza pandemic mortality data is difficult to apply to today's situation, due to significant environmental changes since the beginning of the 20th century. These include improvements in medical care and technology, establishment of global health monitoring and early warning systems, emergency preparedness plans, better communication methods and improved socio-economic conditions (Baumgart et al., 2007). On the other hand, some changes may increase the impact of future influenza pandemics such as a higher percentage of the population at older ages, increased urban population density and increased human mobility through international air passenger travel (Faulds & Bridel, 2009). There are no explicit adjustments made to account for these changes in this paper given the substantial uncertainty surrounding their impact. In any case, the range of historical influenza pandemic severities already provides a wide range of potential scenarios.

4.3.1 Overall general population excess mortality rate

The range of general population excess mortality rate assumptions used by the influenza pandemic studies is broadly consistent with the range of U.S. excess mortality during the past four influenza pandemics (as shown in Table 1 and Table 2). The 1918-1919 Spanish Flu is generally considered as the upper bound on future influenza pandemic mortality, even though there is no logical or biological reason why it should represent the maximum possible mortality as random mutations may produce a more devastating virus (Murray et al., 2006). Notwithstanding, historical experience suggests that the general population excess mortality rate may vary between 0 and 5 per 1,000.

4.3.2 Age-specific distribution of excess mortality rates

For the purposes of this paper, four shapes of age-specific distribution of excess mortality rates are considered: "U", "V\" and "W" and a flat curve. The first three are coherent with the studies shown in Table 2, and a flat shape is considered as it serves as a reference point for the other shapes.

4.3.3 Excess mortality rate ratio of insured versus general population

Potential differences in mortality between insured and general populations in the event of a pandemic are unclear since the effects of underwriting and economic self-selection may cease to apply. As a result of their higher socioeconomic status the insured population may have better access to healthcare and be more educated about the impact of influenza, but on the other hand also more likely to engage in international travel and live in high density urban areas. A lack of data exacerbates this uncertainty. Woolnough et al. (2007) suggest an insured to general population mortality ratio of 88% from the 1957-1958 and 1968-1969 influenza pandemics, and as per Table 2 the ratio assumed by influenza pandemic studies ranges from 40% to 100%.

In this paper, the mortality ratio of the insured versus general population is assumed to vary from 40% to 120% to capture the uncertainty regarding this relationship.

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[18] The clinical attack rate refers to the rate of illness in the whole population. The case fatality rate refers to the rate of mortality among people who are infected by the disease (Stitt, 2006).

[19] It is uncertain whether increases in mortality caused by a historical influenza pandemic should be treated as additive (i.e. absolute) or multiplicative (i.e. relative) to baseline mortality rates for the purpose of estimating future impact of a "similar" pandemic. Since baseline mortality rates have decreased over time, the two approaches produce quite different results when applied to the current baseline mortality rate. For example, the Spanish Flu caused an additive increase of baseline mortality rates of approximately 5 per 1,000 or a multiplicative increase of 30% of baseline mortality rates. When applying the additive increase to the Australian standardised baseline mortality rate of 5.7 per 1,000, this results in a multiplicative increase of 88% instead of 30% (ABS, 2010).

4.3.4 Duration of the influenza pandemic and severity of waves each year

Historical evidence from Section 2.1 suggests influenza pandemics may begin at any time during the year, and also indicates that influenza pandemics have varying severity of waves over two calendar years. In contrast, influenza pandemic studies assume that the duration is one year as shown in Table 2. We assume that the influenza pandemic occurs with varying severity of waves each year over one, two or three calendar years. Although a three year pandemic has not been historically recorded, it is considered because of the potential impact on the bond payoff given that the mortality index is measured over a two year calendar period.

4.4 Life insurer's claims model

The life insurer's claims model simulates the aggregate annual claims for a typical Australian life insurer's portfolio of individual fully underwritten YRT insurance. This requires assumptions about the number of policies, average sum insured and distribution of sum insured by age and gender. In reality, a life insurer may wish to hedge the exposure to catastrophic mortality risk across all life insurance products.

The aggregate annual simulated claims[20] include sampling risk, which is the risk that the "realised" mortality is different from the "intrinsic" mortality due to a small population size. A Bernoulli distribution is used to model the death process of each policyholder where the policyholder dies if a simulated random number between 0 and 1 is less than the policyholder's mortality rate.

The portfolio is assumed to be comprised of 20,000 policies, consistent with a small to medium Australian life insurer. A small portfolio size is chosen for ease of calculation and because it is more effective in illustrating the relative impacts on hedge effectiveness from varying key parameters. The portfolio composition by age and gender is assumed to follow that for the IAAust IA95-97 life tables, as shown in Table 3. The smoker status of policyholders was not considered as baseline mortality and influenza pandemic excess mortality rates are not subdivided by smoker status[21].

Table 3: Portfolio composition by age and gender

Age band	Male	Female	Age band	Male	Female
15-24*	0.62%	0.76%	55-64	6.20%	1.52%
25-34	10.54%	9.12%	65-74	0.00%	0.00%
35-44	22.94%	16.72%	75+	0.00%	0.00%
45-54	21.70%	9.88%	*Subtotal*	*62.00%*	*38.00%*

Source: Hayes (2008) * A minimum age of 18 years old is assumed.

The ages are assumed to be uniformly distributed within each age and gender group. It is also assumed that the portfolio composition remains static over the risk period. This requires the assumption that the aging of policyholders, lapses of in-force policies and deaths of policyholders are compensated by future new business that replicates the assumed portfolio composition by age and gender.

The average sum insured is assumed to be $365,000[22]. Table 4 and Table 5 provide the gender-specific distributions of sum insured by age. The sum insured values are assumed to be uniformly distributed within each sum insured band and randomly distributed within each age band[23].

Table 4: Male distribution of sum insured by age band

Age band	Sum insured bands

[20] Calculated as the total of the sum insured of policyholders that have died during the calendar year.

[21] The difference in smoker status between the general and insured population may then also contribute to basis risk as the bond cannot be calibrated for this difference.

[22] This is based on a 2007 YRT average sum insured of approximately $330,000 (Palmer, 2009), an inflation rate of 3.2% per annum since that time (RBA, 2011), and on advice from a life insurance actuary, a take up rate of 80% of policyholders. The take up rate is the proportion of policyholders who choose to increase their sum insured each year by the inflation rate.

[23] One exception is the $3m-$5m sum insured band, where the lower quarter of the band is weighted three times more likely than the upper three quarters of the band to reflect that it is unlikely for the sum insured to be uniformly distributed at larger covers.

	$20,000 - $150,000	$150,000 - $500,000	$500,000 - $1,000,000	$1,000,000 - $3,000,000	$3,000,000 - $5,000,000
34 and less	55%	33%	10%	2%	0%
35 – 54	40%	29%	20%	9%	2%
55 and greater	70%	20%	8%	2%	0%

Table 5: Female distribution of sum insured by age band

Age band	Sum insured bands				
	$20,000 - $150,000	$150,000 - $500,000	$500,000 - $1,000,000	$1,000,000 - $3,000,000	$3,000,000 - $5,000,000
34 and less	65%	26%	8%	1%	0%
35 – 54	60%	24%	12%	3%	1%
55 and greater	80%	13%	6%	1%	0%

4.5 Catastrophic mortality bond payoff model

4.5.1 Construction of contingent claim payoff mechanism

The catastrophic mortality bond payoff component models the contingent claim payoff mechanism, as described in Section 3.2. Construction of the contingent claim payoff mechanism is taken from Swiss Re Capital Markets (2008).

4.5.2 Calibration of the catastrophic mortality bond

The catastrophic mortality bond must be calibrated according to the life insurer's hedging objectives, which we assume for this paper is to protect against additional claims arising from a one year influenza pandemic causing a general population excess mortality rate of 1 to 2 per 1,000 with a "V\" age-specific distribution. Assuming an excess mortality rate ratio of insured versus general population of 80%, this equates to an insured population excess mortality rate of 0.8 to 1.6 per 1,000. Under this specified hedging objective, the life insurer intends to retain the loss from claims caused by all baseline mortality plus excess mortality up to 0.8 per 1,000. The losses from these claims will be referred to as "retained" claims.

The duration is chosen as one year. A general population excess mortality rate of 1 to 2 per 1,000 is chosen as this range of excess mortality rates results in attachment and exhaustion points that are consistent with the range observed in the market[24]. The "V\" shape of age-specific distribution of excess mortality is chosen because this shape has the highest impact on insured lives.

The start of the risk period is assumed to be 1st January 2011, the maturity of the bond is five years, and the influenza pandemic is arbitrarily assumed to occur in 2013 since this is the middle of the risk period. We assume that the general and insured population mortality improvement follow the AGA 25 year trend.

For simplicity, there is only one tranche. The attachment and exhaustion point are chosen to be 122.33% and 151.77% as this is equal to the expected mortality index values with the given mortality assumptions at an excess mortality rate of 1 and 2 per 1,000. The size of age bands is set to five years consistent with previous transactions, while the age and gender weightings were chosen according to portfolio sum insured weightings. The principal amount is set at $6,466,841, which is equal to the difference between the expected aggregate claims with an excess mortality rate of 1 and 2 per 1,000. It should be noted that in reality the characteristics of a bond are driven heavily by investor demands to ensure that the issuance is well received by investors.

The mortality rates that are required for the construction of the mortality index are calculated as the simple average of forecast mortality rates for individual ages within 5 year age group bands[25]. It is also assumed that

[24] It is noted that with the market attachment and exhaustion points issued to date, a catastrophic mortality bond is unable to cover the entire range of excess mortality from 0 to 5 per 1,000 observed in historical influenza pandemics.

[25] This assumes that there are equal proportions of individual ages within each age group band. In ABS Australian population projections for the five years from 2011, the proportions of each individual age within each five year age group bands for the ages of

there is no sampling risk in the general population since the number of individuals in each age is relatively large (in contrast to the life insurer's claims model).

4.6 Hedge effectiveness model

Hedge effectiveness can be defined as the degree of risk reduction of the unhedged exposure where the risk metric could be the value at risk (VaR), tail value at risk (TVaR) or variance (Cairns et al., 2011; Coughlan et al., 2011; Cummins et al., 2004; Li & Hardy, 2011). The unhedged and hedged exposures are defined as the value of the liability and the value of the liability plus the value of the hedging instrument, respectively. In accordance with this, the hedge effectiveness (hereafter HE) is chosen in this paper as the degree of risk reduction of the unhedged exposure, with the VaR chosen as the risk metric since the hedging objective is defined in terms of a liability value. In particular, a VaR at the confidence level of 5% over the assumed duration of the influenza pandemic is examined as it indicates the minimum level of coverage with a high probability. Furthermore, the estimated HE at the median is also considered as well as the estimated mean HE since the bond was calibrated on an expected value approach. The hedge effectiveness is calculated as follows:

$$HE = 1 - \frac{VaR_{\alpha}(\mathrm{H})}{VaR_{\alpha}(\mathrm{U})}$$

Where:

HE	=	The hedge effectiveness;
H	=	The hedged exposure, equal to the actual aggregate claims minus the bond payoff and retained claims;
U	=	The unhedged exposure equal to the actual aggregate claims minus the retained claims;
$VaR_{\alpha}(H)$	=	The value at risk for the hedged exposure, H, at confidence level α%;
$VaR_{\alpha}(U)$	=	The value at risk for the unhedged exposure, U, at confidence level α%.

We run 10,000 simulations with the specified assumptions at an excess mortality rate of 1 and 1.5 per 1,000 to obtain an empirical distribution of the retained claims and actual aggregate claims, respectively. An excess mortality rate of 1.5 per 1,000 is chosen as it corresponds to the middle of the range of excess mortality rate targeted. Each simulation generates a value for the actual aggregate claims, retained claims and bond payoff, which are used to calculate a value for the HE. The simulated HE values are averaged to calculate the estimated mean HE and sorted to give the estimated HE at the 5th percentile and median.

4.7 Sensitivity analysis

A sensitivity analysis is conducted on the characteristics of the life insurer's portfolio[26]. In performing this analysis, the bond is recalibrated for scenarios (A) 1. and (A) 2. below but not for scenario (A) 3. The changes that are considered include:

(A) 1. Increasing the number of policies in the portfolio to 40, 60, 80 and 100 thousand, produced by replicating the original portfolio[27];

(A) 2. A flat distribution of sum insured with an equivalent average sum insured; and,

(A) 3. A portfolio composition with the age of policyholders increased and decreased by 5 years[28].

Given the inherent uncertainty surrounding future mortality, a sensitivity analysis is also conducted on the mortality assumptions. The changes that are considered include:

(B) 1. Combinations of the AGA 25 year mortality improvement, 100 year mortality improvement, and no mortality improvement for each of the general and insured populations;

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15 to 59 years and 60 to 64 years fluctuate from 19% to 21% and 18% to 22%, respectively (ABS, 2008). Hence, the assumption of equal proportions of individual ages within five year age group band is reasonable.

[26] The same set of random numbers for the 10,000 simulations is used for each of the scenarios to ensure that the effect of changing the parameters is isolated.

[27] As there are a greater number of policyholders in these scenarios, more random numbers were generated to complete the simulations.

[28] A change in the gender composition of the portfolio is not considered as excess mortality rates for males and females are assumed to be the same and hence, by construction, there will be little impact on the hedge effectiveness.

(B) 2. An overall general population excess mortality rate (per 1,000) of 1, 1.25, 1.75, 2 and 2.25;
(B) 3. An age-specific distribution of excess mortality rates of "U", "W" and flat;
(B) 4. An excess insured to general population mortality rate ratio of 40%, 60%, 100% and 120%;
(B) 5. The influenza pandemic occurs in 2011, 2012, 2014, or 2015; and,
(B) 6. An influenza pandemic duration of 2 and 3 years with different severity of waves each year. The scenarios examined include a 2 year influenza pandemic with an excess mortality rate of 1 and 0.5 per 1,000 in the first and second year, respectively; a 2 year influenza pandemic with an excess mortality rate of 0.5 and 1 per 1,000 in the first and second year, respectively; and, a 3 year influenza pandemic with an equal excess mortality rate of 0.5 per 1,000 in each year.

The bond is not recalibrated for these scenarios as the purpose is for potential issuers to examine the effect on HE of various possible outcomes once the bond has been put in place. Given that actual outcomes will differ from those assumed in calibrating the bond, the question of interest is the extent to which the protection provided by the bond is impaired or possibly improved over a range of possible scenarios.

5 Results

5.1 Base scenario

The base scenario represents the situation where actual mortality experience exactly matches the mortality assumptions used to calibrate the bond. Table 6 shows the estimated mean and variance of net claims, where net claims are defined as the aggregate claims minus the bond payoff. The mean and variance of the net claims increase when a pandemic occurs as the higher than expected mortality causes the death of more policyholders with varying sum insured amounts. The difference between the mean of net claims for the pandemic with no bond and pandemic with bond scenarios is equal to the bond payoff, which is constant under each deterministic scenario as no sampling risk was assumed in the general population. For this reason, the estimated variance of net claims is also the same for these two scenarios.

Table 6: Estimated average and variance of life insurer's net claims

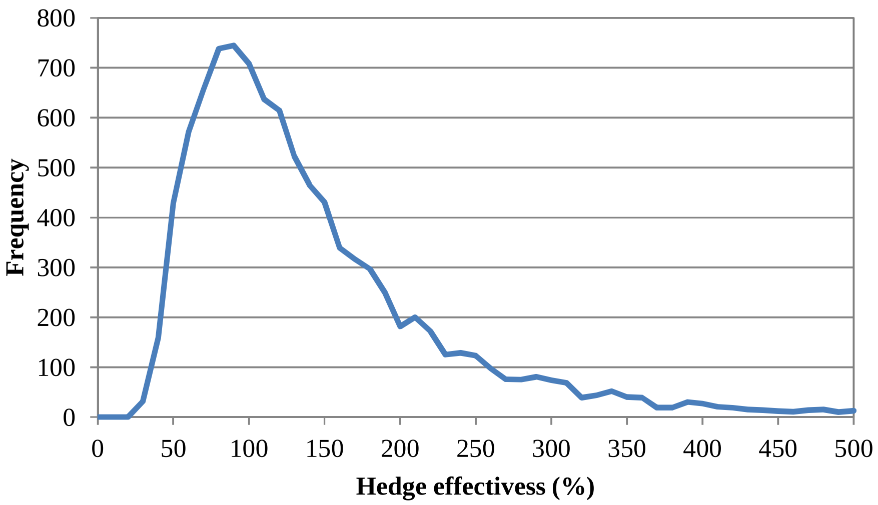
Scenario	Estimated mean of net claims ($ Millions)	Estimated variance of net claims ($ Millions)
No pandemic with no bond	6.77	7.77
Pandemic with no bond	16.38	18.35
Pandemic with bond [a]	13.15	18.35

[a] In this scenario, the bond payoff is is equal to $3.23 million or equivalently half the principal amount because the excess mortality of 1.5 per 1,000 assumed corresponds to the middle of the range of excess mortality rate targeted in the specified hedging objectives.

The distribution of HE under the base scenario is shown in Figure 2[29]. The median HE is 115%, the mean HE is 153%, and the HE at the 5th percentile is 48%[30]. Despite the bond being calibrated on an expected value approach, the estimated mean HE is actually 153% and not 100% as intended which indicates over-hedging[31]. The distribution of HE shows significant skewness, with a long right tail indicating the possibility of gains. This is caused by the combination of a relatively small portfolio size and a non-uniform distribution of sums insured, and is key to the effectiveness or otherwise of catastrophic mortality bonds as an alternative risk management tool. This is considered further in the scenarios chosen for the sensitivity analysis.

Figure 2: Estimated distribution of HE under the base scenario

[29] The estimated distribution of hedge effectiveness is constructed by placing the simulated hedge effectiveness in bins of 10% starting from 0% and ending at 500%.
[30] For clarification, this means that the HE is 48% or less for 5% of simulated runs.
[31] An HE of 100% corresponds to a perfect hedge, an HE lower than 100% implies "under-hedging", and an HE higher than 100% implies "over-hedging". Here the bond provides an average 53% more coverage than required.



5.2 Sensitivity analysis on the characteristics of the life insurer's portfolio

In the following analysis, the HE is considered to have improved either when all the examined HE measures increase, or the distribution of HE becomes less spread[32].

5.2.1 (A) 1. Number of policies

Table 7 shows that as the number of policies increases, the estimated HE at the 5th percentile improves, and both the estimated median and mean HE decrease towards 100%. The latter result suggests that an expected value approach for calibrating the bond may result in a perfect mean HE for larger portfolio sizes.

Table 7: Estimated HE when varying the number of policies

Number of policies	Estimated HE (%)		
	Mean	Median	5th percentile
20,000*[33]	153	115	48
40,000	119	107	57
60,000	114	106	62
80,000	109	103	65
100,000	107	102	68

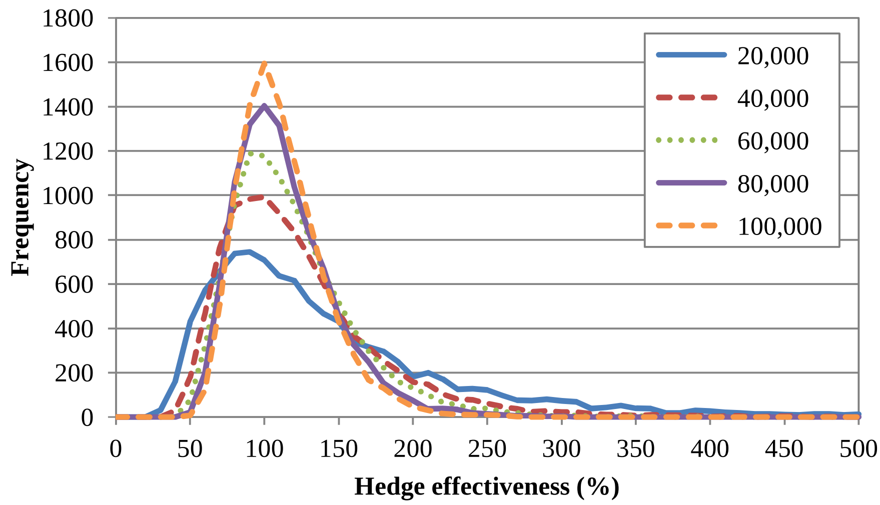
Figure 3 shows that the estimated distribution of HE becomes less spread, less positively skewed and more peaked as the number of policies increase. Overall, this confirms that the HE is substantially improved as portfolio size increases[34] and clearly demonstrates the potential beneficial effect for insurers of considering pooling their portfolios when seeking protection via these instruments.

Figure 3: Estimated distribution of HE when varying the number of policies

[32] "Less spread" is taken to mean that the estimated mean and median HE are closer to 100% and the estimated HE at the 5th percentile increases. This is considered to improve HE despite the estimated mean and median HE decreasing as it implies less variation in the HE and higher minimum HE with a high confidence level.

[33] In this and all further Tables, * indicates the base scenario.

[34] Although a larger portfolio size may be more realistic for many insurers, this was not used in all simulations. This is because the relative changes in the hedge effectiveness when changing the model parameters will remain the same for larger portfolio sizes; the absolute differences in hedge effectiveness at larger portfolio sizes will be smaller and hence, may be more difficult to interpret; and simulations for a smaller portfolio are more tractable as fewer random numbers and calculations are required.



5.2.2 (A) 2. Flat sum insured distribution

Table 8 shows that a flat sum insured distribution has improved HE compared with the base scenario. The estimated mean HE is far closer to 100% while the estimated median HE also falls towards 100%. In addition, the estimated HE at the 5th percentile increases significantly.

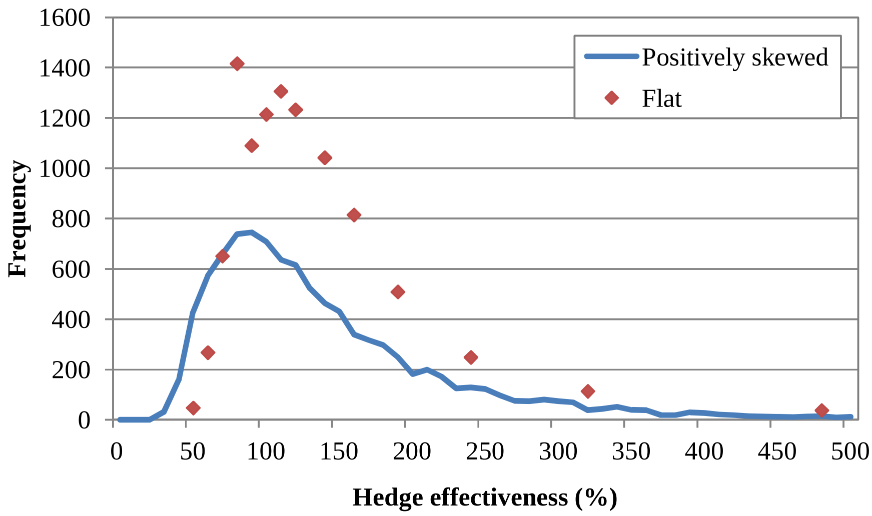
Table 8: Estimated HE for a flat sum insured

Distribution of sum insured	Estimated HE (%) Mean	Median	5th percentile
Positively skewed*	153	115	48
Flat	114	105	63

Figure 4 shows that the estimated distribution of HE with a flat sum insured distribution has a higher peak than the base scenario[35]. The results suggest HE is improved when the catastrophic mortality bond is used as a hedge for a portfolio that has a flat sum insured distribution, and this demonstrates the potential for effective use of a bond in combination with a surplus reinsurance arrangement.

Figure 4: Estimated distribution of HE when varying the distribution of sum insured

[35] The estimated HE distribution is shown as points for the flat sum insured distribution. The HE takes only several values because the actual aggregate claims minus the retained claims is always being a multiple of the assumed, uniform $365,000 sum insured for all policyholders, and the bond payoff is constant under each deterministic scenario.



5.2.3 (A) 3. Portfolio composition by age

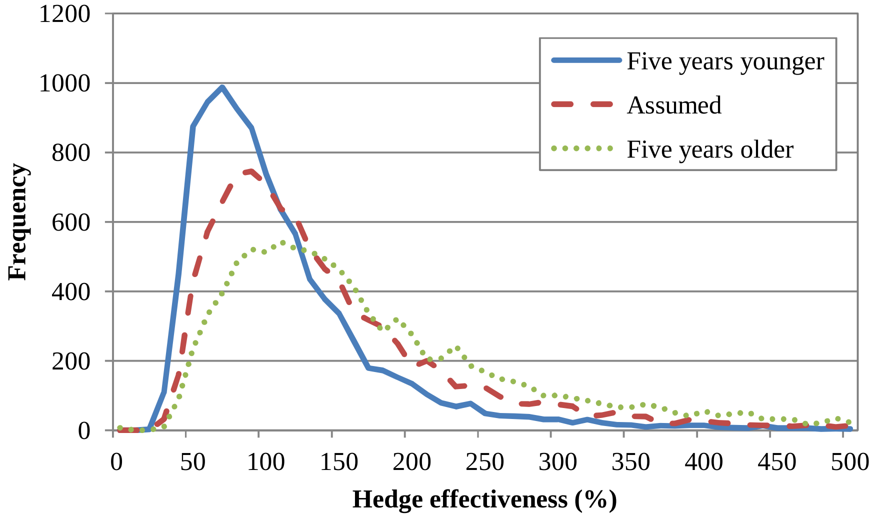
Table 9 indicates that a change in the portfolio composition by age without a change in the calibration of the bond may significantly impact the HE. When the portfolio is five years younger, all the HE measures decrease in comparison to the base scenario. This is because the bond payoff remains the same while claims increase since policyholders on aggregate have increased excess mortality due to the "V\" shape affecting younger policyholders more. This represents a deterioration in HE. In comparison, all the HE measures increase with respect to the base scenario when the portfolio is five years older, thus improving HE.

Table 9: Estimated HE when varying the portfolio composition by age

Portfolio composition by age and gender	Estimated HE (%)		
	Mean	Median	5th percentile
Five years younger	110	88	39
Assumed*	153	115	48
Five years older	217	147	55

Figure 5 illustrates. This finding demonstrates that the inflexibility of the bond to adjust the age (and gender) weightings for the mortality index may have significant consequences for the HE if the portfolio composition changes during the term of the bond.

Figure 5: Estimated distribution of HE when varying portfolio composition by age



5.3 Sensitivity analysis of mortality assumptions

5.3.1 (B) 1. Mortality improvements

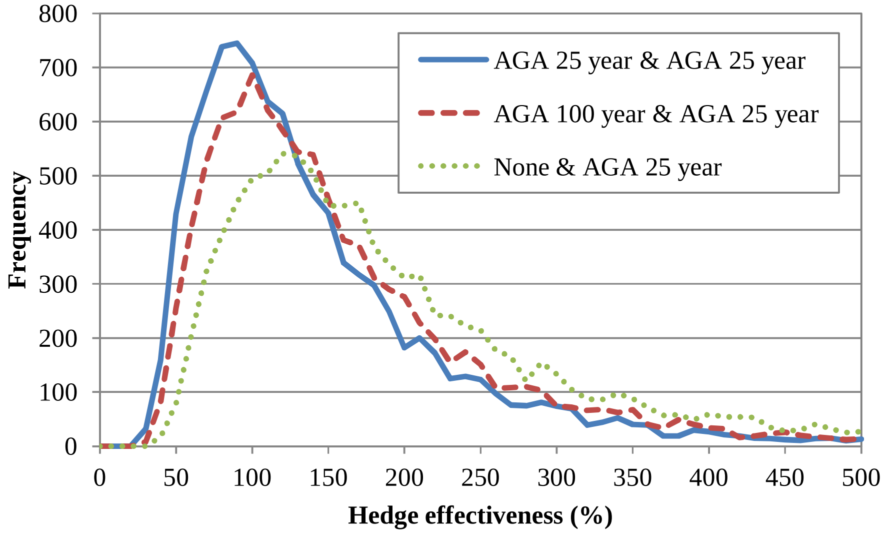
Table 10 shows that the HE is sensitive to changes in the general population mortality improvements but not those in the insured population mortality improvements. As the general population mortality improvements decrease progressively in aggregate from the AGA 25 year trend to the AGA 100 year trend and then to no trend, all the examined measures of HE increase significantly as the bond payoff increases while the claims remained unchanged. The bond payoff increases as the mortality index is higher than in the base scenario. The changes in the insured population mortality improvements do not materially affect the HE as the chosen measure only considers the claims caused by influenza pandemic excess mortality and not baseline mortality.

Table 10: Estimated HE when varying the general and insured population mortality improvements

General population mortality improvement	Insured population mortality improvement	Estimated HE (%)		
		Mean	Median	5th percentile
AGA 25 year*	AGA 25 year*	153	115	48
AGA 25 year	AGA 100 year	153	115	48
AGA 25 year	None	154	114	47
AGA 100 year	AGA 25 year	174	131	54
AGA 100 year	AGA 100 year	174	131	54
AGA 100 year	None	175	130	54
None	AGA 25 year	214	161	67
None	AGA 100 year	214	161	67
None	None	215	160	66

Figure 6 demonstrates that the estimated distribution of HE becomes more spread as the mortality improvements weighted by the bond's age and gender calibration decrease.

Figure 6: Estimated distribution of HE when varying the general population mortality improvements



5.3.2 Overall general population excess mortality rate

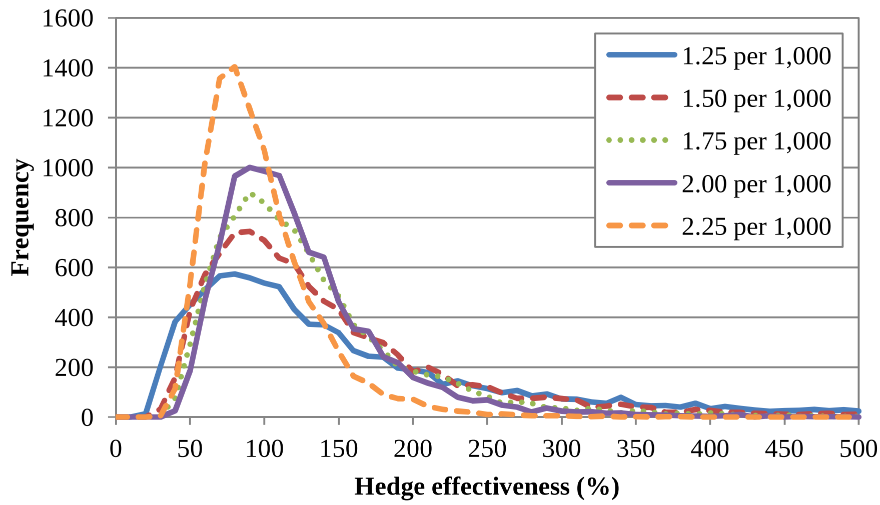
Table 11 reports the estimated HE when varying the overall general population excess mortality rate. The measures are 0% in the scenario with an excess mortality rate of 1 per 1,000 because the bond is not triggered. When the excess mortality rate increases above 2 per 1,000, the bond has already paid the entire original principal amount to the life insurer so the HE measures decrease substantially at an excess mortality rate of 2.25 per 1,000 (compared to 2 per 1,000) as the increase in claims is no longer offset by an increase in the bond payoff. These results are consistent with the intended hedging objectives of hedging against claims caused by an excess mortality rate of 1 to 2 per 1,000. As the excess mortality rate increases from 1 to 2 per 1,000, the estimated mean and median HEs decrease while the estimated HEs at the 5th percentile increase.

Table 11: Estimated HE when varying the overall general population excess mortality rate

Overall general population excess mortality rate (per 1,000)	Estimated HE (%)		
	Mean	Median	5th percentile
1.00	0	0	0
1.25	250	125	37
1.50*	153	115	48
1.75	129	110	53
2.00	120	107	57
2.25	93	84	48

Figure 7 demonstrates that the estimated distribution of HE becomes less spread, less positively skewed and more peaked as the excess mortality rate increases from 1 to 2 per 1,000. After the excess mortality rate exceeds 2 per 1,000, the estimated distribution of HE shifts to the left and becomes more peaked. Overall, this suggests the HE is improved when the excess mortality rate is closer to the upper bound of the range used to calibrate the exhaustion point.

Figure 7: Estimated distribution of HE when varying overall general population excess mortality rate



5.3.3 Age-specific distribution of excess mortality rates

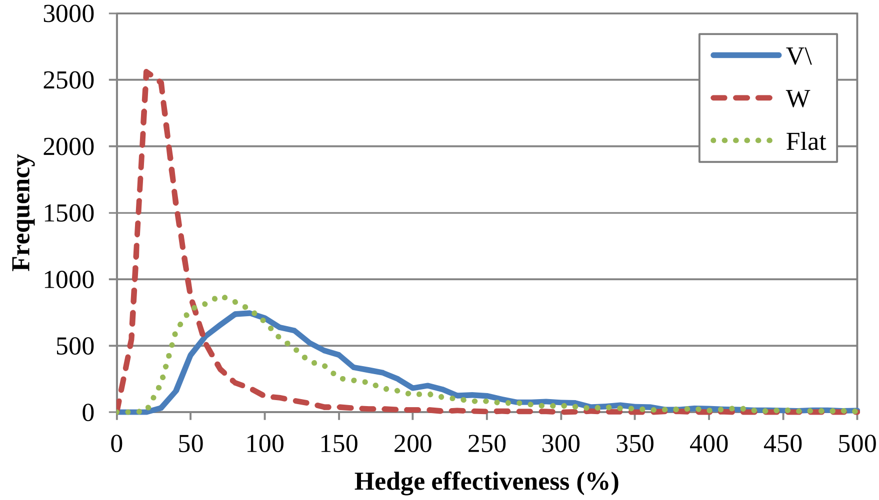
Table 12 indicates that the HE is highly sensitive to changes in the age-specific distribution of excess mortality rates. As the "U", "W" and flat shapes with the same overall general population excess mortality rate result in an increase in the mortality index less than that for the "V\" shape, the bond payoffs for these scenarios are comparatively smaller than the "V\" shape. In addition, the claims for these scenarios are also smaller, but the decrease in bond payoff is proportionally greater than the decrease in claims. This explains the lower estimated HE measures for the "U", "W" and flat shapes in comparison to the "V\" shape. In particular, the estimated HE measures for the "U" shape are 0% because the bond is not triggered in this scenario as the "U" shape primarily affects infants and the elderly, who are given a small weighting in the mortality index. Although the HE measures are poor for the "W" and flat shapes, it is noted that the mean net claims are similar to the "V\" shape.

Table 12: Estimated HE when varying the age-specific distribution of excess mortality rates

Age-specific distribution of excess mortality rates	Estimated HE (%)		
	Mean	Median	5^{th} percentile
V\ *	153	115	48
U	0	0	0
W	42	27	10
Flat	134	91	35

Figure 8 shows that the estimated distribution of HE is fairly similar between the "V\" and flat shape while it differs considerably between the "V\" and "W" shape. Overall, this indicates the HE of the bond is highly sensitive to the shape of age-specific distribution of excess mortality rates in a pandemic event.

Figure 8: Distribution of HE when varying the age-specific distribution of excess mortality rates



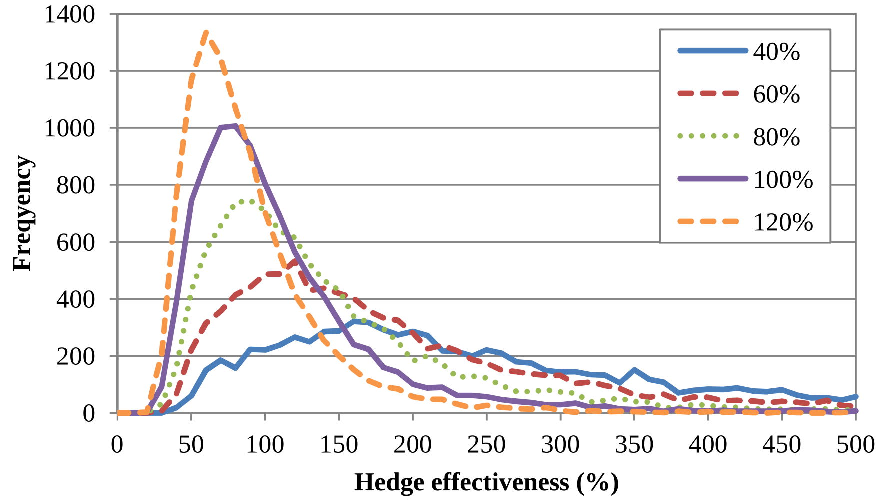
5.3.4 Excess mortality rate ratio of insured versus general population

Table 13 demonstrates that the estimated HE measures fall as the excess mortality rate ratio increases since higher insured mortality rates result in a greater number of policyholder deaths causing claims to increase while the bond payoff remains unchanged. However the fall in HE from higher than assumed excess mortality rate ratio is small relative to the rise in HE from lower than assumed excess mortality rate ratio. Figure 9 illustrates.

Table 13: Estimated HE when varying excess mortality rate ratio of insured versus general population

Excess mortality rate ratio of insured versus general population	Estimated HE (%)		
	Mean	Median	5th percentile
40%	521	250	76
60%	245	160	57
80% *	153	115	48
100%	110	89	40
120%	86	72	35

Figure 9: Estimated distribution of HE when varying excess mortality rate ratio of insured versus general population



5.3.5 Timing of the influenza pandemic

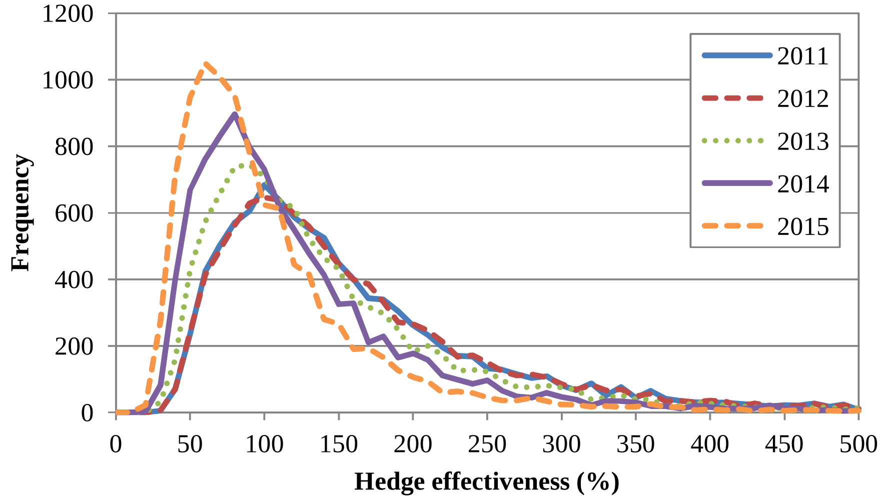
Table 14 reports the estimated HE when varying the timing of the influenza pandemic. The HE measures for an influenza pandemic occurring in 2011 or 2012 are broadly the same. The bond payoff is made at the end of 2012 in both these scenarios since the construction of the mortality index requires two years of mortality experience. Thereafter, the estimated HE measures decrease approximately linearly every year after 2012 since the assumed positive mortality improvements decrease the general population mortality rates every year, which reduces the bond payoff. The fall in insured population mortality rates due to mortality improvements does not affect the HE as the chosen HE measure only considers the claims caused by influenza pandemic excess mortality.

Table 14: Estimated HE when varying the timing of the influenza pandemic

Timing of the influenza pandemic	Estimated HE (%)		
	Mean	Median	5^{th} percentile
2011	177	132	55
2012	178	133	55
2013 *	153	115	48
2014	130	98	40
2015	107	80	33

Figure 10 illustrates. Altogether, the findings suggest there is improved HE when the influenza pandemic occurs earlier than assumed for calibration.

Figure 10: Estimated distribution of HE when varying the timing of influenza pandemic



5.3.6 Duration of the influenza pandemic and severity of waves each year

Table 15 demonstrates that the HE is sensitive to changes in the duration of the influenza pandemic and severity of waves each year, but not the order of these waves. A two year influenza pandemic results in lower estimated mean, median and 5^{th} percentile HE compared to a one year influenza pandemic. This is because a two year influenza pandemic has a lower bond payoff since the mortality index has decreased by one more year of mortality improvements. When the impact of influenza pandemic is spread equally over 3 years, the bond payoff is not triggered and consequently, the estimated HE measures are 0%[36].

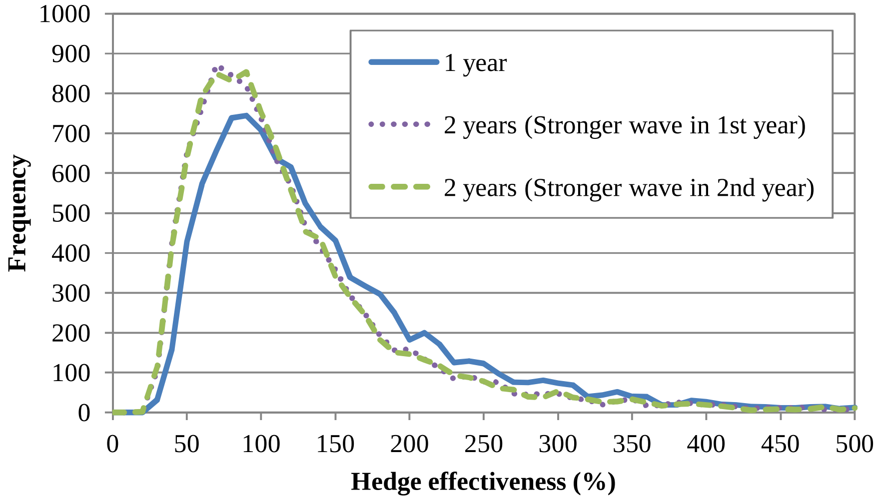
[36] It is noted that this result is highly sensitive to changing the severity and order of waves each year since the mortality index is calculated over a two year measurement period.

Table 15: Estimated HE when varying duration of influenza pandemic and severity of waves each year

Duration of the influenza pandemic and severity of waves each year	Estimated HE (%)		
	Mean	Median	5th percentile
1 year *	153	115	48
2 years (Stronger wave in 1st year)	128	97	40
2 years (Stronger wave in 2nd year)	128	97	39
3 years (Equal waves each year)	0	0	0

Figure 11 indicates that the estimated distribution of HE for a one year influenza pandemic varies somewhat from the two year influenza pandemic scenarios. The two year influenza pandemics with unequal waves have similar distributions. This suggests that the order of the waves does not affect HE in this case. In conclusion, it appears that the HE deteriorates for a two year influenza pandemic of equivalent total severity as the base scenario.

Figure 11: Estimated distribution of HE when varying the duration of the influenza pandemic and severity of waves each year



6 Conclusion

The analysis of the base scenario finds that the hedge effectiveness of catastrophic mortality bonds is highly variable. Although the bond is intended to provide perfect hedge effectiveness the actual estimated mean hedge effectiveness implies substantial over-hedging. This is primarily attributed to the positively skewed distribution of sum insured and the relatively small portfolio size assumed in the base scenario.

The sensitivity analysis on the characteristics of the life insurer's portfolio suggests that catastrophic mortality bonds have improved hedge effectiveness under certain circumstances. Catastrophic mortality bonds appear to be viable alternative risk management tools for large portfolio sizes particularly where the distribution of sum insured is more uniform, and when the life insurer's underlying exposure remains relatively stable.

As the number of policies in the portfolio increases, the overall hedge effectiveness improves significantly. In addition, the estimated mean hedge effectiveness converges to 100% as intended when using the expected value approach for calibrating the bond. This is coherent with the current use of catastrophic mortality bonds as a risk management tool for large, globally diversified insurers and reinsurers. In comparison, reinsurance or retrocession coverage is likely to remain a significantly better risk management tool compared to catastrophic mortality bond for smaller insurers or reinsurers since there is significant basis risk and variation in the hedge effectiveness at smaller portfolio sizes. However, it may be possible for smaller insurers or reinsurers to pool their exposures and issue a catastrophic mortality bond for the aggregated portfolio.

Although age, gender, country and financial exposure in the form of sum insured can be calibrated for catastrophic mortality bonds to match the life insurer's underlying exposure, the hedge effectiveness is highly sensitive to changes in the portfolio composition. As the age and gender weightings are fixed at issuance, any change in the portfolio composition may have a substantial impact on the hedge effectiveness. In particular, a change in the age composition is likely to have a greater impact than a change in gender composition because historical influenza pandemic mortality experience suggests excess mortality rates vary considerably across age, but not by gender. Consequently, factors that may affect the portfolio composition such as a change in marketing and advertising strategy will have serious ramifications for the hedge effectiveness of catastrophic mortality bonds.

Catastrophic mortality bonds provide lower variation in hedge effectiveness for portfolios where the distribution of sum insured is more uniform. A possible hedging strategy stemming from this result is the combined implementation of surplus reinsurance and catastrophic mortality bonds. Firstly, surplus reinsurance should be used to transfer the volatility in the sum insured exposure above a specified retention. Secondly, a catastrophic mortality bond should be used to cover the life insurer's retention. The surplus reinsurance effectively reduces the spread of the distribution of sum insured for which the catastrophic mortality bond is used to provide coverage.

The sensitivity analysis on the mortality assumptions highlights the significant uncertainty surrounding the basis risk and hedge effectiveness of catastrophic mortality bonds. This is due to the inherent uncertainty regarding future mortality rates, particularly in a pandemic scenario where the actual epidemiological characteristics are impossible to predict. In general, catastrophic mortality bonds provide improved hedge effectiveness when: the general population mortality improvements are lower than assumed; the overall general population excess mortality rate is at the upper bound of the range used to calibrate the exhaustion point; the age-specific distribution of excess mortality rates follows the assumed shape; the excess mortality rate ratio of insured versus general population is lower than assumed; the influenza pandemic occurs at the start of the risk period; and, the duration of the influenza pandemic is one or two years.

The research could be extended to analyse the hedge effectiveness for aggregate mortality exposure across a range of life insurance products. For example, traditional products, retirement income products and other risk products could be examined. Other methods of calibrating the characteristics of catastrophic mortality bonds could also be explored as there seems to be no existing literature regarding this area. A detailed investigation into the calibration of catastrophic mortality bonds should provide a better understanding of how to optimise the hedge effectiveness.

Furthermore, a holistic approach to enterprise risk management may consider the interaction of catastrophic mortality bonds with existing risk management strategies such as reinsurance. For example, the previously suggested hedging strategy of pooling portfolios for a bond issuance and/or using both surplus reinsurance and catastrophic mortality bonds to hedge against catastrophic mortality events could be explicitly investigated.

Appendix A

Table 16: Summary of catastrophic mortality bond transactions

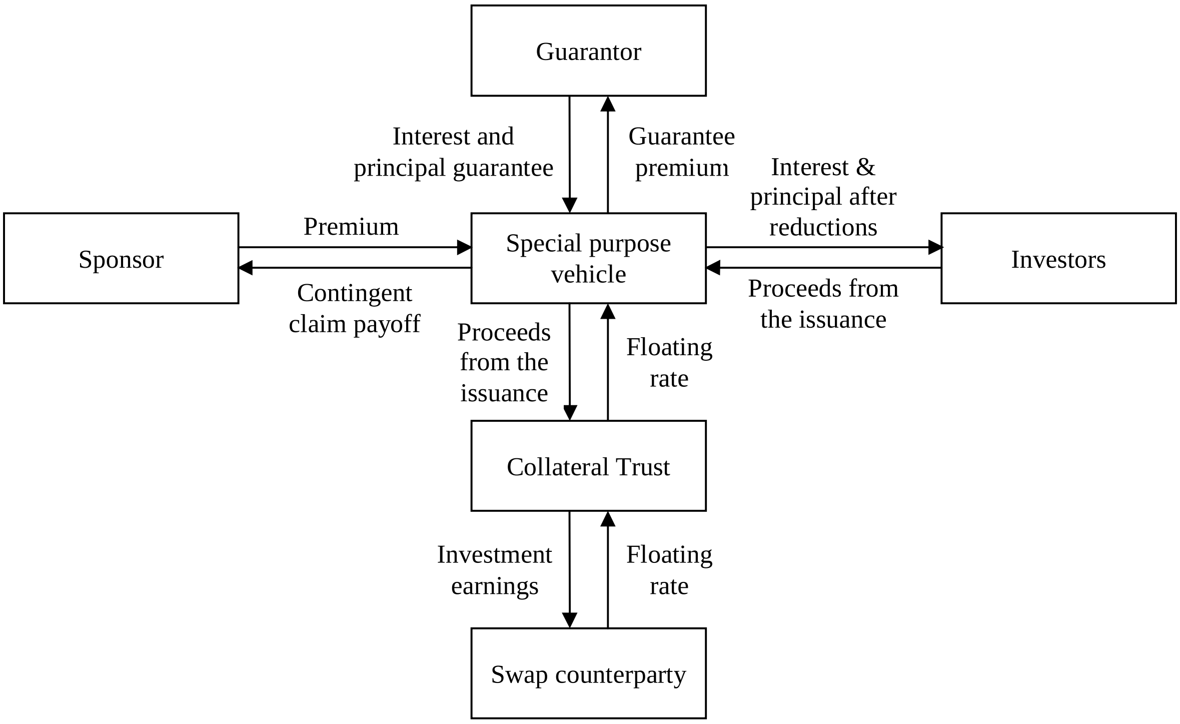
Year	Special purpose vehicle	Sponsor	Maturity (Years)	Principal amount (Millions)	S&P rating at issuance	Initial spread to 3 month LIBOR / EURIBOR (bps)	Attachment / Exhaustion point (%)	Covered Area
2003	Vita Capital I	Swiss Re	4	USD 400	A+	135	130 / 150	U.S. 70%, U.K. 15%, France 7.5%, Italy 5% & Switzerland 2.5%
2006	Vita Capital II	Swiss Re	5 5 5	USD 62 USD 200 USD 100	A- BBB+ BBB-	90 140 140	120 / 125 115 / 120 110 / 115	U.S. 62.5%, U.K. 17.5%, Germany 7.5%, Japan 7.5% & Canada 5%
2006	Tartan Capital	Scottish Re	3 3	USD 75* USD 80	AAA BBB+	19 300	115 / 120 110 / 115	U.S. 100%
2006	Osiris Capital	AXA	4 4 4 4	EUR 100* EUR 50 USD 150 USD 100	AAA A- BBB BB+	20 120 285 500	114 / 119 114 / 119 110 / 114 106 / 110	France 60%, Japan 25% & U.S. 15%
2006	Vita Capital III	Swiss Re	4 4 4 4 4 5 5 5 5	USD 100* USD 100* USD 90 EUR 30 EUR 55* USD 100* EUR 55 USD 50* USD 50	AAA AAA A A AAA AAA AA- AAA A	21 21 110 110 22 20 80 21 112	125 / 145 125 / 145 120 /125 120 / 125 120 / 125 125 / 145 125 / 145 120 / 125 120 / 125	U.S. 62.5%, U.K. 17.5%, Germany 7.5%, Japan 7.5% & Canada 5%
2008	Nathan	Munich Re	5	USD 100	A-	135	120 / 130	U.S. 45%, U.K. 25%, Canada 25% & Germany 5%
2009 to 2011	Vita Capital IV	Swiss Re	5 4 5 5 5 5	USD 75 USD 50 USD 100 USD 75 USD 100 USD 80	BB+ BB+ BB+ BB+ BBB- BB+	650 525 375 370 N/A N/A	U.K.: 112.5/120 & U.S.: 105/110 U.K.: 112.5/120 & U.S.: 105/110 Japan: 107.5/115 & U.S.: 105/110 Canada: 111.5/120 & Germany: 110/115 Canada: 120/130 & Germany: 125 / 135 Canada / Germany: 110 / 115, U.K.: 115 / 120 & U.S.: 105 / 110	U.K. & U.S. U.K &.U.S. Japan & U.S. Canada & Germany Canada & Germany Canada, Germany, U.K. & U.S.

Source: Standard & Poor's (2011)

***** These tranches have been credit enhanced by "monoline" insurers who guarantee the interest and principal payment.

Appendix B

Figure 12: Basic catastrophic mortality bond transaction structure



Source: Linfoot (2007)

Additional technical notes:

The general and insured population excess mortality rate for five year age group *i*, $GPEMR_i$ and $IPEMR_i$, that are applied over the assumed duration of the influenza pandemic are calculated as follows:

$$GPEMR_i = OGPEMR * R_i$$
$$IPEMR_i = GPEMR_i * EMRR$$

Where:

$GPEMR_i$	=	The general population excess mortality rate for five year age group *i*;
$OGPEMR$	=	The overall general population excess mortality rate; and,
R_i	=	The ratio of general population excess mortality rate for five year age group *i* to the overall general population excess mortality rate.
$IPEMR_i$	=	The insured population excess mortality rate for five year age group *i*;
$EMRR$	=	The excess mortality rate ratio of insured versus general population.

The catastrophic mortality bond payoff at the end of measurement period in calendar year *t*, $CMBP_t$, can be expressed as followed:

$$CMBP_t = P \times R_t^C$$

$$R_t^C = Max\left(\frac{Index_t^C - A^C}{E^C - A^C} - R_{t-1}^c, 0\right)$$

Where:

$CMBP_t$	=	The catastrophic mortality bond payoff at the end of measurement period in calendar year *t*;
P	=	The original principal amount;

R_t^C	=	The principal reduction factor for measurement period ending in calendar year *t* and country *C* where R_t^C = 0 for the start of the risk period and $0\% \leq \sum_t R_t^C \leq 100\%$;
$Index_t^C$	=	The mortality index for measurement period ending in calendar year t and country *C*;
A^C	=	The attachment point for country *C*; and,
E^C	=	The exhaustion point for country *C*.

The mortality index for measurement period ending in calendar year *t* and country *C*, $Index_t^C$, can be expressed as:

$$Index_t^C = \frac{\overline{q}_t^{\mathrm{C}}}{\overline{q}_{\text{reference years}}^{\mathrm{C}}}$$

$$\overline{q}_t^{\mathrm{C}} = \frac{1}{2} * (q_t^{\mathrm{C}} + q_{t-1}^{\mathrm{C}})$$

$$q_t^C = \sum_x (w_{x,m}^{\mathrm{C}} * q_{m,x,t}^{\mathrm{C}} + w_{x,f}^{\mathrm{C}} * q_{f,x,t}^{\mathrm{C}})$$

Where:

$Index_t^C$	=	The mortality index for measurement period ending in calendar year *t* and country *C*;
$\overline{q}_t^C$	=	The two year average mortality rate over measurement period ending in calendar year *t* for country *C* where the reference years correspond to the two years before the start of the risk period;
q_t^C	=	The annual mortality rate for country *C* in calendar year *t*;
$q_{m,x,t}^C$	=	The mortality rate for males of country *C* and age group *x* in calendar year *t*;
$q_{f,x,t}^C$	=	The mortality rate for females of country *C* & age group *x* in calendar year *t*;
$w_{x,m}^C$	=	The weight applied to male mortality rates of country *C* and age group *x*;
$w_{x,f}^C$	=	The weight applied to female mortality rates of country *C* and age group *x*.

The future average sum insured in year *t*, ASI_t, can be expressed by the following formula:

$$ASI_t = ASI_s * \prod_{x=s}^{t-1} (1 + TUR * AIR_x)$$

Where:

ASI_t	=	The future average sum insured in year *t*;
ASI_s	=	The past average sum insured in year *s*, where *s* < *t*;
TUR	=	The take up rate; and,
AIR_x	=	The annual inflation rate in year *x*.

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