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Pension de-risking choice and firm risk: Traditional versus innovative strategies

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ABSTRACT

We examine the determinants of firms defined-benefit pension plan de-risking strategy choices and their impact on firm risk. We compile a hand-collected dataset for FTSE 350 firms for the period of 2009–2017. We find that *hard freezing* and pension *buy-ins* are more likely to be implemented when pension plans have longer investment horizons. In particular, pension plans that are exposed to higher investment risk are more likely to adopt pension *buy-ins*. Firms with larger capital expenditure and market capitalization are more likely to utilise innovative de-risking strategies (i.e. *buy-in* and *longevity swap*) in addition to traditional strategies (i.e. *soft* and *hard freezing*). Financially constrained firms are more likely to implement *longevity swap* over pension *buy-ins*. We also find that implementing pension de-risking strategies reduce firm risk. However, the effectiveness varies depending on the strategy with *buy-ins* having the largest impact in reducing risk.

1. Introduction

Management of pension scheme risks has come to the core of financial management in recent years. Once a key part of firms' remuneration packages, defined-benefit (DB) pension plans are now often seen as a source of financial risk and part of inside debt (Sheikh, 2021). Negative equity returns and low interest rates in the early 2000s, and significant falls in asset values and historically low interest rates in the post-Great Financial Crisis (GFC) period, have resulted in deficits in the majority of DB pension plans (Gallagher & McKillop, 2010). As a consequence, firms have been struggling to maintain their DB pension plans as both contributions and liabilities increase. For example, in 2017, the pension liabilities of FTSE 100 firms amounted, on average, to 38% of their total market capitalisation, the highest ever level (Lane, Clark & Peacock, 2017).[1] Pension funding ratios have also decreased, from 97 to 86% over the period of 2006–2016 (The Pensions Regulator, 2016), signalling an increasing likelihood that firms will be unable to make payments.[2]

Firms will face greater payment obligations in the future as pension plans mature and longevity increases. In addition, pension obligations limit firms' financial management options and current investment capacity, as earnings may have to be used to honour pension promises made to employees by previous management. Hence, firms with DB pension plans are increasingly focusing on reducing pension obligations to alleviate their impact on investment and strategic decisions, which in turn reduces the risk exposure of the shareholders. Having pension debt liabilities may also aggravate the underinvestment problem, also known as debt overhang (Myers, 1977), influencing firms' investment choices negatively. It is argued that high debt levels can lead to rejection of positive net present value projects by the managers, decreasing firm value.[3] Various DB pension de-risking strategies are available to firms. Traditional methods, such as *soft* and *hard freezing*, aim to transfer pension obligation, and investment and longevity risks from the firm to its' employees (Broadbent, Palumbo, & Woodman, 2006; Ippolito, 1995, 1997). Innovative strategies, such as pension *buy-ins, buy-outs* and *longevity swaps*, allow firms to transfer some pension obligation risks to

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[1] FTSE 100 firms paid a total of £17.3 billion in pension contributions in 2017.

[2] Between 2006 and 2016, UK DB pension assets increased from £770 billion to £1341 billion, and DB pension liabilities rose from £792 billion to £1563 billion (The Pensions Regulator, 2016). Increases in pension assets and liabilities indicate that firms will face huge payment obligations when their DB pension plans reach maturity.

[3] Mayers and Smith (1987), Schnabel and Roumi (1989), and Garven and Macminn (1993) extends this work and show that a property insurance contract could be used to bond subsequent corporate investment decisions, solving the underinvestment problem.

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third parties (i.e. insurers) by paying a premium up-front.

A growing literature is emerging on the impact of DB pension de-risking on firm risks, and several studies have examined the effect of *freezing* (Bodie, Light, Morck, & Taggart, 1985; Choy, Lin, & Officer, 2014; Gallagher & McKillop, 2010; Lin, MacMinn, & Tian, 2015; Maher, 1987; Martin & Henderson, 1983; McFarland, Pang, & Warshawsky, 2009; McKillop & Pogue, 2009; Milevsky & Song, 2010; Wiedman & Wier, 2004). Empirical evidence shows that *freezing* may decrease firms' overall financial risks, as it reduces the growth rate of pension benefits and costs as well as employee compensation (Milevsky & Song, 2010). Similarly, firms with lower pension risks are found to have lower cost of debt (Gallagher & McKillop, 2010) and have higher credit ratings, signalling decreasing in credit risk (McKillop & Pogue, 2009). In contrast, it is argued that de-risking through *freezing* may reduce firm value owing to costs such as employee resistance, and drops in employee motivation and productivity, which may offset the benefits of de-risking (Lin et al., 2015; McFarland et al., 2009). Overall, evidence of the impact of pension de-risking on firm risk is inconclusive.

In this paper, we examine the financial determinants of firms' choice of a de-risking strategy to manage pension risk and the effectiveness of these strategies in reducing it. We utilise a unique hand-collected dataset for FTSE 350 firms for the period of 2009–2017. Given that finance managers now have a wider range of tools to manage pension risks, especially with the recently introduced innovative instruments, it is imperative to understand the selection process of alternative strategies and its implications on overall firm risk.

We find that *hard freezing* and pension *buy-ins* are more likely to be implemented when pension plans have longer investment horizons, indicating higher levels of risk exposure owing to investment uncertainty. Pension plans that are exposed to more investment risk are more likely to engage in pension *buy-ins*. Firms that have higher market capitalisation and capital expenditure are more likely to implement innovative de-risking strategies. Firms that are financially constrained may go for *longevity swaps*. We also find that implementing pension de-risking strategies reduce firm risk. However, the effectiveness varies with *buy-ins* being the most effective in reducing risk.

Our contribution to the literature is twofold. First, we are interested in how firms choose between alternative de-risking strategies. Previously, Lin, Shi, and Arik (2017) developed an optimization model and examined the impact of hedging costs on hedging decisions in three pension hedging strategies (i.e., longevity hedge, buy-in and buy-out). However, their study does not include an empirical analysis from the sponsoring firms' perspective. De-risking decision may relate to firm's specific financial conditions as well as factors relating to the DB pension plan. Accordingly, we contribute to the literature by empirically investigating which pension fund attributes and firm financial characteristics may influence the choice of pension de-risking strategies. Additionally, we also compare determinants of traditional (i.e. *soft freezing* and *hard freezing*) versus innovative strategies (i.e. *buy-in* and *longevity swap*).[4,5] Previous studies have only examined the effectiveness of traditional methods.[6] There is a dearth of literature on how firms choose among different pension de-risking strategies and, particularly, between traditional and innovative ones. We significantly contribute to the literature by providing the first empirical evidence on the determinants of de-risking strategy choices by compiling a unique dataset.

Second, we contribute to the literature by examining the impact of different pension de-risking strategies on firm risk. Pension de-risking may lead to changes in firms' market value, as pension obligations relate to firm risk and creditworthiness. However, the literature is inconclusive on the direction of the impact, and is also limited to only examining traditional de-risking strategies. Innovative pension de-risking strategies differ substantially, as they transfer pension obligation risks to third parties. Hence, whether alternative de-risking strategies may lead to different risk-shifting outcomes is unknown, as they also result in different costs for firms. We contribute to the literature by providing the first evidence on the impact of innovative de-risking strategies on firm risk. In particular, this is the first empirical paper to investigate the pension *buy-ins* and *longevity swaps* in this context. Our analysis enhances the understanding of whether innovative pension de-risking strategies are effective in reducing firm risk. We also contribute to the literature by sampling a broader set of international firms listed on the London Stock Exchange's FTSE 350. A shortcoming of the existing literature is that the empirical evidence is often based on US data.

The remainder of this paper is structured as follows. Section 2 presents the background to alternative pension de-risking strategies available to the firm, and Section 3 reviews the previous literature. Section 4 explains the data and methodology. In Section 5 we present the results and Section 6 concludes.

2. Background to pension de-risking strategies

In this paper, pension de-risking strategies are defined as *soft freezing*, *hard freezing*, *buy-ins* and *longevity swaps*. This section explains the background to each of these strategies and their development in the UK.

2.1. Freezing

Freezing a DB pension plan transfers the risk from employer to employees (Atanasova & Hrazdil, 2010) and reduces pension benefits to members (Dobbins & Dundon, 2017). In *soft freezing*, new employees are barred from joining the plan, while existing employees who are currently in the plan continue to accrue pension benefits and vesting service (Munnell, Golub-Sass, Soto, & Vitagliano, 2007). *Soft freezing* may increase firm risk because it may lead to an increase in firms' pension contribution rate for providing DB pension plans to existing members, as fewer younger employees will be contributing to the plan.

In *hard freezing*, firms stop their DB pension plans for all employees. The value of pension benefits ceases to increase after the date of the freeze, and pension assets remain in the plan to be paid out when the employees retire (Munnell et al., 2007). All benefits paid to employees are fixed at the level prevailing at the date of the freeze. In a *hard freeze*, firms' benefit responsibility and contribution costs are significantly reduced. It is argued that *hard freezing* has a more significant impact on firms and pension funds than *soft freezing* (Choy et al., 2014; Comprix & Muller, 2011).

Freezing is regarded a key de-risking strategy in the UK. DB pension plans traditionally dominated the UK occupational pension system, while defined-contribution (DC) pension plans were offered to a small proportion of employees. However, the proportion of employees in open DB pension plans declined sharply, from 66 to 19% between 2006 and 2016, and the percentage of DB pension plans remaining open to all employees dropped from 43% in 2006 to 13% in 2016 (The Pensions Regulator, 2016). Overall, in recent years UK firms have been taking significant measures to de-risk their pension plans.

2.2. Pension buy-ins and buy-outs

Pension *buy-ins* are utilised to transfer pension obligations to insurers

[4] We use the term *innovative* for pension buy-ins/buy-outs as these instruments are relatively new and innovative compared to traditional de-risking strategies of soft and hard freezing. The volume of pension buy-out market was very small before 2004 (Monk, 2009). In the past, pension buy-outs were only used for insolvent firms to transfer pension obligations to third parties. The market for pension buy-ins/buy-outs started to develop significantly after 2008 and has reached a peak (£43.8 billions) in 2019 (Lane, Clark & Peacock, 2020).

[5] We had to exclude buy-outs from the analysis as we only have two observations of this de-risking strategy in our sample.

[6] Innovative de-risking strategies have attracted research attention, but only from an asset-pricing perspective (see, for example, Blake & Burrows, 2001; Lin & Cox, 2008; Lin et al., 2017).

(Lin et al., 2017). In a *buy-in,* the firm sponsoring the DB pension plan buys an annuity (typically form the insurer), of which its payments are used to serve the pension scheme that continues to run. A *buy-in* removes the risks of investment, longevity, interest rate changes and inflation for the plan's members. However, under a *buy-in*, a pension scheme continues to run and policyholders see no change in their benefits with the sponsoring firm. In addition to *buy-in*, a *buy-out* is an insurance policy that is issued to each member individually, which enables the scheme to be closed. Pension buy-outs remove pension assets and liabilities completely from a firm's financial statements and transfer all pension risk to the insurer. Premiums for *buy-outs* are higher than for *buy-ins* as the insurers take on more risk in *buy-out* contracts.

There is an established and growing market for pension *buy-ins* and *buy-outs* in the UK (Lin et al., 2017), which has expanded since 2006 following a significant pension regulation change with the introduction of the Pensions Act 2005. The size of the market increased from £2.9 billion in 2007 to £12.3 billion in 2017 (Lane, Clark & Peacock, 2017). This growth is attributable to UK policy makers' positive view of pension *buy-in* and *buy-out* transactions as a safe means of removing pension obligations from firms' liabilities (Monk, 2009). However, given the data limitation on pension *buy-outs*, we only focus on pension *buy-in* in this paper.

2.3. Longevity swaps

Longevity risk is the risk arising from pension scheme policy holders' increasing life expectancy, which may eventually result in higher than expected pay-out ratios.[7] It is argued that longevity risk is one of the most significant risk faced by DB pension plans (Tilba & Wilson, 2017). *Longevity swaps* are insurance policies that remove only the longevity risk from DB pension plans (Blake & Burrows, 2001), giving certainty for the period over which the pension plan will be required to make payments.[8] Unlike pension *buy-ins/buy-outs*, *longevity swaps* entail no significant up-front costs. Instead, regular payments are made to the insurer for the duration of the agreement. In return, the insurer covers the extra pay-outs if the members live longer than expected.

In the UK, an increase of one year in the mortality rate would increase pension obligations by 4.5% (Accounting Standards Board, 2007). Over the past two decades, UK life expectancy at 65 has increased by four years for males and 3.7 years for females. There is an increasing interest in *longevity swaps*. Although life expectancy assumptions have been revised downward in recent years, it is arguable whether this is a new trend or a temporary slowdown. A slowdown in life expectancy rises provides an opportunity for competitive *longevity swaps* pricing. Increasing interest in *longevity swaps* is reflected in the fact that the volume of such contracts are more than doubled between 2016 and 2017, from £2.6 to £6.4 billion (Lane, Clark & Peacock, 2018).

3. Literature review

3.1. Pension plan specific determinants of de-risking

De-risking strategy choices may depend on pension investment horizons and investment strategies. Pension schemes often have long-time horizons, with new members likely to be drawing a pension many years later, and therefore need to make long-term investment decisions to meet their liabilities. In particular, the horizon sensitivity is very important for investors who have to deal with inflation risk (Schotman & Schweitzer, 2000). Hence, firms with longer pension plan investment horizons (i.e. maturity) are more likely to implement de-risking as they are exposed to a greater pension plan risk (Amir, Guan, & Oswald, 2010). Such firms' pension plans tend to have a larger number of young employees, which eases the implementation of de-risking as younger employees tend to offer less resistance (Munnell et al., 2007).[9] *Buy-ins* are more attractive for firms with low-risk investment strategies (Lane, Clark & Peacock, 2018) and holding less volatile assets in pension funds, such as government bonds (Lin et al., 2015). In contrast, *longevity swaps* may be more suitable for pension plans with high levels of investment risk due to longevity risk (Lin et al., 2015).

Pension plan size may also be a determining factor. Firms with larger pension funds are more likely to choose *longevity swaps*, as these instruments are designed for larger plans and provides flexibility for taking risk on pension investments (Lane, Clark & Peacock, 2018). Firms with smaller pension plans may prefer *buy-ins*, as these are comparatively affordable for smaller plans. Firms with higher funding levels may also choose pension *buy-ins* because higher funding levels lead to lower costs. In particular, if the pension plan is fully funded then employees are likely to be less resistant. However, it can be argued that firms with larger pension plans are subject to higher pension costs and, therefore, they may prefer to engage in pension *buy-ins* as they will result in greater risk reduction than other de-risking strategies. On the other hand, *freezing* a considerably large DB pension plan may provoke more resistance from employees because it significantly affects their benefits due to underfunding (Comprix & Muller, 2011).

3.2. Firm specific determinants of pension de-risking

Upfront costs incurred by the firm may influence the choice of de-risking strategy, and, therefore, financial constraints may determine de-risking strategy choice. *Freezing* does not require immediate and significant cash payments from sponsoring firms (Choy et al., 2014). In contrast, *buy-ins* require greater financial resources in order to make additional contributions to the pension plan and eliminate any deficit before de-risking. Providing evidence for this argument Bartram (2018) finds that less profitable firms have lower levels of pension contributions and funding, which makes it difficult for them to engage in pension *buy-ins*. Such firms may also struggle to pay the up-front premium. *Longevity swaps*, in contrast, are less costly and more affordable in comparison to other de-risking strategies (Cox, Lin, Tian, & Zuluaga, 2013; Lin et al., 2015), which may make them an ideal choice for removing the longevity risk in cases where removing all pension risks is costly.

Leverage may also determine firms' pension plan de-risking decisions. Empirical evidence shows that highly leveraged firms are risk averse (Rauh, 2008), and are more likely to reduce risk taking in pension investments in order to decrease the likelihood of triggering debt covenants (Amir et al., 2010). Vafeas and Vlittis (2018) argue that less leveraged firms may keep DB pension plans as they may benefit from debt tax shield provided by its liabilities. Higher leverage may also indicate a poorer financial condition and such firms may be unable to afford to pay the up-front premium required for *buy-ins*. It is worth to note that, there may be dissimilarities between the UK and the US regarding the impact of leverage on pension investment strategy due to differences in institutional settings (Rauh, 2008). UK regulations appear to allow pension trustees more freedom to take risk in pension plans.

[7] See Macminn and Brockett (2017) and Zelenko (2014) for a discussion on issuance of longevity bonds from the insurer company perspective and why these markets is dormant.

[8] Regulations prevent UK pension plans from undertaking transactions directly with the reinsurer offering the longevity swap. Therefore, the sponsoring firm must find an intermediary insurer to take responsibility for administering payments. This intermediary insurer transacts with the reinsuring firm to complete the longevity swap, and the sponsoring firm must pay the intermediary. The intermediary insurer bears the longevity reinsurer's credit risk. Employing an intermediary insurer makes longevity transactions complex and more costly (Lane, Clark & Peacock, 2018).

[9] Munnell et al. (2007) argue that middle-aged employees have far more to lose than younger ones when firms freeze their DB pension plans.

Cocco and Volpin (2007) provides empirical evidence that in the UK highly leveraged firms take more risk in pension investments.

Dividend and investment policies may also determine the choice of de-risking strategy. It is argued that firms facing pension contribution constraints tend to make lower dividend pay-outs (Liu & Tonks, 2013); hence, firms with lower dividend pay-out ratios may have a greater incentive to *freeze* pension plans. Firms where pension contributions constrain dividends may benefit more from *freezing* and *buy-ins* since these remove pension obligations directly – reducing firms' future pension contributions.

3.3. The impact of pension de-risking on firm risk

Theoretically speaking, removing DB pension plan risks through de-risking should reduce overall firm risk. Testing these arguments empirically, Milevsky and Song (2010), examining 75 US firms' DB pension plan announcements, finds a positive market reaction to *soft* and *hard freezing.* They explain that firm risks are reduced because *soft freezing* decreases the growth rate of pension benefits and *hard freezing* decreases pension costs and employee compensation. Moreover, they find the positive impact to be more pronounced for firms that would be likely to face financial distress were they to maintain their traditional pension plans and the associated long-term promises. Similarly, Yu (2016) finds a positive market reaction to *hard-freezing* announcements of 106 US firms. In contrast, McFarland et al. (2009), examining a dataset of 82 US firms, report negative or insignificant abnormal market returns following announcements of *freezing.* They argue that the benefits of *freezing* DB pension plans may be offset by the costs, including employees' resistance, possible drops in employee motivation and productivity, and market caution about the long-term effect of freezing. Similarly, Lin et al. (2015), developing an optimisation model, argue that poor implementation of pension de-risking strategies increases firm risk, and that implementation is sensitive to various costs. Hence, the costs of pension *buy-ins* and *longevity swaps* cannot be ignored. Overall, it can be argued that previous findings relating to the impact of pension de-risking strategies on firm risk are inconclusive.

Pension obligations are viewed as an integral part of corporate debt (Bodie et al., 1985; Gallagher & McKillop, 2010; Martin & Henderson, 1983; McKillop & Pogue, 2009). Research has found that corporate credit ratings are associated with the level of pension obligations, with a higher pension risk resulting in a lower rating. For example, McKillop and Pogue (2009), examining the relationship between DB pension plans' funding risk and the corporate debt ratings of FTSE 100 firms, find that the probability of obtaining a higher debt rating is lower for firms with greater pension risk. Similarly, Gallagher and McKillop (2010), using a cross-country sample, find that DB pension risk is a significant and positive determinant of the option adjusted spreads of corporate bonds, resulting in higher cost of borrowing. Moody's also regards key DB pension de-risking strategies as credit positive. Overall, both academic research and anecdotal evidence suggest that pension de-risking strategies may have an impact on firms' credit risk.

4. Methodology and data

4.1. Methodology

4.1.1. Determinants of the de-risking strategy

We estimate the following multinomial logit model to examine firm- and pension plan-specific financial factors that influence the choice of de-risking strategy:

$$Pr(PDS_t = s) = \delta_0 + \delta_1 BOND_{t-1} + \delta_2 HOR_{t-1} + \delta_3 FUND_{t-1} + \delta_4 PLAN\_SIZE_{t-1} + \delta_5 DIV\_PAYOUT_{t-1} + \delta_6 LEV_{t-1} + \delta_7 CAPEX_{t-1} + \delta_8 MACAP_{t-1} + \delta_9 CF_{t-1} \quad (1)$$

where *PDS* is the log-odds ratio of the probability of choosing one of the following options: i) no de-risking implemented (coded as 0), ii) *soft freeze* (coded as 1), iii) *hard freeze* (coded as 2), iv) pension *buy-ins* (coded as 3),[10] and v) *longevity swap* (coded as 4). *PDS* is the main dependent variable that captures a firm's implementation of one of the pension de-risking strategies. The following examples demonstrate how this variable is coded. If firm X undertakes a soft freeze in the year 2012, then *PDS* is coded as 0 for the years before the *soft-freeze* (2009–2011), 1 in 2012 and will remain as 1 throughout the rest of period (2012–2017). In the data Firm X's *PDS* record for the period of 2009–2017 will be recorded as 0, 0, 0, 1, 1, 1, 1, 1, 1. In a similar fashion if firm Y implements a *soft freeze* in 2012 followed by a *hard freeze* in 2016 the data will be coded as 0, 0, 0, 1, 1, 1, 1, 2, 2 to reflect the change. In other specifications, we also examine the differences between traditional and innovative pension de-risking strategies. In this alternative setting, *PDS* is coded as 0 if a firm does not implement a pension de-risking strategy, 1 if a firm employs traditional de-risking strategies (*soft* or *hard freezes*), and 2 if a firm engages in innovative de-risking strategies (*buy-in* or *longevity swap*).

Pension plan-specific variables are *BOND, HOR, FUND* and *PLAN_SIZE. BOND* is the percentage of pension assets allocated to bonds and used as a proxy to measure the pension fund's investment risk. Pension *buy-ins* are particularly useful to remove investment risk of pension plans. Thus, we expect that pension plans with higher investment risk are more likely to engage in pension *buy-ins*. In contrast, longevity swaps may be more suitable for pension plans with high levels of investment risk seeking to remove the longevity risk (Lin et al., 2015). *HOR,* indicating the pension horizon*,* is the natural logarithm of projected benefit obligations divided by service costs. Firms with longer investment horizons for their pension plans (indicating pension fund maturity) may be more likely to implement pension de-risking strategies as they are exposed to greater pension plan risk. Such firms' pension plans tend to have a larger number of younger employees, which eases the implementation of de-risking as the firm may face less resistance from younger employees (Munnell et al., 2007). *FUND* is the fair value of pension assets divided by projected benefit obligations. *PLAN_SIZE* is the projected benefit obligations divided by total assets. Firms with larger pension funds are more likely to choose pension *buy-ins* or *longevity swaps* as they were originally designed for such plans in terms of complexity and costs (Lane, Clark & Peacock, 2018). However, freezing a large DB pension plan may provoke more resistance from employees because it significantly affects employees' benefits (Comprix & Muller, 2011).

Firm-specific variables are *DIV_PAYOUT, LEV, CAPEX, MACAP* and CF. *DIV_PAYOUT* is the dividend pay-out ratio. Firms facing pension contributions crowd out dividend payments and investments (Liu & Tonks, 2013). Firms where pension contributions constrain on dividends may benefit more from *freezing* and *buy-ins* since they remove pension obligations directly, thus reducing firms' future pension contributions. In contrast, *longevity swaps* have a lesser impact on pension contributions as they only freeze mortality assumptions. Therefore, we expect that firms with less dividend payment are more likely to engage in pension de-risking. *LEV* is calculated as the long-term debt divided by the sum of long-term debt and the market value of equity. Cocco and Volpin (2007) finds that highly leverage firms are more risk-taking in pension investments in the UK. Therefore, we expect that highly leverage firms are less likely to engage in de-risking strategies. In addition, firms with higher leverage indicate poorer financial condition, and such firms may find payment of an up-front premium for pension *buy-ins* and *longevity swaps* less affordable. *CAPEX* is capital expenditure divided by total assets. *MACAP* is the natural logarithm of market capitalisation. We expect that large firms are more likely to seek to financial instruments to reduce pension risk. Thus, higher *CAPEX* and *MACAP* are expected to be

[10] We do not take account of different types of pension buy-in contracts and focus on the aggregated determinants and effect of pension buy-ins.

related to pension *buy-ins* and *longevity swaps*. CF is the cash flow from operating activities divided by total equity.

4.1.2. Impact of pension de-risking on firm risk

We measure overall firm risk using three alternative indicators: *earnings volatility*, *volatility of returns on capital invested,* both balance sheet risk metrics; and Altman's *Z-score,* capturing the probability of default. We estimate the following models:

$$Std\_ROA_t = \delta_0 + \delta_1 Strategies_{t-1} + \delta_2 SALES_t + \delta_3 SALES\_GROWTH_t + \delta_4 MB_t + \delta_5 ROA_t + \delta_6 LEV_t + \delta_7 CAPEX_t + \delta_8 MACAP_t + \sum \beta_s Year\_dummy + \sum \beta_r Industry\_dummy + \mu \quad (2)$$

$$Std\_RETURN_t = \delta_0 + \delta_1 Strategies_{t-1} + \delta_2 SALES_t + \delta_3 SALES\_GROWTH_t + \delta_4 MB_t + \delta_5 ROA_t + \delta_6 LEV_t + \delta_7 CAPEX_t + \delta_8 MACAP_t + \sum \beta_s Year\_dummy + \sum \beta_r Industry\_dummy + \mu \quad (3)$$

$$ZScore_t = \delta_0 + \delta_1 Strategies_{t-1} + \delta_2 FUND_t + \delta_3 LEV_t + \delta_4 SALES\_GROWTH_t + \delta_5 SIZE_t + \delta_6 PROFIT_t + \delta_7 TANGIBILITY_t + \sum \beta_s Year\_dummy + \sum \beta_r Industry\_dummy + \mu \quad (4)$$

where *Std_ROA* is the standard deviation of net income scaled by average total assets and measured over the last three years[11]; *Std_RETURN* is the standard deviation of net operating profit after tax scaled by average invested capital, measured over the current and last five years; and *ZScore* is the Altman Z-score (Altman, 2000).[12] $Strategies_t$ include variables $Soft_{t-1}$, $Hard_{t-1}$, $Buyin_{t-1}$ and $Longevity_{t-1}$, representing *soft freezing*, *hard freezing*, *buy-ins* and *longevity swaps*, respectively. There is one-year lag for each pension de-risking strategy as there may be a gradual effect of pension de-risking on overall firm risk.[13]

Following the literature, we use a set of control variables that may also have an impact on firm risk (Choy et al., 2014; Hovakimian, Kayhan, & Titman, 2009). *SALES* is the natural logarithm of sales or revenues. *SALESGROWTH* is the difference in *SALES* between times *t* and *t*-1. *MB* is the market-to-book ratio of assets, computed as the ratio of the market value of assets to the book value of assets. *ROA* is net income divided by total assets. We expect that firms with higher sales (*SALES*), more sales growth (*SALES_GROWTH*), higher market-to-book ratios (*MB*), and return on assets (*ROA*) have lower firm risk. Other control variables (*LEV, CAPEX* and *MACAP*) are defined as previously. Firms with higher leverage (*LEV*) are expected to have higher firm risk. However, firms with higher capital expenditure (*CAPEX*) and market capitalization (*MACAP*) tend to have lower firm risk.

The sample for these estimations includes all FTSE 350 index firms that have DB pension plans, as we aim to capture the impact of various de-risking strategies on firm risk. For the impact models (Eqs. 2, 3 and 4), we use year fixed effects control for prevailing market conditions, and industry fixed effects control for the possibility that unspecified industry-specific factors may influence the analyses.

We also utilise a measure that captures the firm credit risk. We expect that pension de-risking strategies may have an impact on credit risk and model this relationship as follows:

$$CR_t = \delta_0 + \delta_1 Strategies_{t-1} + \delta_2 StdROA_t + \delta_3 FUND_t + \delta_4 LEV_t + \delta_5 SALES\_GROWTH_t + \delta_6 SIZE_t + \delta_7 PROFIT_t + \delta_8 TANGIBILITY_t + \sum \beta_s Year\_dummy + \sum \beta_r Industry\_dummy + \mu \quad (5)$$

where *CR*[14] is the Standard and Poor's credit rating at time *t*. Given that *CR* is ordinal variable, Eq. (5) is an ordered probit model. All other control variables are defined as above.

We check the robustness of the results using a two-stage least square (2SLS) estimation to support the causal relationship between each of pension de-risking strategy and firm risk measures. In this setting, we adopt a two-year lag of each pension de-risking strategy as instrumental variables (IV), including $Soft_{t-2}$, $Hard_{t-2}$, $Buyin_{t-2}$ and $Longevity_{t-2}$.

4.2. Data and descriptive statistics

Our unique dataset comprises FTSE 350 firms that has a DB pension plans and covers the period of 2009–2017. We identify firms that have implemented a de-risking strategy during this period and construct the dataset by combining data from various different sources. We hand-collected DB pension plan particulars and information on *soft* and *hard freezing* from the firms' annual reports. Data on *buy-ins* and *longevity swaps* are hand-collected from research reports provided by Lane, Clark & Peacock, 2018 and Robertson (2017). We treat multiple *buy-in* transactions for the same firm in the same year as a single pension *buy-in* event. Firms' financial information was obtained from Bloomberg. The data are merged into a single unbalanced panel dataset.

Table 1 provides descriptive statistics for the explanatory and control variables. All continuous variables are winsorised at the top and bottom 1%. We observe that most of the firms in the sample implemented pension de-risking via *soft freezing* (79.1%) followed by *hard freezing* (22.8%). *Longevity swap* is only utilised in 3.3% of the cases. Mean standard deviation of returns on assets (*Std_ROA*) is 2.965 and volatility of total returns on capital invested (*Std_RETURN*) is 3.165, respectively. The mean *ZScore* is 3.983. The average credit rating (*CR*) is 9.5, indicating that, on average, the sample firms are within BBB and BBB+ rating categories. On average, 38.3% of pension assets are allocated to bonds. Pension funds have an average funding level of 89.2%, and the average pension plan size is 35.2% of total assets. We present pairwise correlation coefficients across the variables in Table 2, showing that the impact of multicollinearity is minimal in the models. We observe in Column 1 that *HOR* has a positive and the highest correlation coefficient (0.309) with *PDS*, indicating that pension funds with longer horizons are more likely to be de-risked. Table 3 presents the yearly distribution of de-risking strategies used by the sample firms. There are 16 *soft freeze*, 62 *hard freeze*, 17 *buy-ins* and 12 *longevity swaps* events across the sample years.

Table 4 Panel A reports the results of *t*-tests comparing firms' financial and pension fund characteristics between firms that have (*PDS*) and have not (*NON*) employed a pension de-risking strategy. Results show that pension funds that engage in pension de-risking strategies have invested less in bonds, have longer investment horizons and higher funding levels. Panel B of Table 4 reports t-tests comparing firms that engage in traditional pension de-risking strategies (i.e. *soft* and *hard freezing*) versus in innovative de-risking strategies (i.e. *buy-ins* and *longevity swaps*). We find that pension funds that are de-risked using innovative strategies tend to be larger in size and have longer

[11] We conduct a robustness check with alternative measures for *Std_ROA* and *Std_RETURN* using the standard deviation for last five- and three year-periods, respectively. We obtain very similar results to our findings reported here. For brevity we do not report these results, however they are available from the corresponding author upon request.

[12] *Z*-score is obtained from the Bloomberg database. It is calculated with the following formula: 3.3*EBIT/Total Assets +1.0*Sales/total Assets +1.4*Retained Earnings/Total Assets +1.2*Net Working Capital/Total Assets.

[13] We used one-year lag as we can capture the impact of de-risking strategies on firm risk to take effect in the medium and long-term. A one-year lag is relevant as the main dependent variables (*Std_ROA* and *Std_RETURN*) are measures of volatility that capture risk over a past period. Hence, it is plausible to expect the impact of a de-risking not to be captured fully in the short term.

[14] The credit ratings are issued by credit rating agency, Standard & Poor's, and collected from the Bloomberg database. Following the credit rating literature (Alissa, Bonsall, Koharki, & Penn, 2013), credit rating is treated as an ordinal variable, coded from 1 to 17. The highest credit rating of AAA is coded as 17 and a credit rating equal to or lower than CCC+ is coded as 1.

Table 1
Descriptive statistics.

Variable	Mean	St.Dev	Min	Max	25th	Median	75th
PDS	1.254	0.960	0	4	1	1	2
Soft	0.791	0.407	0	1	1	1	1
Hard	0.228	0.419	0	1	0	0	0
Buy-in	0.097	0.297	0	1	0	0	0
Longevity	0.033	0.178	0	1	0	0	0
Std_ROA	2.965	4.248	0.040	33.053	0.811	1.720	3.288
Std_RETURN	3.165	4.858	0.018	17.763	0.242	0.948	1.820
ZScore	3.983	2.730	−0.102	23.381	2.315	3.340	4.970
CR	9.508	2.439	2	15	8	9	11
BOND	0.383	0.178	0.007	0.860	0.238	0.386	0.510
HOR	4.591	0.983	2.032	7.655	3.949	4.420	4.992
FUND	0.892	0.132	0.396	1.299	0.821	0.897	0.969
PLAN_SIZE	0.352	0.381	0.002	1.883	0.110	0.231	0.434
DIV_PAYOUT	71.368	90.02	0	600.971	35.663	51.621	72.455
LEV	0.289	0.175	0.005	0.820	0.155	0.266	0.388
CAPEX	−0.042	0.040	−0.246	0	−0.057	−0.031	−0.015
MACAP	8.023	1.450	5.380	11.514	6.964	7.763	8.747
CF	0.102	0.059	−0.062	0.372	0.064	0.094	0.132
SALES	10.433	3.855	5.943	36.584	8.890	9.676	10.715
SALES_GROWTH	0.031	4.041	−27.559	25.57	−0.032	0.037	0.112
MB	1.689	0.757	0.651	5.669	1.189	1.495	1.980
ROA	6.629	6.051	−20.744	35.865	3.286	5.779	9.092
SIZE	8.298	1.596	5.231	13.517	7.134	8.014	9.180
PROFIT	0.099	0.073	−0.110	0.508	0.054	0.085	0.133
TANGIBILITY	0.268	0.234	0	0.914	0.071	0.201	0.423

Note: This table reports descriptive statistics for the sample of FTSE 350 firms with DB pension plans between 2009 and 2017. Data on soft and hard freezing of DB pension plans were hand-collected from annual reports. Pension buy-in data and longevity swap information were hand-collected from research reports (Lane, Clark & Peacock, 2016; Robertson, 2017). Accounting information was collected from Bloomberg database. All continuous variables are winsorised at the top and bottom 1%. All variable definitions are reported in the Appendix.

Table 2
Correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) *PDS*	1.000										
(2) *Std_ROA*	−0.009	1.000									
(3) *Std_RETURN*	−0.041	0.035	1.000								
(4) *ZScore*	−0.025	−0.026	−0.173*	1.000							
(5) *CR*	0.027	−0.177*	−0.163*	0.132*	1.000						
(6) *BOND*	−0.048	0.033	0.042	0.026	0.104*	1.000					
(7) *HOR*	0.309*	0.009	−0.028	0.020	−0.149*	0.167*	1.000				
(8) *FUND*	0.132*	0.042	0.017	0.027	−0.033	0.048	0.180*	1.000			
(9) *PLAN_SIZE*	0.191*	0.081*	−0.120*	−0.053	−0.149*	−0.055	0.213*	0.062*	1.000		
(10) DIV_PAYOUT	0.037	0.051	−0.007	−0.075*	0.013	−0.031	0.010	0.022	−0.029	1.000	
(11) LEV	−0.076*	−0.053	0.123*	−0.535*	−0.239*	−0.112*	−0.087*	−0.111*	−0.010	0.046	1.000
(12) CAPEX	0.162*	0.004	−0.042	0.151*	0.075	0.019	0.190*	0.019	0.013	0.059	−0.165*
(13) MACAP	0.039	−0.043	0.040	−0.056	0.796*	0.171*	−0.167*	−0.034	−0.091*	0.063*	−0.024
(14) CF	−0.060	0.034	−0.168*	0.380*	−0.019	0.053	−0.112*	−0.014	0.084*	−0.087*	−0.317*
(15) SALES	−0.047	−0.011	−0.011	0.036	0.228*	−0.017	−0.047	−0.076*	−0.100*	0.050	−0.077*
(16) SALES_GROWTH	−0.018	−0.012	−0.014	0.013	−0.004	0.014	−0.018	−0.022	0.001	0.040	0.004
(17) MB	0.088*	−0.014	−0.263*	0.579*	0.049	0.026	0.063*	0.035	0.261*	−0.013	−0.493*
(18) ROA	0.031	0.064*	−0.226*	0.519*	0.036	0.087*	0.017	0.009	0.150*	−0.082*	−0.448*
(19) SIZE	−0.001	−0.060	0.132*	−0.308*	0.730*	0.137*	−0.195*	−0.060	−0.176*	0.061*	0.303*
(20) PROFIT	−0.088*	0.097*	−0.115*	0.488*	0.026	−0.041	−0.116*	−0.070*	0.152*	−0.105*	−0.409*
(21) TANGIBILITY	−0.127*	0.032	0.055*	−0.276*	−0.114*	−0.037	−0.151*	−0.055*	0.004	−0.044*	0.357*
Variables	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**	**(19)**	**(20)**	**(21)**	
(12) CAPEX	1.000										
(13) MACAP	−0.150*	1.000									
(14) CF	−0.399*	0.097*	1.000								
(15) SALES	0.032	0.054	−0.001	1.000							
(16) SALES_GROWTH	0.014	−0.022	−0.016	0.571*	1.000						
(17) MB	0.033	−0.014	0.494*	0.000	−0.020	1.000					
(18) ROA	−0.055	0.043	0.541*	−0.009	−0.010	0.605*	1.000				
(19) SIZE	−0.151*	0.884*	−0.142*	0.045	0.010	−0.362*	−0.220*	1.000			
(20) PROFIT	−0.181*	−0.044*	0.651*	0.034*	−0.017	0.612*	0.786*	−0.348*	1.000		
(21) TANGIBILITY	−0.588*	−0.019	0.047*	−0.020	0.001	−0.194*	−0.031*	−0.013	−0.013	1.000	

Note: * shows significance at the 0.1 level.

Table 3
Sample split by pension de-risking strategy across the years.

Year	Soft freeze	Hard freeze	Buy-in	Longevity swap
2009	2	3	1	2
2010	1	8	2	1
2011	2	8	1	2
2012	4	7	2	0
2013	5	6	2	3
2014	1	5	3	3
2015	0	9	1	0
2016	1	9	3	0
2017	0	7	2	1
Total	16	62	17	12

Note: This table presents the distribution of pension de-risking strategy observations per year.

Table 4
Mean comparisons.

Panel A: *NON* versus *PDS* firms					
	Mean NON Firms ($N = 198$)	Mean PDS Firms ($N = 839$)	Difference	Std. Error	t-value
BOND	0.414	0.376	0.037	0.014	2.7***
HOR	4.300	4.660	−0.359	0.077	−4.7***
FUND	0.838	0.905	−0.068	0.010	−6.6***
PLAN_SIZE	0.317	0.360	−0.043	0.030	−1.4
DIV_PAYOUT	69.016	71.924	−2.907	7.115	−0.4
LEV	0.296	0.288	0.009	0.014	0.6
CAPEX	−0.046	−0.042	−0.005	0.003	−1.6
MACAP	8.172	7.988	0.184	0.115	1.6
CF	0.104	0.102	0.003	0.005	0.6

Panel B: Firms engaging in traditional versus innovative de-risking					
	Mean Traditional ($N = 724$)	Mean Innovative ($N = 115$)	Difference	Std. Error	t-value
BOND	0.379	0.357	0.022	0.018	1.3
HOR	4.594	5.075	−0.480	0.096	−5.1***
FUND	0.903	0.915	−0.012	0.012	−1.1
PLAN_SIZE	0.328	0.560	−0.233	0.038	−6.1***
DIV_PAYOUT	70.535	80.66	−10.124	8.813	−1.2
LEV	0.290	0.268	0.023	0.018	1.3
CAPEX	−0.043	−0.030	−0.013	0.004	−3.1***
MACAP	7.897	8.567	−0.670	0.138	−4.9***
CF	0.101	0.103	−0.002	0.006	−0.3

Note: This table reports t-tests for two-sample mean differences. *NON* indicates firms that do not implement any pension de-risking strategy. *PDS* indicates firms that implement one of the pension de-risking strategies. Panel A compares the means of variables in the group of firms that do not engage in pension de-risking with firms that do so. Panel B compares the means of variables in the group of firms that engage in traditional pension de-risking strategies (i.e. *soft* and *hard freezing*) with firms that engage in innovative pension de-risking strategies (i.e. *pension buy-ins* and *longevity swaps*). t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

investment horizons. Firms that implement innovative methods have higher market capitalisation and capital expenditure.

5. Results

5.1. Determinants of the pension de-risking choice

We estimate Eq. 1 with a multinomial logit estimator and results are presented in Table 5. Columns 1 to 4 report the results for comparing each pension de-risking strategy with the choice of no implementation, or *NON* (i.e. *PDS* equals 0 set as the benchmark). We find that pension funds with less pension assets allocated to bonds (*BOND*) are more likely to choose pension *buy-ins* (column 3) or choose not to de-risk. Hence, firms with higher pension investment risks tend to remove their investment risk via *buy-ins* if they prefer to do so. We find that *HOR* is positive and significant for *hard freezing* and pension *buy-ins* (columns 2 and 3), suggesting that firms are more likely to prefer hard freeze or buy-ins to de-risk when pension investment horizon is longer. This is consistent with the findings of previous literature that firms with longer pension fund investment horizon face more uncertainty (Amir et al., 2010), and hence are more likely to remove the uncertainty embedded in DB pension plans by de-risking. We find that the coefficient of *FUND* is positive and significant in columns 1 and 3, showing that firms with higher pension plan funding levels are more likely to de-risk utilising *buy-ins* or do not de-risk. We find that the coefficient of *PLAN_SIZE* and *LEV* are positive and statistically significant in column 4. This shows that firms with higher leverage and larger DB pension plans are more likely to de-risk through *Longevity swap* or do not de-risk. We find that firms with higher capital expenditure (*CAPEX*) and market capitalization (*MACAP*) are more likely to implement *buy-ins* or *longevity swap* (columns 3 and 4). This implies that larger firms are more likely to implement innovative pension de-risking strategies.

In columns 5 to 7, we present the results for models where the benchmark is set as *soft freezing* (i.e. *PDS* equals 1) and compared with the options of *hard freezing*, *buy-ins* and *longevity swaps*. The positive and significant coefficient of *HOR*, in columns 5 and 6, suggests that pension funds with longer investment horizons are more likely to choose *hard freezing* and *buy-ins* over *soft freezing*. They are, however, indifferent between *soft freezing* and *longevity swaps* (column 7). When the pension horizon is longer, firms seem to prefer strategies that reduce the risk more significantly, given the increased uncertainty. *Hard freezing* is preferred, as it has a more significant impact on reducing pension risk than *soft freezing* (column 5). Similarly, *buy-ins* aim specifically to remove pension risk. Leveraged firms (*LEV*) are more likely to choose *soft freezing* over *hard freezing* (column 5) and prefer *longevity swaps* over *soft freezing* (column 7). We find that firms with higher capital expenditure (*CAPEX*) and market capitalisation (*MACAP*) are more likely to choose *buy-ins* or *longevity swaps* rather than *soft freezing* (columns 6 and 7) but indifferent between *soft* and *hard freezing*. Higher leverage firms with larger pension plans (*PLAN_SIZE*) are more likely to implement *longevity swaps* rather than *soft freezing* (column 7). They are indifferent when choosing between other de-risking options (columns 5 and 6). These results are consistent with the fact that most *longevity swaps* are purchased by firms with larger pension plans (Lin et al., 2015).

In columns 8 and 9, we present the results of comparing the choice of insurance contracts (*buy-ins* and *longevity swaps*) with *hard-freezing* decisions (i.e. *PDS* equals 2 is set as a benchmark). We find that firms with more leverage (*LEV*) and larger pension plans (*PLAN_SIZE*) are more likely to implement *longevity swap* rather than *hard freezing*. However, these variables do not have a significant influence when the choice is between *hard freezing* and *buy-ins*. We also find that firms with higher market capitalisation (*MACAP*) are more likely to implement pension *buy-ins* or *longevity swaps* over *hard freezing*.

Column 10 presents the results of comparing pension *buy-ins* and *longevity swaps* (i.e. *PDS* equals 3 is set as a benchmark). We find that firms are more likely to implement *longevity swaps* in comparison to *buy-ins* when pension funds are larger (*PLAN_SIZE*) and sponsored by larger firms (*MACAP*). Firms with less pension assets allocated to bonds are more likely to choose pension *buy-ins* over *longevity swaps*. This suggests that firms with greater pension investment uncertainty are more likely to choose pension *buy-ins*, which have a significant impact on removing all types of pension fund risk. Firms with higher leverage (*LEV*) are more likely to implement *longevity swaps* rather than pension *buy-ins*. These results show that firms in a better financial position perhaps find pension *buy-ins* more affordable, which is consistent with the arguments of Lin et al.'s (2017).

5.2. Traditional versus innovative de-risking strategies

Subsequently, we compare the drivers of the broader groups of

Table 5
Multinomial logit regression for the choice of pension de-risking strategies.

Benchmark:	NON ($PDS = 0$)				SF ($PDS = 1$)			HF ($PDS = 2$)		BI ($PDS = 3$)
	NON vs SF	NON vs HF	NON vs BI	NON vs LS	SF vs HF	SF vs BI	SF vs LS	HF vs BI	HF vs LS	BI vs LS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$BOND_{t-1}$	−1.505	−2.053	−5.229***	−0.847	−0.548	−3.723***	0.659	−3.176**	1.206	4.382*
	(0.955)	(1.266)	(1.579)	(2.252)	(0.949)	(1.369)	(2.238)	(1.369)	(2.189)	(2.349)
HOR_{t-1}	0.040	0.895***	0.987***	0.669	0.855***	0.948***	0.629	0.092	−0.226	−0.319
	(0.251)	(0.266)	(0.322)	(0.541)	(0.175)	(0.279)	(0.510)	(0.230)	(0.501)	(0.560)
$FUND_{t-1}$	3.989***	2.257	4.673**	4.573	−1.732	0.684	0.584	2.416	2.316	−0.100
	(1.312)	(1.396)	(2.199)	(5.023)	(1.152)	(2.120)	(4.983)	(1.923)	(4.907)	(5.235)
$PLAN\_SIZE_{t-1}$	−0.294	−0.442	0.087	3.546***	−0.149	0.381	3.840***	0.530	3.989***	3.459***
	(0.428)	(0.726)	(0.567)	(1.028)	(0.620)	(0.512)	(1.126)	(0.690)	(1.090)	(1.066)
DIV_PAYOUT_{t-1}	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.001	0.001
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
LEV_{t-1}	0.662	−1.463	−0.598	4.968***	−2.124**	−1.259	4.306***	0.865	6.430***	5.565***
	(0.926)	(1.059)	(1.560)	(1.343)	(0.866)	(1.488)	(1.330)	(1.547)	(1.363)	(1.715)
$CAPEX_{t-1}$	0.706	6.644	11.919**	60.620***	5.938	11.214**	59.915***	5.275	53.976***	48.701***
	(4.079)	(5.461)	(5.956)	(13.661)	(4.604)	(5.710)	(13.689)	(6.405)	(13.486)	(14.285)
$MACAP_{t-1}$	−0.050	−0.096	0.403*	1.185***	−0.046	0.453**	1.235***	0.499**	1.281***	0.782**
	(0.142)	(0.170)	(0.209)	(0.279)	(0.135)	(0.181)	(0.261)	(0.212)	(0.268)	(0.322)
CF_{t-1}	2.519	−3.336	4.720	−0.856	−5.854**	2.201	−3.375	8.056	2.479	−5.576
	(3.104)	(3.982)	(6.577)	(6.923)	(2.827)	(6.241)	(6.753)	(5.855)	(6.602)	(8.276)
Constant	−2.022	−3.509*	−10.978***	−20.729***	−1.487	−8.956***	−18.708***	−7.469**	−17.221***	−9.751**
	(1.821)	(2.002)	(3.000)	(4.115)	(1.677)	(2.840)	(4.085)	(2.922)	(4.062)	(4.972)
Log p-likelihood	−1131.908									
R^2	0.152									
Wald chi^2	165.455									
N	1037									

Note: This table reports the results of a multinomial regression model that regresses pension de-risking strategy decisions on firms' financial and pension fund characteristics. The dependent variable is *PDS*. *PDS* equals 0 set as the benchmark. *NON* indicates firms that do not implement any pension de-risking strategy. SF is soft freezing, HF is hard freezing, *BI* is buy-in, and LS is longevity swap. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

traditional de-risking strategies with the innovative ones. The results are presented in Table 6. We start by comparing both groups of strategies with the baseline of no de-risking, i.e. *NON* (columns 1 and 2). We find that firms with more investment risk (*BOND*) are more likely to implement pension de-risking. Once again, this result amplifies the fact that pension funds with greater uncertainty are more likely to engage in pension de-risking strategies similar to the findings of the literature (Amir et al., 2010; Munnell et al., 2007). *FUND* is positive and significant, showing that firms with higher pension plan funding levels are likely to engage in de-risking using either innovative or traditional tools. We find that larger pension plans (*PLAN_SIZE*) as well as plans with longer investment horizon (*HOR*) either prefer innovative strategies or no de-risking. In column 3, we compare the two sub-groups and find that firms with longer investment horizons and larger pension plans are more likely to choose innovative methods. This result confirms that firms with smaller pension plans find it easier to transfer the pension risk to employees than to insurers, as they may face less resistance from employees than larger firms (Munnell et al., 2007). We also find that firms with higher investment risk seem to prefer innovative methods. Firms with higher market capitalisation and capital expenditure tend to choose innovative strategies for de-risking. This shows that economic scale of the firm is associated with the decision to buy insurance policies for de-risking, as such transactions have significant upfront costs.

In summary, our findings in Sections 5.1 and 5.2 highlight two major themes relating to firms' choice of pension de-risking strategies in relation to pension plan characteristics. First, we observe that firms that are facing greater pension plan risk are more likely to engage in de-risking. One indicator of a greater level of risk is the length of the investment horizon. We find that firms with longer investment horizons choose *hard freezing* and pension *buy-ins* for de-risking. Another indicator is the investment risk due to current pension portfolio allocation to bonds. We find that firms with higher investment risk are more likely to choose pension *buy-ins*. Overall, our results show that *hard freezing* and *buy-ins* are preferred if the pension risks are high as both of these two methods allow firms to remove pension risk significantly in comparison to *soft freezing* and *longevity swaps*. Second, we observe that use of innovative strategies for de-risking strongly relates to the size of the pension plan. Firms with large pension plans are more likely to de-risk in comparison to small firms, and they prefer innovative de-risking strategies. In terms of firm characteristics our main finding is that larger firms are more likely to de-risk via innovative strategies. There is also some evidence that leveraged firms tend to choose *longevity swaps* over pension *buy-ins* possibly due to the up-front costs attached to the latter method.

5.3. Impact of pension de-risking on firm risk

In Table 7 we summarise the results by only reporting the coefficients of the de-risking variables obtained in each of the four models. Hence, each column in Table 7 includes combined results from four different regressions. The full models are presented in the Appendix C (in Tables C1 to C4).

In columns 1 (Fixed effects - FE) and 2 (Instrumental Variables – IV) we present results for Eq. (2), where *Std_ROA* is the dependent variable. We find negative and significant coefficients for all of the de-risking strategies, including *soft freezing* ($Soft_{t-1}$), *hard freezing* ($Hard_{t-1}$), *buy-ins* ($Buyin_{t-1}$) and *longevity swaps* ($Longevity_{t-1}$). These results show that, when risk is measured with *Std_ROA*, all de-risking strategies are effective in reducing firm risk. However, the degree of the impact varies between alternative strategies, and we find that *longevity swaps* and *buy-*

Table 6
Multinomial logit regression for the choice of traditional versus innovative de-risking strategies.

Benchmark:	NON		Traditional
	NON vs Traditional	NON vs Innovative	Traditional vs Innovative
	(1)	(2)	(3)
$BOND_{t-1}$	−1.660*	−3.877***	−2.217*
	(0.947)	(1.407)	(1.138)
HOR_{t-1}	0.322	0.857***	0.535***
	(0.215)	(0.263)	(0.196)
$FUND_{t-1}$	3.459***	4.594**	1.135
	(1.211)	(1.988)	(1.798)
$PLAN\_SIZE_{t-1}$	−0.352	1.148**	1.499***
	(0.417)	(0.490)	(0.454)
DIV_PAYOUT_{t-1}	0.000	0.001	0.001
	(0.001)	(0.001)	(0.001)
LEV_{t-1}	0.091	0.504	0.413
	(0.853)	(1.330)	(1.209)
$CAPEX_{t-1}$	1.132	20.900***	19.767***
	(3.938)	(7.244)	(6.788)
$MACAP_{t-1}$	−0.062	0.542***	0.605***
	(0.137)	(0.179)	(0.145)
CF_{t-1}	1.103	3.434	2.331
	(2.946)	(5.734)	(5.232)
Constant	−1.980	−11.952***	−9.973***
	(1.722)	(2.564)	(2.287)
Log p-likelihood	−747.667		
R^2	0.111		
Wald chi^2	52.907		
N	1037		

Note: This table reports the results of a multinomial regression model that regresses pension de-risking strategy decisions on firms' financial and pension fund characteristics. The dependent variable is *PDS*. *NON* indicates firms that do not implement any pension de-risking strategy. Traditional includes *soft* and *hard freezing*. Insurance includes *buy-ins* and *longevity swaps*. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

Table 7
Summary of the impact of de-risking strategies on firm risk.

Dependent variable	Std_ROA_t		Std_RETURN_t		$ZScore_t$		CR_t	
	OLS	IV	OLS	IV	OLS	IV	Oprobit	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Soft_{t-1}$	−0.8137*	−1.35***	−0.9224**	−0.77***	0.1489	−0.0442	0.2886	−0.148
	(0.4359)	(0.246)	(0.3999)	(0.219)	(0.2477)	(0.119)	(0.1894)	(0.180)
$Hard_{t-1}$	−0.7770*	−1.186***	−0.7962*	−0.544**	−0.1902	−0.633	0.2834	−0.268
	(0.4425)	(0.285)	(0.4338)	(0.270)	(0.2869)	(0.544)	(0.2647)	(0.224)
$Buyin_{t-1}$	−1.1961*	−2.014**	−1.3876***	−2.380***	−0.0625	−0.0743	0.6277**	0.050***
	(0.6302)	(0.892)	(0.5217)	(0.742)	(0.1680)	(0.244)	(0.3034)	(0.015)
$Longevity_{t-1}$	−4.0933***	−4.366***	−1.2666	−1.105	−0.0108	−0.0743	0.0066	0.0502
	(1.0018)	(1.270)	(0.8360)	(1.061)	(0.2609)	(0.244)	(0.2730)	(0.250)
Observations	2134	2134	2244	2244	1617	1617	531	531
Plan characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Firm characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Firm dummy	YES	YES	YES	YES	YES	YES	YES	YES
Year dummy	YES	YES	YES	YES	YES	YES	YES	YES

Note: This table reports a summary of the results by only reporting the coefficients of the de-risking variables obtained in each of the four models. Each column includes combined results from four different regressions and the full models are presented in the Appendix (in Tables A1 to A4). The dependent variables are earnings volatility (*Std_ROA*), return in invested capital volatility (*Std_RETURN*), default risk (*ZScore*) and credit ratings (*CR*). Plan characteristics include *BOND*, *HOR*, *FUND*, *PLAN_SIZE*. Models, in columns (1, 3, 5) are estimated using year and industry fixed effects. Column (2, 4, 6) and (8) report 2SLS results with an instrumental variable, two-year lag of the employed de-risking strategy. Column (7) reports the result from ordered probit model. Firm characteristics include *DIV_PAYOUT*, *LEV*, *CAPEX*, *MACAP* and CF. Full models are reported in the Appendix in Tables A1 to A4. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

Table 8
Multinomial logit regression for the choice of pension de-risking strategies with restricted sample.

Benchmark:	NON (*PDS* = 0)				SF (*PDS* = 1)			HF (*PDS* = 2)		BI (*PDS* = 3)
	NON vs SF	NON vs HF	NON vs BI	NON vs LS	SF vs HF	SF vs BI	SF vs LS	HF vs BI	HF vs LS	BI vs LS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$BOND_{t-1}$	−2.329	−1.799	−0.406*	26.445	0.530	−1.923*	28.774***	−1.393*	28.244***	26.851***
	(2.387)	(1.598)	(0.200)	(14.419)	(2.020)	(0.963)	(8.972)	(0.604)	(8.637)	(9.056)
HOR_{t-1}	0.526	1.307*	0.078*	−2.454***	0.781	0.604*	−2.980***	1.384*	−3.761***	−2.376**
	(0.488)	(0.680)	(0.036)	(0.951)	(0.745)	(0.281)	(1.150)	(0.750)	(1.144)	(1.068)
$FUND_{t-1}$	4.045**	−2.822	0.587*	15.954**	−6.867***	−3.458	11.909	3.410	18.776**	15.366*
	(1.907)	(1.724)	(0.267)	(7.423)	(2.242)	(4.165)	(7.357)	(4.627)	(7.330)	(8.455)
$PLAN\_SIZE_{t-1}$	1.591*	2.304	1.396	14.146***	0.712	−0.196	12.555**	−0.908	11.843**	12.751**
	(0.889)	(1.468)	(1.468)	(4.929)	(1.409)	(1.415)	(4.981)	(1.962)	(5.108)	(5.126)
DIV_PAYOUT_{t-1}	0.000	−0.004	−0.001	−0.004	−0.004	−0.001	−0.005*	0.003	−0.001	−0.003
	(0.001)	(0.008)	(0.001)	(0.003)	(0.008)	(0.001)	(0.003)	(0.008)	(0.008)	(0.003)
LEV_{t-1}	2.267	−3.087	−2.714	13.495**	−5.353	−4.980	11.228*	0.373	16.581**	16.208***
	(2.569)	(4.041)	(2.421)	(5.372)	(4.572)	(3.322)	(5.752)	(4.529)	(6.612)	(6.067)
$CAPEX_{t-1}$	22.512*	−36.163	20.841*	34.853*	−58.674*	−1.671	12.341*	57.004*	71.016*	14.012
	(12.581)	(32.715)	(10.867)	(18.178)	(34.430)	(13.435)	(5.944)	(33.775)	(37.133)	(18.934)
$MACAP_{t-1}$	0.513	−0.523	0.458*	2.471***	−1.036***	−0.054	1.958**	0.981*	2.994***	2.013**
	(0.312)	(0.366)	(0.208)	(0.884)	(0.323)	(0.441)	(0.897)	(0.505)	(0.934)	(1.015)
CF_{t-1}	1.720	−23.736	−9.565	2.473	−25.456	−11.285*	0.753	14.171	26.209	12.038
	(5.890)	(15.961)	(6.244)	(7.811)	(15.721)	(6.192)	(7.009)	(16.213)	(16.949)	(8.289)
Constant	−10.946**	−2.293	−4.169	−53.368***	8.653*	6.777	−42.422**	−1.875	−51.075**	−49.200**
	(4.351)	(4.420)	(5.861)	(20.264)	(4.959)	(6.946)	(20.527)	(7.204)	(20.382)	(21.521)
Log p-likelihood	−192.743									
R^2	0.218									
Wald chi^2	918.371									
N	258.000									

Note: This table reports the results of a multinomial regression model that regresses pension de-risking strategy decisions on firms' financial and pension fund characteristics after removing from the sample the firms that have already implemented a pension de-risking strategy before 2009. This leads to the reduction of firm-year observations to 258 from 1037. The dependent variable is *PDS*. NON indicates firms that do not implement any pension de-risking strategy. SF is soft freezing, HF is hard freezing, BI is buy-in, and LS is longevity swap. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

ins have the largest effect in reducing the risk. We report similar results for Eq. 3 where we proxy firm risk with *Std_RETURN* in columns 3 (FE) and 4 (IV). We find that, apart from $Longevity_{t-1}$, coefficients of all de-risking strategies are negative and statistically significant. Having the largest coefficient, *buy-ins* have the highest impact in reducing firm risk. In columns 5 and 6, we present the estimation results for Eq. 4 with *ZScore,* and do not find significant relationships between de-risking strategies and default risk. Similarly, in columns 7 and 8, reporting results for Eq. 5, we find that only $Buyin_{t-1}$ has a significant relationship with credit risk (*CR*).[15]

Overall, the results show that the pension plan de-risking reduces firm risk; however, this impact is only captured for risk measures that reflects the volatility of the firm's income from the investors perspective. These findings are plausible for the impact of *soft* and *hard freezing* on firm risk. Implementation of *soft freezing* will decline the pension plan size gradually over time due exclusion of new employees. Implementation of *hard freezing* will reduce a firm's pension contribution costs and halts the growth of payments. Among all strategies, pension *buy-ins* seems to the most effective strategy in reducing firm risk, including the credit risk. Pension *buy-ins* transfer pension obligation risk to third parties; therefore, removes most of the risks arising from sponsoring a pension plan. In contrast, *longevity swaps* tend to have a weaker impact on firm risk as they only removes the mortality risk from pension plans.

5.4. Robustness checks

We test the robustness of our results regarding two possible concerns that may lead to biased estimations. Firstly, it could be that a traditional pension de-risking strategy may have already been employed by a firm in our sample before the start of the sampling period. It is also probable that traditional strategies were employed more in the past as the innovative ones were less likely to be available. Hence, one may argue that the sample start period should not be treated as homogeneous. To alleviate this potential concern, we re-run our estimations by removing firms that have already implemented traditional pension de-risking before 2009. This restriction, firstly, allows both traditional and innovative pension de-risking strategies to be observed, and, secondly, limits

Table 9
Hausman test of IIA assumption for the Multinomial logit regression model. Ho: Odds(Outcome-J vs Outcome-K) are independent of other alternatives.

Panel A: Suest-based Hausman tests of IIA assumption

Omitted	chi2	df	P > chi2
1	39.767	30	0.109
2	41.776	30	0.075
3	40.778	30	0.091
4	26.325	30	0.658

Panel B: Small-Hsiao tests of IIA assumption

Omitted	lnL(full)	lnL(omit)	chi2	df	P > chi2
1	−258.628	−232.569	40.119	30	0.103
2	−366.116	−345.297	41.638	30	0.077
3	−461.565	−442.448	38.233	30	0.144
4	−564.716	−545.599	38.234	30	0.144

Note: A significant test is evidence against H_o.

[15] We do not discuss the coefficients related to the control variables as our focus is on the pension de-risking strategies. However, we can report that other control variables employed in the estimations are mostly in line with the results reported by the previous literature (Alissa et al., 2013; Hovakimian et al., 2009).

Table 10
Determinants of pension de-risking strategies – Robustness checks.

	$Soft_t$	$Hard_t$	$Buyin_t$	$Longevity_t$
	(1)	(2)	(3)	(4)
$BOND_{t-1}$	−0.7369	−0.1185	−1.8385***	1.1428
	(0.4885)	(0.4824)	(0.6235)	(1.0157)
HOR_{t-1}	0.1091	0.3791***	0.2833**	0.0469
	(0.1260)	(0.0910)	(0.1140)	(0.2257)
$FUND_{t-1}$	1.7090**	−0.5097	0.5594	1.2267
	(0.7360)	(0.5961)	(0.9622)	(1.7809)
$PLAN\_SIZE_{t-1}$	−0.1444	0.0293	0.0686	2.2426***
	(0.2220)	(0.2527)	(0.2284)	(0.4869)
DIV_PAYOUT_{t-1}	0.0000	−0.0002	0.0001	0.0004
	(0.0007)	(0.0005)	(0.0006)	(0.0009)
LEV_{t-1}	0.2699	−0.7593	−0.2338	3.2380***
	(0.4716)	(0.4862)	(0.6177)	(0.7572)
$CAPEX_{t-1}$	0.8927	3.6004	4.0702*	35.3973***
	(2.2957)	(2.7144)	(2.3368)	(8.7147)
$MACAP_{t-1}$	−0.0246	−0.0790	0.1271	0.5805***
	(0.0769)	(0.0832)	(0.0912)	(0.1518)
CF_{t-1}	1.3461	−3.2640**	0.9927	−0.3262
	(1.5238)	(1.5955)	(2.8002)	(3.8696)
Constant	−1.0777	−1.4302	−3.8905***	−10.5185***
	(1.0509)	(0.9187)	(1.4383)	(2.3066)
Observations	1037	1037	1037	1037
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Pseudo R^2	0.046	0.167	0.120	0.508

Note: This table reports the results of probit models that examine the determinants of each pension de-risking strategy independently. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

the sample to firms that have not implemented any de-risking strategy before 2009.[16] We present the results in Table 8. We find that there is positive and significant coefficient on *HOR* for *hard freezing* and *buy-ins*, supporting our main finding that firms with longer investment horizon are more likely to implement these two pension de-risking strategies. The negative and significant coefficient for *buy-ins* show that firms that invest more pension asset to equity, and are taking more investment risk, are more likely to engage in *buy-ins* to remove such risk. In addition, our main finding that innovative pension de-risking strategies (i.e. *buy-ins* and *longevity swaps*) are more likely to be implemented by larger firms is confirmed. Overall, results are consistent with our main findings.

Secondly, it could be argued that choices of traditional and innovative pension de-risking strategies may not be entirely exclusive from each other, violating the assumption of "independence of irrelevant alternatives (IIA)" for multinomial logit regressions (Greene, 2003; Hausman & McFadden, 1984) and, therefore, leading to biased results. IIA states that the odds of preferring one alternative over another do not depend on the presence of other alternatives. For example, in our setting, a company that has not undertaken any pension de-risking prior may choose to start with a simpler method rather than a more sophisticated one. To check whether such bias has an impact on our results, we conduct Suest-based Hausman test and Small-Hsiao tests for IIA. Results of both tests, presented in Table 9, suggest that IIA assumption is met. As a second alternative to check the robustness, we also run the regressions with binary dependent variables for each pension de-risking strategy. This exercise allows us to examine the determinants of each pension de-risking strategy independently. Results, present in Table 10, are consistent with our main findings.

Table 11 provides robustness tests for the impact each pension de-risking strategy on firm risk. All indicator variables for each pension de-risking strategy are included in the model. Results confirm our main findings presented in Tables 5 to 7. This suggest that *soft freezing* has significant impact on the volatility of ROA and returns on capital invested and *hard freezing* has significant impact on returns on capital invested. *Buy-ins* reduce volatility of ROA and return on capital invested, and improve firms' credit ratings. *Longevity swaps* have less impact on firm risk as it only reduces volatility of ROA.

Table 11
Impact of pension de-risking strategies on firm risk.

	Std_ROA_t	Std_RETURN_t	$ZScore_t$	CR_t
	(1)	(2)	(3)	(4)
$Soft_{t-1}$	−0.7695*	−0.7711*	0.0983	0.2793
	(0.4601)	(0.4385)	(0.1673)	(0.1774)
$Hard_{t-1}$	−0.6088	−0.7554*	−0.0956	0.2300
	(0.4402)	(0.4261)	(0.1150)	(0.2861)
$Buyin_{t-1}$	−1.2774**	−1.4125***	−0.0584	0.6517**
	(0.6286)	(0.5221)	(0.1683)	(0.3221)
$Longevity_{t-1}$	−4.1886***	−1.2804	−0.0133	0.0028
	(1.0035)	(0.8363)	(0.2615)	(0.2684)
$SALES_t$	0.0275	−0.0993***		
	(0.0420)	(0.0338)		
$SALES\_GROWTH_t$	−0.0011	0.0640***	−0.0007	−0.0112
	(0.0302)	(0.0245)	(0.0070)	(0.0130)
MB_t	0.6949***	−0.1695		
	(0.2305)	(0.1825)		
ROA_t	0.0154	−0.0404***		
	(0.0188)	(0.0153)		
LEV_t	0.6620	−0.5723	−3.2503***	−4.7137***
	(1.3045)	(1.0703)	(0.3301)	(0.6480)
$CAPEX_t$	−3.2456	−4.4138		
	(4.8159)	(3.8439)		
$MACAP_t$	−1.9270***	0.2685		
	(0.3464)	(0.2743)		
$FUND_t$			1.4389***	0.2845
			(0.3825)	(0.5975)
$SIZE_t$			−0.0388	0.8535***
			(0.1269)	(0.1226)
$PROFIT_t$			8.8015***	1.0790
			(0.5649)	(1.4272)
$TANGIBILITY_t$			−1.8847**	−0.4685
			(0.7367)	(0.5994)
Std_ROA_t			−0.0208***	−0.0342**
			(0.0077)	(0.0152)
Constant	15.5802***	2.6690	3.0058***	
	(2.7674)	(2.2069)	(1.1289)	
Observations	2134	2244	1617	531
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Adj. or Pseu. R^2	−0.128	−0.163	0.244	0.318

Note: This table reports the results of a year and firm fixed-effects regression that examines whether each of pension de-risking strategy is likely to have an impact on firms' earnings volatility, return in invested capital volatility, default risk measured by the Altman *Z*-score and sponsoring firms' credit ratings. Column (4) reports the result from ordered probit model. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

Finally, we also test our arguments employing market implied risk measures, using the information embedded in the stock prices reflecting the expectations of investors. First, we employ stock return volatility as a dependent variable to examine the effect of de-risking strategy on equity risk. For this we use price volatility, *PRICE_VOL*, defined as annualized standard deviation of the relative price change for the 360 trading days closing price, expressed as a percentage. Second, we look at the potential impact of de-risking on implied credit risk, using The Bloomberg

[16] The soft and hard freezing data are available from 2002 to 2017, allowing us to identify firms that have soft (28 firms) or hard (8 firms) frozen their DB pension plans before 2009.

Table 12
Impact of pension de-risking strategies on implied firm risk.

	PRICE_VOL	*CDS_DEFAULT*	*PRO_DEFAULT*
	(1)	(2)	(3)
$Soft_{t-1}$	−16.5718*	−2.3478*	−0.0009
	(9.9855)	(1.2387)	(0.0022)
$Hard_{t-1}$	−5.5324	−0.7227	−0.0037**
	(6.9694)	(0.8647)	(0.0015)
$Buyin_{t-1}$	−24.8858**	−2.4586*	−0.0048**
	(10.8305)	(1.3435)	(0.0024)
$Longevity_{t-1}$	−10.8442	2.5283	0.0008
	(16.2326)	(2.0134)	(0.0035)
$SALES_t$	2.3784***	−0.0132	0.0002
	(0.6425)	(0.0793)	(0.0001)
$SALES\_GROWTH_t$	−1.5414***	0.0041	0.0001
	(0.4601)	(0.0570)	(0.0001)
MB_t	4.8186	0.6423	0.0056***
	(3.5451)	(0.4321)	(0.0008)
ROA_t	0.0024	−0.1126***	−0.0001**
	(0.2883)	(0.0360)	(0.0001)
LEV_t	309.1062***	13.4182***	0.0667***
	(20.4297)	(2.5496)	(0.0045)
$CAPEX_t$	−375.1044***	18.8527**	−0.0445***
	(72.8802)	(9.0465)	(0.0159)
$MACAP_t$	−53.9602***	−5.3242***	−0.0112***
	(5.3325)	(0.6636)	(0.0012)
Constant	464.6577***	83.4081***	0.0756***
	(42.5572)	(5.2952)	(0.0093)
Observations	2247	2234	2247
Firm FE	YES	YES	YES
Year FE	YES	YES	YES
Adjusted R^2	0.353	0.543	0.324

Note: This table reports the results of a year and firm fixed-effects regression that examines whether each of pension de-risking strategy is likely to have an impact on default risk implied credit default swap (*CDS_DEFAULT*), price volatility (*PRICE_VOL*) and Bloomberg Default probability (*PRO_DEFAULT*). Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

Corporate Default Risk (*DRSK*) indicators.[17] Accordingly, default risk implied credit default swap (*CDS_DEFAULT*) is defined as 5-year credit risk swap spread for the company implied by the *DRSK*. Default probability (*PRO_DEFAULT*) is defined as probability of default of the issuer over the next 2 years calculated by *DRSK*. Such additional analysis will help to confirm the robustness of our results as it is argued that credit ratings can only partially assess the firm credit risk and estimation of the firm default probability from market information could alleviate this potential problem (Chang et al., 2017).

We report the results in Table 12, employing the same control variables as defined previously. For *soft-freezing*, we find evidence that implementation of *soft freezing* on DB pension plans reduces price volatility and CDS implied default risk, as there is a negative and significant relationship (at 10% significant level) between $Soft_{t-1}$ and *CDS_DEFAULT,* and $Soft_{t-1}$ and *PRICE_VOL*. For *hard freezing*, we find that coefficient of *PRO_DEFAULT* to be significant at 5% level, indicating that DB de-risking via *hard freezing* reduces default probability. For pension *buy-ins*, we find consistent evidence that it reduces all three market implied risk measures as $Buyin_{t-1}$ is negative and significantly associated with *PRICE_VOL, CDS_DEFAULT,* and *PRO_DEFAULT*. For *longevity swap*, we do not find any significant results. Overall, our results with implied risk indicators are broadly consistent with our main findings that implementing pension de-risking strategies may reduce implied firm risk. In particular, implementation of pension *buy-in* has a significant impact in reducing implied firm risk.

6. Conclusion

In this paper, we examine the determinants of DB pension de-risking strategies and their impact on firm risk using a unique hand-collected dataset covering FTSE 350 firms for the period of 2009–2017. We find that firms with longer investment horizons, indicating greater investment uncertainty, are more likely to implement *hard freezing* and *buy-ins*. We find that firms with larger capital expenditure and market capitalization prefer innovative de-risking strategies. We suggest that usage of innovative strategies relates strongly to economic scale of the firm. Pension plans with less asset allocated to bonds, indicating higher investment risk, are more likely to choose pension *buy-ins.* Leveraged firm choose *longevity swap*.

We also find that implementing pension de-risking strategies reduce firm risk. However, the effectiveness of each de-risking strategy varies. Both *soft freezing* and *hard freezing* tend to reduce firm's balance sheet risk. Among all strategies, pension *buy-in* is the most effective strategy in reducing firm risk. Our results show that *longevity swaps* tend to have a lower impact on firm risk.

Our research has policy implications for pension policy makers and sponsoring firms that are planning to de-risk their DB pension plans. The results show that transferring pension liability risks to third parties is an effective method for sponsoring firms to off-load their pension risk. Hence, pension policy makers might encourage the development of innovative pension de-risking strategies to reduce pension risk for firms with DB pension plans. However, most sponsoring firms appear to be concerned about the costs of pension de-risking strategies. Therefore, they must trade off the costs and benefits of de-risking.

Our research is limited by the data availability for the scale of the *buy-in* transactions to total pension obligations and relative size of them to firm size. Potentially, these are two important determinants for pension *buy-in* decisions. In addition, implementation of innovative pension de-risking strategies largely relies on the pricing of the pension *buy-in* and *longevity swap* contracts. However, such information is not publicly available and accounting for these factors could be an avenue for future research.

Data availability

Data will be made available on request.

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[17] The *DRSK* public model estimates forward-looking real-world default probabilities for publicly traded firms. The model assigns credit grades based on the estimated default probabilities. *DRSK* utilises a hybrid Merton-Black-Cox model to calculate the default probabilities (see Bondioli et al., 2021 for more details).

Appendix A. Definitions of variables

Variable	Definition
Dependent variables	
PDS	Equals to 0 if the firm does not implement any pension de-risking strategies, 1 if the firm implements a soft freeze, 2 if the firm implements a hard freeze, 3 if the firm implements a pension buy-in, and 4 if the firm implements a longevity swap.
Std_ROA	Standard deviation of net income scaled by average total assets, measured over the last three years. The average total assets is the average of the beginning balance and ending balance of total assets.
Std_RETURN	Standard deviation of net operating profit after tax scaled by average invested capital at time *t*, measured over the last five years. Where average invested capital is the average of the beginning and ending of total invested capital.
CR	Credit ratings (Standard & Poor's) at times *t* for the sponsoring firm. The highest credit rating is coded as 17 and the lowest as 1.
ZScore	Calculated as 3.3 × EBIT/Total Assets+1.0 × Sales/total Assets+1.4 × Retained Earnings/Total Assets+1.2 × Net Working Capital/Total Assets.
PRICE_VOL	A measure of the risk of price moves for a security calculated from the standard deviation of day to day logarithmic historical price changes. The 360-day price volatility equals the annualized standard deviation of the relative price change for the 360 most recent trading days closing price, expressed as a percentage.
CDS_DEFAULT	5 Year CDS (credit default swap) spread for the company implied by the Bloomberg Issuer Default Risk model.
PRO_DEFAULT	Probability of Default of the issuer over the next 2 year calculated by the Bloomberg Issuer Default Risk model.
Main independent variables	
Soft	Equals to 1 if firm soft freezes DB pension plan in a particular year and remains fixed as 1 for the following years, and 0 otherwise.
Hard	Equals to 1 if firm hard freezes DB pension plan in a particular year and remains fixed as 1 for the following years, and 0 otherwise.
Buyin	Equals to 1 if firm engages in pension buy-in in a particular year and remains fixed as 1 for the following years, and 0 otherwise.
Longevity	Equals to 1 if firm engages in longevity swap in a particular year and remains fixed as 1 for the following years, and 0 otherwise.
Control variables	
BOND	Pension assets allocated to bonds at time *t* divided by total pension assets.
HOR	Natural logarithm of projected benefit obligations at time *t* divided by service costs.
FUND	Fair value of pension assets divided by projected benefit obligations.
PLAN SIZE	Projected benefit obligations divided by total assets.
DIV_PAYOUT	Dividend payout ratio.
LEV	Long-term debt divided by the sum of long-term debt and the market value of equity.
CAPEX	Capital expenditure divided by total assets.
SIZE	Natural logarithm of total assets.
CF	Cash flow from operating activities divided by total equity.
SALES	Natural logarithm of sales or revenues.
SALES_GROWTH	Natural logarithm of sales from time *t* to time *t-1*.
MB	Market-to-book ratio of assets, computed as the ratio of the market value of assets (book value of assets minus book value of equity plus market value of equity) to the total book value of assets.
ROA	Earnings before interest and tax divided by total assets.
MACAP	Natural logarithm of total market capitalization.
TANGIBILITY	Changes in total property, plant and equipment scaled by total assets.
PROFIT	Operating income scaled by total assets.

Appendix B. Costs and benefits of pension de-risking strategies

	Costs	Benefits
Soft Freezing	• May reduce the attractiveness of the company to potential employees	• Cuts retirement benefit responsibility and contribution costs for new employees
Hard freezing	• Costs negotiating with labour unions and employees to close DB pension plans. • May reduce the attractiveness of the company to potential employees	• Cuts retirement benefit responsibility and contribution costs for all employees. • Transfer the investments and demographic risks to employees.
Pension buy-ins	• Up-front cost. • Pension buy-in may increase the pension risk for the part of pension obligation left in the companies.	• Transfers part costs arising from pension obligations to insurers. • Remove significant amount of pension obligations from liabilities. • Insurers may have superior expertise in effective management of pension assets and liabilities.
Longevity swap	• Fixed payments for the duration of the agreement.	• Removes longevity risk from pension obligations. • No up-front costs in comparison to pension buy-in

Appendix C

Table C1
Impact of *soft freezing* on firm risk.

Dependent var.	Std_ROA_t		Std_RETURN_t		$ZScore_t$		CR_t	
	FE	IV	FE	IV	FE	IV	Oprobit	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Soft_{t-1}$	−0.8137*	−1.35***	−0.9224**	−0.77***	0.1489	−0.0442	0.2886	−0.148
	(0.4359)	(0.246)	(0.3999)	(0.219)	(0.2477)	(0.119)	(0.1894)	(0.180)
$SALES_t$	−0.0122	0.0274	−0.0232	−0.0444*				
	(0.0549)	(0.0402)	(0.0421)	(0.0265)				
$SALES\_GROWTH_t$	0.0087	−0.0122	0.0212	0.0216	−0.0069	−0.005	−0.017	−0.001

(*continued on next page*)

Table C1 (*continued*)

Dependent var.	*Std_ROA*$_t$		*Std_RETURN*$_t$		*ZScore*$_t$		*CR*$_t$	
	FE	IV	FE	IV	FE	IV	Oprobit	IV
	(0.0318)	(0.0424)	(0.0216)	(0.0250)	(0.0079)	(0.0124)	(0.0148)	(0.0272)
MB$_t$	0.3486	0.214	−0.5723***	−0.50***				
	(0.3257)	(0.187)	(0.1987)	(0.111)				
ROA$_t$	0.0442	0.0595**	−0.0326	−0.04***				
	(0.0358)	(0.0244)	(0.0199)	(0.0158)				
LEV$_t$	−0.3412	0.475	2.1545	1.568**	−4.5396***	−5.01***	−4.732***	−3.528***
	(1.2932)	(0.773)	(1.3944)	(0.717)	(0.6973)	(0.363)	(0.6278)	(0.636)
CAPEX$_t$	8.9554**	1.976	−3.6291	−0.162				
	(4.2514)	(2.700)	(5.1977)	(2.534)				
MACAP$_t$	−0.3846**	−0.21***	0.3685**	0.324***				
	(0.1546)	(0.0779)	(0.1577)	(0.0725)				
FUND$_t$					0.884	−0.251	0.3546	1.614***
					(0.8582)	(0.382)	(0.6167)	(0.548)
SIZEt					−0.289***	−0.19***	0.8472***	1.168***
					(0.1020)	(0.0361)	(0.1138)	(0.0528)
PROFIT$_t$					12.776***	13.85***	1.371	2.303**
					(2.0888)	(1.467)	(1.4526)	(1.161)
TANGIBILITY$_t$					−2.341***	−1.13***	−0.426	−0.499
					(0.6994)	(0.267)	(0.5883)	(0.416)
Std_ROA$_t$					−0.048**	−0.023*	−0.032**	−0.056***
					(0.023)	(0.0135)	(0.015)	(0.0168)
Constant	9.0969***	5.024***	−0.0051	2.165***	7.2979***	6.187***		−1.637**
	(1.8184)	(0.915)	(1.6934)	(0.721)	(1.4155)	(0.534)		(0.800)
Observations	2134	2134	2244	2244	1617	1617	531	531
Firm dummy	YES	YES	YES	YES	YES	YES	YES	YES
Year dummy	YES	YES	YES	YES	YES	YES	YES	YES
Adj. or Pseu. R^2	0.0744	0.035	0.0619	0.057	0.508	0.438	0.311	0.587

Note: This table reports the results of a year and firm fixed-effects regression that examines whether soft freezing is likely to have an impact on firms' earnings volatility, return in invested capital volatility, default risk measured and credit ratings in column (1), (3), (5) and (7). Column (2), (4), (6) and (8) report 2SLS results with an instrumental variable, two-year lag of *soft freezing.* Column (7) reports the result from ordered probit model. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

Table C2
Impact of *hard freezing* on firm risk.

	Std_ROA$_t$		*Std_RETURN*$_t$		*ZScore*$_t$		*CR*$_t$	
	FE	IV	FE	IV	FE	IV	Oprobit	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hard$_{t\text{-}1}$	−0.7770*	−1.186***	−0.7962*	−0.544**	−0.1902	−0.633	0.2834	−0.268
	(0.4425)	(0.285)	(0.4338)	(0.270)	(0.2869)	(0.544)	(0.2647)	(0.224)
SALES$_t$	−0.0167	0.0364	−0.0214	−0.0388				
	(0.0546)	(0.0409)	(0.0426)	(0.0266)				
SALES_GROWTH$_t$	0.0120	−0.0182	0.0205	0.0185	−0.0074	−0.00601	−0.0151	−0.00205
	(0.0318)	(0.0434)	(0.0216)	(0.0247)	(0.0080)	(0.0124)	(0.0138)	(0.0286)
MB$_t$	0.2826	0.228	−0.5647***	−0.486***				
	(0.3274)	(0.189)	(0.2080)	(0.113)				
ROA$_t$	0.0517	0.0538**	−0.0348*	−0.0457***				
	(0.0359)	(0.0247)	(0.0199)	(0.0159)				
LEV$_t$	−0.3888	−0.253	1.7926	1.188	−4.5474***	−5.189***	−4.665***	−3.614***
	(1.3204)	(0.785)	(1.4034)	(0.726)	(0.6929)	(0.359)	(0.6277)	(0.636)
CAPEX$_t$	8.2596*	1.350	−3.7622	−0.637				
	(4.2584)	(2.741)	(5.0688)	(2.507)				
MACAP$_t$	−0.2809*	−0.257***	0.3187**	0.297***				
	(0.1622)	(0.0803)	(0.1535)	(0.0721)				
FUND$_t$					0.9559	−0.123	0.5887	1.518***
					(0.8593)	(0.371)	(0.6494)	(0.532)
SIZEt					0.0683	−0.194***	0.8353***	1.169***
					−0.2915***	(0.0353)	(0.1147)	(0.0525)
PROFITt					(0.1003)	13.40***	1.6133	2.106*
					12.7842***	(1.456)	(1.4872)	(1.158)
TANGIBILITYt					(2.0834)	−1.189***	−0.5000	−0.480
					−2.3101***	(0.269)	(0.5856)	(0.420)
Std_ROA$_t$					−0.0491**	−0.0271**	−0.0335**	−1.586**
					(0.0227)	(0.0134)	(0.0149)	(0.801)
Constant	8.9392***	4.906***	0.1621	2.017***	7.2894***	6.370***		−1.586**
	(1.8199)	(0.953)	(1.6893)	(0.745)	(1.4091)	(0.524)		(0.801)

(*continued on next page*)

Table C2 (*continued*)

	Std_ROA$_t$		*Std_RETURN$_t$*		*ZScore$_t$*		*CR$_t$*	
	FE	IV	FE	IV	FE	IV	Oprobit	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Observations	2134	2134	2244	2244	1617	1617	531	531
Firm dummy	YES	YES	YES	YES	YES	YES	YES	YES
Year dummy	YES	YES	YES	YES	YES	YES	YES	YES
Adj. or Pseu. R^2	0.0834	0.027	0.0576	0.053	0.500	0.442	0.310	0.589

Note: This table reports the results of a year and firm fixed-effects regression that examines whether hard freezing is likely to have an impact on firms' earnings volatility, return in invested capital volatility, default risk and credit ratings in column (1), (3), (5) and (7). Column (2), (4), (6) and (8) report the 2SLS results with an instrumental variable, two-year lag of *hard freezing*. Column (7) reports the result from ordered probit model. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

Table C3
Impact of *buy-ins* on firm risk.

Dependent var.	*Std_ROA$_t$*		*Std_RETURN$_t$*		*ZScore$_t$*		*CR$_t$*	
	FE	IV	FE	IV	FE	IV	Oprobit	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Buyin$_{t-1}$	−1.1961*	−2.014**	−1.3876***	−2.380***	−0.0625	−0.0743	0.6277**	0.050***
	(0.6302)	(0.892)	(0.5217)	(0.742)	(0.1680)	(0.244)	(0.3034)	(0.015)
SALES$_t$	0.0241	0.0141	−0.0996***	−0.113***				
	(0.0422)	(0.0423)	(0.0338)	(0.0360)				
SALES_GROWTH$_t$	0.0003	0.00327	0.0636***	0.0654**	−0.0006	−0.00125	−0.0098	0.002
	(0.0304)	(0.0305)	(0.0245)	(0.0259)	(0.007)	(0.007)	(0.0126)	(0.017)
MB$_t$	0.6715***	0.550**	−0.1801	−0.223				
	(0.2312)	(0.229)	(0.1825)	(0.193)				
ROA$_t$	0.0148	0.00321	−0.0410***	−0.0457***				
	(0.0189)	(0.0184)	(0.0153)	(0.0156)				
LEV$_t$	0.5215	0.749	−0.5528	−0.353	−3.2362***	−4.095***	−4.674***	−1.486***
	(1.2989)	(1.274)	(1.0626)	(1.080)	(0.3290)	(0.298)	(0.6219)	(0.403)
CAPEX$_t$	−3.1921	−0.0587	−3.9744	−3.292				
	(4.8293)	(4.799)	(3.8418)	(4.003)				
MACAP$_t$	−1.9587***	−1.441***	0.2837	0.574**				
	(0.3470)	(0.285)	(0.2738)	(0.238)				
FUND$_t$					1.4053***	−0.226	0.4440	−0.114
					(0.3775)	(0.373)	(0.6509)	(0.411)
SIZEt					−0.0409	−0.183***	0.8489***	0.0720
					(0.1266)	(0.0358)	(0.1222)	(0.142)
PROFIT$_t$					8.8225***	13.83***	1.1432	3.083***
					(0.5638)	(1.466)	(1.3673)	(0.634)
TANGIBILITY$_t$					−1.8208**	−1.174***	−0.4362	0.815
					(0.7323)	(0.271)	(0.5802)	(0.778)
Std_ROA$_t$					−0.0206***	−0.0225*	−0.0327**	−0.0473***
					(0.0076)	(0.0135)	(0.0149)	(0.00818)
Constant	16.2440***	13.77***	2.1085	0.492	3.0875***	6.156***		8.938***
	(2.7269)	(2.390)	(2.1649)	(2.003)	(1.1081)	(0.532)		(1.437)
Observations	2134	2134	2244	2244	1617	1617	531	531
Firm dummy	YES	YES	YES	YES	YES	YES	YES	YES
Year dummy	YES	YES	YES	YES	YES	YES	YES	YES
Adj. or Pseu. R^2	0.044	0.027	0.020	0.014	0.360	0.333	0.314	0.210

Note: This table reports the results of a year and firm fixed-effects regression that examines whether pension buy-ins are likely to have an impact on firms' earnings volatility, return in invested capital volatility, default risk and credit ratings in column (1), (3), (5) and (7). Column (2), (4), (6) and (8) report the 2SLS results with an instrumental variable, two-year lag of *pension buy-ins*. Column (7) reports the result from ordered probit model. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

Table C4
Impact of *longevity swap* on firm risk.

Dependent var.	*Std_ROA$_t$*		*Std_RETURN$_t$*		*ZScore$_t$*		*CR$_t$*	
	FE	IV	FE	IV	FE	IV	Oprobit	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Longevity$_{t-1}$	−4.0933***	−4.366***	−1.2666	−1.105	−0.0108	−0.0743	0.0066	0.0502
	(1.0018)	(1.270)	(0.8360)	(1.061)	(0.2609)	(0.244)	(0.2730)	(0.250)

(*continued on next page*)

Table C4 (*continued*)

Dependent var.	Std_ROA_t		Std_RETURN_t		$ZScore_t$		CR_t	
	FE	IV	FE	IV	FE	IV	Oprobit	IV
$SALES_t$	0.0271	0.0178	−0.0988***	−0.110***				
	(0.0420)	(0.0421)	(0.0339)	(0.0360)				
$SALES\_GROWTH_t$	−0.0017	0.000356	0.0622**	0.0620**	−0.0007	−0.00125	−0.0154	0.00190
	(0.0303)	(0.0303)	(0.0245)	(0.0259)	(0.0070)	(0.00700)	(0.0139)	(0.0172)
MB_t	0.6904***	0.574**	−0.1794	−0.213				
	(0.2305)	(0.228)	(0.1828)	(0.193)				
ROA_t	0.0148	0.00357	−0.0415***	−0.044***				
	(0.0188)	(0.0183)	(0.0153)	(0.0156)				
LEV_t	0.6178	0.809	−0.4970	−0.483	−3.238***	−4.095***	−4.679***	−1.486***
	(1.2942)	(1.268)	(1.0639)	(1.080)	(0.3290)	(0.298)	(0.6152)	(0.403)
$CAPEX_t$	−3.2333	−0.193	−3.8304	−3.445				
	(4.8111)	(4.777)	(3.8461)	(4.002)				
$MACAP_t$	−1.9239***	−1.436***	0.3083	0.469**				
	(0.3457)	(0.281)	(0.2741)	(0.236)				
$FUND_t$					1.4129***	1.135***	0.5494	−0.114
					(0.3778)	(0.362)	(0.6502)	(0.411)
$SIZE_t$					−0.0412	0.104	0.8395***	0.0720
					(0.1268)	(0.109)	(0.1142)	(0.142)
$PROFIT_t$					8.8195***	7.669***	1.5072	3.083***
					(0.5641)	(0.532)	(1.4581)	(0.634)
$TANGIBILITY_t$					−1.8220**	−1.873**	−0.4412	0.815
					(0.7326)	(0.743)	(0.5849)	(0.778)
Std_ROA_t					−0.021***	−0.0202***	−0.0320**	−0.0473***
					(0.0076)	(0.00756)	(0.0153)	(0.00818)
Constant	15.8793***	13.56***	1.9155	1.155	3.0835***	3.080***		8.938***
	(2.7171)	(2.371)	(2.1678)	(1.997)	(1.1103)	(0.980)		(1.437)
Observations	2134	2134	2244	2244	1617	1617	531	531
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Adj. or Pseu. R^2	0.051	0.036	0.018	0.014	0.245	0.3329	0.309	0.2138

Note: This table reports the results of a year and firm fixed-effects regression that examines whether Longevity swaps are likely to have an impact on firms' earnings volatility, return in invested capital volatility, default risk measured by the Altman Z-score and sponsoring firms' credit ratings in column (1), (3), (5) and (7). Column (2), (4), (6) and (8) report the 2SLS results with an instrumental variable, two-year lag of *longevity swap*. Column (7) reports the result from ordered probit model. Robust standard errors are reported in parentheses. *, **, and *** represent significance levels of ten, five and 1%, respectively (two-tailed). Standard errors are clustered by firm. All variable definitions are reported in the Appendix.

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