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Discounting and the market valuation of defined benefit pensions*

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Abstract

We investigate how defined benefit pension schemes of FTSE firms are valued by the equity market, focusing on how future liabilities are discounted (since UK data allows us to estimate the duration of pension liabilities fairly accurately). We find that equity market valuation is consistent with discounting without allowing for credit risk. This differs from the approach used in published accounts for which IAS 19 (and SFAS No. 158, its US equivalent) allows for discounting with a corporate bond yield. The difference is significant, as credit risk free discounting would decrease the reported value of FTSE 100 firms by about 7%.

JEL Classification: M41, G32

Keywords: Defined benefit pensions, IAS 19, Valuation, UK companies

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1 Introduction

A defined benefit pension (DB) requires the sponsoring company to provide its employees a pension, computed according to a contractually agreed benefit formula; this usually takes into account the employees' wage and years of service and is indexed to inflation.[1] These obligations are then financed by a pool of pension fund assets. Despite the fact that the pension scheme's assets and liabilities are formally separated from the company, the shareholders are ultimately responsible for its solvency hence pension deficits/surpluses affect the firm's value. The IAS 19 accounting standard introduced in the EU in 2006 aimed to make this potential liability explicit by requiring the sponsoring firm to report any pension fund deficit/surplus on its balance sheet. Thanks to the convergence of accounting standards worldwide, the rules in the United States are very close to IAS 19 as SFAS No. 158, issued in 2006, prescribes the recognition of the defined benefit deficit/surplus on the balance sheet.

Whilst pension assets are generally easy to value, the unique features of DB pension liabilities make them problematic from both the accounting and the valuation perspective. Pension liabilities are not quoted in any market and are by their nature long term, hence depend crucially on a wide range of long term assumptions, such as inflation, discount rate, life expectancy, salary growth, employee turnover etc.

Although UK companies have been steadily moving from defined benefit to defined contribution pensions, DB schemes still represent a substantial commitment for most companies. Table 1 below presents some statistics highlighting the importance of DB pensions in the UK, indicating that in 2012 (the last year before the introduction of IAS 19 revised) DB liabilities - as measured under IAS 19 standards - were about 30% of market capitalisation for both the FTSE 100 and FTSE 350 and that the overall DB deficit (pension assets minus liabilities) stood at over 3% of market capitalisation for both indices.[2] [3] The sheer size of these liabilities makes them important from a valuation perspective and there is growing evidence they have a significant impact

[1]The benefits granted in a DB scheme also depend on the relevant regulation of the jurisdiction where the employment contract is signed. There are considerable difference in regulation among different jurisdictions: for instance, in the UK the indexation of DB pension is enshrined in law, while in the US is not. We discuss the UK's regulatory framework for DB pensions in section 3.

[2]Under risk-free discounting discussed below, liabilities stand at around 37% of market capitalisation and the deficit at about 11% for the FTSE 100.

[3]We describe the revision to IAS 19 in section 6.

on the free cash flow of the parent company and its investment decisions.[4]

Table 1: DB Pension Facts

	FTSE 100	FTSE 350	UK DB universe
Firms with DB scheme	77	210	6225
of which open	8	31	841
of which closed to future accruals	4	36	-
total reported DB liabilities	526.8	599.9	1329.2
as percent of market cap	29.50%	29.95%	-
total reported deficit	57.7	65.8	210.8
as share of market cap	3.23%	3.28%	-
contributions as share of earnings	18%	18.70%	-

Values at the end of 2012 fiscal year using IAS 19 data, but for market capitalisation, computed at the corresponding reporting date. Data for the UK DB universe come from the Purple Book 2013. We defined schemes as closed to future accruals if their service cost is zero. Liabilities of schemes closed to future accrual represent around 0.6% of the total for FTSE 100 companies and around 2.4% for FTSE 350 Companies. Figures are in billion pounds.

Another important insight from Table 1 is that, despite their importance, almost all DB schemes are now closed to new members. This reflects the large scale move to defined contribution schemes that has occurred over the last few years. We do not address the causes behind the closure of DB pensions in the UK, but Kiosse and Peasnell (2009) argue that accounting regulations have a role in determining both the size of pension deficits and how companies respond to these shortfalls. Also, Klumpes et al. (2009) reach a similar conclusion showing that pension curtailment decisions are linked to both strategic corporate risk management considerations and economic and regulatory pressures.

In this paper we estimate the impact of pension deficits/surpluses on the market value of FTSE 100 and FTSE 350 companies. We employ a slight modification of the residual income model, first proposed by Feltham and Ohlson (1995) and widely used in the value relevance literature. As a robustness check we also use a variant of Tobin's Q model as used by Feldstein and Seligman (1981) for US pensions and by Liu and Tonks (2010) for the UK. While the value relevance of DB pensions has been studied extensively in the US context, the literature on

[4]See for instance Rauh (2006) that shows how DB pensions affect firms' investment in fixed assets and Liu and Tonks (2013) who look at the impact of mandatory contributions to DB pension funds on investment and dividends for UK companies. Alderson and Betker (2009) shows that after the burst of the dotcom bubble firms with underfunded pension scheme redirected investment towards activities that produce higher cash flow, while Duygun et al. (2017) find that DB coverage influences the propensity of making major investments and the type of such investments. Sasaki (2015) shows that actuarial losses cause a significant decrease in investment for Japanese manufacturing firms.

European countries is much scarcer. Our contribution aims to reduce this gap, however our focus is on one key aspect of pension valuation, the discount rate used to value future pension liabilities. Using data available in the notes of most company accounts we create an alternative value of liabilities based on 'risk-free' (government bond yield) discounting and compare the market impact of pension deficits/surpluses based on that measure as compared with the published measure. In doing so we link to a stream of the literature that adjusts reported pension liabilities to a common basis to make them comparable (Asthana, 1999; Hann et al., 2007b; Salewski and Zülch, 2015; Billings et al., 2017), with an important difference: while most of the previous literature standardises actuarial assumptions to industry medians, we can use the unique features of UK data to recover the duration of pension liabilities for each company and thus use the appropriate risk-free rate to discount them.[5]

We find that only in the case of risk-free discounting are our estimates consistent with the prediction that a £1 increase in the tax-adjusted deficit has a £1 impact on the value of the sponsoring company.[6] It is also the case that model estimates based on risk-free discounting are statistically superior and that, as expected, the difference between the market valuation and reported value of pensions is larger for firms with longer duration pension liabilities. This result implies that the market's valuation of pension liabilities is closer to their buy-out value rather than their accounting value.[7]

The rest of the paper is organized as follows. Section 2 offers a brief review of the empirical literature about the DB pension valuation. Section 3 describes concisely the institutional background in the UK, highlighting the differences with the US. Section 4 gives an overview of the debate over the pricing of pension liabilities, focusing in particular on the appropriate discount rate. Section 5 describes the techniques we employ to investigate the pricing of DB schemes and how we adjust the discounting of pension liabilities. The next two sections describe the data we use and present our main results. Their robustness is discussed in section 8, which includes also a different empirical specification using Tobin's Q model and extends our results to a wider sample. Section 9 discusses the similarities and differences between this work and Anantharaman

[5] Also mortality assumptions have a material impact on the size of pension liabilities. However they depend on the composition of the workforce of each company, making it impossible to adjust them reliably.

[6] We document that this is the case for financially healthy firms. We do not have companies in clear financial distress in our sample, and sorting observations by Z-score does not provide any additional insights.

[7] See section 4 for a discussion of the buy-out valuation of pension liabilities.

and Henderson (2016), a recent working paper that analyzes the issue of discounting pension liabilities in the US context. The last section concludes, further robustness tests are presented in the appendices.

2 Empirical Research on the Valuation of Defined Benefit Pension Schemes

A full review of the literature on corporate DB schemes is outside the scope of this paper so in the next sub-sections we refer to the papers that are most relevant to our work. For a broader discussion of the academic work on DB pension see, for example, Cocco (2014).

2.1 Pension impact on market valuation and returns

Most papers investigating the impact of defined benefit pension schemes on companies' valuation have focussed on the US and over the period when reporting standards were arguably more opaque. Before the introduction of SFAS No. 158 the value of pension assets and of the projected benefit obligation (PBO) were disclosed only in the notes to the financial statements, while the number recognized on the balance sheet was just an accounting accrual representing the difference between contributions paid and costs charged to the income statement.[8] The first set of papers taking the market valuation approach to study US DB pensions dates back to the 1980s and found that stock prices fully reflected the funding situation of the pension plans. The main examples in this literature are the works by Feldstein and Seligman (1981), Feldstein and Morck (1983), Landsman (1986) and Bulow et al. (1987). Barth (1991) uses a different methodology, investigating which measures of pension assets and liabilities are most closely associated with share prices, and finds that investors use the disclosure in the notes to value DB pensions rather than the accrual recognised on the balance sheet under SFAS No. 87.

A number of more recent papers use the Ohlson model to address the value relevance of DB pensions. Barth et al. (1993) finds that firms' market values reflect the fair value of DB pension disclosed in the notes, while the pension cost component is largely redundant once pension balance sheet variables are included in the regression. These findings are in sharp contrast with

[8] This was also the case in the UK prior to the introduction of IAS 19.

those of Coronado and Sharpe (2003) and Coronado et al. (2008), who using a similar research design find that investors and analysts seem to fixate on the earnings impact of DB pensions and disregard the net position of the pension plans disclosed in the notes. Work by Hann et al. (2007a) is somewhat in between, arguing that both earnings and the pension plan net position are taken into account by market participants. Their study compares the value relevance of smoothed pension amounts under SFAS No. 87 with their more volatile counterparts disclosed at fair value in the notes, finding that net pension assets are valued similarly under both measures while pension cost components are less persistent and hence less value relevant under fair value accounting.

The introduction of SFAS No. 158 has been investigated by a number of authors trying to disentangle the different impact of disclosed and recognized DB pensions deficits/surpluses. Mitra and Hossain (2009) find a negative relation between stock returns and the pension transition adjustment caused by this accounting reform, while Beaudoin et al. (2011) find no difference in the value relevance of pensions between the two regimes. Yu (2012) uses a larger sample and finds that the value relevance under both regimes depends on the level of institutional ownership and analyst following of each firm: the market prices more accurately disclosed information for firms that enjoy a high level of attention by financial institutions, while recognition improves the pricing of pension surpluses/deficits of companies that have less analyst following or lower institutional ownership.

Looking at the impact of DB pensions on returns rather than market value, Franzoni and Marin (2006) find that companies with severely underfunded pension plans earn significantly lower returns, controlling for a set of other factors; they argue that pension deficits impact companies' profitability with a lag. Their findings are reinforced by Picconi (2006), who shows that analysts systematically fail to take into account the effect of DB pensions in forecasting earnings. Jin et al. (2006) take a slightly different approach, focusing on the risk that a pension plan adds to the sponsoring company; they observe that for firms with normal leverage ratios the risk of pension liabilities is similar to that of corporate debt, whereas the portion of plan's assets invested in equities (or similar securities) has a significantly higher risk profile. Using a model much in the spirit of the CAPM they find that firms' betas reflect the additional risk generated by the DB schemes' assets and liabilities. Choy et al. (2014) find evidence that firms are comfortable taking more risks after freezing their defined benefit pension plans, increasing research and development expenses and leverage. On the other hand, Phan and Hegde (2013) find that firms freezing their DB scheme improve their financial position, but do not increase capital spending significantly.

As Glaum (2009) notes in his review, the literature on DB schemes for European countries is much scarcer. Moreover, as Gordon and Gallery (2012) argue using pension accounting as an example, different institutional settings may appear similar giving an illusion of comparability. In their analysis of optimal asset allocation of DB schemes McCarthy and Miles (2013) show that institutional details are crucial in understanding the trustee's payoff and hence in explaining the actual portfolios of pension funds. It is therefore far from given that the conclusions of the US literature can be readily applied to the UK or EU context. In the German setting, where most of the schemes are unfunded, Fasshauer and Glaum (2012) find that DB pensions are value relevant. Salewski and Zülch (2015) use the same research approach as Hann et al. (2007b) with German data, finding that only the non discretionary part of pension liabilities is priced by equity market participants. Liu and Tonks (2010) use UK data, testing both a market valuation model and the asset price approach; they find that pension deficits reduce the market value of the sponsoring firm but less than one-for-one. A similar result is found by McKillop and Pogue (2009), who also find that pension deficits have an impact on credit ratings. Cardinale (2007) focuses on the bond market and finds that pension deficits have a non-monotonic impact on credit spreads, for both the UK and the US. It should however be noted that these works on the UK use data before 2006 and the implementation of IAS 19, which significantly increased the transparency in pension accounting. The change in accounting standard could be responsible for the different results that we find in this paper, though we do not address this question directly as our sample starts in 2006.

There is little research using accounting data after the introduction of IAS 19, either in the UK or the rest of Europe. Notable exceptions are Barthelme et al. (2019), who show that the revision of IAS 19 that eliminated the corridor method for actuarial gains and losses caused firms to shift their pension asset allocation out of equities and towards fixed income, and Glaum et al. (2018), who show that companies used opportunistically the choices available under IAS 19 accounting. Billings et al. (2017) use a panel of UK companies accounting under IAS 19 and show that management chooses actuarial assumptions in order to reduce the reported pension liabilities. The literature investigating managerial discretion in setting actuarial assumptions is vast, especially in the US, and indicates that management uses this discretion in opportunistic ways.[9] We refer to the papers investigating opportunistic choices of the discount rate in the next section, but we do not discuss the rest of this literature as it is tangential to our study.

3 UK institutional background

As mentioned above, there are significant differences between jurisdictions in the laws and regulations concerning DB pensions. This short section gives an overview of the most important rules governing DB pensions in the UK context, highlighting the difference with the institutional background of United States, the most commonly studied market. Besides the accounting rules, the most important piece of legislation regulating DB pensions in the UK during our sample is the Pension Act 2004.[10] It contains a number of provisions that make the institutional framework in the UK considerably different from that of the US.

Following the work of Bulow (1982), there has been a considerable debate in the US literature concerning whether the appropriate measure of pension liabilities is the Projected Benefit Obligation (PBO), which is a measure of liabilities that include future accruals, or the Accumulated Benefit Obligation (ABO), which reflect the liabilities of the sponsoring company as of today, not including future accruals. In other words, if the sponsor were to terminate the DB scheme today, it would be liable only for the ABO. Bulow (1982) argues that the ABO is the best measure of the sponsors' liabilities and a number of subsequent empirical works have compared the value relevance of both measures.

While under US GAAP accounting both ABO and PBO are disclosed, this is not the case under IAS accounting, where only the PBO is disclosed. In the UK context we believe that a number of factors point to the PBO being the most relevant measure of pension liabilities from an investors' perspective. Following the Pension Act 2004, pension benefits effectively vest after 3 months of service.[11] Moreover, the same law mandates the revaluation of both deferred

[9] This is the conclusion that Glaum (2009) draws in his survey of the literature.

[10] This legislation integrated and replaced the previous Pension Act 1997.

[11] If the employment relationship is terminated after more than 3 months but before the vesting of the benefits under the scheme's rules, the benefits earned by employee can be transferred into a new plan.

benefits and pension in payment to inflation (with a cap). This is likely to reduce significantly the difference between the ABO and the PBO in the UK. On the other hand, in the US there is no such a rule, with cost of living adjustment being a part of pension contract between employer and employee rather than regulated by law.

The other main difference between the ABO and the PBO comes from future salary increases, but this is relevant only in the context of a final salary pension scheme: the PBO includes an estimate of future salary growth, while the ABO does not. No company in our sample is still offering a final salary DB, all the open schemes are career average (where each year employee accrue pension benefits based on their current salary) but some companies still have legacy sections of their schemes with final salary accruals. Given the vesting and indexation rules in the UK discussed above, for a career average salary DB scheme the ABO and the PBO are effectively identical. Even for a final salary scheme, the difference between ABO and PBO is likely to be small: as deferred benefits are linked to inflation, the two only differ if wage growth is substantially different from inflation.

Another consequence of the Pension Act 2004 is effectively to make unilateral changes of the pension benefits by the employer more complicated, so it is difficult for companies to walk away from their pension commitments. If an employer wants to reduce future benefits (for instance by increasing the retirement age, closing to new members or decreasing the rate of future benefits accrual), it has to consult the trustees of the scheme, the employees and the unions. While this is a consultation rather than a consent requirement, the employer has to take into account any objections raised during the process, thus making the changing future benefits more difficult. The rules are much stricter concerning proposed changes to actual rather than future benefits, in which case consent is necessary but for the case of actuarial equivalence (i.e. the proposed benefits are actuarially equivalent to the actual ones).[12] In the US, on the other hand, a firm could close its pension scheme freezing the benefits and hence only be liable for the ABO, in the UK this is effectively impossible as the law makes clear that if a solvent sponsor decides to wind up its scheme liabilities should be valued on a full buy-out basis.

[12]These rules also have implication for the value of the pension put in the UK, which we discuss in Appendix A.

4 Discounting of Pension Liabilities

Although both IAS 19 in Europe and SFAS No. 158 in the US prescribe that net pension assets should be recognized in the sponsoring company's balance sheet, there are a number of assumptions in the process of determining pension liabilities that are controversial. Given their long duration probably the single most important of these debated assumptions is the discount rate used to estimate the present value of those liabilities. This debate is summarised in Brown and Pennacchi (2016) who argue that, whilst it is appropriate for the future pension recipients to include some measure of default risk when valuing their future pension benefits, from the sponsoring firm's point of view the pension liability has no default risk and so should be valued without allowing for credit risk (in practice using government bond yields). In other words, Brown and Pennacchi (2016) point out that the appropriate discount rate for pension liabilities depends on the objective of the valuation exercise. The risk-free rate should be used to measure the funding of a pension scheme, while a discount rate reflecting the risk of the sponsoring company is appropriate when measuring the value of the company's pension promises (i.e. to members of the pension scheme). Novy-Marx (2015) stresses a similar point, arguing that the valuation of pension liabilities depends on both the concept of liability being used and from whose point of view the liabilities are valued.

To see why they argue that pension liabilities should be discounted using a risk-free rate it is useful to split the process of their determination in two parts. The first is estimation, where the schedule of future pension payments is computed using a range of actuarial assumptions that depend upon the specific situation of each DB scheme and the demographics of its participants. Once the future cash outflows of the pension fund have been estimated, they need to be discounted to compute the projected benefit obligation (PBO) that the sponsoring company has to fund and disclose in its financial statements. From the sponsor's perspective these future benefit payments are not subject to default risk.[13] However the risk of sponsor default does complicate the market valuation of pensions somewhat and this is discussed in appendix A.

Indeed, in the UK, the settlement rate for pension liabilities (the discount rate used to

[13]The only way in which a company could reduce the burden of future pension payments is to renegotiate the contributions or benefits of the pension scheme's participants. This is effectively equivalent to a salary cut.

value liabilities for pension buy-outs) is based on a risk-free rate. While the buy-out market in the UK has been steadily growing, it remains small when compared to the UK DB universe, possibly because buy-outs appear expensive for DB sponsors (i.e. the buy-out valuation of pension liabilities is significantly higher than the accounting value, partly because the buy-out valuation uses a risk-free discount rate).[14] The consultancy Mercer publishes a global pension buy-out index, where the UK section estimates that the cost of a buy-out at 140 per cent of the accounting liabilities.[15] Lin et al. (2015) show in their simulations that de-risking strategies such as buy-outs have significant costs, and that the benefits do not always justify these costs.[16]

In the US context (where the literature also highlights the valuation of public DB schemes) a number of papers, most notably Novy-Marx and Rauh (2011) and Brown and Wilcox (2009), discuss the discount rate for pension liabilities, and argue that a credit risk-free rate is appropriate. Fabozzi (2015) focuses on the investment policy and liability valuation concept of the Pension Benefit Guaranty Corporation, maintaining that a correct valuation of liabilities is key to design an optimal investment strategy and arguing the this valuation should be undertaken using risk-free rates for both public and private pension plans.

Various papers have also documented that managers choose the discount rate on pension liabilities opportunistically. Bodie et al. (1987) and Feldstein and Morck (1983) find that the discount rate is higher for companies where the pension deficit is large relative to the sponsors' equity or assets, while Godwin et al. (1996) and Asthana (1999) show that well funded plans use more conservative discount rates. Bodie et al. (1987), Godwin et al. (1996) and Asthana (1999) also find that the discount rate choice is linked to the financial health of the sponsor, with management using their discretion to mitigate adverse circumstances. Kisser et al. (2017) find evidence that US corporate DB scheme sponsors manipulate reported pension liabilities, underestimating them by approximately 10 per cent on average, mainly using discount rates that are higher than appropriate. Also Comprix and Muller (2011) find that companies are

[14] As we discuss below, the Pension Protection Fund - PPF - also uses risk-free discounting to value pension liabilities of bankrupt firms.

[15] See Mercer (2017) for the details of this estimation. It is worth nothing that there are other factors beside the discount rate that contribute to the difference between the accounting and buy-out valuation of pension liabilities. Insurers have strict solvency capital requirements and the buy-out price also takes into account their profit margins. Moreover there are considerable administrative costs in running a DB scheme, which in the case of buy-out are transferred to the insurer.

[16] There are other strategies to reduce the risk of DB pensions, such as buy-ins and longevity swaps. Blake et al. (2013) reviews them discussing the development of the market for longevity and mortality risks.

opportunistic in choosing the discount rate and other assumptions, providing evidence that firms use them to exaggerate pension commitments before freezing benefits. The literature on the UK is scarcer, but the evidence available tends to confirm the US findings discussed above. Li and Klumpes (2013) find that firms use inflated discount rates to manage their leverage ratio,[17] while Byrne et al. (2007) show that companies with well funded pension plans tend to use high discount rates. Billings et al. (2017) use a panel of UK companies reporting under IAS 19 and find that sponsors manage the discount rate (and other actuarial assumptions) to improve the funding status of their DB scheme when this is weak and its size is big relative to that of the sponsor. We interpret this evidence as an additional possible explanation of why market participants do not take the companies' accounting pension deficits at face value.

Despite the arguments put forward against allowing for credit risk in the discount rate of pension liabilities discussed above, both IAS 19 and SFAS No. 158 allow discounting using corporate bond yields that are significantly above those of government bonds due, largely, to perceived credit risk. Under both standards, the pension obligation is discounted using high quality corporate bonds yields; most of the companies interpret this provision as AA rated corporate bonds of currency and duration matching those of their pension obligation.[18] There is however a long standing debate about which discount rate should be used, discussed in Napier (2009). Kiosse and Peasnell (2009) in their review of the evidence on the effect of accounting rules on pension provisions conclude that the determination of the discount rate is a complex matter and that arguably the most appropriate choice would be the rate applied by an insurance company in a buy-out, that is a (credit) risk-free rate. Indeed there is some apparent contradiction within IAS 19 itself as to the nature of the discount rate. Paragraph 83 and 84 of the last version of IAS 19 read as follows:

> 83. The rate used to discount post-employment benefit obligations (both funded and unfunded) shall be determined by reference to market yields at the end of the reporting period on high quality corporate bonds. (...) 84. One actuarial assumption that has a material effect is the discount rate. The discount rate reflects the time

[17] As their sample spans 1998 to 2002, the relevant accounting standard is SSAP 24 (and the transition to FRS 17), so in their case the expected return on pension assets and the discount rate on pension liabilities coincide.

[18] The wording of the two accounting standards is slightly different, but their practical implementation has been identical.

> value of money but not the actuarial or investment risk. Furthermore, the discount rate does not reflect the entity-specific credit risk borne by the entity's creditors, nor does it reflect the risk that future experience may differ from actuarial assumptions.[19]

Paragraph 84 seems to suggest the use of a risk-free rate, contradicting the previous provision. In fact, the interpretation committee of the IFRS has been requested to clarify the passage above and the amendment for paragraphs 83-84 proposed by the IFRS' staff explicitly mentions credit risk:

> The objective of the discount rate is to reflect only the time value of money and at most very low credit risk, the currency and the estimated term of the post-employment benefit obligations. The discount rate does not reflect the actuarial or investment risk of the plan assets (as defined in paragraph 28). Furthermore, the discount rate does not reflect the entity-specific credit risk borne by the entity's creditors, and nor does it reflect the risk that future experience may differ from actuarial assumptions.[20]

Even in this formulation it remains unclear why the discount rate should reflect "at most very low credit risk" since pension liabilities are not subject to such risk from the sponsoring firm's perspective.

Unsurprisingly, the decision to use a discount rate that reflects some credit risk is not uncontroversial in the accounting industry. Among others, the Accounting Standard Board (ASB), the former British accounting standard setter, has recommended in a discussion paper (Pro-Active Accounting Activities in Europe, 2008) that pension liabilities should be discounted at a (credit) risk-free rate. A similar position has been expressed also by Blake et al. (2008) in a report authored by the Pension Institute. It is also striking that the UK Pension Regulator and the Pension Protection Fund (PPF) use government bond yields rather than corporate bond rates as the basis on which to discount defined benefit obligations in their annual publication investigating the DB universe (the Purple Book) and in calculating the levy that each sponsor has to pay to fund the PPF's guarantee.[21] The last revision of IAS 19 could have incorporated these

[19] IASB (2011)

[20] IFRS (2013)

[21] See The Pension Protection Fund (2016) for a detailed discussion of the PPF's valuation method for pension liabilities.

suggestions, but the IASB preferred to oblige the companies to disclose a sensitivity analysis of the pension obligation to various assumptions used in its determination, including the discount rate, to provide the users of financial statements with a measure of the risk underlying the DB obligation. This change became mandatory from 2013 onwards.

Of course, although it is often argued that credit risk should not be allowed for when estimating the present value of pension liabilities from the sponsor's perspective, it is possible that other considerations mean that the effective discount rate need not be the yield on government bonds. The literature (e.g.Brown and Wilcox, 2009) highlights two important differences between government bonds and pension liabilities that may make bond yields inappropriate for discounting DB liabilities. First, government bonds are significantly more liquid than pension liabilities as, although the latter can be traded, it is a complex process unlike government bonds trading. This liquidity premium would tend to mean that the yield on government bonds is too low a rate for discounting pension liabilities. Second, since pension liabilities tend to be at least partially indexed to inflation, they have a lower inflation risk premium than nominal government bonds (see Breedon and Chadha, 2003 and Buraschi and Jiltsov, 2005 for evidence on the inflation risk premium in nominal bonds). Thus the yield on nominal government bonds may be too high a rate for discounting pension liabilities (sadly we have too little information on indexing to estimate the present value of real liabilities using inflation indexed bond yields). Since there is no consensus on the scale of either of these effects (and they work in opposite directions), the approach of previous papers has been to assume the cancel each other out.[22]

A recent working paper by Anantharaman and Henderson (2016) tackles similar issues in the US context. They find that discounting at the expected return on pension assets provides the best fit in explaining both equity values and credit ratings (for financially healthy firms). We discuss the similarities and the differences between our work and theirs in section 9.

5 Model Specification

The main model we employ is a parsimonious specification of the residual income model as put forward by Feltham and Ohlson (1995). In their model the market value of a firm's equity is

[22] We discuss other factors that may influence this calculation in appendix A.

expressed as the sum of the value emanating from the company's non-financial core activities plus the unrelated financial activities. We modify this model to make room for pensions as in Coronado and Sharpe (2003) and Coronado et al. (2008), dividing both income statement and balance sheet variables into pension and non-pension components. This model expresses the market value of equity (Mcap) as a function of the core book value of equity (BVc) defined as non-pension assets minus non-pension liabilities.[23] Net pension assets in turn represent the economic deficit/surplus of the DB pension schemes of the company; we define it as pension assets minus pension liabilities, not taking into account any surplus restriction, minimum funding liability, corridor adjustment or deferred tax asset arising under the current accounting standard.[24] As noted earlier, although entering pension assets and liabilities separately into the model rather than the net position might be useful for our analysis, the high correlation between the two items means it is not practical to do so.

For income statement variables, we divide earnings into core earnings (Ec) defined as net earnings minus net periodic pension cost (NPPC) and NPPC itself. The NPPC collects all the pension related entries in the income statement: service cost (benefits accrued during the accounting period), interest cost (the effect of time on the pension obligation), expected return on plan's assets and temporary events such as curtailment and settlements.[25] Coronado and Sharpe (2003) and Coronado et al. (2008) use a slightly different definition of NPPC, where service cost is considered as a core expense rather than a pension item. We prefer to aggregate all the pension variables, but changing this definition has no major effect on the results. Hence we use the following models, where all variables are standardized by total company assets to make the series stationary and reduce heteroskedasticity:

$$Mcap_{i,t} = \alpha + \sum_{s=1}^{10} \gamma_s S_s + \sum_{t=1}^{7} \gamma_t T_t + \beta_1 BVc_{i,t} + \beta_2 NPAt_{i,t} + \beta_3 Ec_{i,t} + \beta_4 NPPC_{i,t} + \epsilon_{i,t} \quad (1)$$

[23]This is equivalent to the book value of equity minus the net pension assets (NPA)

[24]We do not consider the deferred tax assets disclosed by the companies as this disclosure its patchy at best. In most of our estimates we adjust NPA for the associated tax asset using the corporate tax rate, as discussed below.

[25]Excluding these exceptional events altogether does not alter our results.

$$Mcap_{i,t} = \alpha + \sum_{i=1}^{75} \gamma_i I_i + \beta_1 BVc_{i,t} + \beta_2 NPAt_{i,t} + \beta_3 Ec_{i,t} + \beta_4 NPPC_{i,t} + \epsilon_{i,t} \quad (2)$$

where subscript i and t identify firm and year, respectively. The only difference between the two specification is given by the fixed effects, which we include at either the sector and year or the company level.[26]

As contributions to the pension fund are tax deductible in the UK, our estimates are based on a tax adjusted NPA that adds back the associated deferred tax asset/liability.[27] We compute this as NPA times the corporation tax rate that the companies in our sample face every year.[28] Although we do not directly observe the marginal tax rate paid by companies, the fact that the average tax rate paid by our sample of companies is about 24% provides support to the assumption that our firms face a marginal tax rate equal to or very close to the corporation tax rate. Shivdasani and Stefanescu (2010) provide evidence that firms incorporate the tax implications of DB pensions in their capital structure decisions, so disregarding the tax credit associated with pension contributions could limit the validity of our results. We use the tax adjusted NPA in the main body of the paper and include in appendix B estimates based on unadjusted NPA as a robustness check.

5.1 Estimating risk-free pension liabilities

As discussed in section 4, an important question mark over pension liabilities as they are reported in company accounts is the discount rate used to estimate their present value. In this section we describe how we adjust that valuation such that liabilities are discounted at the 'risk-free' rate - the yield on UK government bonds (known as gilts). Although not required to do so over our sample, most of the companies in the FTSE 100 disclose a sensitivity analysis to help users of financial statements understand the impact of the assumptions used in calculating the pension obligation. However for our sample almost none of the firms in the FTSE 350, other than those in the FTSE 100, report this information. It is for this reason we conduct most of our analysis

[26]We used the Global Industry Classification Standard (GICS) and take the broadest sectoral definition, using 10 different sectors in total.

[27]In the UK there is a strong link between scheme funding and employer's contribution, sponsors of scheme in deficit have to agree a schedule of additional contribution with the trustees of the pension fund to address the deficit.

[28]UK Corporation tax has been changing during the period that we take as our sample, starting at 30% and being lowered first to 28% in 2009, then to 26% in 2011 and finally to 24% in 2012.

on the FTSE 100, though we report some more limited results for the FTSE 350 in section 8.

We use the interest rate sensitivity analysis to compute the duration of the defined benefit obligation; this in turn allows us to find the corresponding gilt rate appropriate for that liability and calculate the value of pension liabilities under 'risk free' discounting; we label the resulting estimate risk-free pension liabilities and obtain the associated risk-free NPA by subtracting it from the reported pension assets (as these are already marked-to-market, no adjustment is necessary).[29] The formula used in both passages above is just the standard duration approximation:

$$\frac{\Delta P}{P} = -\frac{\Delta i}{1+i} D \tag{3}$$

where P is the price of a bond, i its yield and D its duration. The duration of the pension obligation averages about 18 years, with a median very close to it but with wide variation over a span of more than 15 years; half of the companies are within the 15 to 20 year range. Since only a minority of companies disclose this sensitivity analysis for every year in our sample, we impute the duration of missing years based on the closest available year for which a duration estimate is available. Since pension liabilities are very long term nature and almost all schemes in our sample are closed to new members we find that this is a relatively accurate method.[30] The alternative approach of dropping these observations delivers similar results (albeit with larger standard errors).[31]

The yields on UK gilts come from the Bank of England historical yield curve data; in adjusting the pension liabilities, we retrieved the yields at the balance sheet closing date. Changing the discount rate of pension liabilities to the gilt rate increases the size of the pension commitments considerably. On average the increase amounts to more than 20 per cent of the reported liabilities. Thus, under risk-free discounting, only five companies have posted a surplus in at least one year and none has had a consistent surplus throughout our sample period with the median company having a deficit totalling more than 5 per cent of assets.

[29] We did not adjust NPA to account for the deferred tax credit/debit that they generate in this section. We choose not to present the results with both adjustments as they are nearly identical to the ones in this section.

[30] Relative to the schemes that disclose duration for all the years in our sample.

[31] These results are available in appendix B.

6 Dataset Construction and Summary Statistics

Our main dataset includes all the FTSE 100 constituents with a defined benefit pension scheme.[32] It spans from 2006, the first year when IAS 19 became mandatory, until 2012, when the revised version of IAS 19 became mandatory. We decided not to include the data from 2013 onwards as this revision could significantly influence our results and so we preferred to have a homogeneous sample. The major changes for IAS 19R from IAS 19 were: immediate recognition of actuarial gains and losses, recognition of changes, use of net interest income (expense) rather than expected return on plan assets. These changes could be important to our study since many firms in our sample were deferring gains and losses using the corridor approach and especially since the impact of the use of net interest expense would differ according to discount rate choice. This change in the role of the discount rate is potentially problematic given our focus in this paper. Indeed, there is a growing body of work that shows the revision had a significant effect on firm behaviour in ways that could distort our results, as in Anantharaman and Chuk (2018) and Barthelme et al. (2019).

To deal with the wide variation in balance sheet closing dates, we defined time in our sample as fiscal year, i.e. all the companies closing their accounts from May 2008 to April 2009 are considered in year 2008. All the pension related variables have been hand-collected from the notes to the financial statements. The rest of the companies' account data have been retrieved from Bloomberg, using the balance sheet closing date as reference; for companies that do not use sterling as their reporting currency, the data have been converted into pounds using the closing exchange rate at the balance sheet date. The market capitalisation of each company has been retrieved at the reporting date instead of the balance sheet date, focusing on when the financial statements became publicly available. This leaves us with 83 companies that have a DB scheme for at least one of the years in our main sample of FTSE 100 constituents;[33] we drop two of them (Burberry and Lonmin) because their DBs were demerged or wound up in 2008. We also drop Fresnillo and Vedanta Resources because they do not have a DB scheme in

[32]Recall that we use the FTSE 100 for the main part of the paper because the pension reporting - particularly of interest rate sensitivity is superior to that of the FTSE 250. We present results for the FTSE 350 in section 8.

[33]During this period there was a major merger between British Airways and Iberia. For the sake of dataset construction, we consider the resulting company (International Airlines Group) as a new firm that takes the place of BA.

Europe or the United States, but only very small arrangements in developing countries.[34] We also drop four companies that do not disclose any duration or sensitivity analysis in any of their accounts (including them with duration fixed at the sample mean or median does not influence the results). These exclusions do not affect our results in any material way.

Table 2: Descriptive Statistics

variable	N	mean	standard dev	1st quartile	median	3rd quartile
Market Capitalisation	511	0.9416	0.7420	0.4223	0.7560	1.3519
Core Book Value	511	0.3355	0.1821	0.1918	0.3535	0.4859
Tax-adjusted NPA	511	-0.0207	0.0378	-0.0288	-0.0077	-0.0009
Pension Liabilities (PL)	511	-0.3048	0.4159	-0.3606	-0.1939	-0.0400
Risk-free NPA	511	-0.0986	0.1311	-0.1124	-0.0626	-0.0127
Risk-free PL	511	-0.3750	0.5028	-0.4689	-0.2432	-0.0496
Core Earnings	511	0.0644	0.0722	0.0213	0.0615	0.0958
NPPC	511	-0.0028	0.0054	-0.0045	-0.0018	-0.0003

All variables are standardised by total company assets and were collected on the balance sheet closing date, except market capitalisation which was retrieved at the reporting date.

Given that for some companies we do not have the full seven years of data, our main dataset includes 511 observations. Table 2 below summarizes the variables used in the estimation for the main sample of FTSE 100 firms, already standardized by assets. The main variable of interest for this study, net pension assets, averages at about - 2 per cent of assets when adjusted for the associated tax credit, but the distribution is considerably skewed to the right so the median company has a deficit of only 0.8 per cent. Also the distribution of pension liabilities is skewed to the right, with some supersized pension funds pushing the mean up to 30 per cent. For the median company pension liabilities represent about 19 per cent of assets, but in some cases the pension fund is actually bigger than the company itself. Obviously using a risk-free rate to discount pension liabilities increases their size considerably. Non pension earnings average at 6.5 per cent of assets, while the direct impact of DB schemes on the sponsoring firms' income statement is very modest as testified by NPPC. Moreover, nearly 15 per cent of our sample's companies are actually booking negative pension expenses, with the DB scheme contributing to firm profitability despite being in deficit in some cases. We should however note that a great deal of these profits comes from settlements and curtailments related to the restructuring of the

[34] In 2012 their combined pension liabilities were under 100m £, less than 0.2 per cent of the whole liabilities of FTSE 100 constituents.

pension fund.

Table 3: Correlation table

	(1)	(2)	(3)	(4)	(5)	(6)
(1) Market Capitalisation	1					
(2) Core Book Value	0.098	1				
	(0.014)					
(3) Tax-adjusted NPA	0.017	-0.145	1			
	(0.666)	(<0.01)				
(4) Risk-free NPA	-0.899	-0.066	0.302	1		
	(<0.01)	(0.114)	(<0.01)			
(5) Core Earnings	0.141	0.273	-0.055	-0.047	1	
	(<0.01)	(<0.01)	(0.168)	(0.258)		
(6) NPPC	0.024	-0.033	0.421	0.134	-0.050	1
	(0.543)	(0.412)	(<0.01)	(<0.01)	(0.210)	
(7) Pension Liabilities	0.002	-0.069	0.664	0.357	-0.152	0.450
	(0.958)	(0.081)	(<0.01)	(<0.01)	(<0.01)	(<0.01)

Table presents the Pearson correlation of variables in the main FTSE 100 sample, already standardised by total assets. P-values are shown in parenthesis below the correlation coefficients.

Table 3 shows the correlation among variables of interest. Net pension assets, pension liabilities and pension costs (NPPC) appear all to be uncorrelated with market value. This is not the case for pension deficits when liabilities are discounted at a risk-free rate, with risk-free net pension assets displaying a strong negative correlation with market value. This negative correlation might look perplexing at first blush, implying that an increase in pension deficit increases the value of the sponsoring company. However at a closer inspection this correlation is explained by the correlation between equity value and the risk premium on AA rated corporate bonds: our adjustment of the discount rate depends entirely upon the spread between AA corporate bonds and gilts. As this spread increases (decreases), the equity value is depressed (increased), hence the negative correlation. Pension liabilities are correlated with net pension assets, indicating that companies with larger liabilities show a larger deficit. This effect is stronger using risk-free discounting. Also pension expenses are positively correlated with liabilities, as companies with larger DB schemes have higher accounting pension costs.

7 Estimation and Results

Columns 1 and 2 of table 4 report the parameter estimates for the basic Ohlson model, using only book value and earnings as independent variables. The estimation in column 1 includes sector and year fixed effects, while in column 3 we use company fixed effects. Throughout the paper we run our specification both in cross-section, using controls for years and sectors, and controlling at the firm level. The former specification focuses on the differences in market valuation across firms, controlling for unobserved time and sector effects. The latter specification using company level fixes effects highlights the difference in valuation at the company level across years, controlling for time invariant unobserved effects specific to each firm in our sample.

Estimates for the model with sector and year fixed effects correspond quite closely to those found in the US literature (see for example Hann et al., 2007a and Dechow et al., 1999) even though the book value coefficient is only marginally significant in our case (though it is better estimated when we include FTSE 250 companies as in table 7). The use of company fixed effects is less common in the literature since the firm level dummies often pick up some of the impact of book value and earnings making the coefficients on those variables more difficult to interpret, but despite this the coefficients in our estimation are both significant. Interestingly, the coefficient estimates that we get with company fixed effects are much closer to the Ohlson's model implied values that Dechow et al. (1999) find assuming a 12% cost of capital and using the realized persistence of abnormal earnings, suggesting that company fixed effects absorb some of this persistence. Column 3 and 4 show our results for equation (1) and (2) with net pension assets. A comparison of columns 1 with 3 and 2 with 4 shows that our modification of the Ohlson model to make room for pensions does not have a big impact on the estimated coefficients on book value and earnings, even though in column 3 the coefficient on core book value is estimated less precisely. Although NPA is only marginally significant in the sector and years dummy case, the specifications seem to give some support to the transparent view that net pension assets influence market valuation. The estimated coefficient on pension expenses is noisy and indistinguishable

Table 4: Residual income model

	(1)	(2)	(3)	(4)
Book Value	0.502*	1.490***		
	(0.255)	(0.391)		
Earnings	4.849***	2.019***		
	(1.271)	(0.733)		
Core Book Value			0.431	1.591***
			(0.266)	(0.395)
Tax-adjusted NPA			2.120*	1.115
			(1.200)	(0.744)
Core Earnings			4.802***	2.113***
			(1.239)	(0.737)
NPPC			4.635	-5.689
			(8.339)	(6.504)
Fixed Effects	Sector, Year	Company	Sector, Year	Company
N	511	511	511	511
R^2	0.598	0.834	0.602	0.836

Table presents results using the main FTSE 100 sample, stretching from 2006 to 2012. The independent variable is market capitalisation at the reporting date. Core book value is non-pension assets minus non-pension liabilities, core earnings are net income minus net periodic pension cost (NPPC), the measure of pension-related earnings in income. Tax-adjusted NPA is the difference between pension assets and liabilities for each firm, adjusted for the tax credit associated with pension contributions in the UK. All the variables are standardized by total company assets. When imposing fixed effect at the sector level, we use the broadest GISC sector classification with 10 sectors in total. The standard errors are clustered at the company level.

from zero, implying that pension costs do not have an impact of firms' valuation.

Although it is positive and significant as the transparent view of pension accounting would predict, the coefficient on NPA in column 3 is puzzling as it is consistently larger than one implying that the market gives a disproportionate weight to pension deficits, with £1 of net pension deficit reducing the market value of the company by about £2. Although this result is not present in the specifications where we include fixed effects at the company level (column 4) this is probably because the discount rate effect we discuss below is mitigated by the firm level fixed effects (since the difference between Risk-free NPA and the reported value is firm specific and moves only slowly through time, in this specification their effect is likely to be captured at least partially by the company fixed effects).

In all the specifications in main paper we decided to cluster the standard errors at the company level as Petersen (2009) suggests is appropriate for panel data with a relatively short time dimension. We present estimates that allow for standard errors to be correlated at the sector rather than the company level in appendix B. Assuming correlation at sector rather than the company level is a less restrictive assumption about the structure of our data, but it has the problems of unequal cluster size and small number of clusters. Of the various bootstrap based improvements proposed by the literature, in appendix B we choose to use the wild cluster bootstrap of t-statistics as in Cameron et al. (2008) since this method corrects for both the small number of clusters and the unequal cluster size. Overall, both results using sector level clustering and their bootstrap version are similar to those presented in table 4, in most cases the standard errors are actually smaller.

7.1 Risk-free pension liabilities: results

We now compare the estimates of the impact of pension deficits using our alternative 'risk-free' measure described in section 5.1. First, we re-estimate equation (1) using gilt discounted liabilities. As column 1 in table 5 shows, on this basis the coefficient on net pension assets is more precisely estimated and close to its predicted value of one, while column 2 shows that this result is robust to firm fixed effects as in equation (2). As in the previous estimation, we cluster the standard errors at the company level and present results using sector level clustering (and its bootstrap improvement) in appendix B. To confirm the importance of the risk-free measure, column 3 separates the NPA and the additional component due to the gilt adjustment, creating a variable named Risk-free adjustment (Adj) defined as Risk-free NPA - NPA which amounts to testing the following:

$$Mcap_{i,t} = \alpha + \sum_{i=1}^{75} \gamma_i I_i + \beta_1 BVc_{i,t} + \beta_2 NPAt_{i,t} + \beta_3 Adj_{i,t} + \beta_4 Ec_{i,t} + \beta_5 NPPC_{i,t} + \epsilon_{i,t} \quad (4)$$

.

Both the coefficients on NPA and on the adjustment are significant and very close to what we found for the risk-free net pension assets. Whilst this result indicates that it is the variation of the adjustment across firms (due to differences in the duration of their pension liabilities) that makes the adjustment significant, column 4 confirms this by testing directly the prediction that companies with long duration liabilities should see a larger coefficient on their reported liabilities. We define a new variable called Ddif, equal to the duration of each company's pension liabilities minus the average duration across the sample, and interact it with pension liabilities.[35] This amounts to testing:

$$Mcap_{i,t} = \alpha+\sum_{s=1}^{10}\gamma_s S_s+\sum_{t=1}^{7}\gamma_t T_t+\beta_1 BVc_{i,t}+\beta_2 PL_{i,t}+\beta_3 Ddif_{i,t}+\beta_4 PL{*}Ddif_{i,t}+\beta_5 Ec_{i,t}+\beta_6 NPPC_{i,t}+\epsilon_{i,t} \tag{5}$$

The interaction sign is significant and has the predicted sign, indicating that firms with longer duration liabilities have a larger coefficient on reported pension deficits. This ensures that our results for Risk-free NPA is genuinely driven by discounting rather than by an additional premium attached to pension liabilities irrespective of their firm specific characteristics. In this specification we only use fixed effects at the sector and year level as this is a test of the cross-section properties of pension liabilities.

Overall, our results suggest that risk-free discounting is the most plausible explanation for the higher than expected impact of pension deficits on market valuation, not least since the effect is larger for firms with longer duration liabilities.

7.2 Model selection tests

Standard model selection tests of whether the model with Risk-free NPA is preferable to the model using the accounting NPA is problematic in our framework as the two models are non-nested, thus we use two approaches most commonly used in this context.

First, we use the Vuong (1989) test statistic, as Hann et al. (2007b) do in this literature. Vuong (1989) is a likelihood based test statistic that allows to compare the explanatory power

[35] Using NPA or the accounting deficit for the interaction yield results with the same interpretation.

Table 5: Risk-free pension liabilities

Variable	(1)	(2)	(3)	(4)	(5)
Core Book Value	0.398	1.627***	1.623***	0.360	1.624***
	(0.267)	(0.379)	(0.382)	(0.263)	(0.380)
Risk-free NPA	0.949**	1.010***			1.021***
	(0.399)	(0.327)			(0.375)
Core Earnings	4.896***	2.028***	2.034***	4.908***	2.029***
	(1.232)	(0.735)	(0.741)	(1.230)	(0.740)
NPPC	0.751	-4.338	-4.254	1.750	-4.292
	(7.766)	(6.381)	(6.700)	(7.398)	(6.705)
Tax-adjusted NPA			1.336**		-0.043
			(0.660)		(0.732)
Risk-free Adjustment			0.963**		
			(0.368)		
Pension Liabilities				0.384**	
				(0.149)	
Duration Difference				0.031**	
				(0.013)	
Ddiff*Pension Liabilities				0.064**	
				(0.032)	
Fixed Effects	Sector, Year	Company	Company	Sector, Year	Company
N	511	511	511	511	511
R^2	0.611	0.838	0.838	0.624	0.838
R^2 using Tax-adjusted NPA	0.602	0.836			
Difference in R^2	0.009	0.002			
Vuong Z-Statistic	2.036	1.454			
p-value	0.042	0.146			

Table presents results using net pension assets discounted at a risk-free rate (UK gilt yields). The independent variable is market capitalisation at the reporting date. Core book value is non-pension assets minus non-pension liabilities, core earnings are net income minus net periodic pension cost (NPPC), the measure of pension-related earnings in income. Adjustment is defined as Risk-free NPA minus reported NPA. Duration difference is the duration of pension liabilities minus its average across the sample. All the variables but duration difference are standardized by total company assets. Fixed effects at the sector level are based on the broadest GISC sector classification with 10 sectors in total. The standard errors are clustered at the company level. We compare models' fit between the specifications using Tax-adjusted NPA (column 3 of table 4 for sector and years fixed, column 4 of the same table for company fixed effects) and those using Risk-free NPA (columns 1 and 2 of this table) using Vuong (1989) test statistic.

of non-nested econometric models. It does indeed confirm that the risk-free model is better specified, preferring it to the specification with reported NPA at the 5% confidence level using sector and year fixed effects, while the test statistic is just shy of significance at the conventional level using company fixed effects. In the latter specification the test has less power as the company dummies common to both models push the R^2 up and reduce the improvement of model fit provided by Risk-free NPA. Second, we effectively force the two models to be nested by running a regression with both Risk-free NPA and NPA as independent variables. We do this in column 5 of table 5, where Risk-free NPA completely dominates its reported counterpart: the coefficient and standard errors on Risk-free NPA are almost unchanged from what we present in columns 1 and 2 of table 5 whilst NPA is insignificant and has a coefficient very close to zero.

Therefore for both approaches it seems that pension deficit based on risk-free discounting dominates the reported deficit in terms of financial market impact.

8 Extensions

This section presents a set of extensions to our basic results that aim to confirm the validity of our results. First, we extend our sample to the full FTSE 350, though the lack of liability duration data for smaller firms means we cannot recalculate pension liabilities using a risk-free rate. Second we use Tobin's Q model rather than the residual income model as the basis of our estimation. Further extensions are presented in the appendices.

8.1 FTSE 350 firms

In the extended sample of FTSE 350 constituents we have 215 firms with a defined benefit pension scheme for at least one year in our sample. The disclosure of firms in the FTSE 250 is not as comprehensive as that of the constituents of the FTSE 100, so for those firms we could not calculate the duration of the pension obligation and hence the discount rate adjustment. We drop all the observations that have a negative book value of equity together with two firms that experienced exceptional circumstances during the years that we consider in our sample, namely Howden Joinery and ITV. This leaves us with 1408 firm-year observations.

As table 6 shows, the FTSE 350 sample is remarkably similar to the FTSE 100 for the

Table 6: Descriptive Statistics for FTSE 350

variable	N	mean	standard dev	1st quartile	median	3rd quartile
Market Capitalisation	1408	0.9695	0.8556	0.4376	0.7487	1.2665
Core Book Value	1408	0.3881	0.1904	0.2621	0.3893	0.5205
Tax-adjusted NPA	1408	-0.0201	0.0369	-0.0305	-0.0900	-0.0007
Pension Liabilities	1408	-0.2826	0.3470	-0.3896	-0.1729	-0.0399
Core Earnings	1408	0.0624	0.0796	0.0259	0.0570	0.0928
NPPC	1408	-0.0020	0.0068	-0.0036	-0.0013	-0.0001

All variables are standardised by total company assets and were collected on the balance sheet closing date, except market capitalisation which was retrieved at the reporting date.

variables that we consider, even if the pension commitments of companies in the FTSE 250 are only a fraction of those of their bigger peers.[36]

Our estimates for the enlarged sample of FTSE 350 companies are reported in table 7, which has the same structure as table 4. The first two columns report estimates for the Ohlson model with just book value and earnings as independent variables using sector and year controls in column 1 and company fixed effects in column 2. The estimated coefficient are remarkably similar to the estimates for core book value and earnings in the following two columns. Columns 3 and 4 report estimates for equation (1) and (2). Net pension assets are still overvalued but slightly less than in our main sample of FTSE 100 constituents when using sector and year fixed effect, while the overvaluation is reduced using company fixed effects, as it was the case in the main FTSE 100 sample. As we discuss above, this difference is likely to be due to the firm level fixed effects absorbing at least part of duration effect. The estimated coefficient on pension expenses is quite noisy. Indeed, in one specification the coefficient on pension earnings is significant but negative. This is due to the service cost anomaly, a fact well documented in the literature: effectively service cost expenses are a proxy for human capital formation and hence can contribute positively to the value of the company.[37] As in the previous estimation we use clustered standard error at the company level.

[36] See section 1, in particular table 1.

[37] The service cost anomaly was first documented by Barth et al. (1992). Its explanation as proxy for the value created by human capital is suggested by Hann et al. (2007a). Given our focus on the valuation of pension liabilities and the limited role of the service cost anomaly in our data, we do not investigate this issue further.

Table 7: FTSE 350 companies

	(1)	(2)	(3)	(4)
Book Value	1.002***	1.461***		
	(0.222)	(0.269)		
Earnings	4.511***	1.339***		
	(0.779)	(0.387)		
Core Book Value			1.026***	1.535***
			(0.225)	(0.279)
Tax-adjusted NPA			1.625**	1.157*
			(0.809)	(0.635)
Core Earnings			4.564***	1.395***
			(0.787)	(0.396)
NPPC			-3.985	-3.856*
			(3.289)	(2.034)
Fixed Effects	Sector, Year	Company	Sector, Year	Company
N	1408	1408	1408	1408
R^2	0.467	0.818	0.471	0.819

Estimation results using the enlarged FTSE 350 sample, from from 2006 to 2012. The independent variable is market capitalisation at the reporting date. Core book value is non-pension assets minus non-pension liabilities, core earnings are net income minus net periodic pension cost (NPPC), the measure of pension-related earnings in income. Tax-adjusted NPA is the difference between pension assets and liabilities for each firm, adjusted for the tax credit associated with pension contributions in the UK. All the variables are standardized by total company assets. When imposing fixed effect at the sector level, we use the broadest GISC sector classification with 10 sectors in total. The standard errors are clustered at the company level.

8.2 Tobin's Q

The second model we employ to test the valuation of defined benefit pension schemes for FTSE 100 constituents is derived from Tobin (1969), much in the spirit of Feldstein and Seligman (1981) and Liu and Tonks (2010). We defined Q as in the latter, namely as market value of equity plus book value of long term debt over total firm assets. Under strict assumptions, the value of Q should be equal to one in equilibrium; however the situation in the real world could be different. To take this into account, we include a set of control variables that may have an effect on Q, following Liu and Tonks (2010).

We define Total earnings (Etot) as net earnings plus interest expenses on debt.[38] To control for the growth trajectory of the firm, we include 5 year earnings growth, defined as the average of the last five years earnings minus the average of the five previous years; we also define its three years equivalent to limit the loss of observations caused by the data requirement of this variable. We also include net debt, defined as cash holdings minus total debt; hence a positive value indicates that the firm is a net creditor. All these variables are standardized by total company assets. The last control variable we add is the firm's CAPM beta, computed using one year of weekly returns against the FTSE 100 index. We test this model using both the reported and gilt adjusted value for net pension assets, bringing to the data the following equations:

$$Q_{i,t} = \alpha + \sum_{s=1}^{10} \gamma_s S_s + \sum_{t=1}^{7} \gamma_t T_t + \beta_1 Etot_{i,t} + \beta_2 5yGrowth_{i,t} + \beta_3 NPAt_{i,t} + \beta_4 Debt_{i,t} + \beta_5 Beta_{i,t} + \epsilon_{i,t} \tag{6}$$

In the estimation we progressively drop the control variables to ensure that they are not driving the results. The values for Tobin's Q are plausible, with an average about 1.1 and median close to 1; for most of the financial companies in our dataset (mainly the high street banks) the value for Q is understandably lower. Excluding them from the sample as in Liu and Tonks (2010) does not materially change our results. Net debt averages at about 18 per cent of total assets but with considerable variation, with most firms being net debtors as expected. The beta against the FTSE 100 is very close to one on average. The estimation results are

[38] Using net earnings instead of this variable does not alter our results.

Table 8: Tobin's Q Model

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Total Earnings	4.061***	5.237***	5.191***	3.068***	3.965***	5.244***	5.214***	3.074***
	(1.296)	(1.554)	(1.299)	(0.928)	(1.253)	(1.532)	(1.286)	(0.926)
Beta	-0.105*	-0.095	-0.076	-0.112*	-0.111*	-0.097	-0.078	-0.111*
	(0.061)	(0.062)	(0.058)	(0.059)	(0.060)	(0.064)	(0.059)	(0.061)
Net Debt	-0.777**	-0.545	-0.617*		-0.732**	-0.462	-0.535	
	(0.347)	(0.387)	(0.343)		(0.342)	(0.387)	(0.345)	
Tax-adjusted NPA	1.848*	1.949*	1.907*	2.598**				
	(1.062)	(1.025)	(0.983)	(1.269)				
Risk-free NPA					0.968***	0.877**	0.862**	1.032**
					(0.342)	(0.354)	(0.339)	(0.391)
5y Earnings Growth	2.415**				2.791***			
	(1.056)				(0.901)			
3y Earnings Growth		-0.353				-0.339		
		(0.686)				(0.677)		
N	395	433	463	497	395	433	463	497
R^2	0.565	0.566	0.582	0.540	0.581	0.576	0.592	0.550
R^2 using Tax-adjusted NPA					0.565	0.566	0.582	0.540
Difference in R^2					0.016	0.010	0.010	0.010
Vuong Z-Statistic					2.550	2.321	2.309	2.134
p-value					0.011	0.020	0.021	0.033

Table presents our estimation results for the Tobin's Q model. Q is defined as market value of equity plus long term debt over total assets. Total earnings are net earnings plus interest expenses, net debt is cash minus total debt. The CAPM beta is computed against the FTSE 100. Tax-adjusted NPA is the difference between pension assets and liabilities for each firm, adjusted for the tax credit associated with pension contributions in the UK. Its risk-free version is obtained discounting liabilities using gilt rates. All specification include sector and year fixed effects. We cluster the errors at the company level. We compare models' fit using Vuong (1989) test statistic.

presented in table 8. We start with equation (6) in the first column, then substitute the 5 year growth term with its 3 year counterpart in column 2 (total earnings average about 50 per cent above net earnings. The growth trajectory of earnings is positive for most companies, both if measured over a five or three year period). Column 3 drops the earnings growth term entirely, while column 4 drops the net debt term as well. Columns 5 to 8 repeat the same exercise using Risk-free NPA instead of the reported values. The results in table 8 broadly confirm the findings we highlighted in the previous sections: the coefficients on net pension assets are consistently above one, even though their significance depends on the specification and the sample. On the other hand, adjusting their value using a discount rate that does not allow for credit risk gives estimates very close to unity with substantially lower standard errors, irrespective of the different samples and controls. As above, we cluster the standard errors at the company level.

As with the Ohlson model, we compared the models with Risk-free NPA in table 8 with their counterparts that use reported NPA as measure of pension deficit. Vuong's test statistics indicates that each Risk-free NPA model is always preferred to its counterpart at least with a 5% confidence level. Also enforced nesting confirms that Risk-free NPA is preferred (results not reported for brevity).

9 Comparison with Anantharaman & Henderson (2016)

A recent paper by Anantharaman and Henderson (2016) (henceforth AH) tackles the same issue as this paper with a similar methodology but using US data. Their results are somewhat different to ours since they find that valuation by the US credit market appears to use the corporate bond yield as the discount rate for pension liabilities whilst the equity market pricing is consistent with return on assets discounting (using the expected return on plan assets - ERPA - as the discount rate, a rate that is used for some US funds such as public sector plans but is not used at all in the UK).[39] Given the divergent results, this section explores two key factors that might explain this: differences in methodology and institutional differences between the UK and US that might influence discounting.

[39] Discounting at the ERPA was allowed in the UK under SSAP 24, until the year 2000 when the transition to FRS 17 (the standard that preceded IAS 19 in the UK) began. SSAP 24 used an actuarial logic in representing DB pensions on financial statements and as such is completely different from the current IAS and US GAAP.

On methodology, although both papers take the same approach in considering the cash-flow profile of pension funds as given and focusing on discounting, the key difference is that with UK data we can arrive at a fairly accurate estimate of the duration of pension liabilities using the sensitivity analysis published in company accounts (as described in section 5.1).[40] AH, on the other hand, estimate this duration more indirectly. In practice they use two steps to do this. First, they match the discount rate reported by each company with the corresponding rate on the AA corporate yield curve thus giving a duration estimate based on the closest match. Second, they match changes in these interest rates with changes in actuarial gains and losses as a proxy for the interest rate sensitivity of the pension obligations.

Both these proxies have problems associated with them and so to help judge their accuracy we attempted to replicate the methodology for UK data to see how significant estimation errors could be compared with our more direct estimates of duration. First, looking at interest rate matching, we use Bloomberg estimates of a AA yield curve for the UK. We find that we can match the discount rate disclosed by the company on the yield curve only for periods after 2010: before then the curve is either flat or concave at maturities above 15 years, giving perverse results.[41] Focussing on the post 2010 sample, our estimates using AH yield curve methodology tend to somewhat overestimate duration, with an average error of 2.4 years and average absolute error of 4.1 years when compared with our direct estimates. Overall, therefore this method seems to give a reasonable estimate of duration for periods when the AA yield curve has a significant slope.

The methodology based on actuarial gains and losses is more problematic. AH's methodology aims to recover the sensitivity of pension obligations to changes in the discount rate using actuarial gains and losses.[42] This is a rough approximation, as actuarial gains and losses capture

[40]There are other small differences between AH's methodology and ours. First, they use both the ABO and the PBO as measures of pension liabilities, while we focus only on the latter as the ABO is not disclosed under IAS 19. However, most of the pension funds that we study are closed and some have frozen at least part of the benefits, so the two measures should be close in our sample. Second, AH analyse companies in financial distress separately. Our sample is smaller and more homogeneous than the whole Compustat pension universe that they use, so sorting companies by Z-score does not provide additional insights.

[41]The Citigroup Pension Discount Curve used by AH shares these features in many points in time.

[42]We use the same formula as AH to create these:

$$Actuarial\ Gains\ (Losses) = PL_t - PL_{t-1} - Service\ Cost_t - Interest\ Cost_t + Benefits\ Paid_t$$

In doing so we lose observations in year 2006 due to its data requirements.

not only changes in the discount rate but also the effect of changes in all other assumptions (inflation, salary growth, mortality, benefit formula and so forth). AH then assume a linear relationship between changes in interest rate and changes in the pension obligation, which, given the nature of those obligations, is a duration approximation.[43] To exclude unreasonable results AH assume the sensitivity of the PBO to a 1% change in interest rate to be limited to a range from 3.45% to 20.39%, discarding more than 60% of their sample in the process. Applying the same cutoff to our data causes us to lose almost half of our observations and the resulting duration estimates for the UK are biased downwards with respect to what we have estimated using companies' disclosure (the bias is significant, with an average error of 5.7 years and an average absolute error of 6.9 years). This significantly lower duration estimate may explain why AH find higher discount rates are required to explain the impact of discount rate changes on the market value of pension obligations (though of course the fact that we find an underestimate of duration for UK data need not necessarily mean AH underestimate duration for US data even though the methodology will tend to produce downward biased estimates due to the measurement error in the independent variable).

Another potentially important methodological difference is that AH's sample is much longer than ours, starting in 1995 rather than 2006. We chose a shorter sample to ensure the accounting regime is identical throughout our sample, while theirs spans different accounting regimes. In particular their sample includes the period before the move from disclosure to recognition of pension deficits/surpluses with SFAF No. 158 in 2006. There is evidence in the literature that this change in regime also resulted in a change in investors' perceptions of pension commitments, at least for some companies.[44]

The alternative explanation for the difference in results is the different institutional setting in the UK. In the UK risk-free discounting is widespread while discounting at ERPA is effectively non existent. As we noted in section 4, the UK pension protection fund uses risk-free discounting routinely and the UK accounting standard setter proposed it for pension liabilities. Crucially, in the buy-out market discounting of pension liabilities is undertaken using risk-free rates, this is

[43] it is thus unclear why AH do not use the yield curve based estimate of duration for this part of their calculation too.

[44] This accounting reform has been studied extensively, see for instance Mitra and Hossain (2009), Yu (2012) and Beaudoin et al. (2011).

the relevant measure if a company wanted to close its pension scheme altogether and settle the resulting obligation.[45] Also in case of bankruptcy the pension deficit is calculated using risk-free discounting.[46]

As we discuss in 3, given the institutional setting in the UK and the characteristics of our sample for most of the schemes that we study the PBO on which we focus is likely to be close to the ABO, which is not disclosed under IAS 19 accounting. So the different results that we find compared to AH might be due to the fact that DB schemes in our sample are more mature and settlement-ready, making a settlement rate (i.e. the risk-free rate) the most appropriate discount rate for liabilities, while schemes in AH's sample are younger, with an ABO significantly smaller than PBO, and hence is more appropriate to discount the benefits using a higher rate.

9.1 Anantharaman & Henderson (2020)

The same authors have another recent working paper (Anantharaman and Henderson, 2020) that looks at the issue of valuation of pension liabilities from a slightly different angle, comparing the value and credit relevance of different measures of pension deficits/surpluses. The authors compare the accounting measure of pension liabilities with their settlement value, which is assumed to be the ABO discounted at AA corporate bond rates, and their going concern measure, given by the PBO discounted at the scheme specific expected return on plan assets (ERPA). Moreover, they partition the sample according to the estimated duration of the pension plan and see how the results differ for three buckets of pension plans ranked by duration.

As in the paper discussed above, Anantharaman and Henderson (2020) find that the best fit in terms of equity valuation is given by the going concern measure of pension liabilities, using ERPA discounting, but for the plans with the shortest duration, in which case the settlement measure of pension liabilities (the ABO) gives the best fit. In this work the authors drop the method for estimating duration that we discuss above, instead relying on the method proposed by Hann et al. (2007b) to estimate the PBO using different discount rates. While appropriate for US data, this method assumes that the DB schemes are final salary and that the benefits are

[45] As we noted above the buy-out market is still quite small but has grown significantly in recent years. The Purple Book provides a comprehensive discussion of buy-out valuation. See for instance The Pension Protection Fund (2017), page 16.

[46] We discuss bankruptcy and the public guarantee of UK pensions in appendix A.

not linked to inflation, making it inappropriate for our sample and the UK institutional setting. Moreover, this method relies on the difference between the PBO and the ABO, which is not disclosed under IAS 19. The authors then partition the schemes in their sample in three buckets according to their duration according to the method of Blankley et al. (2018), using the ratio of forward benefits paid to the PBO to approximate the duration of the plan, assuming that plans that pay out a larger proportion of the PBO are more mature and hence have lower duration.

Anantharaman and Henderson (2020) find that the settlement measure of pension liabilities gives the best fit in explaining both credit and equity investors' valuation of pension plans in the short duration bucket, while the going concern measure fits the data best in the case for the schemes in the longer duration bucket. Given the UK institutional setting and the characteristics of our sample, where most of the schemes are mature and hence similar to what they consider to be shorter duration schemes, these results seem to agree with what we find our work, highlighting the importance of a settlement valuation for DB schemes.

10 Conclusion

Our analysis focuses on the value relevance of DB pensions deficits/surpluses in the UK context, filling a gap in the literature that has mostly focused on investors' valuation of US pensions and also allowing us to measure liability duration more precisely than has been done in other studies. We find that the net position of pension plans is reflected in equity values, but that investors use a different valuation for pension liabilities than that prescribed by the international accounting standards, discounting at the risk-free rate rather than using corporate bond yields as in the published accounts. As the pension schemes in our sample are mature and mostly closed, our finding that investors use a risk-free rate to discount pension liabilities points to investors' valuation of DB pensions being close to their settlement value, that is the value at which the sponsoring company could wind-up its pension scheme though a buy-out or a buy-in with an insurer. This result complements the findings of Anantharaman and Henderson (2020) in the US context.

Even though our results are limited to UK firms and mostly closed schemes, our ability to measure the duration of pension liabilities fairly accurately allows us to contribute empirically to the thorny debate concerning the discount rate on pension liabilities, most notably by using cross section variation in duration to sharpen estimates of discount rate effects. Our results therefore complement the theoretical discussions that have criticised the recognised pension deficit/surplus as an "unreal" number (for example Blake et al., 2008), showing that investors are able to process complex information disclosed in the notes and go beyond the headline number recognised on the balance sheet.

While our results show that for equity investors the risk-free valuation of pension liability is more relevant than the accounting measure, this does not necessarily imply that the IAS should move to risk-free discounting for pension liabilities. Determining the appropriate discount rate for financial reporting is a complex task that involves considerations that go beyond the equity markets' valuation on which we focus here. While our findings imply that the market looks through standard financial statement measures, they might also imply that increased disclosure could improve market pricing. This is important, especially as the IASB is currently at the early stages of a review into the disclosure requirements of IAS 19. Our work highlights the importance of information disclosed in the notes in helping value complex items such as pension liabilities and so suggests that more detailed disclosure of other assumptions used to determine the size of pension liabilities (the most important being mortality assumptions) could materially effect market values.

11 Appendix A: Beta of Pension Liabilities and Pension Put

In the main paper we argue that pension liabilities should be discounted at a risk-free rate. There are two main issues that can potentially undermine our claim: pension liabilities could have a degree of systematic risk that justifies a higher discount rate and the existence of public insurance for DB schemes of bankrupt sponsors could create an option to offload the pension deficit on the Pension Protection Fund. We address them in turn.

Do the pension liabilities have a degree of systematic risk that justifies discounting them at a rate incorporating some risk premium? In their model Sundaresan and Zapatero (1997) assume that wages and the stock market are perfectly correlated, and thus wage-related pension liabilities will also be correlated with the market. While in their model this assumption is a necessary simplification as it guarantees a closed form solution, the empirical evidence supporting it is very limited. Most empirical papers (e.g. Jin et al., 2006 and Cooper, 2009) suggest that the beta of pension liabilities is in fact the same as that of government bonds. Table 9 shows estimates of the beta of pension liabilities and of government bonds (gilts) over our sample. The first line shows the relationship between the yearly returns on pension liabilities and the market index (FTSE 100 or FTSE 350). The point estimates are around -0.3 and statistically significant. Although this estimate does suggest that the beta of pension liabilities could be higher than that of gilts, there is a potential bias in the estimate. Since the pension liabilities reported by the firm are discounted by the AA corporate bond yield, the fact that the credit spread on these bonds is likely to be correlated with the market index may create a spurious relationship. The second line of table 9 shows the relationship between the market index and pension liabilities discounted at the risk-free discount rate (based on government bond yields, see section 5.1 for details of how this adjustment was undertaken). This estimate is very close to zero and more comparable with the beta on gilts shown in the last line of the table. Overall, therefore it seems that over our sample the beta on pension liabilities is close to zero and similar to that on gilts. This is in line with other empirical studies and suggests that the gilt yields are an appropriate discount rate for UK pension liabilities.

The creation of the Pension Benefit Guaranty Corporation (PBGC) in the United States[47]

[47] The PBGC was created by the Employee Retirement Income Security Act (ERISA) in 1974.

Table 9: Beta of the Pension Liabilities

Method	Beta estimate	Standard Error
Beta of pension liabilities	-0.3	0.033
Beta of risk-free discounted pension liabilities	-0.04	0.032
Beta of monthly returns on gilts	-0.08	0.093

The first two lines show the beta of pension liabilities against the FTSE 100 index, using a simple CAPM regression with yearly data. The last line shows the same model using monthly returns on a coupon-stripped gilt with duration of 18 years against the FTSE 100, using all in-sample observations.

gave rise a lively academic discussion on the implication of state guarantee for defined benefit pensions, focused on evaluating the put option for the firm created by this regulation, its implication for the management of the pension liabilities and the solvency of PBGC itself. One of the first papers to discuss the issue is Sharpe (1977) that shows qualitatively how the value of the pension put is increasing in the size of the pension plan relative to firm's assets, its underfunding and the riskiness of the assets it holds. A more recent theoretical treatment of the subject is provided by Love et al. (2011), who investigate how government insurance provides incentive for risk shifting if it is mispriced, though Rauh (2009) in his empirical investigation on US companies finds that firms with low credit rating and underfunded pension funds tend to invest in safer assets than their stronger peers. Bartram (2018) provides more evidence that companies integrate DB schemes in their overall financial management, but his findings are mostly supportive of risk management, with limited evidence of risk shifting during major economic downturns.

Although, as discussed in the paper, there are many differences between US and UK pension accounting (which also effect the valuation of any pension put), one similarity is that, the defined benefit pension schemes in our sample are insured by the Pension Protection Fund (PPF), so if the sponsoring company goes bankrupt the workers do not lose their pensions entirely. As the literature discusses, this insurance may give rise to a put option for the sponsoring entity if in case of bankruptcy it can offload the pension fund's deficit on the PPF, thus leaving the other creditors of the company with a higher chance of getting at least a partial repayment. If this option exists under the UK regulation, then it should be accounted for in pricing pension liabilities. Although the existence of a Pension Put may not alter the appropriate discount rate for pension liabilities, it may indicate that the true value of those liabilities for the firm is lower than the reported one (i.e. the true value should adjust for the value of the put that the firm holds).

However, it is quite hard to envision a significant pension put in the UK. As we discuss in section 3, the institutional framework regulating DB pensions in the UK is different from that of the US: in the UK is quite hard for a company to exit its pension commitments. Moreover, the Pension Act 2004 makes it difficult for a company to systematically underfund its schemes. If the actuarial valuation shows a deficit, the sponsor has to agree a schedule of contribution with the trustees to address the shortfall. If in case of bankruptcy of the sponsor a scheme enters in the PPF, the latter has an unsecured credit towards the failed sponsoring company equal to the deficit of its pension fund calculated on a full (gilt yield discounted) buy-out basis, which is always substantially higher than the reported deficit. Although a recent judgement by the Supreme Court in the Nortel/Lehman case made clear that the PPF does not have any precedence over other unsecured creditors, schemes insured by the PPF have to pay a levy to fund the operation of the PPF itself where the levy structure is related to the riskiness of the firm. Even though McCarthy and Neuberger (2005) show that this risk-related premium is not precisely fairly priced, it does significantly reduce the market value of the pension put since the risk-related levy firms pay to the PPF offsets the value of the put they hold. Indeed, Guan and Lui (2016) find that the risk-adjusted levy limits risk-shifting in the UK context. Given these circumstances and our focus on the components of FTSE 100 index, we do have little evidence that the pension put has a material impact on the market value of pension liabilities over our sample.

12 Appendix B: Robustness

This section presents estimations that test the robustness of our results. First we present results clustering the standard errors at the sector rather than the firm level, thus allowing for a richer correlation structure of the error terms. However, this presents some problems since clustered standard errors are unbiased when the number of clusters approaches infinity and in our setup we have only ten sectors. Moreover each sector is different in size, further compounding the problem of over-rejection of the null hypothesis. Of the various bootstrap based improvements proposed by the literature we choose to use the wild cluster bootstrap of t-statistics as in Cameron et al. (2008) since this method corrects for both the small number of clusters and the unequal cluster size.

Then we show that our results are robust to controlling for the number of analyst following each firm as in Yu (2012) and to a model specification that uses changes (first differences) rather than levels. After we show that using the balance sheet figure for NPA rather than the tax-adjusted measure that we use in the main paper does not change our results. Lastly, we limit our analysis to the companies that disclose the sensitivity analysis of the pension obligation in the notes to their financial statements.

12.1 Clustering standard errors at the sector level

Table 10 shows how our main estimation using clustering at the sector level. While there are some minor difference in the significance of regressors from the tables in the main paper, the results have the same interpretation. As it was the case in the main paper, the Vuong test confirm that the Risk-free NPA model is better specified, even if the test statistics is just shy of significance using company fixed effects.

12.2 Bootstrap t-statistic

Clustering at the sector level allows us to assume the richest correlation structure for standard errors, but it is problematic in our data due to the small number of clusters and their unequal size. The wild bootstrap of the t-statistics solves both problems, so we employ this technique to correct our standard errors. Moreover, we use the weight structure proposed by Webb (2013) and later endorsed in Cameron and Miller (2015) when the number of clusters is smaller than 15. Mackinnon and Webb (2017) discuss in detail the properties of this technique, showing how it approaches the true rejection rates even with unbalanced cluster size. The procedure for using the cluster wild bootstrap of Cameron et al. (2008) to perform the test on β_2 in equation (1) is as follows:

1. Estimate equation (1) by OLS.

2. Calculate $\hat{t}_2$, the t-statistic for $\beta_2 = 0$, using cluster robust standard errors.

Table 10: Clustering by sector

	(1)	(2)	(3)	(4)	(5)	(6)
Book Value	0.502	1.490***				
	(0.457)	(0.321)				
Earnings	4.849**	2.019***				
	(1.636)	(0.525)				
Core Book Value			0.431	1.591***	0.398	1.627***
			(0.459)	(0.420)	(0.459)	(0.457)
Tax-adjusted NPA			2.120*	1.115***		
			(1.130)	(0.326)		
Risk-free NPA					0.949***	1.010***
					(0.259)	(0.177)
Core Earnings			4.802**	2.113***	4.896**	2.028***
			(1.614)	(0.558)	(1.621)	(0.544)
NPPC			4.635	-5.689*	0.751	-4.339
			(3.338)	(2.603)	(3.292)	(2.851)
Fixed Effects	Sector, Year	Company	Sector, Year	Company	Sector, Year	Company
N	511	511	511	511	511	511
R^2	0.598	0.834	0.602	0.836	0.611	0.838
R^2 using Tax-adjusted NPA					0.602	0.836
Difference in R^2					0.009	0.002
Vuong Z-Statistic					2.036	1.454
p-value					0.042	0.146

Table presents our estimation results using the main FTSE 100 sample, using standard errors clustered at the sector level. The independent variable is market capitalisation at the reporting date. Core book value is non-pension assets minus non-pension liabilities, core earnings are net income minus net periodic pension cost (NPPC), the measure of pension-related earnings in income. Tax-adjusted NPA is the difference between pension assets and liabilities for each firm, the tax adjustment is due to the tax credit associated with pension contributions in the UK. The calculations behind Risk-free NPA are described in section 4.1 of the main paper. All the variables are standardized by total company assets. When imposing fixed effect at the sector level, we use the broadest GISC sector classification with 10 sectors in total. We compare models' fit using Vuong (1989) test statistic.

3. Estimate by OLS the restricted regression

$$Mcap_{i,g} = \alpha + \beta_1 BVc_{i,g} + \beta_3 Ec_{i,g} + \beta_4 NPPC_{i,g} + \epsilon_{i,g} \tag{B.1}$$

where the subscript g indicates the cluster, imposing the null hypothesis that $\beta_2 = 0$.

4. Store the restricted residual $\tilde{\epsilon}_{i,g}$ and the restricted estimate $\tilde{\beta}_{H_0}$.

5. For each of B bootstrap replications, generate a new set of bootstrap dependent variables $y^{\star}_{i,g}$ using the data generating process

$$y^{\star}_{i,g} = \tilde{\beta}_{H_0} + \tilde{\epsilon}_{i,g} v^{\star}_g \tag{B.2}$$

where $v^{\star}_g$ is a random variable that takes values $-\sqrt{\frac{3}{2}}$, -1, $-\sqrt{\frac{1}{2}}$, $\sqrt{\frac{1}{2}}$, 1, $\sqrt{\frac{3}{2}}$ with equal probability. [48]

6. For each bootstrap replication, indexed by j, estimate regression (1) using $y^{\star}_{i,g}$ as the regressand and calculate $\hat{t}^{\star}_{2,j}$, the bootstrap t-statistic for $\beta_2 = 0$ using clustered standard errors.

7. Calculate the bootstrap p-value as

$$\hat{p}^{\star}_s = \frac{1}{B} \sum_{i=1}^{B} I(|\hat{t}^{\star}_{2,j}| > |\hat{t}_2|) \tag{B.3}$$

We run 1000 replication for each of our estimations. The resulting p-values for NPA in table 10 are 0.2 using sector and year fixed effects (columns 3), and 0.03 using company fixed effects (column 4). As in the other specifications that we test, the coefficient on Risk-free NPA is more precisely estimated, with an empirical p-value of 0.04 in cross section (column 5) and 0.003 using company fixed effects (column 6).

[48] This is the weight distribution proposed by Webb (2013). The original Cameron et al. (2008) uses Rademacher weights.

12.3 Analyst following

This section expands our main analysis by investigating whether the impact of pension deficits/surpluses depends on the richness of information available to investors valuing the companies, proxied by the number of analysts following each firm. Using US data, Yu (2012) finds that the value relevance of disclosed pensions information is higher for firms with a large number of analysts following (or high institutional ownership) and that the move to recognition of net pension assets due to SFAS No. 158 increased the value relevance of NPA for companies that enjoy less attention from sell-side analysts and institutional investors. Our context is different, but it could nonetheless be the case that the value relevance of pensions depends on investor sophistication, especially given our main finding that market participants discount pension liabilities at a risk-free rate.[49] To address this issue we control for the number of analysts following each firm in our sample at the end of their financial year. Following prior literature, we use the rank of analysts following to facilitate the interpretation of results. We calculate the rank of analysts following for each firm/year by grouping this variable in 10 bins by decile points. We then rescale the resulting variables so that it takes values from 0.1 (companies with the lowest number of analyst following) to 1 (companies with the highest coverage).[50] We then interact this variables with Tax-adjusted NPA and Risk-free NPA to investigate whether their value relevance depends upon the number of analyst following the firm. Hence we bring to the data equation (1) and (2) adding to them the variables capturing analyst following and the interaction term.

Table 11 presents the results adding analyst following as a control. The main variable of interest is the interaction between analyst following and Tax-adjusted NPA (columns 1 and 2) or Risk-free NPA (columns 3 and 4). The results in column 1 suggest that the reported pension deficit/surplus has a much bigger impact on market value for companies that have a low analysts following, while its effect is almost muted for companies in the highest rank. This seems to indicate that investors think that companies which have less coverage tend to understate their pension deficits, however the effect is not statically strong: for no decile we can reject the

[49] As we limit our analysis to FTSE 100 constituents, our sample is more homogeneous than what Yu (2012) uses.

[50] For one company we were unable to retrieve the number of analysts due to a merger. We imputed it a value of 0 in the analysts variable to keep the sample consistent with the main analysis, but excluding it has no effect on the results.

Table 11: Analyst following

	(1)	(2)	(3)	(4)
Core Book Value	0.403	1.596***	0.368	1.639***
	(0.261)	(0.400)	(0.261)	(0.383)
Tax-adjusted NPA	3.282**	0.780		
	(1.518)	(0.946)		
Tax-adjusted NPA * Analyst following	-2.633	0.654		
	(2.095)	(1.621)		
Risk-free NPA			1.215**	0.912***
			(0.561)	(0.336)
Risk-free NPA * Analyst following			-0.571	0.311
			(0.762)	(0.647)
Analyst following	-0.229*	-0.155	-0.259**	-0.155
	(0.116)	(0.108)	(0.125)	(0.118)
Core Earnings	4.826***	2.131***	4.934***	2.041***
	(1.247)	(0.741)	(1.241)	(0.735)
Net Periodic Pension Cost	4.635	-5.771	0.475	-4.505
	(8.335)	(6.507)	(7.662)	(6.395)
Fixed Effects	Sector, Year	Company	Sector, Year	Company
N	511	511	511	511
R^2	0.607	0.837	0.617	0.840
R^2 using Tax-adjusted NPA			0.607	0.837
Difference in R^2			0.010	0.003
Vuong Z-Statistic			1.944	1.576
p-value			0.052	0.115

Table presents our estimation results adding analysts following as control. The independent variable is market capitalisation at the reporting date. Core book value is non-pension assets minus non-pension liabilities, core earnings are net income minus net periodic pension cost (NPPC), the measure of pension-related earnings in income. Tax-adjusted NPA is the difference between pension assets and liabilities for each firm, the tax adjustment is due to the tax credit associated with pension contributions in the UK. Risk-free NPA are net pension assets discounted at a risk free rate (UK gilt yields). Analysts following are grouped in deciles and rescaled from 0 to 1. All the variables but for analysts following are standardized by total company assets. When imposing fixed effect at the sector level, we use the broadest GISC sector classification with 10 sectors in total. The standard errors are clustered at the company level. We compare models' fit using Vuong (1989) test statistic.

hypothesis that the sum of coefficients on Tax-adjusted NPA and its interaction with analysts following is different from the 1.964 that we estimated in table 4 without considering analyst following. Moreover, the effect of analysts following in completely absorbed by firms fixed effects in column 2. Columns 3 and 4 show that the number of analysts following has no impact on the value relevance of Risk-free NPA: the interaction coefficient is never significant, irrespective of the level of fix effects we impose in the regression. Moreover the coefficient on Risk-free NPA is very close to what we estimated disregarding analyst following, reinforcing our main conclusion that investor value pension deficits/surpluses using risk-free discounting. Also the Vuong test statistic confirms that the model using Risk-free NPA are better specified.

12.4 Changes model

In the main body of the paper we used a levels model, consistent with Barth et al. (2001) and the following literature that prefers this type of models to investigate value relevance. This section shows that our main findings are robust to using a changes model, even if that entails losing 1 year of observations.[51]

Table 12 reports our estimates for equation (1) (column 1 and 3, using Tax-adjusted NPA and Risk-free NPA respectively), equation (2) (column 2 and 4) and equation (4) using deltas (first differences) rather than levels. We define all the variables as their value at the end of the year t minus their value at the end of year $t-1$ and standardize them by total assets at the end of year $t-1$.[52] While column 1 and 2 show that the results for NPA are weak and imprecisely estimated, its risk-free counterpart remains strongly significant also using deltas, with both fixed effects at the sector and company level (columns 3 and 4 respectively).[53] Column 5 presents the results of equation (4) in deltas, showing that the difference between Risk-free NPA and reported NPA is an important component to explain market values, as we found in the main paper.

[51] Our main level model gives results with the same interpretation as what we have discussed in the main paper also in this smaller sample.

[52] Standardising all variables by market capitalisation at $t-1$ rather than assets as in Yu (2012) gives very similar results.

[53] The results for this model are generally more unstable and less significant that what we found withe the levels model in the main paper. Trimming the sample to exclude the most extreme value of the dependant variable improve the precision of the estimate without changing their interpretation.

Table 12: Changes model

	(1)	(2)	(3)	(4)	(5)
ΔCore Book Value	0.942*	0.246	1.004*	0.492	0.369
	(0.508)	(0.548)	(0.512)	(0.541)	(0.548)
ΔTax-adjusted NPA	-0.182	-0.308			1.062*
	(0.765)	(0.609)			(0.538)
ΔRisk-free Adjustment					1.667***
					(0.381)
ΔRisk-free NPA			0.660*	1.502***	
			(0.386)	(0.338)	
ΔCore Earnings	0.394	0.784*	0.342	0.533	0.572
	(0.569)	(0.456)	(0.578)	(0.464)	(0.468)
ΔNet Periodic Pension Cost	-1.695	-3.584	-2.013	-3.605	-2.318
	(3.528)	(3.777)	(3.315)	(3.159)	(3.564)
Fixed Effects	Sector, Year	Company	Sector, Year	Company	Company
N	436	436	436	436	436
R^2	0.238	0.182	0.245	0.226	0.232
R^2 using Tax-adjusted NPA			0.238	0.182	
Difference in R^2			0.007	0.044	
Vuong Z-Statistic			0.734	2.162	
p-value			0.463	0.031	

Table presents our estimation using changes (first differences) rather than levels for all variables. The independent variable is market capitalisation at the reporting date. Core book value is non-pension assets minus non-pension liabilities, core earnings are net income minus net periodic pension cost (NPPC), the measure of pension-related earnings in income. Tax-adjusted NPA is the difference between pension assets and liabilities for each firm, adjusted due to the tax credit associated with pension contributions in the UK. Risk-free NPA are net pension assets discounted at a risk free rate (UK gilt yields). Risk-free adjustment is the difference between Risk-free NPA and NPA. All variables are differences between the value at end of year t and year $t-1$, standardized by total company assets at $t-1$. When imposing fixed effect at the sector level, we use the broadest GISC sector classification with 10 sectors in total. The standard errors are clustered at the company level. We compare models' fit using Vuong (1989) test statistic.

12.5 Companies with missing sensitivity analysis

As discussed in section 5.1, about one third of the companies in our sample lack the sensitivity analysis that we need to compute the duration of the pension obligation and the corresponding Risk-free NPA. While in our main estimation we use the financial statements from 2013 to estimate the duration of the pension obligation of these companies, this section reports our main estimates using a restricted sample that drops all the companies that did not publish any sensitivity analysis during the years covered by our sample. Doing so increases the standard errors in nearly all the estimates, but does not impair the significance of our variables of interest.

13 Appendix C: Accounting NPA

As section 5 discusses, our main estimates are based on Tax-adjusted NPA. In this section we show that the estimation results for unadjusted NPA are very similar to what we present in the main paper, for both the FTSE 100 and the FTSE 350 samples. Clearly the accounting deficit is larger without taking the associated tax credit into account, averaging at 2.86 per cent of assets for the FTSE 100 sample and at 2.78 per cent of assets for the enlarged sample of FTSE 350 constituents. Table 14 presents the estimation results for the Ohlson model using the unadjusted figures. As expected, the coefficients on unadjusted NPA are slightly smaller without taking the tax credit into account, leaving our interpretation unaffected.

Table 13: Restricted sample with sensitivity analysis

	(1)	(2)	(3)	(4)	(5)	(6)
Book Value	-0.065	1.903***				
	(0.347)	(0.610)				
Earnings	4.507**	1.270*				
	(1.687)	(0.670)				
Core Book Value			-0.187	2.183***	-0.149	2.220***
			(0.372)	(0.608)	(0.365)	(0.505)
Tax-adjusted NPA			1.102	1.301		
			(1.301)	(0.809)		
Risk-free NPA					0.799	1.249***
					(0.556)	(0.331)
Core Earnings			4.253**	1.359*	4.326**	1.203*
			(1.618)	(0.723)	(1.601)	(0.659)
NPPC			9.872	-1.955	5.566	-0.034
			(7.643)	(6.722)	(7.551)	(6.833)
Fixed Effects	Sector, Year	Company	Sector, Year	Company	Sector, Year	Company
N	358	358	358	358	358	358
R^2	0.626	0.851	0.634	0.854	0.644	0.859
R^2 using Tax-adjusted NPA					0.634	0.854
Difference in R^2					0.010	0.005
Vuong Z-Statistic					1.843	1.688
p-value					0.065	0.092

Table presents our estimation results using the main FTSE 100 sample excluding all the companies that do not report any sensitivity analysis in their notes to the financial statements. The independent variable is market capitalisation at the reporting date. Core book value is non-pension assets minus non-pension liabilities, core earnings are net income minus net periodic pension cost (NPPC), the measure of pension-related earnings in income. Net pension assets are the difference between pension assets and liabilities for each firm, the tax adjustment is due to the tax credit associated with pension contributions in the UK. All the variables are standardized by total company assets. When imposing fixed effect at the sector level, we use the broadest GISC sector classification with 10 sectors in total. The standard errors are clustered at the company level. We compare models' fit using Vuong (1989) test statistic.

Table 14: Unadjusted NPA

	(1)	(2)	(3)	(4)
Core Book Value	0.430	1.588***	1.026***	1.544***
	(0.267)	(0.394)	(0.225)	(0.276)
NPA	1.530*	0.820	1.192**	0.928**
	(0.871)	(0.543)	(0.585)	(0.439)
Core Earnings	4.803***	2.114***	4.565***	1.389***
	(1.239)	(0.736)	(0.787)	(0.395)
NPPC	4.590	-5.779	-4.037	-3.984**
	(8.375)	(6.498)	(3.293)	(2.013)
Fixed Effects	Sector, Year	Company	Sector, Year	Company
N	511	511	1408	1408
R^2	0.602	0.836	0.471	0.819

Table presents our estimation results using unadjusted NPA for both our samples, the first two columns report estimates for the FTSE 100 while the last two report results for the FTSE 350. The independent variable is market capitalisation at the reporting date. Core book value is non-pension assets minus non-pension liabilities, core earnings are net income minus net periodic pension cost (NPPC), the measure of pension-related earnings in income. Net pension assets are the difference between pension assets and liabilities for each firm. All the variables are standardized by total company assets. When imposing fixed effect at the sector level, we use the broadest GISC sector classification with 10 sectors in total. The standard errors are clustered at the company level.

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