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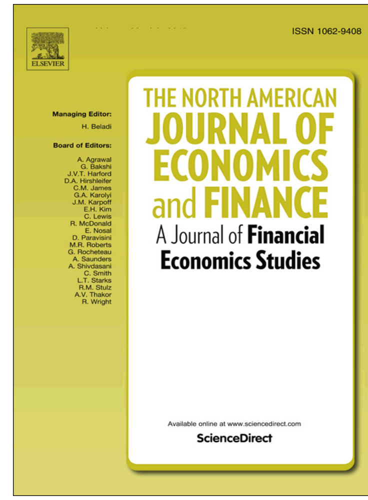

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Hui-Hsuan Liu, Ariana Chang, Yung-Ming Shiu

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Hui-Hsuan Liu
Department of Finance
Ling Tung University
Tel: +886-4-23892088
Email: huihsung911@teamail.ltu.edu.tw

Ariana Chang
Department of Business Administration
Fu Jen Catholic University
Email: 140517@mail.fju.edu.tw

Yung-Ming Shiu
Professor, Department of Risk Management and Insurance,
Research Fellow, Risk and Insurance Research Center, College of Commerce
National Chengchi University, Taiwan
64, Sec. 2, Zhi-Nan Road, Wen-Shan District, Taipei 11605, Taiwan
Tel: +886-2-29393091 ext. 81014
Fax: +886-2-29393864
Email: yungming@nccu.edu.tw

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ABSTRACT

Our primary aim in this study is to determine the relation that exists between the use of interest rate derivatives by public-traded life insurance firms and their exposure to interest rate risk. Based upon the annual reports and 10-K filings of US life insurers, covering the years 2000 to 2016, we find that those insurers with greater inherent exposure to interest rate risk also have a propensity for extensive engagement in the use of interest rate derivatives. We further reveal that life insurers with a propensity for the extensive use of such instruments during the 2000-2009 sub-period tend to have greater observable exposure to interest rate risk. However, during the 2010-2016 sub-period life insurers that use more interest rate derivatives tend to have smaller interest rate exposure. Since restructuring the balance sheet of a life insurer is costly, our results suggest that managers probably use derivatives as a means of modifying their risk tolerance to achieve the same results of direct duration matching.

Keywords: Interest rate derivatives; Interest rate risk exposure; Life insurers.

JEL Classification: G32.

1. INTRODUCTION

Interest rate risk, which is one of the major risk elements to be faced by life insurers, is due largely to the mismatches that exist between the duration of their insurance products and their asset holdings;[1] for example, life insurance products (such as permanent life insurance and annuities) are generally of a long-term nature, with some of these products also including savings elements, guarantees and policyholder options. Therefore, in order to mitigate their exposure to interest rate risk, life insurers tend to concentrate their investments on interest rate-sensitive assets at the longer end of the maturity spectrum, such as government bonds and corporate securities, including bonds, stocks and mortgages (Cummins et al., 1997; Saunders and Cornett, 2008).[2]

In addition to the asset-liability management issue referred to above, as noted in several of the prior studies, over recent decades, the use of derivatives has gradually increased among life insurers in the US as a means of mitigating their exposure to interest rate risk.[3] Prior to such widespread use of derivatives, exposure to interest rate risk among life insurers was mainly determined by their business operations, such as the

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1 Interest rate risk arises from changes in interest rates, with these changes affecting the value of a firm through their effect on the present value of the firm's net cash flows, as reflected in the value of the their assets and liabilities (Harrington and Niehaus, 2004).

2 Unlike life insurers, nonfinancial firms are primarily concerned with hedging against exchange rate risk (Naylor and Greenwood, 2008; Bartram et al., 2011). In addition, interest rate risk is also one of the most important risks that are faced by banks. Both the value of asset and liability on their balance sheet are affected by interest rate fluctuations. Consequently, banks are impacted by changes in the term structure of interest rates, changes in interest rate spreads, and the volatility of interest rates (Hirtle, 1997). Banks have relied increasingly on interest rate derivatives (Kim and Kopennhaver, 1993; Brewer et al., 1996; Li and Mao, 2003; Purnanandam, 2007).

3 See Hoyt (1989), Colquitt and Hoyt (1997) and Cummins, Phillips and Smith (1997).

composition of their asset and liability portfolios (including type, maturity dates, liquidity and market value). In most cases, the business operations of insurers are relatively stable, which is an essential element in meeting their own business objectives, and as such, their operations cannot normally be adjusted within a short period of time. Thus, there is some likelihood that insurers will need to use interest rate derivatives to modify their interest rate exposure to a desirable level.

It is, however, worth noting that most states limit the use of derivatives by insurers to hedging purposes only; thus, the firms are subject to strict and detailed regulations on the permitted use of derivatives. For instance, the National Association of Insurance Commissioners (NAIC) Derivative Instruments Model Regulation sets standards for the use of derivatives by insurers, such that they are required to submit a derivatives usage plan to the state insurance department for prior approval. Insurers should, therefore, seek to establish written guidelines for engaging in derivative transactions.[4]

Given that the empirical results reported in the prior related studies on the impact of underlying risk exposure on derivative usage have been somewhat mixed,[5]

[4] The guidelines should include, for example, the type and maturity of derivatives, the asset/liability management practices regarding derivative transactions, the limitations on derivative usage and the impact of such usage on the operations of the insurers.

[5] For example, Colquitt and Hoyt (1997) suggested that life insurers with greater exposure to interest rate risk also appeared to have stronger incentives to participate in futures and options transactions. Conversely, Cummins, Phillips and Smith (2001) and De Ceuster, Flanagan, Hodgson and Tahir (2003) found that life insurers with larger maturity gaps tended to be less reliant on derivative usage. Nevertheless, neither study could find any significant impact of the maturity gaps of life insurers on their use of derivatives.

we set out in the present study with the aim of reexamining the entire issue. Furthermore, to the best of our knowledge, no research has yet been undertaken into the potential impact on the observable risk exposure of insurers arising from their use of derivatives.[6] We argue that interest rate derivatives are used by life insurers as a means of adjusting their exposure to interest rate risk. Given that research into the impact of underlying risk exposure on derivative usage and the influence of such usage on observable risk exposure does not yet appear to have been carried out within a single research setting, we aim to fill this gap within the literature.

Consistent with our expectations, we find that life insurers with greater underlying exposure to interest rate risk are not only more likely to use interest rate derivatives, but also prone to engaging in the extensive use of such instruments. We also find evidence in support of the view that life insurers using interest rate derivatives, particularly those with a propensity for the extensive use of such instruments, can operate under higher levels of exposure to interest rate risk. This finding is in line with the notion that life insurers may use interest rate derivatives as a means of modifying their interest rate exposure to a more acceptable level. We further divide our sample period into two sub-periods, including pre-crisis (2000-2009) and post-crisis (2010-2016) sub-periods. We find that the relation between interest rate derivatives usage and

[6] In contrast to the present study, from an examination of derivative usage by general insurers and the effects on their overall level of solvency, Shiu (2010) found that non-life insurers using derivative hedging had a lower level of solvency; however, no relationship was discernible between the derivative hedging activities and solvency of life insurers.

interest rate risk exposure is significantly positive during the pre-crisis sub-period, while negative during the post-crisis sub-period.

Our study is closely linked to that of Hentschel and Kothari (2001), although there are several areas in which there are obvious major differences.[7] Firstly, their study used data on US corporations over a relatively limited sample period, covering the years 1992 to 1993, and with all insurance companies being excluded; in contrast, we use data from the US life insurance industry covering the years 2000 to 2016. In this study, we test the relation between interest rate derivative use and interest rate risk exposure. The life insurance sector provides a potentially interesting setting within which to conduct our test for the following reason. Life insurers face a common exposure to interest rate movement to a great extent. It is very likely that insurers with high underlying interest rate risk exposure have stronger incentives to hedge with interest rate derivatives. We there build a model that controls for the underlying exposure of an insurer to interest rate risk (i.e., mismatch between assets and liabilities) in order to avoid the difficulties in interpreting cross-sectional tests of derivative use (Guay, 1999). Our study offers a potentially clear empirical test of the relation of life insurers' interest rate derivative use and risk exposure even when they are mandated to use derivatives to hedge. Secondly, in their volatility regression,

[7] In their volatility regression, Hentschel and Kothari (2001) indicated the possibility that derivative usage may be endogenous and therefore carried out an instrumental variable regression analysis as a check for robustness. Their analysis is essentially equivalent to the 2SLS approach adopted in the present study.

Hentschel and Kothari (2001) included only leverage, the market value of equity and the book-to-market ratio as the control variables. In contrast, we identify additional control variables based upon the related literature, and go on to consider their possible effects on interest rate risk exposure. Thirdly, we further test whether our results are sensitive to time periods and insurers size.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

The bi-directional relationships between derivative usage and a firm's exposure to risk are generally examined separately for banking and non-financial firms within the finance literature;[8] and indeed, it has often been suggested that firms with greater inherent exposure to risk also have a greater likelihood of engaging in the use of derivatives (Shiu and Moles, 2010), as well as a propensity for the extensive use of such instruments (Sinkey and Carter, 2000; Adkins, Carter and Simpson, 2007).

However, the evidence on the effects of derivative usage by firms on their exposure to risk remains inconclusive. For example, it is argued in several of the prior studies that no correlation exists between derivative usage and firm risk,[9] whilst others suggest that derivative usage leads to a reduction in firm risk;[10] furthermore, it

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[8] It is worth noting that banks are not faced with the same restrictions as insurers with regard to the use of derivatives for non-hedging purposes. In the derivatives markets, banks may act as end users or dealers, or both. As end users, banks can use derivatives either to hedge or to speculate. For trading purposes, large banks may act as dealers by providing over-the-counter derivative products to non-financial firms or other banks.

[9] Examples include Koski and Pontiff (1999), Hentschel and Kothari (2001) Guay and Kothari (2003) and Bali, Hume and Martell (2007).

[10] See Shanker (1996), Goldberg, Godwin, Kim and Tritschler (1998), Guay (1999), Allayannis and Ofek (2001) and Yang, Song, Yi and Yoon (2006).

is even argued that the use of interest rate derivatives actually increases the exposure of banks to interest rate risk (Hirtle, 1997; Yong, Faff and Chalmers, 2009).

Unlike their non-life counterparts, life insurers, particularly those issuing long-term guaranteed insurance contracts, have inherent exposure to high levels of interest rate risk (Hoyt, 1989). Although decisions by life insurers on what type of assets to invest in are based upon their liability portfolio, and whilst they also have a sense of urgency with regard to applying asset/liability management tools to manage their overall interest rate risk (Santomero and Babbel, 1997), they may deliberately choose not to match the maturities of assets and liabilities in order to obtain profits, or indeed, they may simply be unable to find appropriate assets with maturities which can match certain insurance liabilities with extremely long maturities. Thus, the use of interest rate derivatives (such as interest rate swap contracts) has become common practice for the management of interest rate risk within the life insurance industry.

Brewer, Carson, Elyasiani, Mansur and Scott (2007) noted that in terms of the value of a life insurer, exposure to interest rate risk is an important and influential factor, essentially because the equity of such firms is sensitive to long-term interest rate risk. Daniel and Steven (2005) found that when firms had greater underlying exposure to interest rate risk, they tended to actively engage in the use of interest rate derivatives as a means of offsetting such exposure. If firms use derivatives for hedging purposes, we would expect to find riskier firms holding more derivatives than less risky firms.[11] Since insurers are restricted to using derivatives only for hedging purposes, we would expect to find that life insurers with higher underlying exposure to interest rate fluctuations would be more likely to use interest rate derivatives, and that they would also exhibit a propensity for the extensive use of such instruments.

According to the survey carried out by Hoyt (1989), the most common applications for life insurers using financial futures were "to lock in the current yield for an anticipated inflow of cash in the near future", "to hedge against the depreciation of fixed-income assets as interest rates rise" and "to adjust the duration of assets in order to reduce the asset/liability mismatch". All of these uses are related to interest rate risk, which therefore suggests that it is actually quite commonplace to find life insurers using derivatives specifically as a means of managing their interest rate risk.

Cummins et al. (1997) further noted that the most common types of derivatives used by life insurers were interest rate swaps, caps and floors, along with bond futures, from which they concluded that life insurers were apparently using derivatives as their primary means of managing both their interest rate risk and their

[11] However, it is unclear whether derivative use would rise or fall with increases in the firms' underlying risk exposure if they used derivatives for non-hedging (e.g., speculative or trading) purposes.

currency risk. Venkatachalam (1996) suggested that the overall perception was that the use of derivatives for hedging purposes generally leads to a reduction in firm risk; and indeed, Tufano (1996) also found that derivatives were used in the gold mining industry as a means of reducing the gold price risk.

Brewer, Jackson and Moser (1996) documented a negative relationship between the volatility of equity returns and interest rate derivative usage, along with a similar negative relationship between the volatility of stock returns and the use of interest rate swap agreements by a depository institution. Shanker (1996) also noted that derivatives were very effective in reducing the interest rate risk of large banking firms, whilst Guay (1999) further pointed out that there was a considerable decline (of 22 per cent) in the exposure to interest rate risk amongst firms in the year in which their use of interest rate derivatives began.

Sinkey and Carter (2000) provided evidence to show that those banks with a higher probability of bankruptcy were more likely to use derivatives in order to reduce their insolvency risk, whilst Yang et al. (2006) noted that capital market participants generally perceived the use of derivatives by banks as a hedge against risk. Based upon the analysis of the relationship between bank characteristics and interest rate risk management behavior, Purnanandam (2007) found that derivative usage could minimize the risk of external shocks on the operational policies of a firm.

Turning to some of the more recent studies, Yong et al. (2009) documented a negative effect on the short-term exposure to the interest rate risk of banks arising from their use of derivatives (particularly with regard to interest rate derivatives), whilst Singh (2009) also provided evidence of a reduction in exposure to interest rate risk for lodging firms following their initial use of interest rate derivatives. Nevertheless, it is argued in many related studies that there is no evidence of any discernible correlation between derivative usage and the observed risk of the firms.

Koski and Pontiff (1999), for example, demonstrated that there were no statistical differences between derivative users and non-users in the mutual fund industry, in terms of either their measured risk or their return performance. Hentschel and Kothari (2001) also noted that the use of derivatives by firms did not result in any measurable change (increase or reduction) in the volatility of their returns. Other related studies have similarly found that the exposure of firms to variations in interest rates has no direct correlation with their derivatives positions.[12]

A third string of the literature further demonstrates the contradictory results on the effects on firm risk attributable to derivative usage; for example, using evidence on a sample of US banks, Hirtle (1997) showed that an increase in the use of interest rate derivatives corresponded to greater exposure to interest rate risk, which is

[12] No significant relationship was found between derivative usage and exposure to interest rate risk in either Simons (1995) or Angbazo (1997).

consistent with the notion that bank-holding companies use derivatives to enhance their interest rate exposure. Yong et al. (2009) also found that banks with higher levels of derivative usage, particularly interest rate derivatives, had higher long-term exposure to interest rate risk. Based on the above discussion, we make no prior assumptions on the direction of the effects of interest rate derivatives on exposure to interest rate risk.

3. METHODOLOGY AND EMPIRICAL FRAMEWORK

The decision by a firm to engage in hedging is, theoretically, dependent upon its underlying risk exposure and the extent to which it is exposed to the factors motivating risk reduction, such as tax and managerial incentives. In more specific terms, the underlying exposure of a firm to interest rate risk is determined by its asset and liability portfolios, with such exposure being primarily captured by the asset-liability mismatch variable (Colquitt and Hoyt, 1997). The observable risk level exposure would then be primarily determined by the underlying exposure of the firm, whether the firm hedges, and if so, the extent of such hedging. We therefore specify the following models which are consistent with the underlying economic framework discussed above.[13]

$$IRD_{i,t} = f_1\left(Mismatch_{i,t}, CV_{1,i,t-1}\right) + e_{1,i,t} \quad (1)$$

[13] Under this economic framework, two assumptions are made. Firstly, we assume that the firm's liability structure is exogenous to its decision to hedge. Secondly, the firm's decision on how to invest in the assets is also assumed to be exogenous. In this case, the firm's underlying exposure to interest rate risk is determined by its assets and liabilities.

$$IREX_{i,t} = f_2\left(IRD_{i,t}, CV_{2,i,t-1}\right) + e_{2,i,t} \quad (2)$$

where $IRD_{i,t}$ is a dummy variable indicating the decision to engage in interest rate derivative usage (interest rate derivative users are assigned a value of 1, whilst non-users are assigned a value of 0), or a continuous variable (*IRD_Usage*, proxied by the balance of the year-end notional value of interest rate derivatives scaled by the total assets of the life insurer) representing the decision made by insurer *i* with regard to the extent of derivative usage in year *t*.[14]

Mismatch is an interest rate exposure variable indicating the underlying mismatch between an insurer's assets and liabilities. $IREX_{i,t}$ denotes the observable exposure to interest rate risk of insurer *i* in year *t*; CV_1 and CV_2 are two different sets of control variables which are identified based upon the theoretical arguments and empirical evidence presented in the extant insurance and finance literature;[15] and $e_{1i,t}$ and $e_{2i,t}$ are classical disturbances.

The decision to engage in interest rate derivative usage is estimated using a Probit regression, whilst the extent of such engagement in interest rate derivative usage is estimated using a Tobit regression. We also estimate Equation (1) using one-way and two-way fixed-effects models. It is worth noting that since the sample of insurers engaging in the use of derivatives is not a random sample, this thereby

[14] Sinkey and Carter (2000) and Shiu and Moles (2010) considered the year-end notional value of derivatives to be a satisfactory measure of the involvement of banks in derivatives.
[15] See Guay (1999) and Hentschel and Kothari (2001).

indicates a selection issue; we therefore used the two-step method to address the endogeneity of the decision to engage in derivative usage.

In more specific terms, Equation (1) was used to obtain the fitted values of *IRD* and *IRD_Usage* (that is, *IRD_hat* and *IRD_Usage_hat*); these fitted values for *IRD* and *IRD_Usage* were then included into Equation (2). We also used the Heckman (1979) two-stage approach for the estimation of the model with regard to the effect of engagement in derivative usage on the observable interest rate exposure.[16] We further adopted 'ordinary least squares' (OLS) and both one- and two-way fixed-effects estimation models to determine the relationship between derivative usage and observable interest rate exposure.

We subsequently went on to undertake a variable addition test, as proposed by Wu (1973), in order to examine the endogeneity of the control variables. As expected, the results revealed that several explanatory variables, including *Leverage* and *Liquidity*, were found to be at least partially endogenous.[17] We also followed several of the prior studies to lag the independent control variables as a further control for potential endogeneity (e.g., Tufano, 1996; Guay, 1999).

Following Flannery and James (1984) and Bali et al. (2007), we measured the

[16] We began by estimating a Probit model on the decision to engage in derivative usage in order to obtain the inverse Mills ratio; this ratio was then used as an additional regressor in the OLS model estimation. As shown in Table 5, the inverse Mills ratio is found to be insignificant in Equation (2), thereby suggesting that there is no severe selection bias problem in our data (Johnston and DiNardo, 1997).
[17] The results are not reported here for space considerations, but are available on request.

observed interest rate exposure as the coefficient β_{1i} from the following equation:

$$SR_{i,t} = \beta_{0,t} + \beta_{1,i,t} IR_t + \beta_{2,i,t} R_{m,t} + e_{i,t} \tag{3}$$

where $SR_{i,t}$ is the common stock return of life insurer i in month t; IR_t is the percentage change in the six-month LIBOR rate in month t;[18] $R_{m,t}$ is the rate of return on the market index in month t; and $e_{i,t}$ is the error term. A time interval of three years is employed for our estimations.[19] $\beta_{0,t}$ is a constant, with $\beta_{1,i,t}$ representing the exposure to interest rate risk, which is measured as the percentage change in the rate of return on the common stock of the life insurer as a result of a 1 per cent change in interest rates, and $\beta_{2,i,t}$ representing the rate of return on the CRSP equally-weighted index for market capitalization in the NYSE, AMEX and NASDAQ.

4. DATA AND VARIABLES

4.1 Data

From 1992 onwards, the NAIC required the derivative activities of life insurers to be reported in Schedule DB of their statutory annual reports.[20] As a result, the Financial

[18] We follow Hentschel and Kothari (2001) and Singh (2009) to use the six-month LIBOR rate, essentially because this is a common benchmark for short-term and floating interest rate instruments.

[19] For instance, each insurer's exposure for the year 2005 is estimated using monthly returns data during the three-year period surrounding 2005 (2004-2006).

[20] As will be explained later, as opposed to using Schedule DB, in this study we use the data from a number of sources (including Compustat, Edgar 10-K filings, company annual reports and the CRSP stock database) for the following two reasons. Firstly, we need data on stock returns for our empirical analysis, and although the NAIC statements are on an individual firm basis, some insurers are publicly traded through financial groups or holding companies; therefore, the necessary data must cover the use of derivatives by both the insurers and their groups. Secondly, stockholders are presumably more concerned with financial information on an ongoing basis rather than on a liquidation basis; derivative instrument reporting in Schedule DB is based on statutory accounting principles (SAP). We also use the same databases adopted in several of the related studies in order to facilitate a comparison of our results with theirs (see Hentschel and Kothari, 2001; Guay and Kothari, 2003; Bali, et al., 2007).

Accounting Standards Board (FASB) issued Statement No. 119 (SFAS 119), effective from June 1994, which required firms to disclose the details of their derivative contracts, including the amounts, nature and terms of the derivatives. In January 2001, SFAS 119 was superseded by SFAS 113. Under this new requirement, insurers were required to classify their derivative holdings as either assets or liabilities, and to ensure that they were measured at fair value.

Insurers were required to identify their risk exposure, establish adequate systems for measuring and controlling such exposure and appropriate limits for various types of identifiable exposure relevant to all derivative transactions. Insurers were also required to establish adequate internal control procedures to effectively deal with derivative usage prior to engaging in derivative transactions. By the year 2008, the US life insurance industry was ranked the world leader, generating annual premiums of US$578.21 billion (Swiss Reinsurance Company, 2009).

A search of the Standard & Poor's Compustat database, which facilitated the identification of firms with a four-digit 'standard industrial classification' (SIC) code of 6311, provided us with an initial study sample of 45 life insurers from 2000 to 2016. As shown in Table 1, several criteria were employed to exclude firms from our initial sample. Based on the selectin criteria listed in the table, the resulting sample includes 37 life insurers, out of which 26 insurers are listed firms. The insurance firms within this sample were required to have returns data listed on the Center for Research in Security Prices (CRSP) stock database. The availability of returns data enables us to estimate the interest rate exposure of these insurers. We therefore only include the 26 listed firms with 412 firm-years observations in our final sample. Out of these 412 firm-years observations, 301 observations are from interest rate derivatives users, while 111 observations are from non-users. The years in which the sample firms use interest rate derivatives are reported in Table 2. These insurers had disclosed detailed information on their use of derivatives in both their EDGAR Online 10-K filings and annual reports over the sample period. Survivorship bias is not regarded as a problem in our study as our dataset includes all life insurers in existence during the analysis period, each of whom had complete data for analysis, even if they failed to survive until the end of the period.

<Tables 1 and 2 are inserted about here>

Our dataset was constructed on the basis of a search of keywords (e.g. Derivatives; Hedge; Interest rate risk; Swaps; Options; Forward et al.) relating to derivatives, with the information on the derivative activities of insurers being collected from 10-K filings and annual reports, including (1) Item 7A: Quantitative and Qualitative Disclosures About Market Risk; (2) Market Risk Exposures of Financial Instruments-Interest Rate Risk; (3) Derivative Financial Instruments; (4)

Market Risk Exposures; (5) Market Risk Related to Interest Rates; (6) the Management Discussion and Analysis and Footnotes in company annual reports. Individual searches of the websites of the firms were also carried out in order to ensure the correctness of the data. Table 3 presents the number of listed life insurers that use interest rate derivatives and their usage amount, while Table 4 reports the usage amount of different types of interest rate derivatives.

<Tables 3 and 4 are inserted about here>

As shown in Figure 1, the interest rate derivatives increased significantly during the sample period, from US$ 167,000 million in 2000, to US$ 478,000 million in 2016. This figure also illustrates the types of derivative contracts used by life insurance firms; as we can see, consistent with the prior studies, interest rate swaps are found to be the most commonly used instruments by life insurers, followed by options and forwards/futures.[21] The reasons provided in the public disclosures of the insurers for their use of interest rate derivatives included managing their exposure to fluctuations in interest rates, reducing income statement volatility and converting interest receipts on floating-rate securities to fixed rates.[22]

[21] Refer to Simons (1995), Sinkey and Carter (2000) and Reichert and Shyu (2003). In a capital markets special report presented by the NAIC's Capital Markets Bureau, it is also documented that interest rate swaps are the most common swaps (83%), followed by currency swaps (8%), total return swaps (4%) and credit default swaps (3%) as of December 31 2015 (source: *https://www.naic.org/capital_markets_archive/170323.htm*).

[22] Other reasons included mitigating the interest rate risk associated with mortgage loan commitments, reducing interest rate risk and duration imbalances determined in asset/liability analyses, hedging some of the exposures related to investments backing both insurance products and company borrowings, offsetting risks associated with the guaranteed living benefits features of certain variable

< Figure 1 is inserted about here>

Figure 2 further illustrates the trend of interest rate derivative usage and its corresponding interest rate exposure for life insurers. It appears that interest rate derivative usage and its corresponding interest rate exposure are positively related to each other before 2009, while negatively afterwards.

< Figure 2 is inserted about here>

4.2 Variables

The decision by a firm to engage in interest rate derivative usage is measured in this study using a dummy variable, whilst their overall derivative usage is measured using a continuous variable (Guay, 1999; Hentschel and Kothari, 2001). The *IRD* dummy takes the value of 1 for interest rate derivative users, otherwise 0; the *IRD_Usage* variable is measured as the year-end notional value of the interest rate derivatives scaled by the total assets of the firm (the notional value of the derivatives represents the principal amounts on which interest payments are based, and thus, contains information on overall derivative usage).[23]

The *Mismatch* variable, which refers to the underlying interest rate exposure of an insurer, reveals the mismatch between its assets and liabilities. We follow Flannery

annuity products and protecting investment spread from interest rate changes during mismatches in the timing of cash flows between product sales and the related investment activity.

[23] Under current accounting standards, mark-to-market information on derivative usage is unavailable. The use of notional value ignores the potential netting effect since the notional amount aggregates long and short positions. Nevertheless, it is still considered in the prior studies (such as Colquitt and Hoyt, 1997 and Sinkey and Carter, 2000) as a satisfactory measure of the extent of derivative usage.

and James (1984: 1144) and Colquitt and Hoyt (1997: 656) to use two variables, *Mismatch_MISSASST* and *Mismatch_MISSLIAB*, for the measurement of the underlying interest rate risk exposure, with the former representing the mismatch between long-term assets and long-term liabilities (where the resulting difference is positive), and the latter representing the absolute value of the mismatch between long-term assets and long-term liabilities (where the resulting difference is negative).[24] The rationale for the use of these variables is that they will help to assess whether these two types of mismatch have different effects on the decisions by insurers to engage in derivative usage (Colquitt and Hoyt, 1997).

The definitions of all of the dependent and explanatory variables are presented in Table 5 and further discussed in the subsequent sub-sections. Since those variables that can effectively explain the variations in derivative usage may also affect the exposure to interest rate risk, it is not surprising to find that a similar (although not entirely the same) set of control variables is used in both Equations (1) and (2).

<Table 5 is inserted about here>

Based upon the prior related studies, we identify *Leverage*, *Liquidity*, growth opportunities (*Growth_Opp*), *Firm_Size*, the business mix variables (*Res_IndLife/*

[24] The values of long-term assets and liabilities are obtained from company annual reports. It is worthwhile to note that the difference in the value of long-term assets and the value of long-term liabilities is not a perfect measure of maturity mismatch. Unfortunately, detailed information on the maturity of major asset classes and the cash-flow patterns of major liability classes of our sample firms are simply unavailable. We cannot therefore compute their maturities/durations of assets and liabilities.

Annuity, *Res_GpAnnuity* and *Res_GuarInvContracts*) and *Reinsurance* as the control variables for both equations. These explanatory variables are considered to affect *IRD_Usage* by influencing interest rate risk exposure. Furthermore, we hypothesize that *Tax* will only affect *IRD_Usage*.[25]

5. EMPIRICAL RESULTS

5.1 Univariate Analysis

The sample comprising of only publicly-traded stock insurers provides a total of 412 firm-year observations, 301 of which reported interest rate derivative usage for hedging, whilst the remaining 101 were recorded as non-users. We use a parametric *t*-test and a non-parametric Wilcoxon signed-rank test to examine the equality of the means between the derivative users and non-users. The descriptive statistics of the variables are reported in Table 6, from which we can see that most of the associated *p*-values are less than 1 per cent, thereby suggesting that these variables are potential determinants of interest rate derivative usage.

<Table 6 is inserted about here>

The Pearson correlation coefficient matrix is reported in Table 7. Consistent with our expectations, a statistically significanty positive correlation is discernible

[25] For space-saving considerations, we do not provide the rationale for including these variables as control variables within our explanation of the equations; however, those control variables that are found to be significant are discussed in the empirical results section. Interested readers should refer to studies on the determinants of derivative usage (Cummins, et al., 1997, 2001; Hardwick and Adams, 1999; and Colquitt and Hoyt, 1997) and exposure to risk (Brewer et al., 1996; Shanker, 1996; Hirtle, 1997; Koski and Pontiff, 1999; Guay, 1999; Hentschel and Kothari, 2001; and Singh, 2009).

with observable exposure to interest rate risk for participation in (overall usage of) interest rate derivatives, with a correlation coefficient of 0.388 (0.438). The correlations are all generally modest. Moreover, both *Mismatch* variables are found to be positively correlated with *IRD*, *IRD_Usage* and *IREX*.

<Table 7 is inserted about here>

We also calculate the variance inflation factor (VIF) values for all of the explanatory variables and find that these are less than 10, which suggests that in the analysis carried out in the present study, the problems associated with multi-collinearity are unlikely to be of any relevance (Gujarati, 1995).

5.2 Multivariate Analysis

The results of our analysis in this study on the relationship between participation in interest rate derivative usage and exposure to interest rate risk are shown in Tables 8 and 9, whilst Tables 10 and 11 present the results on the relationship between the extent of such derivative usage and exposure to interest rate risk. As the tables show, all of the Chi-squared values and *F*-statistics for the overall statistical goodness of fit of the models are found to be significant at the 1 per cent level, thereby confirming that the fitted models are better than a null model with no explanatory variables.[26] The McFadden Pseudo and adjusted R^2 for all models range between 0.3821 and 0.7952, with all of the estimated parameters being found to be robust to both

[26] In the Heckman two-stage regression model, the coefficient on the inverse Mills ratio is not found to be statistically significant. This indicates that self-selection is not a major problem in our sample.

heteroskedasticity and autocorrelation.

<Tables 8 to 11 are inserted about here>

Consistent with our earlier predictions, as well as the results of the univariate analysis presented earlier, the coefficients on the *Mismatch* variables are found to be positive in the models for both participation in, and overall usage of, interest rate derivatives, with statistical significance at conventional levels. This evidence is consistent with the view that as compared to life insurers with lower exposure to interest rate risk, those with higher underlying exposure to such risk are more likely to take the decision to use interest rate derivatives, and to engage in the extensive use of such instruments. This result is in line with the findings of both Daniel and Steven (2005) and Shiu and Moles (2010), with the evidence providing strong support for the view that life insurers use interest rate derivatives as a means of hedging against their underlying exposure to interest rate risk.

Interest rate derivative usage is found to have positive effects on observed exposure to interest rate risk at conventional levels of significance, which thereby suggests that those life insurers engaging in more extensive use of interest rate derivatives tend to operate with a correspondingly greater exposure to interest rate risk. One of the possible explanations for this is that interest rate derivatives are used by life insurers specifically as a means of shaping their interest rate risk exposure.

Since the liabilities of life insurers are generally long-term and difficult to adjust, derivatives provide insurance firms with an effective and relatively cheap and efficient means of adjusting their exposure to interest rate risk without altering the composition of their asset and liability portfolios. This explanation is consistent with the Hirtle (1997) argument that banks use derivatives to enhance their risk exposure.

It is worthwhile to note that financial institutions as financial intermediaries are unavoidably faced with interest rate risk to a certain extent. In theory, they of course can change immunize themselves against the risk by changing the durations of their assets and liabilities. However, in practice restructuring the balance sheet of a financial institution with complex businesses is costly and cannot be done quickly. Managers can achieve the same results of direct duration matching by using derivatives (Saunders and Cornett, 2018: 257).

Another possible explanation is that if a life insurer with a propensity for the extensive use of interest rate derivatives for hedging purposes, it can operate at a higher interest rate risk exposure because interest rate hedging allows insurers to take on more interest rate risk. In one sense, this explanation is consistent with Shiu's (2010) argument that hedging allows insurers to operate at a lower solvency margin and Leland's (1998) argument that firms can take on more debt because of hedging.

In both the derivative participation model and the model examining the extent of such derivative usage, the coefficient on *Firm_Size* is found to be positive and significant at conventional levels, thereby suggesting that as compared to small life insurance firms, larger life insurers have an inherent tendency to engage in interest rate derivative usage, with such usage also tending to be much more extensive; this evidence provides support for the 'economies of scale' argument.

Our finding is in line with several of the prior studies; and indeed, consistent with the findings of Singh (2009) and Berends, McMenamin, Plestis and Rosen (2013), *Firm_Size* is found to have a statistically significant positive correlation with observed exposure to interest rate risk (Colquitt and Hoyt, 1997; Cummins et al., 2001). This is probably because larger insurers tend to have separate accounts and are more likely to have more interest-rate-sensitive assets and liabilities than smaller insurers.

Our finding of significance at conventional levels for some of the business mix variables (*Res_IndLife/Annuity*, *Res_GpAnnuity* and *Res_GuarInvContracts*) indicates that the use of interest rate derivatives and observed exposure to interest rate risk are potentially driven by the classes of products that are offered by different life insurers. This evidence lends some support to the notion that insurers will consider differences in the risk involved across different lines of business when reaching their decisions on the use of interest rate derivatives and their exposure to interest rate risk.

In line with Colquitt and Hoyt (1997) and Cummins et al. (2001), we find a positive relationship between the *Reinsurance* variable and both participation in and the overall usage of interest rate derivatives, which provides support for the view that derivative usage and reinsurance are complementary mechanisms for hedging risk. We also find that the *Reinsurance* variable has a positively correlation with the observed exposure to interest rate risk. This is possibly because of the use of reinsurance by insurers as a means of adjusting the duration of their liabilities.

6. ADDITIONAL TESTS

6.1 Time Periods

We divided our sample by time periods to examine the effects of the mismatch between long-term assets and long-term liabilities on both participation in, and overall usage of, interest rate derivatives, as well as the effects of such derivative usage on observed risk exposure. In more specific terms, we divide our whole sample period (2000-2016) into two sub-periods, the pre-crisis (2000-2009) and post-crisis (2010-2016) sub-periods. As shown in Table 12, most of the variables included in the regressions are found to be statistically different between these two sub-periods using *t*- and Wicoxon signed-rank tests, including the variables of interest such as *IRD_Usage*, *IREX*, *Mismatch_MISSASST* and *Mismatch_MISSLIAB*. These results highlight the impact of global financial crisis occurring in 2008 on insurers' interest rate exposure and their use of derivatives .

<Tables 12 are inserted about here>

Table 13 further presents the regression results on interest rate derivative usage and risk exposure between pre-crisis and post-crisis sub-periods. As shown in this table, we document opposite results for the relation between *IRD_Usage* and *IREX* for these two sub-periods. To be more specific, the relation between *IRD_Usage* and *IREX* is significantly positive during the pre-crisis sub-period, while negative during the post-crisis sub-period. These results are consistent with those reported in Figure 1. As shown in Figure 1, the use of interest rate derivatives by life insurers has generally been increasing after the occurrence of financial crisis. However, during the years 2007 to 2009, short-term interest rates were cut by the Federal Reserve to essentially zero by 2009 (Berends, et al., 2013). This phenomenon may be able to explain the negative association between *IRD_Usage* and *IREX* after the crisis.

<Tables 13 are inserted about here>

6.2 Insurer Size

We also examine whether our results vary by insurer size. We use the median as the cut-off point to divide our sample of firms into large and small firms. Similar to the results reported above, our results are not quantitatively changed the inclusion of insurer size;[27] that is, the *Mismatch* variables in Equation (1) and the derivative usage variable in Equation (2) are found to remain positive and significant across insurers of different sizes. We further find that the positive effect of the *Mismatch* variables in Equation (1) is much stronger for larger insurers, in terms of both statistical and economic significance. This suggests that insurer size strengthens the positive effect of the *Mismatch* variables on derivative usage. This is consistent with the view that larger insurance firms with higher-than-average risk exposure are more willing and able to engage in derivative transactions (Cummins, et al., 2001).

Interestingly, the positive effects of *IRD_Usage* on *IREX* are found to be greater for larger insurers than for smaller insurers, thereby indicating that the positive relationship is strengthened by insurer size. This suggests that the impact of derivative usage on observed risk exposure is stronger for larger insurers than smaller insurers. One of the possible reasons for this is that larger insurers may be more heavily reliant upon the use of interest rate derivatives to shape their interest rate risk exposure. Given that larger insurers have more complex asset and liability portfolios, this enables them to operate with greater exposure to interest rate risk.

<Tables 14 are inserted about here>

7. CONCLUSIONS

We set out in this study to examine the relationship between interest rate derivative

[27] Once again, the results are not reported here but are available from the authors upon request.

usage and exposure to interest rate risk using data on US life insurers covering the years 2000 to 2016, and find the existence of a positive correlation between the two. Specifically, life insurers with greater underlying exposure to interest rate risk are found to be more likely to engage in the use of interest rate derivatives than those with lower underlying exposure to such risk, and indeed, such use is likely to be quite extensive. Furthermore, life insurers using interest rate derivatives (and using such instruments more extensively) are found to have greater observable exposure to interest rate risk. However, we also document evidence that the relation between interest rate derivatives and exposure changes to be negative during the post-crisis sub-period.

Future related works could focus on an examination of the relation between interest rate derivatives and exposure using data on emerging countries, with the results subsequently being compared with the findings of the present study and other related studies. Presumably, as compared to insurers in the developed countries, insurers in the emerging countries may be subject to stricter regulations of insurance and capital markets.

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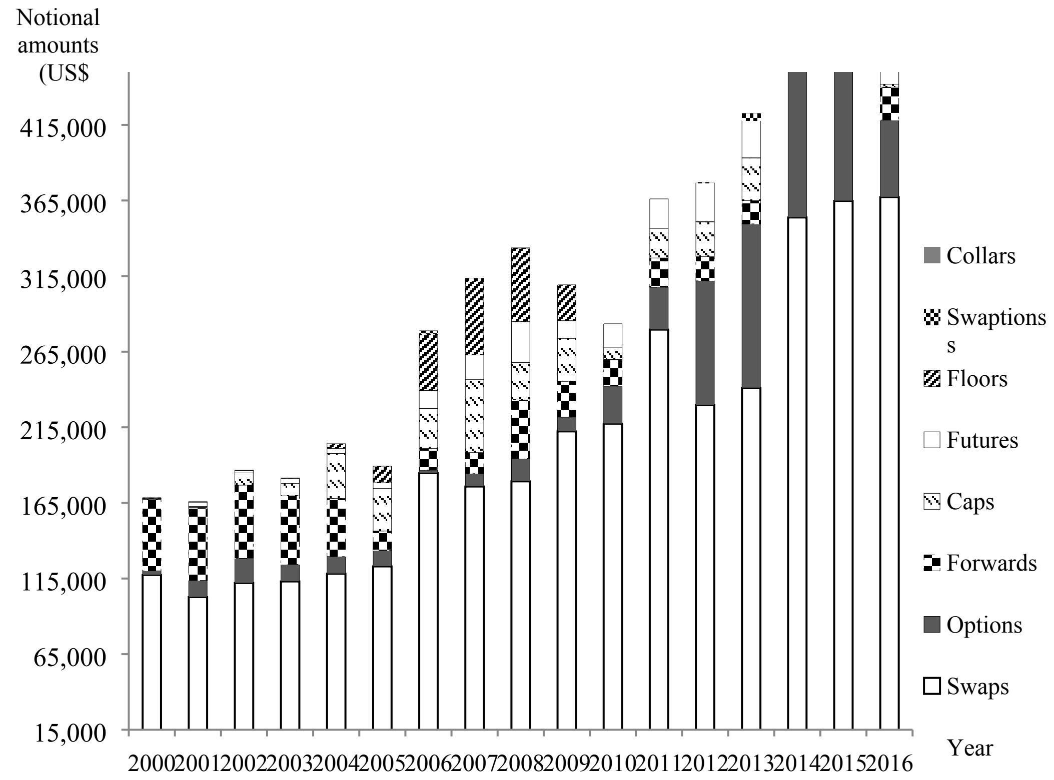

Figure 1 Notional amounts and usage type of interest rate derivatives by life insurance firms, 2000-2016

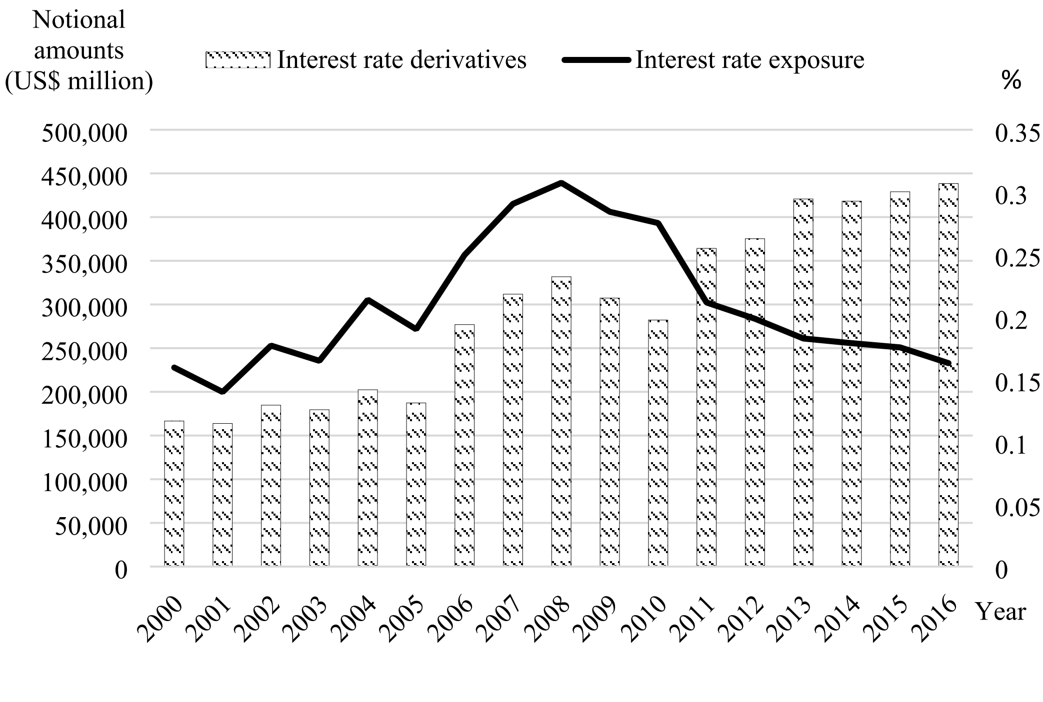

Figure 2 Trend of hedging derivatives usage to interest rate exposure of life insurance firms, 2000-2016

Table 1 Sample selection criteria

Total number of life insurance firms in the Compustat Database	45
Exclusion criteria:	
1. Firms whose substantial part of revenues are from non-life business[28]	4
2. Firms whose business is not mainly based in the U.S.[29]	1
3. The least 75% of revenues not generate from insurance[30]	3
Total number of life insurance firms	37
Listed insurers	26
Non-listed insurers	11

Table 2 The years in which the sample firms use interest rate derivatives

Company Name	Hedging years	Number of hedging years
Hartford Financial Services Group, Inc.	2000-2016	17
Manulife Financial Corporation	2000-2016	17
Phoenix Companies, Inc.	2000-2016	17
Principal Financial Group Inc.	2000-2016	17
Protective Life Corporation	2000-2016	17
Prudential Financial, Inc.	2000-2016	17
MetLife, Inc.	2001-2016	16
Allstate Life Insurance Company of New York	2002-2016	15
Genworth Financial, Inc.	2002-2016	15
American Equity Investment Life Holding Company	2000-2007; 2010-2015	14
Lincoln National Corporation	2003-2016	14
Aegon N. V.	2004-2016	13
ING Group N. V. ADS	2004-2016	13
American National Insurance Company	2001-2002; 2007-2016	12
Citizens Financial Corporation	2003-2014	12
FBL Financial Group, Inc.	2002-2013	12
China Life Insurance Company Ltd. ADS	2001-2009; 2015-2016	11
Kansas City Life Insurance Company	2008-2014	7
National Western Life Insurance Company	2007-2013	7
Presidential Life Corporation	2009-2015	7
Prudential PLC ADS	2010-2016	7
Sun Life Financial Inc.	2000-2005	6
Investors Heritage Capital Corporation	2002-2006	5
Citizens, Inc.	2010-2013; 2016	5
UTG, Inc.	2012-2016	5
Torchmark Corporation	2004-2006	3
Total number of firm-year observations from interest rate derivatives users		301
Total number of firm-year observations from interest rate derivatives non-users		111

[28] *American International Group*, *Delphi Financial Group Corporate* and *Yadkin Valley Financial Corporation* derive a substantial part of its revenue from non-life business. Although it also manages life insurance and annuity policies, *Berkeley Technology Ltd.-ADR* is actualy a venture capital consulting company, which use consulting revenues to finance the development of telecommunications company relationships in Europe and Asia.

[29] *Canada Life Financial Corporation* is actually a Canadian company. As of July 10, 2003, it was acquired by the Great-West Life Assurance Company.

[30] We remove *Annuity & Life Re (Holdings) Ltd.*, *Scottish Re Group Ltd.* and *Reinsurance Group America Inc.* from our sample because their reinsurance assumed account for more than 75 percent of total premium written (Shiu, 2011; Cole and McCullough, 2006; Powell and Sommer, 2007).

Table 3 The number of listed life insurers that use interest rate derivatives and their usage amount

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of life insurers that use interest rate derivatives	8	11	15	16	19	19	18	18	18	19	21	21	22	22	19	18	17
Interest rate derivatives usage amount (US$ billion)	167	164	185	180	202	187	277	312	332	307	282	364	375	421	418	429	438

Table 4 Usage amount of different types of interest rate derivatives

Year \ Derivatives type	Swaps	Options	Forwards	Caps	Futures	Floors	Swaption	Collars
2000	115,335	2,747	47,315	500		400	275	
2001	100,702	11,016	48,351	475	2,977	300		
2002	110,008	16,217	48,569	8,040	1,586	325		
2003	111,060	11,309	45,308	8,040	3,503	325		
2004	116,173	11,342	38,397	29,805	3,339	3,325		
2005	121,000	10,632	12,791	27,990	3,923	10,975		
2006	182,742	1,933	14,389	26,468	11,843	37,437	2,150	
2007	173,843	8,519	13,915	48,498	16,041	48,937	2,050	
2008	177,255	15,140	38,694	24,643	27,147	48,517	356	
2009	210,290	9,469	23,706	28,409	11,643	23,691	100	
2010	215,391	24,854	17,571	8,200	15,566		113	500
2011	277,591	28,056	19,325	19,675	19,472		94	
2012	227,680	82,189	16,119	22,928	25,621		750	
2013	239,077	108,456	15,438	28,181	24,769		4,852	
2014	351,756	128,189	22,631	36,928	37,073		1,662	
2015	362,706	120,083	18,160	49,926	34,866		3,274	
2016	365,251	50,927	21,785	1,936	38,209		302	
Usage amount (US$ million)	3,457,859	641,075	462,465	370,642	277,578	174,232	15,977	500
% of Total	64.03%	11.87%	8.56%	6.86%	5.14%	3.23%	0.30%	0.01%

Table 5 Variables and definitions

Variables	Definitions
Panel A: Dependent Variables	
IRD	Dummy variable for the decision to participate in interest rate derivatives; equal to 1 for derivative users; otherwise 0.
IRD_Usage	Ratio of the year-end notional volume of interest rate derivative usage to total assets.
IREX	Interest rate risk exposure; ratio of the returns on common stocks of life insurers as a result of a 1% change in interest rates.
Panel B: Explanatory Variables	
Mismatch_MISSASST	Difference between long-term assets and long-term liabilities, scaled by total assets (only if a positive value is found, otherwise *Mismatch_MISSLIAB*).
Mismatch_MISSLIAB	Difference between long-term assets and long-term liabilities, scaled by total assets (the absolute value only if a negative value is found, otherwise *Mismatch_MISSASST*).
Leverage	Ratio of the book value of total liabilities to the market value of equity.
Liquidity	Ratio of cash + investment securities to total assets.
Growth_Opp	Growth opportunity: ratio of the book value of equity to the market value of equity.
Firm_Size	Natural logarithm of total assets.
Res_IndLife/Annuity	Percentage of total life and health reserves in individual life insurance and annuities.
Res_GpAnnuity	Percentage of total life and health reserves in group annuities.
Res_GuarInvContracts	Percentage of total life and health reserves in guaranteed investment contracts.
Reinsurance	Ratio of reinsurance ceded to total direct premiums + reinsurance assumed.
Tax	Dummy variable equal to 1 if the insurer paid no federal income or capital gains taxes; otherwise 0.

Table 6 Descriptive statistics

Variables	Full Sample (n = 412)				Users (n = 301)				Non-users (n = 111)				t-test		Wilcoxon signed-rank test	
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max	Mean	p-value	Mean	p-value
IRD	0.7306	2.2112	0.0000	1.0000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	2.5748***	0.0000	3.6621***	0.0000
IRD_Usage	232,081	68,588	0.0000	589,015	317,666	122,070	184,744	589,015	0.0000	0.0000	0.0000	0.0000	3.2527***	0.0000	3.9892***	0.0000
IREX	17.6896	4.3452	0.0196	19.0658	20.5381	6.5219	1.4723	19.0658	9.9652	2.8421	0.0196	9.9634	8.3653***	0.0000	9.2951***	0.0000
Mismatch_MISSASST	5.3832	2.3788	0.0161	5.2522	6.5437	2.5056	1.2915	5.2522	2.2363	0.7188	0.0161	2.2324	4.1693***	0.0000	5.2105***	0.0000
Mismatch_MISSLIAB	4.1956	1.0651	0.0141	4.0685	5.1312	1.8874	1.0627	4.0685	1.6586	0.6122	0.0141	1.6559	3.2965***	0.0000	4.0608***	0.0000
Leverage	11.4137	2.9987	0.0000	12.2203	13.3469	3.1002	1.1266	12.2203	6.1715	1.9688	0.0000	6.1715	6.2193***	0.0002	7.5754***	0.0005
Liquidity	5.4583	2.3543	0.0128	4.8262	5.9981	2.9598	1.1721	4.8262	3.9946	0.8257	0.0128	3.9893	2.6846*	1.9659	3.3194*	2.1968
Growth_Opp	1.8182	0.2656	0.0061	1.9757	1.9893	0.2122	0.0136	1.9757	1.3542	0.3159	0.0061	1.3495	0.6382	0.9242	0.8712	1.0982
Firm_Size	10.4393	2.6588	0.0175	11.4964	12.9659	2.8791	1.4695	11.4964	3.5879	0.9758	0.0175	3.5856	6.1954***	0.0001	7.1638***	0.0000
Res_IndLife/Annuity	2.2327	0.3144	0.0139	2.7222	2.7889	0.3177	0.0667	2.7222	0.7243	0.0547	0.0139	0.7241	2.5721***	0.0000	4.2597***	0.0000
Res_GpAnnuity	1.5124	0.4205	0.0036	1.8169	1.8417	0.3431	0.0248	1.8169	0.6196	0.0612	0.0036	0.6193	2.0334*	1.1879	2.6122**	1.2849
Res_GuarInvContracts	1.9919	0.4412	0.0094	2.4202	2.4748	0.5646	0.0546	2.4202	0.6824	0.0895	0.0094	0.6823	2.1365*	1.2175	3.0027**	1.4388
Reinsurance	7.1151	1.9528	0.0256	8.6851	8.7839	2.3729	0.0989	8.6851	2.5899	0.6959	0.0256	2.5864	5.1721***	0.0000	6.3359***	0.0000
Tax	0.8665	0.0363	0.0000	1.0000	0.8904	0.0423	0.0000	1.0000	0.8018	0.0322	0.0000	1.0000	1.2989	1.2983	1.2699	1.7821

Notes:

[a] The descriptive statistics are reported on all of the independent (explanatory) variables.

[b] The t-test and the Wilcoxon signed-rank test were used to examine whether there are differences in the means between the user and non-user groups.

[c] ***indicates statistical significance at the 0.01 level; **indicates statistical significance at the 0.05 level; and * indicates statistical significance at the 0.1 level.

*Table 7 Pearson correlation matrix**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	–													
(2)	0.456***	–												
(3)	0.388***	0.438***	–											
(4)	0.231**	0.312**	0.288***	–										
(5)	–0.125	–0.202	–0.233	0.379***	–									
(6)	–0.069	–0.088	–0.077	0.284***	0.278**	–								
(7)	0.397***	0.411***	0.362***	0.315***	0.294***	0.262**	–							
(8)	0.276**	0.364***	0.384***	0.232**	0.281**	0.253**	0.358***	–						
(9)	0.248**	0.332***	0.365***	–0.229**	0.217*	0.246**	0.275***	–0.203*	–					
(10)	0.212*	0.291**	0.312**	–0.201*	0.202*	0.214*	0.245**	–0.229*	–0.233*	–				
(11)	0.265**	0.323**	0.467***	0.231**	0.199*	0.218*	0.261***	0.247*	–0.239*	–0.222*	–			
(12)	0.248**	0.319**	0.449***	–0.226**	–0.208*	–0.204*	0.273***	–0.245*	–0.238*	–0.231*	0.375***	–		
(13)	0.362***	0.374***	0.422***	–0.279***	–0.297***	–0.211*	0.319***	–0.412***	–0.399***	–0.281*	0.399***	0.429***	–	
(14)	0.071	0.081	0.198*	0.228*	0.204*	–0.092	0.203*	–0.195*	–0.242*	–0.049	0.211*	0.227*	0.354***	–

Note: * The table reports the correlation matrix for all of the dependent and explanatory variables listed in Table 5, with the numbers on the x and y axes referring to the following corresponding variables: (1) *IRD*; (2) *IRD_Usage*;(3) *IREX*; (4) *Leverage*; (5) *Liquidity*; (6) *Growth_Opp*; (7) *Firm_Size*; (8) *Res_IndLife/Annuity*; (9) *Res_GpAnnuity*; (10) *Res_GuarInv Contracts*; (11) *Mismatch_MISSASST*; (12) *Mismatch_MISSLIAB*; (13) *Reinsurance*; and (14) *Tax*. ***indicates statistical significance at the 1 per cent level **indicates statistical significance at the 5 per cent level; and * indicates statistical significance at the 10 per cent level.

Table 8 Regression results on interest rate derivative usage and risk exposure using Probit and one- and two-way fixed models, based upon Equation (1): Y = IRD[a]

Explanatory Variables	Expected Sign	Probit Model[b,c]		One-way Fixed Model[b,c]		Two-way Fixed Model[b,c]	
		Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Constant		13.5428***	2.3596	–	–	–	–
Mismatch_MISSASST	+	3.9965***	1.2567	4.8109***	1.2843	9.5744***	2.6416
Mismatch_MISSLIAB	+	3.7822***	1.2151	1.9089**	0.8542	2.8392**	1.3897
Leverage	+	2.9829***	0.9262	1.7995*	1.3423	2.6598**	1.2259
Liquidity	–	–1.9866*	1.3265	–0.0088	0.0751	–0.1821	0.5921
Growth_Opp	–	–0.0852	0.0916	–0.0002	0.0265	–0.0069	0.1214
Firm_Size	+/–	3.0200***	1.0081	3.2895***	1.0864	5.2956***	1.7253
Res_IndLife/Annuity	+	2.6722***	0.8522	2.4973***	0.7512	4.3733***	1.2588
Res_GpAnnuity	+	2.3637***	0.7917	2.3412***	0.7225	4.1627***	1.1611
Res_GuarInv Contracts	+	1.9634*	1.3429	1.8409*	1.2139	2.5456**	1.2042
Reinsurance	+/–	3.2286***	1.0654	3.7725***	1.1658	4.8894***	1.4195
Tax	+	0.0577	0.1758	0.0008	0.2866	0.0064	0.5965
F-test		–	–	8.29***	(0.0000)	12.97***	(0.0000)
χ^2-test		129.5421***	(0.0000)	–		–	
McFadden Pseudo- R^2		0.4968		–		–	
Adjusted R^2		–		0.4281		0.6956	
No. of Obs.		412		412		412	

Notes:

[a] Lagged values are utilized for all of the control variables, as suggested by Greene (1993) and Kennedy (1998).

[b] *** indicates statistical significance at the 1 per cent level; ** indicates statistical significance at the 5 per cent level; and * indicates statistical significance at the 10 per cent level.

[c] Figures in parentheses are p-values.

Table 9 Regression results on interest rate derivative usage and risk exposure using Heckman two-stage, OLS and one- and two-way fixed models, based upon Equation (2): Y = IREX[a]

Explanatory Variables	Expected Sign	Heckmann Two-stage Model[b,c]		OLS Model[b,c]		One-way Fixed Model[b,c]		Two-way Fixed Model[b,c]	
		Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Constant		5.2122***	1.6594	57.8988***	18.2454	–	–	–	–
IRD	+/–	3.3433***	1.1121	34.3764***	10.1691	30.2372***	9.3362	32.9775***	10.6591
Mismatch_MISSASST	+	2.6554***	0.7584	29.3833***	9.4789	23.0564***	7.5984	27.8957***	9.1246
Mismatch_MISSLIAB	+	2.2801**	1.1256	24.5127***	6.6572	24.3935***	8.6397	26.3129***	8.4944
Leverage	+	1.9658*	1.4788	11.1952**	4.5755	10.2643**	8.9545	10.4567*	8.5457
Liquidity	–	-0.0073	0.1875	-2.3681	3.1928	-1.4566	3.2986	-1.9828	3.6593
Growth_Opp	–	-0.0066	0.0924	-3.2629	5.1963	-2.2876	3.5457	-1.6546	4.8759
Firm_Size	+/–	2.9655**	1.3528	27.5629***	8.3458	25.3911**	11.2561	26.6297***	8.5149
Res_IndLifeAnnuity	+	2.0021*	1.8596	9.4121*	7.6877	7.6484**	3.3758	8.7654**	4.2182
Res_GpAnnuity	+	1.9546*	1.6522	8.6879*	7.5628	7.9237**	3.4563	6.9891*	4.4418
Res_GuarInvContracts	+	1.8427*	1.7493	6.3933*	5.1923	6.3965*	4.9789	5.9502*	4.3695
Reinsurance	+/–	2.8259***	0.8257	31.1415***	9.8469	26.6672**	12.4172	29.3896***	9.5866
F-test		7.59***	(0.0000)	7.68***	(0.0001)	7.61***	(0.0003)	8.14***	(0.0000)
Inverse Mills Ratio		0.1818	0.2934	–	–	–	–	–	–
Adjusted R^2		0.3821		0.4229		0.4027		0.6283	
No. of Obs.		412		412		412		412	

Notes:

[a] Lagged values are utilized for all of the control variables, as suggested by Greene (1993) and Kennedy (1998).

[b] *** indicates statistical significance at the 1 per cent level; ** indicates statistical significance at the 5 per cent level; and * indicates statistical significance at the 10 per cent level.

[c] Figures in parentheses are p-values.

Table 10 Regression results on interest rate derivative usage and risk exposure using Tobit and one- and two-way fixed models, based upon Equation (1): Y = IRD_Usage [a]

Explanatory Variables	Expected Sign	Tobit Model[b]		One-way Fixed Model[b,c]		Two-way Fixed Model[b,c]	
		Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Constant		39.8769***	12.2593	–	–	–	–
Mismatch_MISSASST	+	21.9651***	7.1227	15.8779***	5.2514	18.5636***	6.1833
Mismatch_MISSLIAB	+	17.3543***	5.6598	14.6354***	4.6653	15.4427***	5.1057
Leverage	+	5.2114***	1.6822	3.7428**	1.7461	4.1485**	2.0093
Liquidity	–	-3.5282*	1.1324	-1.9652	2.3215	-2.4596	3.6361
Growth_Opp	–	-1.1729	1.2801	-0.0788	-0.9652	-2.1122	3.1298
Firm_Size	+/–	18.8226***	6.2259	13.9951***	4.4488	16.4677***	5.3274
Res_IndLife/Annuity	+	9.5684***	3.1471	4.8346***	1.5167	5.9686***	1.6856
Res_GpAnnuity	+	9.4746***	3.1365	4.4438***	1.3566	5.4652**	2.6522
Res_GuarInv Contracts	+	8.8322***	2.3687	3.8979***	1.2599	5.0038*	3.8795
Reinsurance	+/–	11.5981***	3.2546	11.3965***	3.6282	13.5284***	4.3279
Tax	+	3.4766*	3.1219	1.9989*	1.5146	2.5128	3.4975
F-test		–-	–	7.57***	(0.0000)	8.23***	(0.0000)
Adjusted R^2		0.0477 (pseudo R^2)		0.6827		0.7126	
No. of Obs.		412		412		412	
Chi^2		56.7993					

Notes:

[a] Lagged values are utilized for all of the control variables, as suggested by Greene (1993) and Kennedy (1998).

[b] *** indicates statistical significance at the 1 per cent level; ** indicates statistical significance at the 5 per cent level; and * indicates statistical significance at the 10 per cent level.

[c] Figures in parentheses are p-values.

Table 11 Regression results on interest rate derivative usage and risk exposure using OLS and one- and two-way fixed models, based upon Equation (2): Y = IREX[a]

Explanatory Variables	Expected Sign	OLS Model[b,c]		One-way Fixed Model[b,c]		Two-way Fixed Model[b,c]	
		Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Constant		66.8928***	21.8741	–	–	–	–
IRD_Usage	+/–	49.7963***	15.8798	40.4855***	12.1983	45.8596***	14.6253
Mismatch_MISSASST	+	35.6288***	11.1184	32.6728***	10.8126	39.4127***	13.2689
Mismatch_MISSLIAB	+	32.5896***	10.5827	29.9628***	9.7564	32.3312***	10.6527
Leverage	+	4.2658*	3.2117	5.3338	5.4751	10.0287*	7.9853
Liquidity	–	-1.1365	2.6329	-0.0052	3.3426	-0.0077	3.4756
Growth_Opp	–	-1.8122	2.5236	-0.0804	-2.7638	-0.0954	2.9894
Firm_Size	+/–	32.3567***	10.6581	23.2567***	7.6955	31.2217***	10.0582
Res_IndLife/Annuity	+	10.7878**	5.2162	7.9254*	6.7858	10.3659*	9.5647
Res_GpAnnuity	+	10.6352**	4.5385	7.6872*	6.9469	10.0105*	9.1415
Res_GuarInv Contracts	+	9.2889**	4.4128	7.3269*	6.8657	9.6628*	8.5428
Reinsurance	+/–	42.5417***	11.1633	36.7456***	12.2122	39.2359***	12.5639
F-test		8.36***	(0.0000)	8.29***	(0.0000)	8.94***	(0.0000)
Adjusted R^2		0.7314		0.7121		0.7952	
No. of Obs.		412		412		412	

Notes:

[a] Lagged values are utilized for all of the control variables, as suggested by Greene (1993) and Kennedy (1998).

[b] *** indicates statistical significance at the 1 per cent level; ** indicates statistical significance at the 5 per cent level; and * indicates statistical significance at the 10 per cent level.

[c] Figures in parentheses are p-values.

Table 12 T- and Wilcoxon signed-rank tests results on mean differences of variables between pre-crisis and post-crisis sub-periods[*]

Variables	Pre-Crisis			Post-Crisis			*t*-test		Wilcoxon signed-rank test	
	Coefficient		Stand Error	Coefficient		Stand Error	Mean	*p*-value	Mean	*p*-value
IRD_Usage	4.3836	***	1.0096	7.6689	***	2.5162	8.2769 ***	2.5685	9.2549 ***	3.0251
IREX	3.5581	***	1.1157	5.2348	***	1.3288	3.7659 ***	1.1251	4.8963 ***	0.0000
Mismatch_MISSASST	3.9166	***	1.3222	5.5981	***	1.4529	2.7988 ***	0.0865	4.8961 ***	0.0002
Mismatch_MISSLIAB	3.3895	**	1.1588	4.4625	***	1.3985	2.2573 ***	0.0000	3.4876 ***	0.0000
Leverage	8.3432	***	2.4785	3.1722	***	1.0096	1.7921 *	1.1544	2.3123 *	1.1281
Liquidity	−0.1144		1.3168	2.0926	*	1.7493	0.0189	1.2451	0.0271	1.3358
Growth_Opp	3.5949	*	3.0121	1.2919		1.4627	0.0029	0.5673	0.0030	1.0463
Firm_Size	15.3685	***	4.5469	8.0366	***	2.5514	3.1121 ***	1.0052	6.4129 ***	5.0069
Res_IndLife/Annuity	10.8466	**	3.5244	4.9288	***	1.6273	1.9806 **	0.8125	2.1451 **	1.0588
Res_GpAnnuity	8.2925	**	3.1522	3.5964	**	1.5895	1.9723 **	0.7569	2.1029 **	1.0124
Res_GuarInvContracts	7.1569	**	2.9858	3.5411	**	1.5193	1.9629 **	0.6533	1.9837 **	0.7111
Reinsurance	8.3254	***	3.1339	5.3473	**	2.5468	3.4626 ***	0.0000	3.6781 ***	0.0000
Tax	−1.2985		1.1967	0.8957		2.9653	0.0043	0.0082	0.0009	0.0066
F-test	5.88*** (0.0000)			6.13*** (0.0000)						
Adjusted R^2	0.4155			0.4748						
No. of Obs.	239			173						

Notes: [*] The *t*-test and the Wilcoxon signed-rank test were used to examine whether there are differences in the means between pre-crisis and crisis period. ***indicates statistical significance at the 0.01 level; **indicates statistical significance at the 0.05 level; and * indicates statistical significance at the 0.1 level.

Table 13 Regression results on interest rate derivative usage and risk exposure between pre-crisis and post-crisis sub-periods [a]

Explanatory Variables	Expected Sign	2SLS Model[b,c] *Y = IRD_Usage* Pre-Crisis Coefficient		Stand Error	*Y = IRD_Usage* Post-Crisis Coefficient		Stand Error	*Y= IREX* Pre-Crisis Coefficient		Stand Error	*Y= IREX* Post-Crisis Coefficient		Stand Error
Constant		3.6836	***	1.0128	4.3248	***	1.0248	4.6758	***	1.3118	5.7268	***	1.4829
IRD_Usage	+/–							2.8991	***	0.8758	−3.9628	***	1.2566
Mismatch_MISSASST	+	1.7541	***	0.4315	–4.1529	***	1.3211	2.5711	***	0.7822	–4.4321	***	1.4144
Mismatch_MISSLIAB	+	1.2325	***	0.3516	–3.8966	***	1.1567	2.4155	***	0.7568	–5.2262	***	1.5347
Leverage	+	1.2116		1.3129	2.1584	*	1.2154	1.9688	*	1.6257	2.7732	***	0.7625
Liquidity	–	−0.1641		1.3758	−0.0814		1.6144	−0.0323		0.5688	−0.1354		0.2141
Growth_Opp	–	−0.0824		0.7214	−0.0387		0.8892	−0.3884		0.6585	−0.0915		1.3968
Firm_Size	+/–	2.9611	***	0.8215	2.8968	***	0.9128	2.6128	***	0.8121	3.5577	***	1.1884
Res_IndLife/Annuity	+	1.9866	*	1.1658	2.4305	**	1.1121	2.2658	**	1.1462	2.9804	***	0.9356
Res_GpAnnuity	+	1.9428	*	1.4956	2.3868	**	1.1322	2.2862	**	1.1008	2.6578	**	1.2578
Res_GuarInv Contracts	+	1.8993	*	1.0271	2.2641	**	1.1281	2.0356	**	1.0112	2.4185	**	1.3324
Reinsurance	+/–	2.3518	***	0.6215	2.6584	***	0.8248	2.9144	***	0.9341	3.2549	***	1.2124
Tax	+	0.0386		0.0621	0.0487		0.1283						
F-test		4.52*** (0.0000)			4.78*** (0.0000)			4.68*** (0.0000)			4.88*** (0.0000)		
Adjusted R^2		0.3766			0.4252			0.3818			0.4517		
No. of Obs.		239			173			239			173		

Notes: [a] Lagged values are utilized for all of the control variables, as suggested by Greene (1993) and Kennedy (1998).
[b] *** indicates statistical significance at the 1 per cent level; ** indicates statistical significance at the 5 per cent level; and * indicates statistical significance at the 10 per cent level.
[c] Figures in parentheses are p-values.

Table 14 Regression results on interest rate derivative usage and risk exposure using by firm size [a]

Explanatory Variables	Expected Sign	2SLS Model[b,c]							
		Y = IRD_Usage				*Y= IREX*			
		Small firms		Large firms		Small firms		Large firms	
		Coefficient	Stand Error	Coefficient	Stand Error	Coefficient	Stand Error	Coefficient	Stand Error
Constant		2.7281 ***	0.8123	5.6588 ***	1.7829	3.2659 ***	1.0088	6.6987 ***	2.1852
IRD_Usage	+/–					2.9687 ***	0.6658	5.5127 ***	1.7333
Mismatch_MISSASST	+	2.3656 ***	0.7892	4.8516 ***	1.4127	2.8755 **	1.3122	4.3168 ***	1.3529
Mismatch_MISSLIAB	+	2.2158 **	1.0423	3.3966 ***	1.0028	2.7969 **	1.2649	4.2596 ***	1.2788
Leverage	+	2.5845 ***	0.7646	3.9857 ***	1.3238	2.6428 **	1.1957	4.7785 ***	1.3384
Liquidity	–	−1.7681	2.5361	−1.2415	1.8496	−1.0816	1.4533	−1.8901	2.9688
Growth_Opp	–	−0.1026	0.1085	−1.0029	1.0129	−0.1279	0.1625	−1.0486	1.3244
Res_IndLife/Annuity	+	2.4231 **	1.0382	2.4218 ***	0.6521	2.5453 ***	0.7657	2.8622 ***	0.7559
Res_GpAnnuity	+	2.2069 **	1.0833	2.3335 **	1.1246	2.3126 ***	0.7224	2.1129 **	0.9825
Res_GuarInv Contracts	+	2.0567 **	1.0245	1.9889 **	0.9543	2.1025 ***	0.6858	1.9966 *	1.0258
Reinsurance	+/–	2.8196 ***	0.8057	4.3593 ***	1.0694	3.5613 ***	1.0268	5.1963 ***	1.5237
Tax	+	0.9829	1.2653	1.4795	2.4961				
F-test		3.79*** (0.0000)		4.53*** (0.0000)		3.89*** (0.0000)		4.77*** (0.0000)	
Adjusted R^2		0.3616		0.4155		0.3982		0.4381	
No. of Obs.		133		279		133		279	

Notes:

a Lagged values are utilized for all of the control variables, as suggested by Greene (1993) and Kennedy (1998).

b *** indicates statistical significance at the 1 per cent level; ** indicates statistical significance at the 5 per cent level; and * indicates statistical significance at the 10 per cent level.

c Figures in parentheses are p-values.