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Working Paper No. 510
Institutional investor portfolio allocation, quantitative easing and the global financial crisis

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Michael A S Joyce,[1] Zhuoshi Liu[2] and Ian Tonks[3]

Abstract

We examine how the Bank of England's quantitative easing (QE) policy during the global financial crisis affected the investment behaviour of insurance companies and pension funds and whether their behaviour was consistent with the operation of the so-called 'portfolio balance channel' that has been emphasised by UK and US monetary policy makers as a key channel through which QE works. To assess the incremental impact of QE, we need some counterfactual of how the investment behaviour of institutional investors would have changed in the absence of the policy. We construct this by conditioning on variables that explain portfolio allocation but are invariant to the QE policy itself, which allows us to construct both *ex-ante* and *ex-post* counterfactuals. Our analysis of a range of data sources, including national accounts net investment data and micro-data on life insurance companies and pension funds, suggests QE led to institutional investors shifting their portfolios away from gilts towards corporate bonds *relative to the counterfactual*. Although analysis of the micro-data does suggest some heterogeneity in the response to QE across different institutions, the shift into corporate bonds was quite widespread. However, portfolio rebalancing by institutional investors into riskier assets seems to have been limited to corporate bonds and did not extend to equities.

Key words: Institutional investors, asset allocation, quantitative easing, portfolio balance channel, financial crisis.

JEL classification: G11, E61, E65, C22, C23.

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Summary

In its efforts to loosen monetary conditions in March 2009 in response to the effects of the deepening financial crisis on the inflation outlook, the Bank of England's Monetary Policy Committee (MPC) reduced policy rates to their effective lower bound of 0.5% and began a programme of large-scale purchases of financial assets financed through the creation of central bank reserves, so-called quantitative easing (QE).

While the objectives of the QE policy were clear, there has been more debate over how the policy was expected to work. The MPC has often emphasised the portfolio balance channel as a key element in the transmission of the Bank's asset purchases to the rest of the economy during the financial crisis. According to this mechanism, purchases of financial assets from the non-bank private sector (eg insurance companies and pension funds) financed by central bank money initially increase broad money holdings and push up asset prices, as those who have sold assets to the central bank rebalance their portfolios into riskier assets. This then stimulates expenditure by increasing wealth and lowering borrowing costs for households and companies.

Despite the emphasis put on this channel by monetary policy makers, the role of portfolio balance effects in theory remains rather controversial and the empirical evidence in its support rather indirect. Most empirical research on the topic has inferred the importance of this channel from the behaviour of government bond prices/yields and other asset prices, rather than from direct evidence on the behaviour of investors. Although discussions with market contacts have also suggested some asset reallocation occurred in response to QE, particularly during the first phase of asset purchases between March 2009 and January 2010, there has been little hard evidence on the behaviour of insurance companies and pension funds, the group of investors who the Bank specifically targeted by mainly purchasing medium to long-term UK government bonds (one of the main assets held by these institutions).

The aim of this work is to try to fill this gap. We examine the behaviour of institutional investors, ie insurance companies (particularly life companies) and pension funds, both before and during the crisis and whether their portfolio allocation behaviour is consistent with portfolio balance effects. If QE has partly worked through a portfolio balance channel then we would expect that institutional investors will have reduced their holdings of UK government bonds (gilts) below what they would otherwise have been and that they will have increased their demand for riskier assets. This of course raises the difficult issue of inferring what would have happened in the absence of QE (the 'counterfactual'). In order to generate a plausible counterfactual, it is clearly important to allow for a range of other factors that may have been relevant in driving portfolio allocation. At the same time, allowing for the influence of other factors that may have been influenced by QE (eg domestic financial conditions) may lead to understating the potential effects of the policy (a switch into riskier assets will be attributed to improved financial conditions rather than QE, even though the policy may have been behind the improvement). We address this issue by allowing only for factors that influence portfolio allocation, but at the same time are unaffected by the Bank's purchases. These factors include gilt issuance by the Debt Management Office and foreign financial variables. To measure the

impact of QE, we use in and out-of-sample model-based forecasts to construct counterfactuals of what would have happened if the policy had not been implemented.

Our analysis of a range of data sources, including national accounts net investment data and micro-level data on individual life insurance companies and pension funds, is consistent with QE having lead institutional investors to shift their portfolios away from gilts towards corporate bonds relative to the counterfactual. Analysis of the micro-data shows that the switch into corporate bonds apparent in the sectoral data is reflected in remarkably similar behaviour across different types of life insurance companies and pension schemes, but in the case of insurers (who appear to exhibit more heterogeneity) the switch away from gilts was more pronounced for companies that showed less risk aversion (ie were larger than average and more heavily weighted in equities), were under more financial constraints (ie had a lower-than-average ratio of business premiums to assets) and those less constrained on average by their liabilities (ie with a larger share of assets linked directly to liabilities). For pension funds, the switch out of gilts was more pronounced for those funds that were better funded.

Overall the balance of our evidence is consistent with the hypothesis that the Bank of England's QE policy resulted in some portfolio rebalancing behaviour by institutional investors, who appear to have reduced their gilt holdings and reinvested some of the proceeds into corporate bonds relative to the counterfactual. But it appears that portfolio rebalancing was limited to corporate bonds, with most of the evidence suggesting that institutional investors moved out of equities during the period of QE purchases. Of course, this does not necessarily imply equity prices were not supported by portfolio reallocation behaviour, still less from QE, as our analysis only considers insurers and pension funds and we do not investigate the behaviour of other financial institutions; something we leave for further work.

1 Introduction

During late 2008 and 2009 the severity of the global economic and financial crisis intensified and central banks in a number of advanced economies looked to both standard and nonstandard policies to ease monetary conditions sufficiently to meet their price stability objectives. In the United Kingdom, the Bank of England responded to the risk that it would undershoot its 2% target for annual CPI inflation by cutting its policy rate further in March 2009, to a historical low of 0.5%, and introducing a programme of large-scale purchases of financial assets financed through the creation of central bank reserves, so-called quantitative easing (QE). During the first round of QE purchases from March 2009 to the end of January 2010, the Bank bought £200 billion of financial assets, mainly consisting of medium to long-term UK government bonds (gilts). Subsequently, between October 2011 and May 2012, the Bank completed a further £125 billion of gilt purchases and after a short hiatus this was followed by a further £50 billion of gilt purchases between July and November 2012, making a cumulative total of £375 billion to date (an amount equivalent to around 25% of annual GDP).

While the objectives of the QE policy were clear, there has been more debate over how the policy was expected to work. While the literature on the topic suggests a variety of possible channels, the Bank of England's Monetary Policy Committee (MPC) has always emphasised the so-called portfolio balance channel as a key element in the expected transmission of asset purchases to the rest of the economy (see eg, Dale (2012), Bean (2011) and Fisher (2010)). According to this mechanism, purchases of financial assets from the non-bank private sector financed by central bank money initially increase broad money holdings and push up asset prices, as those who have sold gilts to the central bank rebalance their portfolios into riskier assets. This then stimulates expenditure by increasing wealth and lowering borrowing costs for households and companies (see eg Joyce, Tong and Woods (2011)).

Despite the emphasis put on this channel by monetary policy makers both in the United Kingdom and in the United States (eg see Kohn (2009), Bernanke (2012)), the importance of the portfolio balance channel has often been disputed from a theoretical perspective (see eg Woodford (2012)). The empirical evidence in its support is also rather indirect. Most empirical research on the topic has inferred the importance of this channel from the behaviour of government bond prices/yields and other asset prices, rather than from direct evidence on the behaviour of investors (eg see Joyce et al (2011) for UK evidence and Gagnon et al (2011) and D'Amico et al (2012) for US evidence). There has been little or no research to our knowledge that has attempted to assess the direct impact of QE on the investment behaviour of insurance companies and pension funds (ICPFs), the group of investors who the Bank of England specifically targeted. Goodhart and Ashworth (2012) examine recent trends in the ONS data on net investment behaviour by ICPFs, but do not attempt to model their behaviour to provide a counterfactual.[1] For the United States, in a paper most closely related to our own, Carpenter et al (2013) model flow of funds data over the crisis, but this work does not look beyond the aggregate data to look at the behaviour of individual institutions, nor do the authors address the

[1] We repeat some similar analysis for the United Kingdom in Section 3 of the paper.

potential bias to their estimates caused by the correlation between the QE policy variable and other financial control variables (ie a switch into riskier assets may be attributed to improved financial conditions rather than QE, even though the policy may have been behind the improvement in the former).

The aim of this paper is to address this gap in the literature. We examine the behaviour of institutional investors, ie insurance companies (life companies in particular) and pension funds, both before and during the global financial crisis using both aggregate and micro-level data, in order to investigate whether their portfolio allocation behaviour is consistent with portfolio balance effects. If QE has partly worked through a portfolio balance channel then we would expect that institutional investors will have reduced their gilt holdings below what they would otherwise have been and that they will have increased their demand for riskier assets. This of course raises the difficult issue of inferring what would have happened in the absence of QE (ie the counterfactual). In order to generate a plausible counterfactual, it is clearly important to allow for a range of other factors that may have been relevant in driving portfolio allocation. At the same time, allowing for the influence of other factors that may have been influenced by QE (eg domestic financial conditions), may lead to underestimating the potential effects of the policy. We therefore follow Pesaran and Smith (2012) in allowing only for factors that influence portfolio allocation but at the same time are unaffected by the Bank's QE purchases. These include gilt issuance by the Debt Management Office (DMO) and foreign financial variables. To the extent the data allow, we also compliment this *ex-post* in-sample analysis with *ex-ante* out-of-sample forecasts, as an alternative way of generating a counterfactual benchmark.

Another important issue is how developments at the aggregate level are reflected at the level of individual institutions. A movement away from gilts towards risky assets observed at the aggregate level might not be a reflection of uniform behaviour at the level of the different institutions. We use both aggregate and micro-level data on individual institutions for our analysis. The aggregate data allow us to model the effects of QE on the net investment of institutional investors and other investors across different asset classes, enabling us to estimate which sectors sold gilts to the Bank in response to QE and where they reinvested the proceeds. The advantage of these data is that net investments are available at a relatively high (quarterly) frequency and over a relatively long timespan (from 1987 to 2012), but the disadvantage is that the data are partly based on surveys that are known to have incomplete coverage and there is the additional problem of inconsistencies between the two main data sources. To try to get round these limitations, and also to examine some of the heterogeneities across different institutions in their responses to QE, we also look at data at the level of the individual institutions themselves. Micro-data on individual institutions are scattered across various proprietary or confidential databases.[2] In order to look at the behaviour of individual insurers, we use the annual Prudential Regulation Authority (PRA)/Financial Services Authority (FSA) data returns on life insurance companies that are made available through SynThesys. The main advantage of this data series is that it provides a long back-run (from 1985 to 2012), with a reasonably detailed asset breakdown, although this does not extend to the assets held to match linked liabilities, which are a relatively large share of some insurer' total assets. The PRA/FSA returns are also

[2] The ONS have recently made available their microdata to researchers through the Virtual Microdata Laboratory (VML) facility, but the micro-data for ICPFs will be subject to the same incomplete sample coverage problems as the aggregate data (see Section 3).

limited to asset stocks and do not provide evidence on net investment flows. To model the behaviour of pension funds, we use confidential data provided in anonymised form by the Pension Protection Fund (PPF). These data cover a large range of funds but are only available over a short time period (from 2005 to 2010[3]). Again these data are restricted to asset holdings and are annual. Each source of data therefore offers its own challenges and we have used a variety of approaches in what follows based around our general framework.

The rest of this paper is structured as follows. In Section 2 we discuss some of the previous literature on portfolio balance effects and draw out the possible implications for the behaviour of institutional investors. Section 3 discusses the main data sources we use and some of their limitations, as well as recent trends in the data. In Section 4 we then set out our empirical methodology, which includes constructing both ex-ante and ex-post counterfactuals following the methodology recently proposed by Pesaran and Smith (2012). Section 5 then goes on to discuss the evidence using aggregate data on ICPFs produced by the Office for National Statistics. Sections 6 and 7 go on to explore the micro evidence on the portfolio behaviour of life insurance companies and defined benefit pension funds using data from PRA/FSA returns and the PPF respectively. Section 8 offers some conclusions.

2 The portfolio balance channel and institutional investors

There are a number of channels through which QE might be expected to affect the macro-economy. These include policy signalling, portfolio rebalancing and liquidity effects. Monetary policy makers in both the United Kingdom and the United States have, however, placed particular emphasis on the so-called portfolio balance channel, which is our focus in this paper (for the United Kingdom, see eg, Dale (2012), Bean (2011) and Fisher (2010), and for the United States, see eg Kohn (2009) and Bernanke (2012)).

The portfolio balance channel is normally associated with the work of Tobin (1961, 1963 and 1969), who demonstrated how changes in asset supplies lead to changes in financial asset prices when there is imperfect substitutability between financial assets. But these ideas are also developed by a number of other authors, including Brunner and Meltzer (1973) and Friedman and Schwartz (1963). The portfolio balance channel provides a means for central bank asset purchases to affect the real economy. By purchasing assets from the non-bank private sector in return for central bank reserves, QE increases the sellers' broad money holding. If money is seen as an imperfect substitute for the assets being purchased, the sellers will then seek to rebalance their portfolios by buying other assets, which may be riskier (like corporate bonds rather than gilts). The sellers of these assets will in turn want to rebalance their portfolios and so on. During this process of rebalancing, asset prices will rise until investors are indifferent to the overall supplies of money and financial assets. Higher asset prices, or equivalently lower yields, may in turn be passed on into lower borrowing costs for households and firms and also increase the net wealth of asset holders, both of which should stimulate real activity and inflation.

[3] Although the PPF data available to us were compiled in 2012, the underlying asset allocation data are often one or two years older.

In modern macroeconomic models changes in asset quantities do not feed through into asset prices, either because assets are assumed to be perfect substitutes for one another or because of other assumptions which result in the private sector effectively consolidating the public sector balance sheet into its own. The well-known consequence is that policies like QE can only work if they change the private sector's expectations of future policy rates through the signalling channel, as transferring assets between the private and public sectors under QE has no effect in itself (see eg Eggertsson and Woodford (2003) and Woodford (2012)).

Under less restrictive assumptions, this QE neutrality result does not always hold. For example, Andres et al (2004) develop a DSGE model where two types of agent have different preferences for long-term bonds and show that it generates portfolio balance type effects. This kind of model setup can be motivated by so-called 'preferred-habitat' theories (Culbertson, 1957; Modigliani and Sutch, 1966), where investors have a preference for a particular segment of the yield curve. In a widely cited paper, Vayanos and Vila (2009) develop a model with two types of agent: arbitragers (who are mean-variance optimisers) and preferred-habitat investors (who have strong preferences to hold certain maturities of bonds). They show that the supply of bonds can affect yields even in the presence of arbitrageurs, provided the latter are risk averse or capital constrained. Central bank asset purchases in this model would affect yields both through a scarcity effect or 'local supply effect' concentrated (localised) in the bonds being purchased and through a more broad-based duration risk effect, which reflects the fact that reducing the bonds held by the private sector leads to a fall in the quantity of duration risk held by arbitrageurs, which in turn reduces the market price of duration risk and increases the price of all long-duration assets. The present crisis has thrown up a large literature which finds that large-scale asset purchases by central banks had a large impact on the prices of the assets being bought and some pass-through to other assets (for a review see eg Joyce et al (2012)). Whether this reflects the operation of the portfolio rebalance channel is more uncertain, though a number of papers (e.g. Banerjee, McLaren, and Latto (2014)) provide evidence of local supply and duration effects that are indirectly supportive.

The portfolio balance channel had an important bearing on the design of the Bank of England's asset purchase programme. The Bank's purchases were targeted towards non-banks by being restricted to long-term assets (initially gilts with residual maturities ranging between 5 and 25 years and subsequently to gilts with residual maturities above 3 years) that are typically held by financial institutions like life insurance companies and pension funds, as it was thought that these institutions – often thought of as the archetypal preferred habitat investors - were more likely to use the proceeds of gilt sales to invest in other, riskier assets such as corporate bonds and equities (see, eg Fisher (2010)[4]). The purchases themselves were conducted through reverse auctions, with quantity and price bids submitted through the gilt-edged market makers (GEMMs) (see Joyce and Tong (2012) for details). But the issue for us is who the ultimate sellers were.[5]

[4] As Fisher explains in his speech: "[t]he proposition is that, by buying gilts from pension funds and insurance companies (for example), those asset managers would have more cash in their portfolios than they desired, and would be incentivised to use that cash to invest in other, more risky instruments such as corporate bonds and equities."

[5] When the Bank of England buys gilts in the open market it does so from the GEMMs, who act as the counterparties to these trades. But we would anticipate that the GEMMs are intermediaries, who go on to replenish their supply of gilts with purchases from other counterparties. Unfortunately, there are no official reporting requirements on the identity of the ultimate sellers of gilts.

By analysing the portfolio allocation behaviour of institutional investors over the period that QE purchases took place we can potentially identify the importance of institutional investors in selling gilts to the Bank and gauge the extent of portfolio rebalancing by them into riskier assets. In order to do this, we attempt to answer the following three questions:

(1) Did a significant fraction of the Bank's asset purchases come from institutional investors?
(2) Did institutional investors increase their net investment in risky assets more than they would otherwise have done as a result of QE?
(3) Did institutional investors increase their asset allocation towards risky assets more than they would otherwise have done as a result of QE?

An affirmative answer to the first question seems a necessary one for a QE portfolio rebalancing effect to have occurred. If the QE policy worked through a portfolio balance channel to any significant degree then a significant fraction of the purchases must have ultimately come from institutional investors.[6]

Finding an affirmative answer to the second question that institutional investors increased their net investment in risky assets (compared to the counterfactual where QE was not implemented) also seems a necessary condition for a portfolio balancing channel to have worked. Although it is theoretically possible that any effects could come entirely through prices without any flow effects needing to occur, it seems more plausible that at least some adjustment in quantities would occur in practice and this is clearly how portfolio rebalancing is described and for the most part understood. To the extent that additional net investment flows into risky assets could be established to have had a *causal* effect on asset price movements then evidence in support of (2) (in combination with (1)) would seem to be a sufficient condition for establishing a portfolio rebalancing effect of QE, although 'causality' is obviously difficult to pin down with any confidence.

An affirmative answer to (3) would establish a broader portfolio effect but would not on its own be necessary or sufficient to establish the effect of a portfolio rebalancing channel, though it would seem a natural corollary of the workings of such a channel. If net investment in risky asset prices increases then it seems likely that there would also be an increase in the portfolio share of risky assets, but it is not clear that this would necessarily need to be the case for QE to work through this channel. Equally, finding an increase in the share of assets allocated to risky assets (even relative to a no-QE counterfactual) need not establish on its own that QE was working through portfolio balancing, as the effect could just be a consequence of revaluation effects. Unfortunately, when it comes to analysing the micro-data, we have no data on net investment flows, nor do we have price data for the assets held by the individual institutions. So we can only examine the change in asset shares without being able to decompose these further

[6] Of course, it is possible that QE may also have led other agents to rebalance their portfolios, but central banks have emphasised the role of institutional investors, so it seems appropriate to focus on this group of investors. Carpenter et al (2013) highlight the role of hedge funds in their analysis of portfolio rebalancing in response to the Federal Reserve's large-scale asset purchases.

into revaluation (price) effects and quantity effects. However, the main additional advantage of using the micro-data is that they can help inform us on a fourth question:

(4) To what extent were any resultant changes in portfolio allocation uniform across different types of institutional investor?

The more broad-based the changes the more confidence we can have that the aggregate changes reflected a genuine response to the QE policy, rather than an artefact of aggregating the different behaviours of different institutions. At the same time, if QE had more impact on certain institutions then this is also useful information, which has obvious relevance to the debate about the distributional consequences of QE (see Bank of England (2012)).

Given the caveats, positive evidence in favour of (1), (2), (3) and (4) cannot be regarded as a strict test of the portfolio balance channel of QE, but it would certainly be consistent with such an effect, and finding no evidence in favour of at least (1) and (2), or (1) and (3), would clearly cast serious doubt on the importance of this channel. These questions motivate the rest of the empirical analysis we report in the rest of the paper.

The difficulty of assessing the empirical evidence is that in order to evaluate the evidence, we need to allow for a variety of other factors that may have been influencing portfolio investment over the period. In other words, we need to judge the data in terms of a model or a counterfactual of what would otherwise have happened. How we do this is discussed in detail in Section 4 below. This is clearly far from straightforward and our results need to be seen in that context. One difficultly is that the investment behaviour of institutional investors is notoriously slow moving, so it is possible that the response to QE had long and variable lags, which may not be fully captured in our dataset. In addition, if there are reasons for thinking that the effects of portfolio rebalancing will be state contingent then these effects are unlikely to have been constant through time, something we examine to the extent that the data allow by differentiating between the first round of purchases between March 2009 and January 2010 (QE1) and the second round after October 2011 (QE2). Before discussing our econometric analysis, the next section describes the data we examine.

3 Data on portfolio allocation

3.1 Data sources

We make use of a range of data sources on the asset allocations of institutional investors, including national accounts data on the aggregate flow of funds by sector, and micro-data on the investment allocations of individual pension funds and life insurance companies.

The Office for National Statistics (ONS) publishes two different datasets on institutional investors: financial accounts data (contained in the United Kingdom Economic Accounts) that report the net asset acquisition of financial assets by pension funds and insurance companies combined (aggregating both defined benefit and defined contribution pension schemes and life and general insurance companies), as well as other sectors, including overseas investors and other financial institutions; and a second dataset (MQ5) based on a survey of large pension funds (including funds for both defined benefits and defined contribution schemes) and life insurance companies and other institutional investors, from which it is possible to identify the net investment flows for pension funds and life insurance companies separately at the aggregate level. [7] These data are available at a quarterly frequency from 1987-2012. Unfortunately, these two datasets are not fully consistent. The national accounts data on ICPFs are obtained from a combination of sources, which includes the survey data used to produce the MQ5 data but also data from other sources, such as central government and the Bank of England, in order to produce a balanced set of National Accounts.

We also make use of two micro datasets on the asset allocations of individual life insurance companies and defined benefit (DB) pension schemes. These micro datasets are produced as a product of regulation, which requires that individual life insurance companies and DB pension schemes submit annual financial information that includes details of their asset allocations to the relevant regulators documenting their asset allocations for risk assessment reasons. In the case of insurance companies the regulator is the PRA (formerly the FSA[8]), and for DB pensions since 2005 it is The Pensions Regulator. The dataset for life insurance companies is publically available via SynThesys, and for DB pensions it is a proprietary dataset held by the PPF.

The SynThesys Life data cover over 350 life insurance companies that were in existence for at least one year (and therefore filed returns) from 1985-2012. In 1985 there were 229 insurance companies filing returns, but by 2012 this had fallen to just over 100. [9] For each company the data provide annual information on the percentage of total assets (excluding those linked to liabilities)[10] held across a number of broad asset categories. In addition the data provide information on insurance firm-level characteristics including i) firm size (measured by total admissible assets); ii) the free asset ratio (the ratio of excess capital resources available to cover long-term business Capital Resource Requirements (CRR) against total assets); iii) the ratio of business premiums to assets; iv) the proportion of the assets held to match linked liabilities, and (v) the proportion of business that is with-profit.

The pension fund data were supplied to us in anonymised form by the PPF and relate to the universe of defined benefit pension funds for which they are responsible. In 2012 the PPF universe consisted of 6,316 DB schemes, covering 11.7 million members.[11] Although the PPF data available to us were compiled in 2012, the underlying asset allocation data are often one or two years older. For most of the funds, their latest asset breakdown dates are prior 2011. Moreover, the asset breakdown dates are different for different pension funds, which is not satisfactory for our purposes. We adjusted the original dataset by interpolating to obtain the

[7] For life insurance companies, the MQ5 data are obtained from a survey of a sample of the approximately 300 insurance companies that undertake insurance business in the UK and that are authorised by the PRA (formerly FSA). For pension funds, the MQ5 data are obtained from a survey of a sample of 1,500 self-administered pension scheme listed on Pension Funds Online.

[8] The FSA was responsible for the regulation of the financial services industry (including insurance companies) in the United Kingdom between 2001 and 2013.

[9] Over the full sample period the regulations governing the completion of these forms has changed, so that there may be structural breaks in some series.

[10] We obtain these asset allocation data from the PRA/FSA returns Form 13.

[11] Note that the MQ5 aggregate data includes public sector pension funds and also defined contribution schemes, which are excluded from the PPF universe. However, the PPF data include smaller private pension funds, which are not captured by the MQ5 data.

asset allocation at the same time each year.[12] The final asset allocation dataset used in the analysis is year-end data from 2005 to 2010.

For each pension fund, we have annual data on the percentage of total assets held across a number of broad asset categories (including equity, government bonds, index-linked bonds, corporate bonds and cash). The data also provide information on: (i) pension fund size, measured by either the size of liabilities or number of scheme members; (ii) fund maturity, measured by either the number of retired members (pensioners) as a percentage of all members, or the average age of members in the scheme; (iii) the amount of the risk-based levy (RBL) paid by the scheme to the PPF, which is mainly determined by sponsor insolvency risk and scheme underfunding risk ; (iv) funding position, measured by the funding ratio (i.e. value of assets as a percentage of liabilities);[13] and (v) whether the scheme is open or closed.

Combining these datasets we are therefore able to investigate the effect of QE on the portfolio behaviour of institutional investors at both an aggregate level (net investment flows) and at the level of individual funds/companies (asset shares). Although some of the datasets provide quite a rich breakdown of assets, for most of our analysis we will concentrate on four broad categories: equities, government bonds (split into nominal and index linked where possible), corporate bonds (combining UK and foreign bonds) and cash (including bank deposits and other short-term assets). The amounts allocated to property/land and other assets are relatively small.

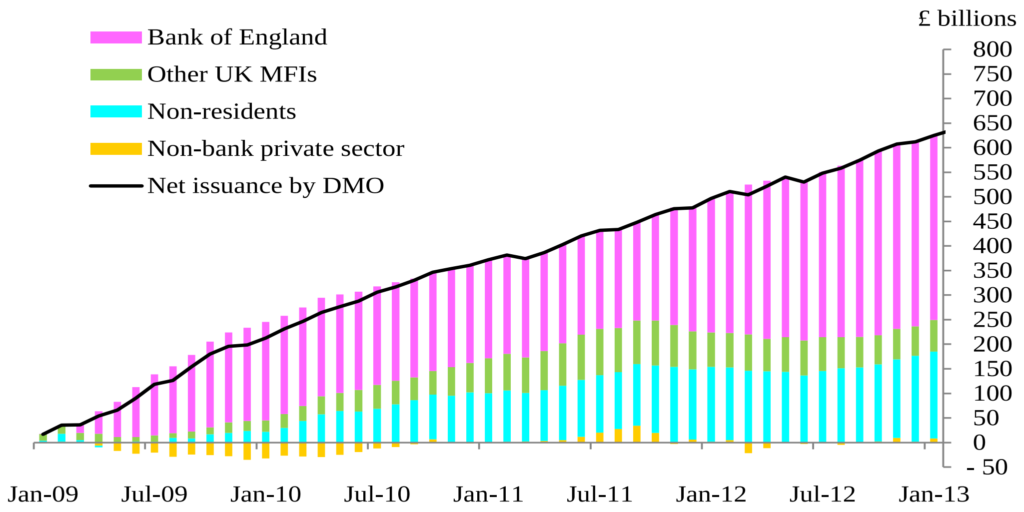
3.2 Recent trends

The Bank of England purchased around £375 billion of government bonds over the period 2009-2012 as part of its QE policy. Figure 1 derived from Bank of England statistics illustrates cumulative monthly changes in gilt holdings by different categories of investor over this period. It can be seen that the Bank of England was a significant purchaser of gilts. Other Monetary Financial Institutions (Other MFIs) were also net purchasers of gilts, as was the overseas sector. But, as Figure 1 shows, the non-bank private sector, which includes ICPFs, purchased relatively small quantities of gilts, which would be consistent with them selling gilts to the Bank of England. And this interpretation is also supported by ONS financial accounts data on ICPFs' annual net investment flows shown in Figure 2.

[12] Where necessary, we adjusted the original data by interpolating the share of assets in a linear fashion with reference to the asset breakdown dates. For example, suppose that the asset share of equities for Fund A was 30% on 31 December 2010 and it increased to 40% on 31 December 2012. We then use a straight line on daily basis to connect the two data points, so that we can infer the equity share on any intervening day. We used this method to estimate the share of assets on 31 December of each year to be consistent with the analysis in the PPF's Purple Book.

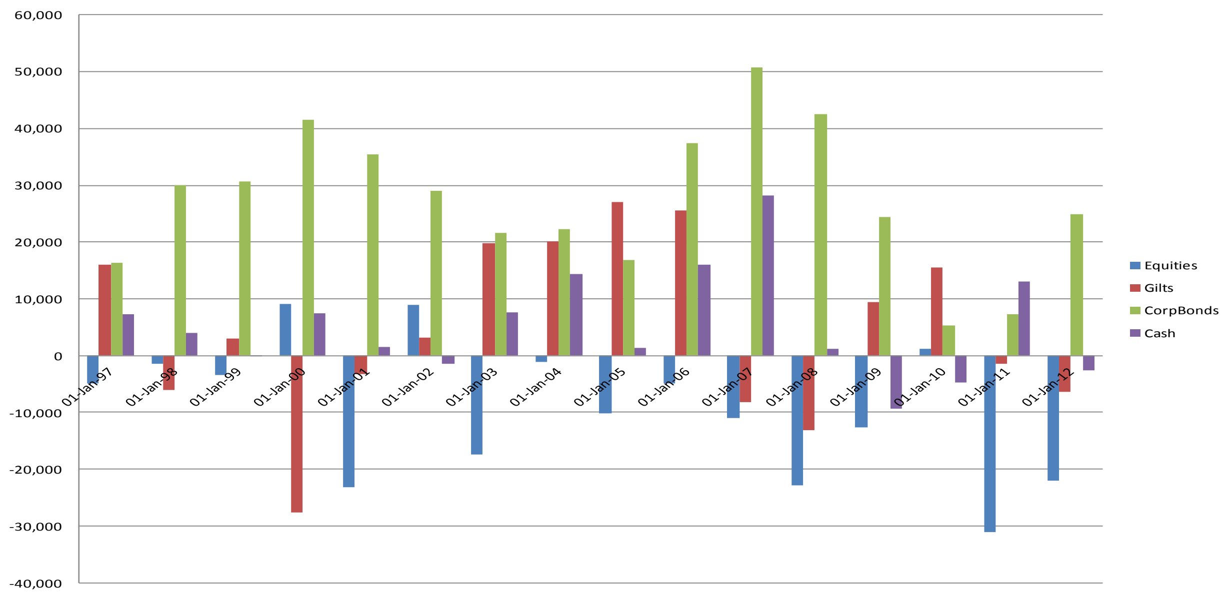
[13] Assets are valued at market values, and the liabilities are based on the s179 valuation. For the latest s179 valuation guidance, see http://www.pensionprotectionfund.org.uk/DocumentLibrary/Documents/Section_179_Assumptions_Guidance_VA6_Apr11.pdf

Figure 1: Cumulative monthly changes in UK gilt holdings by category of investor



Source: Bank of England

Figure 2: ICPF annual net flows into main asset classes (£m, 1997-2012)



Source: ONS

Table 1 reports the average values of the quarterly net fund flows and the annual asset allocations over time into and across the main asset classes for each of our datasets. Given that different datasets often have different ways of grouping assets, it is not possible to work on exactly the same asset classification for different datasets. The notes to Table 1 explain the asset classification for each dataset in detail. Panel A shows that, at the aggregate level, there has been a long-run trend of outflows from equities by institutional investors since the early 2000s, which may have been exacerbated by the financial crisis in 2008. There also appears to have been a shift into corporate bonds, with a reduction in flows into gilts and cash over the crisis. Panels B and C also focus on the aggregate MQ5 data, but split these net flows separately into life insurance companies and pension funds. We are able to further split data on UK gilts into nominal and index-linked gilts for MQ5 dataset. It turns out that the asset allocation behaviour of both sets of institutional investors is similar. Pension funds and life companies were moving out of equities even before the crisis, and both have reduced their allocations to nominal gilts since 2008, with flows going into corporate and index-linked government bonds. One difference is that after the onset of the crisis, pension funds increased the flow of funds into cash, while life companies reduced their cash allocation. Panel D and E provide summary information on the micro datasets for life companies and pension funds. Averaging across companies/funds and years, the longer data set on life companies shows that allocations to equities, nominal and indexed government bonds have varied over time with no obvious long-term trend; but there has been a steady increase in the allocation to corporate bonds, and a reduction in cash holdings. The pension data are more recent, and there seems to have been a move out of equities (though pension funds hold a higher percentage of equities than life companies), and an increase in the share of corporate and index-linked bonds.[14]

Table 1: Net investment flows and asset allocations by institutional investors over time

Panel A: Net flows into asset classes by ICPFs (mean quarterly values, £m)[a]				
Period	Equities	Gilts	CorpBonds	Cash
1987Q1-1992Q4	4,334	246	1,171	824
1993Q1-1997Q4	1,706	4,316	1,629	1,900
1998Q1-2002Q4	-507	-1,537	8,331	572
2003Q1-2007Q4	-2,234	4,209	7,440	3,374
2008Q1-2012Q4	-4,359	202	5,223	-117

Panel B: Net investment flows into asset classes by life insurance companies (MQ5) (mean quarterly values, £m)[b]					
Period	Equities	UK nominal Gilts	UK indexed Gilts	CorpBonds	Cash
1987Q1-1992Q4	1,497	524	80	705	525
1993Q1-1997Q4	2,637	1,759	257	1,074	1,235
1998Q1-2002Q4	1,702	-135	296	6,164	766
2003Q1-2007Q4	-799	1,060	594	3,235	2,183
2008Q1-2012Q4	-3,117	-851	425	2,543	-1,252

Panel C: Net investment flows into asset classes by pension funds (MQ5) (mean quarterly values, £m)					
Period	Equities	UK nominal Gilts	UK indexed Gilts	CorpBonds	Cash
1987Q1-1992Q4	2,329	-579	44	250	208
1993Q1-1997Q4	-1,809	1,063	890	34	715
1998Q1-2002Q4	-1,115	-339	0	1,268	-490
2003Q1-2007Q4	-4,350	482	214	3,056	542
2008Q1-2012Q4	-2,794	-97	1,160	1,619	1,012

[14] Amir, Guan and Oswald (2010) suggest that UK pension funds moved out of equities into bonds as a response to the new accounting standard FRS17 introduced in transitional form from 2001. Jackson and Tonks (2014) report that UK life insurers shifted their asset allocations from equities to bonds following the FSA Tyner reforms of the risk-based regulatory regime for life insurers from 2005.

Panel D: Asset allocation across asset classes by life insurance companies (SynThesys), (mean percent of total) [c]					
Period	Equities	Nominal Govt bonds	Indexed Govt bonds	CorpBonds	Cash
1985-1992	27.97	31.4	3.13	14.17	26.17
1993-1997	30.39	33.69	5.62	17.92	24.52
1998-2002	31.47	33.38	4.93	19.46	20.96
2003-2007	29.82	31.26	2.64	28.89	19.84
2008-2012	33.29	27.46	4.05	32.28	16.85
Panel E: Asset allocation across asset classes by defined benefit pension funds (PPF) (mean percent of total) [d]					
Period	Equities	Nominal Govt bonds	Indexed Govt bonds	CorpBonds	Cash
2005-2007	62.22	16.89	13.99	16.48	7.85
2008-2010	52.59	15.96	16.49	21.71	8.02

Notes:
a Source: ONS Financial Accounts. Equity includes quoted and unquoted UK shares, share and other equity issued by the rest of world, and mutual funds' shares. Gilts refer to government bonds of more than 1 year maturity (including both nominal and index linked) issued by UK central government. Corporate bonds refer to bonds of more than 1 year maturity (in both local and foreign currencies) issued by UK MFIs and other UK residents and the rest of world. Cash is defined as currency plus deposits.
b Source: ONS MQ 5. Equity includes both UK and oversea ordinary shares (including both quoted and unquoted) but not mutual funds' shares. UK nominal gilts include any sterling-denominated British government securities but exclude Treasury bills and index-linked securities. UK indexed gilts include index-linked British government securities denominated in sterling. Corporate bonds include both UK and overseas corporate bonds (in both local and foreign currency). Cash includes cash in hand, balances with banks and building societies, other liquid deposits and other short-term assets such as money market instruments.
c Source: S&P SynThesys PRA/FSA returns. Total assets do not include assets held to match linked liabilities. Equity includes equity shares, and other share investments such as variable yield participations, holdings in collective investment schemes, rights under derivatives contracts, and participation in investment pools. Nominal government bonds refer to approved fixed interest securities which are typically government nominal bonds and include both UK and other governments bonds, though the former tends to dominate. Indexed bonds are approved variable interest securities which are typically government index-linked bonds and include those issued by both the UK and other governments; the former tend to dominate. Corporate bonds refer to other fixed and/or variable interest securities which are typically corporate bonds (including both UK and overseas corporate bonds). Cash includes cash in hand and deposits, such as bank and approved credit and financial instant deposits.
d Source: PPF and Bank of England calculations. Equity includes UK and overseas equity shares but excludes unquoted private equities. Nominal government bonds include both the UK and other governments fixed interest bonds. Indexed bonds are variable interest securities which are typically UK index-linked gilts. Corporate bonds are fixed interest bonds issued by corporate sectors (in both the UK and overseas). Cash includes cash in hand and deposits.

4 Empirical methodology

4.1 Modelling portfolio allocation

For a typical investor, the basic portfolio selection problem is that of investing a given amount of money to maximize his/her utility subject to some budget constraints. The portfolio allocation decision of institutional investors is in principle the same as this standard optimisation problem, but subject to a larger array of complicating factors. The asset allocation decisions of these institutions may be unusual in that they may reflect the risk preferences of several groups, including (sometimes multiple) asset managers,[15] trustees and pensioners, and so may be nonstandard.[16] The institutions themselves may have specific long-term liabilities that they need

[15] Van Binsbergen, Brandt and Koijen (2008) have argued that the process of pension funds employing multiple fund managers (decentralized fund management) may lead to coordination inefficiencies in pension fund asset allocations. Blake et al (2013) study the evolution of UK pension funds' decentralization decisions and find that such coordination inefficiencies are offset by reduced scale inefficiencies and benefits of specialisation from employing multiple fund managers.
[16] For example, McCarthy and Miles (2013) model pension plan trustees as facing non–linear payoffs which are linked to the funding status of the pension scheme because of pension insurance and a sponsoring employer who may share net surpluses.

to satisfy, which will affect their asset choices (eg, long-term assets may be matched to long-term liabilities). At the same time, pension funds will be subject to regulatory requirements that also constrain their asset allocation decisions (Amir, Guan, and Oswald, 2010). At a high level of abstraction, however, these additional complicating factors could be represented through changing the utility function and/or by including additional budget constraints.

In general we might describe the institutional investor's preferences over some asset allocation bundle ($x_{1,t}, x_{2,t} \dots x_{N,t}$) by a utility function, which includes the stock of liabilities (L) (see eg Dinenis and Scott (1993)). The fund's investment criterion is then to maximise the value of the expected utility function tomorrow with respect to the decision on asset allocation today. More formally, this can be written as:

$$\max E\left[U\left(x_{1,t+1}, x_{2,t+1} \dots x_{N,t+1}, L_{t+1}\right)|t\right]$$

Subject to the constraints:

$$E\left(\sum_{i=1}^{N} x_{i,t+1} \,|t\right) = \sum_{i=1}^{N} x_{i,t} \, R_{i,t}$$

$$E(L_{t+1}|t) = L_t E_t(R_{t+1}^L)$$

$$E\left(\sum_{i=1}^{N} x_{i,t+1} \,|t\right) - E(L_{t+1}|t) \geq C_{t+1|t}$$

where $x_{i,t}$ is the value of the holding of asset i at time t, N is the number of different types of asset held by the investor, $R_{i,t}$ is the expected return for the i'th asset over the period between t and t+1, $E_t(R_{t+1}^L)$ is expected liability growth ratio between t and t+1, and $C_{t+1|t}$ is the required capital for time t+1, known at time t.

The solution to this problem is an optimal demand function taking the form:

$$\mathbf{x}_t^* = \mathbf{x}^*(\mathbf{R}_t, E_t(R_{t+1}^L), w_t, L_t, \boldsymbol{\Sigma}_t^{\boldsymbol{x}}, \boldsymbol{\Sigma}_t^{\boldsymbol{xL}}, \Sigma_t^{\boldsymbol{L}}, \boldsymbol{\kappa}_t, \mathbf{x}_{t-1}^*)$$

where $\mathbf{R}_t = \left(R_{1,t}, R_{2,t} \dots, R_{N,t}\right)$, $w_t = \sum_{i=1}^{N} x_{i,t}$, $\boldsymbol{\Sigma}_t^{\boldsymbol{x}}$ is the variance covariance matrix for the asset return of each asset class, $\boldsymbol{\Sigma}_t^{\boldsymbol{xL}}$ is the vector of covariances between the asset return of each asset class and the change in the liability, $\Sigma_t^{\boldsymbol{L}}$ is the variance of the liability growth ratio, and $\boldsymbol{\kappa}_t$ is the vector of other higher moments.

If we ignore the role of liabilities completely and assume they are always of the same value as assets and investors are risk averse, the solution to the optimisation problem above will collapse into the optimal asset allocation solution in a classical mean-variance model.

$$\mathbf{x}_t^* = \mathbf{x}^*(\mathbf{R}_t, w_t, \boldsymbol{\Sigma}_t^{\boldsymbol{x}}, \boldsymbol{\kappa}_t)$$

But, given the important role of the liabilities in the balance sheet of institutional investors and prevalence of asset-liability management, the classical mean-variance model solution may fail to capture their correct investment behaviour. This suggests ideally that in our empirical analysis we should include variables which might affect the behaviour of liabilities (eg their expected growth rate and the associated volatility) and also their correlation with asset returns. We might also want to include variables correlated with the risk preferences (reflected in the utility function) of the institution and variables measuring the likely influence of regulatory constraints. Moreover, the model would also need to include some dynamics to take into account the fact that, although these institutions typically shape their portfolios in line with a strategic asset allocation approach that takes into account the characteristics of the institution and adopts a long-term view of an appropriate asset mix, in the short-term they may deviate from these allocations and engage in tactical asset allocation to take advantage of temporary changes in market conditions.

A lot of the older literature on the asset allocation of institutional investors imposes functional forms and restrictions from consumer theory to derive structural asset demand equations. But a complete structural model would be dynamic and non-linear, which can often be difficult to estimate and prone to misspecification.

4.2 Econometric approach

In a recent paper on the impact of QE on the UK's output growth, Pesaran and Smith (2012) argue that it is not always necessary to estimate a fully structural model if the aim is to estimate policy effects; instead what is needed is a conditional model with parameters that are invariant to the policy change. In constructing such a conditional model of the effects of a policy variable (x_t) on an outcome variable (y_t), they distinguish between control variables that may not be invariant to the policy variable (z_t) and control variables that affect the outcome variable but are not affected by the policy variable (w_t). They argue that only the latter type of control variable is relevant in evaluating the effects of the policy variable. The former type of control can be substituted out of the model provided there are enough lags of the other variables. Thus, their baseline model is given as:

$$y_t = \alpha + \pi x_t + \gamma w_t + \varepsilon_t \qquad (1)$$

where ε_t is the error term and we leave the z_t term out of the equation. The QE policy variable,x_t, is measured by the amount of gilt purchases by the Bank of England.[17]

Following Pesaran and Smith (2012), we adopt a reduced-form approach in our econometric analysis, incorporating the variables that we view as independent of the Bank's asset purchases, which we take to include the debt issuance by the DMO[18], foreign financial variables and (where available) the individual characteristics of specific institutions (to proxy the nature of their liabilities and the regulatory and other constraints they face). The foreign financial variables include the change in the 10-year benchmark US Treasury yield (US_Long_Yield); the change in the US 10-year corporate spread (US_corp_spread), which is the difference between

[17] Data sourced from the Bank of England.
[18] Data sourced from the DMO.

the Barclays US high yield index and the 10-year US Treasury yield; and the return on the S&P 500 (US_SP_Return) and its realised volatility (US_SP_VOL), a measure of uncertainty.[19,20]

To explain net investment y in different asset classes at the sectoral level, we use the following basic equation:

$$y_t^k = \alpha^k + \pi^k x_t + \gamma_1^k DMO\_Control_t + \gamma_2^k Fin\_Control_t + \beta^k y_{t-1}^k + \epsilon_t^k \quad (2)$$

The dependent variable in the regression, y_t^k, is the net acquisition (measured in £ million) of any asset class *k* held by any type of investor in quarter *t*. The regressors include the QE policy variable, x_t, which is measured by purchases of gilts measured in £ million. We also include as controls the net issuance of gilts by the DMO and foreign financial control variables (as discussed above) to account for exogenous financial conditions, which are independent of the Bank of England's QE policy. In addition, we include the lagged value of the dependent variable as a regressor to allow for some inertia in the adjustment process.[21]

We can further examine the relative size of the effects from QE1 and QE2 by replacing the single QE variable, x_t, with the two policy variables x_t^1 and x_t^2, where the former is the amount of gilts bought during QE1 (and zero otherwise) and the latter is the amount of gilts bought during QE2 (and zero otherwise).

This equation is similar to the specification Carpenter et al (2013) use to examine US flow of funds data but differs in that we use net investment rather than changes in asset stocks, so this regression looks at the determinants of net flows into different assets. As revaluation effects would be expected to represent only a small fraction of each quarter's net flows, these regressions enable us to examine the institutions' active portfolio decision making.

We also investigate the asset allocation of individual insurance companies and pension funds by estimating the following panel model:

$$p_{i,t}^k = \alpha_i^k + \pi^k x_t + \gamma_1^k DMO\_Control_t + \gamma_2^k Fin\_Control_t + \gamma_3^k Firm\_Control_{i,t}^k + \beta^k p_{i,t-1}^k + \epsilon_{i,t}^k \quad (3)$$

where $p_{i,t}^k$ is the percentage of any asset class *k* that a life insurance company (or pension fund) *i* invests in period *t*; $Firm\_Control_{it}^k$ are company or fund *i* specific characteristics at t; and as in equation (1) x_t is the quantity of QE purchases (measured in £ bn[22]); DMO_Control[23] and

[19] The returns and realised volatilities are calculated for either 3 months or one year depending on the frequency of the data used.
[20] All the original financial market data used to derive these variables were sourced from Datastream.
[21] When this equation is estimated across each asset class for a given sector, or across all sectors for a given asset class, it becomes possible in principle to impose adding-up constraints for the system as whole. The parameter estimates we report later are freely estimated and do not impose these restrictions, but we find that the data are in any case quite close to satisfying them.
[22] We scale up the QE purchase units from £ million in equation (2) to £ billion in equation (3) for ease of reporting.
[23] We scale DMO debt issuance by nominal GDP for the both SynThesys (the micro-level data for life insurance companies) and PPF (the micro-level data for DB pension funds) data regressions.

Fin_Control are defined as previously. We will discuss the firm level controls in the section below.

As above we can further examine the impact of QE1 vs QE2, by allowing for the policy variable x_t to be split into x_t^1 for the amount of gilts bought during QE1 and x_t^2 is the amount of gilts bought during QE2.

For the micro-level data, the panel regressions shown in equation (3) explain the percentage shares of each asset class in total assets. Although we would ideally like to decompose changes in the shares into those due to investment flows and those due to revaluation effects, as discussed above, this is not possible with the available data.

In addition, we also examine possible heterogeneities in the response to QE across different types of institution. To the extent that portfolio balance effects operate through preferred habitats, we might expect asset purchases to have different effects according to the liability structure of the institution. For the United States, Chen, Sun, Yao and Yu (2012) find some evidence that the maturity of insurance companies' claim liabilities is an important determinant of their bond portfolio durations, and that insurers with stronger liability concerns exhibit a more restrained portfolio reaction to term structure changes. It is equally possible that different responses to QE by institutional investors could occur for other reasons, including their risk preferences (funds that invest a large share of their portfolios in risky assets may be more likely to risk shift) and the extent to which they are constrained by regulatory constraints (funds that have excess capital may be more inclined to take advantage of market movements). So we also test for the importance of various interaction terms between QE and different fund characteristics, including size, capital constraints and the nature of the liability structure.

So the model is extended as follows:

$$p_{i,t}^k = \alpha_i^k + \pi_1^k(dummy_1 * x_t) + \pi_2^k(dummy_2 * x_t) + \cdots + \pi_n^k(dummy_n * x_t) +$$

$$\gamma_1^k DMO\_Control_t + \gamma_2^k Fin\_Control_t + \gamma_3^k Firm\_Control_{i,t}^k + \beta^k p_{i,t-1}^k + \epsilon_{i,t}^k \qquad (4)$$

where $dummy_n = 1$ if a firm is classified into group "n" based on some criterion and it is zero otherwise. We apply the model above to both life insurers and pension funds to examine what affects the size of their response to QE.

It is important to acknowledge that there are some factors that may also have affected the portfolio allocation of institutional investors, which we do not explicitly consider in our modelling approach. These include expected large regulatory and accounting changes at the international level, such as Solvency II,[24] and changes to International Financial Reporting

[24] Solvency II is an EU-wide insurance regulation, which is expected to come into effect on 1 January 2016. Since Solvency II would raise the capital charge on holding equities, it might encourage insurers to move away from equities and into bonds. Moreover, there are reasons why the same regulation might also encourage insurers to favour corporate bonds over government bonds. This is because gilts are exposed to two risks, which could be partly mitigated by investing in corporate bonds: namely, under-performing risk and basis-mismatch risk. The former arises as Solvency II requires liabilities to be discounted by Libor-Swap rates rather than gilt yields. Given that Libor-swap rates are often higher than gilt yields (at least for short maturities), the asset return based on gilts may not match

Standards (IFRS), including IFRS 4 phase 2 and IAS 19,[25] and also national level regulations, such as the PRA's regulatory requirements under the Internal Capital Adequacy Assessment Process (ICAAP) and Individual Capital Adequacy Standards (ICAS), and the Pension Act 2004.[26] It is extremely difficult to account for the impact of these factors directly due to the fact that changes in regulation and accounting rules often take a long time to implement and institutional investors might change their investment strategies well ahead of implementation. To some extent though the impact of these factors should be captured indirectly by the control variables and lagged dependent variables included in our regressions.

4.3 Evaluating ex-ante and ex-post QE impacts

To examine the size and uncertainty of asset purchases in these regression models regarding the aggregate impact of QE on life insurance/pension fund sectors, we construct two kinds of counterfactual comparison (based on Pesaran and Smith (2012)) for the sectoral models.[27]

The first is the ex-ante QE impact, which is calculated as the expected difference between a QE policy scenario and a no-QE policy scenario, where both scenarios are based on the net investment model (ie equation (2)) estimated over the full sample. More formally, the ex-ante impact of QE relative to the counterfactual since the launch of QE (in period T) is defined as:

$$QE\_effect(ex-ante)_{T+h} = E(y_{T+h}|y_T, x_{T+h}, Controls_{T+h}, \Omega_{\text{full}}) - E(y_{T+h}|y_T, x^0_{T+h}, Controls_{T+h}, \Omega_{\text{full}}) \quad (5)$$

where the expectation of the outcome variable y_{T+h} is the linear projection from the model estimated in equation (2), and where $x^0_{T+h} = 0$ is the policy variable assuming there was no QE. $Controls_t$ include both the DMO gilt issuance control and Financial Controls; Ω_{full} is the estimated parameter set based on the full sample estimation. The right-hand side expectation terms are constructed using information from the whole sample, as we cannot estimate the effects of QE in the period prior to the financial crisis.

The second is the ex-post QE impact, which is the difference between the realized outcomes and a no-QE counterfactual, which is estimated from the same equation estimated using the sub-sample which ends just before the beginning of QE. More formally, this is calculated as:

$$QE\_effect(ex-post)_{T+h} = y_{T+h} - E(y_{T+h}|y_T, x^0_{T+h}, Controls_{T+h}, \Omega_{\text{sub}}) \quad (6)$$

the growth of liabilities, which would grow in line with Libor-swap rates. Basis-mismatch risk can arise due to the swap-gilts basis gap, which leads to more capital being needed under Solvency II.

[25] Both these international accounting changes (IAS 19, implemented already, and IFRS 4 phase II, which is expected to come into force in 2015) are likely to produce greater volatility in financial statements, as insurers and DB pension funds will see more of the implied risks of their balance sheets reflected in their financial statements. This may already have led to more liability-driven asset allocation in order to smooth financial statements, involving lower exposure to equity and higher exposure to bonds.

[26] The effect of the PRA's ICAAP /ICAS is likely to be similar to Solvency II, while the Pensions Act 2004 may also have encouraged DB pension funds to move away from equities.

[27] There is no straightforward way of constructing them from the micro-level analysis, as we would need to aggregate up the counterfactuals for each individual institution.

where Ω_{sub} is the parameter set based on the sub sample estimation up to the end of 2008. Therefore the expected no-QE counterfactual is produced using information on the pre-QE sample up to 2008.

In principle, it would seem preferable to use sub-sample estimates when constructing no-QE counterfactuals, as they would be more likely to capture the "true" dynamics of the no-QE scenario and not be "contaminated" by the post-QE data. But we need to use the full sample estimates for the ex-ante QE impact analysis because we need the model to form the expectation under the QE scenario as well as under the no-QE scenario, which is not possible for the sub-sample estimates. Neither ex-ante nor ex-post QE impact estimates are perfect, however, as while the former constructs the counterfactuals based on the full-sample estimates, the latter will be affected by shocks that are not related to QE. However, by looking at both ex-ante and ex-post estimates, we should be able to form a better judgement of the impact of QE and the related model uncertainty around our estimates.

5 Sectoral results

In this section we turn to discuss our empirical results based on sectoral data from the ONS financial accounts and the MQ5 data on institutional investors. We begin by describing our regression results for the different investor types. We then analyse the regression results of ICPFs' portfolio allocations. Finally we examine the implications of ex ante and ex post counterfactual analysis.

5.1 Regression results on the net acquisition of gilts across sectors

The results from estimating equation (2) for the net acquisition of gilts across investor types[28] are reported in Table 2. The models were estimated by OLS but the standard errors and t-statistics of the coefficients are based on Newey–West estimators to adjust for any autocorrelation and heteroskedasticity in the error terms. It should be borne in mind that, as described in the footnote to Table 1, the gilts category in the ONS financial accounts includes both nominal and index-linked bonds issued by the UK central government. This is far from ideal, but further disaggregation is not available across all the sectors. The table shows that for ICPFs the coefficient on the Bank of England's net purchases of gilts variable (BOE_QE) is statistically significantly with a negative sign. The coefficient value of -0.11783 implies that for every £1 of gilts purchased as part of the QE programme, ICPFs reduced their net inflows into gilts by about £0.12. Since we include the lagged value of the dependent variable into this regression, which is statistically significant and positive, we also report the long-run coefficient on QE purchases. This is estimated to be 0.18 in absolute terms, suggesting that the impact increases over time as might have been expected.

From Table 2 we can see that QE purchases are also negative and statistically significant in the equations for three other sectors – OFIs (other financial institutions and financial auxiliaries), MFIs (banks and building societies) and RoW (rest of the world). This would be consistent with investors in each of these sectors reducing their net acquisition of gilts in response to the amount

[28] We omit results for the local and central government sectors.

of QE purchases. On the whole, the lagged dependent variables for these sectors are either small or statistically insignificant, so the long-run effects reported are only slightly different. Although the regressions in Table 2 do not include any adding-up constraints, the sum of the coefficients on the QE purchases variable across investor types is close to unity for both the short-run and long-run effects, as we would expect. Finally, note that the coefficient on the DMO variable, reflecting the quarterly issuance of government debt, is positive and statistically significant for each of these same investor categories, as expected.

The other financial institutions included in the OFI category include the gilt-edged market makers (GEMMs) (as well as unit and investment trusts, hedge funds and private equity). Since the mechanics of the QE programme involved the Bank of England buying from the GEMMs, we would expect to see a large negative short-run coefficient on the QE variable for this category of investors, which is what we observe. While the long-run effect for this sector is similar to the short-run impact, this should probably not be taken as meaning that OFIs were the ultimate sellers, as the dynamics are likely to be more complicated than our models allow. For example, it seems likely that a lot of the gilts sold by OFIs will have been originally sourced from ICPFs, so the long-run impact probably exaggerates the importance of OFIs as ultimate sellers and understates that of ICPFs.[29]

If we take the results at face value, the long-run estimates suggest that, of the £375 billion of total QE, around £68 billion (nearly a fifth) originated from ICPFs. Although probably an underestimate, as the regressions may not fully capture the long-run effects, this still suggests that a significant amount of the Bank's purchases came from institutional investors.[30]

[29] That said, given the greater liquidity in the market as a result of the Bank's presence and the higher balance sheet costs, it is possible that the GEMMs might have been encouraged to hold lower gilt inventories during the QE period, though it is less clear that any effect would have been permanent.
[30] The main results reported in this section are robust to other specifications, using lags of QE spending, or separating out the first and second waves of QE purchases.

Table 2: Net acquisition of government bonds and QE purchases across sectors (sample 1987Q1-2012Q4)

	ICPF	PNFC	PC	OFI	Households	RoW	MFI
BOE_QE (x)	-0.11783***	0.00126	-0.00106	-0.44498***	0.00691	-0.17357**	-0.24967***
	(-2.87)	(0.64)	(-0.66)	(-8.13)	(0.32)	(-2.41)	(-5.82)
DMO_Control	0.10432**	0.00177	0.00047	0.25705***	-0.01198	0.33147***	0.26726***
	(2.51)	(0.81)	(0.39)	(4.77)	(-0.74)	(6.47)	(5.88)
Financial Controls							
US_long_yield	0.10539	-0.00172	0.04342	-1.37961	-0.49756	1.40590*	0.59931
	(0.13)	(-0.04)	(1.17)	(-1.35)	(-0.87)	(1.94)	(0.79)
US_corp_spread	-0.38049	-0.01807	0.02253***	0.77310*	-0.18441	0.08677	0.10891
	(-0.94)	(-0.86)	(2.83)	(1.73)	(-0.70)	(0.22)	(0.37)
US_SP_Return	24.54994	-1.10399	1.09689*	-22.27981	-6.38154	15.83184	-6.03947
	(1.46)	(-0.79)	(1.96)	(-1.07)	(-0.70)	(0.94)	(-0.46)
US_SP_Vol	-8.28184	-1.48852	3.72231	54.95646	20.92484	-85.99511	52.51013
	(-0.15)	(-0.49)	(1.47)	(0.73)	(0.57)	(-0.93)	(0.98)
LDV	0.34686***	0.00331	0.19407***	-0.02561	0.30029**	0.12983*	0.08920
	(3.21)	(0.04)	(2.88)	(-0.42)	(2.07)	(1.68)	(0.86)
Constant	393.30922	16.96295	-66.72447	-456.02746	-451.45204	1814.52066	-1929.50167*
	(0.32)	(0.26)	(-1.06)	(-0.35)	(-0.62)	(1.00)	(-1.95)
Long-run impact	-0.1804	0.0013	-0.0013	-0.4339	0.0099	-0.1995	-0.2741
Obs	103	103	103	103	103	103	103
R-sq	0.313	0.029	0.067	0.677	0.121	0.491	0.51

Notes: T-statistics are based on Newey-West heteroskedasticity consistent standard errors. Following the Newey-West (1994) plug-in procedure, we choose 4 lags for Newey-West. Significance level: ***1%; **5%; *10%. The sectors reported are: ICPFs - insurance companies and pension funds; PNFCs - private non-financial corporations; PCs - public corporations (excluding the Bank of England); OFIs - other financial institutions and financial auxiliaries; RoW – rest of the world investors; MFI - monetary financial institutions, such as banks and building societies.

5.2 Regression results on portfolio reallocation by ICPFs using sectoral data

In Table 3 we provide a further analysis of the investment behaviour of the ICPFs based on ONS financial accounts data where ICPFs include general and life insurance companies and also pension funds. We model their net investment flows into four broad asset categories: government bonds (as before), equities, corporate bonds and cash, where government bonds include both UK nominal and index linked gilts, and equities and corporate bonds include both domestic and overseas securities. As well as the significant negative coefficient on QE purchases in the gilts equation noted above, there is also a significantly positive coefficient on the QE variable in the corporate bonds equation. This is consistent with the idea of portfolio rebalancing, with the coefficient suggesting that £1 of QE leads to ICPFs increasing their long-run flows into corporate bonds by 30 pence. The corporate bond equation in Table 3 also shows that ICPFs respond to the sale of gilts by the Debt Management Office by purchasing fewer corporate bonds than they otherwise would.

Table 3: Portfolio balance regression results for ICPFs (1987Q1-2012Q4)

	Equities	Gilts	Corp Bonds	Cash
BOE_QE (x)	-0.08864	-0.11783***	0.07428**	0.03997
	(-1.37)	(-2.87)	(2.53)	(0.81)
DMO_Control	-0.00318	0.10432**	-0.06615***	-0.06301
	(-0.08)	(2.51)	(-2.63)	(-1.65)
Financial Controls				
US_long_yield	-1.43479	0.10539	0.93573*	-0.92611
	(-1.20)	(0.13)	(1.70)	(-1.26)
US_corp_spread	-0.39986	-0.38049	-0.24713	-0.00552
	(-0.87)	(-0.94)	(-1.17)	(-0.02)
US_SP_Return	6.42466	24.54994	1.55507	-26.47199**
	(0.36)	(1.46)	(0.17)	(-2.39)
US_SP_Vol	-56.04473	-8.28184	1.69084	-102.78972**
	(-1.10)	(-0.15)	(0.05)	(-2.28)
LDV	0.33989***	0.34686***	0.76188***	0.00437
	(2.96)	(3.21)	(8.16)	(0.03)
Constant	1119.58644	393.30922	1513.48090**	3567.72566***
	(1.02)	(0.32)	(2.32)	(3.56)
Long-run impact	-0.1343	-0.1804	0.3119	0.0401
Obs	103	103	103	103
R-sq	0.221	0.313	0.585	0.103

Notes: T-statistics are based on Newey-West heteroskedasticity consistent standard errors. Following the Newey-West (1994) plug-in procedure, we choose 4 lags for Newey-West. Significance level: ***1%; **5%; *10%.

Table 4 further examines the effects of QE on the net investment flows of ICPFs, but by focusing on the impact of QE1 and QE2 separately as we are also interested in the relative effectiveness of QE1 and QE2, as it has been argued that QE was subject to diminishing returns (eg Goodhart and Ashworth (2012)). The table shows the results of a modified version of equation (2), where the variable BOE_QE_1 is the amount of gilts purchased during the QE1 period (March 2009 – January 2010) and zero otherwise; and BOE_QE_2 are the amounts of gilts purchased as part of the QE2 package (October 2011- November 2012). The coefficients on the two QE policy variables for the gilts equation and for the corporate bonds equation are of similar size and significance, in the short-run and long-term. The coefficient on QE2 in the gilts equation is slightly larger and the coefficient in the corporate bonds equation is slightly smaller, but the differences are not statistically significant according to a standard F test. However, there is a marked and statistically significant difference in the equities equation between QE1 and QE2, with the negative coefficient on QE2 gilt purchases being much larger and statistically significant. A larger negative coefficient in the equities equation for QE2 purchases could be thought of a larger reaction by ICPFs to QE but a smaller portfolio balance effect, though the larger coefficient on QE2 purchases in the gilts equation makes this interpretation slightly uncertain. A weaker impact of QE2 on rebalancing into riskier assets could be consistent with the impact of the euro area sovereign crisis during 2011 having led to an increase in risk aversion among investors, which might have partly offset or delayed the rebalancing impact of QE (see, e,g, Joyce, McLaren and Young (2012)). As we will see though, some of our results do not suggest the move away from equities was larger in QE2 than in QE1, compared to the counterfactual.

Table 4: Portfolio balance regression results for ICPFs: QE1 vs QE2 (1987Q1-2012Q4)

	Equities	Gilts	Corp Bonds	Cash
BOE_QE_1 (x1)	-0.02295	-0.09966**	0.08096**	0.08224
	(-0.39)	(-2.19)	(2.10)	(1.45)
BOE_QE_2 (x2)	-0.14856***	-0.13561***	0.06841**	0.00418
	(-3.14)	(-3.11)	(2.25)	(0.11)
DMO_Control	-0.01870	0.10229**	-0.06714***	-0.06910*
	(-0.42)	(2.43)	(-2.63)	(-1.74)
Financial Controls				
US_long_yield	-1.39037	0.11200	0.93902*	-0.89614
	(-1.16)	(0.13)	(1.69)	(-1.23)
US_corp_spread	-0.19636	-0.32530	-0.22496	0.12079
	(-0.46)	(-0.76)	(-1.02)	(0.46)
US_SP_Return	6.96397	24.46952	1.58542	-26.48133**
	(0.40)	(1.44)	(0.17)	(-2.40)
US_SP_Vol	-73.27977	-15.49319	0.15061	-112.53578**
	(-1.35)	(-0.26)	(0.00)	(-2.36)
LDV	0.30127***	0.33705***	0.75973***	0.02315
	(2.66)	(2.92)	(8.07)	(0.14)
Constant	1531.38191	543.95479	1556.07929**	3747.03762***
	(1.34)	(0.41)	(2.28)	(3.55)
Long-run impact (QE1)	-0.0328	-0.1503	0.3370	0.0842
Long-run impact (QE2)	-0.2126	-0.2046	0.2847	0.0043
Obs	103	103	103	103
R-sq	0.239	0.315	0.586	0.120

Notes: T-statistics are based on Newey-West heteroskedasticity consistent standard errors. Following the Newey-West (1994) plug-in procedure, we choose 4 lags for Newey-West. Significance level: ***1%; **5%; *10%.

We now turn to look at the net investment behaviour of life insurance companies and pension funds separately using the ONS's MQ5 data, which are used to construct the ONS financial accounts data, though the latter also incorporate other adjustments which mean that the two datasets are not fully consistent. One advantage of the MQ5 dataset, however, is that it distinguishes between net investment in UK nominal and index-linked gilts, so the results that follow are presented for five rather than four asset classes.

The regression results for life insurance companies in Table 5 show that QE purchases have a statistically significant negative coefficient in the regressions for both nominal and index-linked government gilts. The former is consistent with the interpretation of the results in the earlier tables, but the negative coefficient in the index-linked gilts equation is somewhat surprising, since the QE programme did not involve purchasing index-linked gilts. The equations also show a positive and statistically significant coefficient of QE in the cash equation, which would be consistent with insurers increasing their cash balances in response to QE. There is also a positive coefficient on QE purchases in the corporate bond equation, which might indicate some switching to corporate bonds, though the coefficient is not statistically significant at normal levels. The coefficient on QE in the equities equation is small and not statistically significant.

Table 5: Portfolio balance regression results for MQ5 life insurance companies (1987Q1-2012Q4)

	Equities	UK Nominal Gilts	UK Indexed Gilts	Corp Bonds	Cash
BOE_QE (x)	-0.01113	-0.04355*	-0.04469***	0.02374	0.04910**
	(-0.38)	(-1.70)	(-3.45)	(1.29)	(2.04)
DMO_Control	-0.05131*	0.01054	0.02376**	-0.04919***	-0.09370***
	(-1.93)	(0.58)	(2.10)	(-2.65)	(-3.42)
Financial Controls					
US_long_yield	-0.91139*	0.23232	0.10690	0.42007	-0.16139
	(-1.69)	(0.42)	(0.50)	(1.19)	(-0.32)
US_corp_spread	-0.28696	-0.31212	-0.15210	-0.03820	-0.00647
	(-1.36)	(-1.56)	(-1.41)	(-0.24)	(-0.03)
US_SP_Return	-6.73964	13.45107	3.45631	3.10714	-20.27527**
	(-0.59)	(1.65)	(1.36)	(0.42)	(-2.13)
US_SP_Vol	-55.34013	3.80821	21.19206	38.50180	-98.95600***
	(-1.51)	(0.14)	(1.65)	(1.21)	(-2.63)
LDV	0.30296**	0.21303	0.05405	0.65794***	0.03128
	(2.25)	(1.52)	(0.50)	(7.24)	(0.27)
Constant	1722.66506**	294.37292	-128.21665	679.77682	3150.54785***
	(2.55)	(0.53)	(-0.63)	(1.53)	(4.04)
Long-run impact	-0.01597	-0.05534	-0.04578	0.06940	0.05069
Obs	103	103	103	103	103
R-sq	0.284	0.171	0.159	0.547	0.216

Notes: T-statistics are based on Newey-West heteroskedasticity consistent standard errors. Following the Newey-West (1994) plug-in procedure, we choose 4 lags for Newey-West. Significance level: ***1%; **5%; *10%.

Table 6 shows the results when the same regressions are rerun including the QE1 and QE2 purchases separately. The most striking result is that coefficients for both nominal and index-linked gilts are larger in QE2 than QE1, suggesting that there was a larger reduction in insurer net investment in government bonds in QE2. There was also a statistically significant negative coefficient on the QE2 purchases in the equity regression, suggesting net investment in equities by insurance companies fell against the counterfactual during the QE2 period.

Table 6: Portfolio balance regression results for MQ5 life insurance companies: QE1 vs QE2 (1987Q1-2012Q4)

	Equities	UK Nominal Gilts	UK Indexed Gilts	Corp Bonds	Cash
BOE_QE_1 (x1)	0.01981	-0.00462	-0.02890**	0.02292	0.05559**
	(0.86)	(-0.19)	(-2.25)	(1.08)	(2.00)
BOE_QE_2 (x2)	-0.03606*	-0.08019***	-0.06315***	0.02444	0.04334**
	(-1.89)	(-4.36)	(-4.48)	(1.16)	(2.10)
DMO_Control	-0.05893**	0.00468	0.02280*	-0.04905***	-0.09476***
	(-2.30)	(0.24)	(1.96)	(-2.63)	(-3.42)
Financial Controls					
US_long_yield	-0.88947	0.22220	0.13580	0.41961	-0.15881
	(-1.65)	(0.41)	(0.60)	(1.18)	(-0.31)
US_corp_spread	-0.18473	-0.19572	-0.09012	-0.04074	0.01546
	(-0.84)	(-1.02)	(-0.91)	(-0.23)	(0.07)
US_SP_Return	-6.53798	13.14936	4.02297	3.10696	-20.17451**
	(-0.57)	(1.66)	(1.52)	(0.42)	(-2.11)
US_SP_Vol	-63.75652*	-10.12938	19.34998	38.66052	-100.59738**
	(-1.76)	(-0.39)	(1.60)	(1.20)	(-2.59)
LDV	0.27944**	0.16613	-0.02463	0.65841***	0.02970
	(2.05)	(1.15)	(-0.19)	(7.17)	(0.25)
Constant	1931.66878***	598.03593	-63.72393	674.86712	3186.34864***
	(2.91)	(1.12)	(-0.32)	(1.45)	(3.92)
Long-run impact (QE1)	0.0275	-0.0055	-0.0282	0.0671	0.0573
Long-run impact (QE2)	-0.0500	-0.0962	-0.0616	0.0715	0.0447
Obs	103	103	103	103	103
R-sq	0.295	0.210	0.195	0.547	0.217

Notes: T-statistics are based on Newey-West heteroskedasticity consistent standard errors. Following the Newey-West (1994) plug-in procedure, we choose 4 lags for Newey-West. Significance level: ***1%; **5%; *10%.

Table 7 turns to examine the net investment behaviour of pension funds. The results show a statistically significant negative coefficient on the QE purchase variable for nominal gilts, but a positive and statistically significant coefficient in the equation for index-linked bonds. So pension funds like insurance companies appear to have reduced their net investment in nominal gilts following QE, but unlike insurers they appear to have increased their net investment in index-linked bonds. One explanation could be that, following the 1995 Pension Act, DB pension funds have been required to index link pension entitlements and they may therefore have been buying index-linked securities at the time of QE to match their liabilities. The regressions also suggest pension funds switched their funds into corporate bonds and cash, though the QE purchase variable is only weakly significant for corporate bonds.

Table 7: Portfolio balance regression results for MQ5 pension funds (1987Q1-2012Q4)

	Equities	UK Nominal Gilts	UK Indexed Gilts	Corp Bonds	Cash
BOE_QE (x)	0.02748	-0.05579***	0.04532*	0.02568	0.04448
	(0.77)	(-3.01)	(1.80)	(1.57)	(1.64)
DMO_Control	-0.06872**	0.03507**	0.01980**	-0.01355	0.00080
	(-2.45)	(2.08)	(2.42)	(-1.14)	(0.04)
Financial Controls					
US_long_yield	-0.86701	0.43204	-0.20773	0.06452	0.63927
	(-1.01)	(1.34)	(-0.72)	(0.34)	(0.90)
US_corp_spread	-0.52683	-0.19325	0.16858	-0.14991	0.03875
	(-1.11)	(-0.94)	(1.23)	(-1.37)	(0.12)
US_SP_Return	-11.63280	10.35764	12.99210***	1.64680	13.85307
	(-0.70)	(1.26)	(2.85)	(0.35)	(1.17)
US_SP_Vol	35.77160	-9.64199	-5.71158	-10.52715	-15.63552
	(0.67)	(-0.40)	(-0.36)	(-0.75)	(-0.34)
LDV	0.38002***	0.32508***	-0.01396	0.71649***	-0.04442
	(3.30)	(3.12)	(-0.13)	(4.49)	(-0.38)
Constant	-917.79803	72.95578	112.40260	557.84967*	463.57016
	(-0.78)	(0.16)	(0.35)	(1.95)	(0.68)
Long-run impact	0.04432	-0.08266	0.04470	0.09058	0.04259
Obs	103	103	103	103	103
R-sq	0.236	0.314	0.348	0.485	0.120

Notes: T-statistics are based on Newey-West heteroskedasticity consistent standard errors. Following the Newey-West (1994) plug-in procedure, we choose 4 lags for Newey-West. Significance level: ***1%; **5%; *10%.

Table 8: Portfolio balance regression results for MQ5 pension funds: QE1 vs QE2 (1987Q1-2012Q4)

	Equities	UK Nominal Gilts	UK Indexed Gilts	Corp Bonds	Cash
BOE_QE_1 (x1)	0.03284	-0.04177**	0.00860	0.03585*	0.04452
	(0.69)	(-2.34)	(0.75)	(1.79)	(1.12)
BOE_QE_2 (x2)	0.02275	-0.06937***	0.08281***	0.01662	0.04446*
	(0.62)	(-4.58)	(9.29)	(1.51)	(1.89)
DMO_Control	-0.06958**	0.03335*	0.02688***	-0.01499	0.00080
	(-2.30)	(1.94)	(3.00)	(-1.20)	(0.04)
Financial Controls					
US_long_yield	-0.86411	0.43362	-0.24613	0.07084	0.63927
	(-1.00)	(1.35)	(-0.79)	(0.37)	(0.89)
US_corp_spread	-0.50989	-0.14272	0.03465	-0.11564	0.03886
	(-0.99)	(-0.70)	(0.32)	(-0.96)	(0.11)
US_SP_Return	-11.58032	10.59229	11.74219**	1.67926	13.85285
	(-0.70)	(1.28)	(2.60)	(0.36)	(1.16)
US_SP_Vol	34.45332	-14.13822	-1.68835	-13.23844	-15.64565
	(0.62)	(-0.54)	(-0.11)	(-0.90)	(-0.32)
LDV	0.37946***	0.30639***	-0.09390	0.71093***	-0.04446
	(3.29)	(2.75)	(-0.88)	(4.37)	(-0.34)
Constant	-890.60076	160.42450	23.42015	619.97753*	463.77834
	(-0.72)	(0.33)	(0.07)	(1.98)	(0.63)
Long-run impact (QE1)	0.0529	-0.0602	0.0079	0.1240	0.0426
Long-run impact (QE2)	0.0367	-0.1000	0.0757	0.0575	0.0426
Obs	103	103	103	103	103
R-sq	0.236	0.323	0.444	0.490	0.120

Notes: T-statistics are based on Newey-West heteroskedasticity consistent standard errors. Following the Newey-West (1994) plug-in procedure, we choose 4 lags for Newey-West. Significance level: ***1%; **5%; *10%.

When QE purchases are separated out into QE1 and QE2 (as shown in Table 8), the results suggest that switching into index-linked gilts and cash by pension funds was more marked following QE2. However, the reduction in net investment in nominal gilts seems pronounced under both QE1 and QE2, and the shift from gilts to corporate bonds seems stronger in QE1.

5.3 Evaluating the impact of QE

We can also evaluate the impact of QE by computing the ex-ante and ex-post impacts, as described in equations (5) and (6). Given the way it is constructed (using in-sample regression results), the ex ante impact is essentially a visualisation of the regression results reported in Sections 5.1 and 5.2; the ex post impact is an alternative way of looking at the impact as it depends on out-of-sample forecasts from the model estimated in the period before the start of QE.

Figure 3 shows the ex-ante QE impact on ICPF net investment into each asset class as the difference between the expected QE and no-QE counterfactuals, derived from our full sample estimates using the financial accounts sectoral data. Up to the onset of the start of the QE programme in the first quarter of 2009, the ex-ante QE impact (the difference between the lines) for each asset class is zero, as there is no counterfactual. However, after the start of the QE programme, the expected value of investment flows into each asset class is different from the predicted value under the no-QE counterfactual. Figure 4 plots the corresponding ex-post counterfactuals, which compare the actual value of investment flows with the counterfactual expected in the absence of the QE programme, derived by forecasting from a regression estimated up to the period before QE began. For convenience, Figure 5 plots both the ex-ante and ex-post QE effects for each of the four asset classes (the differences between the lines in Figures 3 and 4). Focusing on this chart, we can see that for government bonds, both the ex ante and ex post QE effects after the start of the QE programme in 2009 are mostly negative, implying that the expected value of investment flows into government bonds would have been higher without QE. This is consistent with our earlier findings that ICPFs were net sellers of government bonds after the introduction of the QE programme. In contrast, for both ex-ante and ex-post QE effects, the net flows into corporate bonds are positive, suggesting that net investment into corporate bonds was higher than would have been expected in the absence of QE. The chart also confirms the earlier result that following QE institutional investors appear to have reduced their net investment into equities. The slightly surprising implication is that in the absence of QE net inflows into equities would have been higher.[31]

[31] In interpreting this result, it needs to be remembered that the equations control for international (US) equity movements, so an alternative way of describing the same result would be to say that at the time of QE net investment into equities by ICPFs was lower than would have been expected given the normal spillovers between US and UK markets. We cannot of course establish that QE caused the change in net investment behaviour, only that the change in behaviour coincided with the timing of QE.

Figure 3: Ex-ante impact of QE on ICPFs: financial accounts data

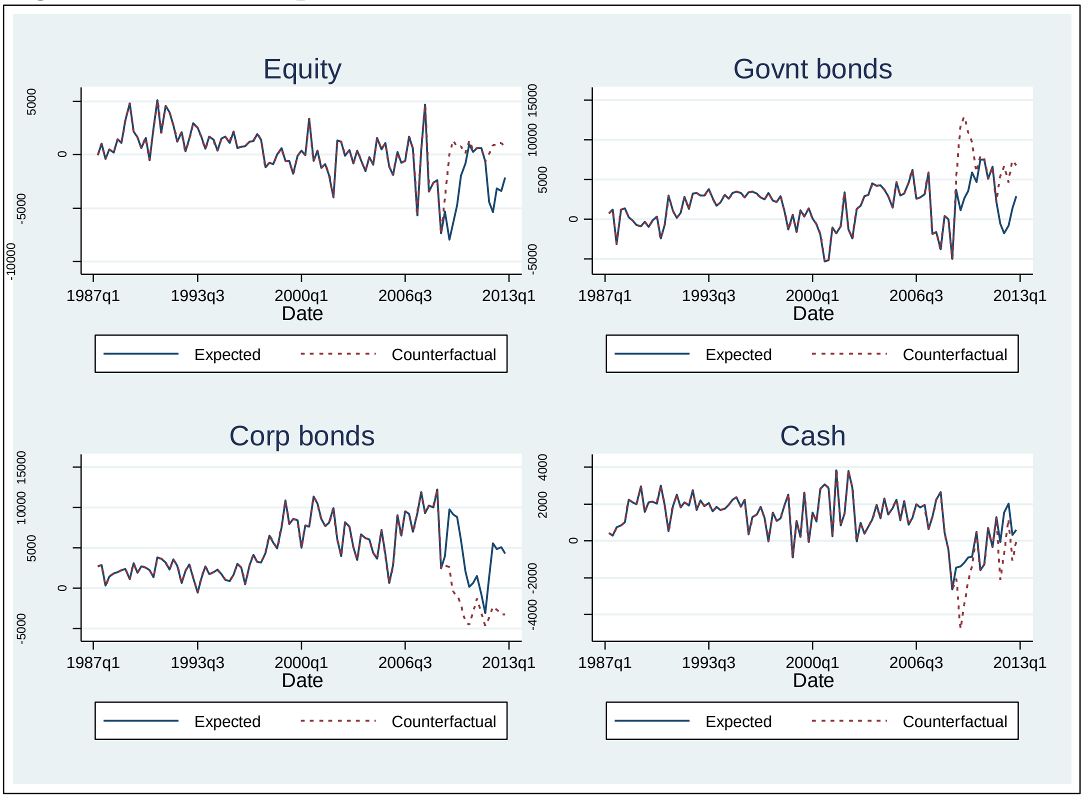


Figure 4: Ex-post impact of QE on ICPFs: financial accounts data

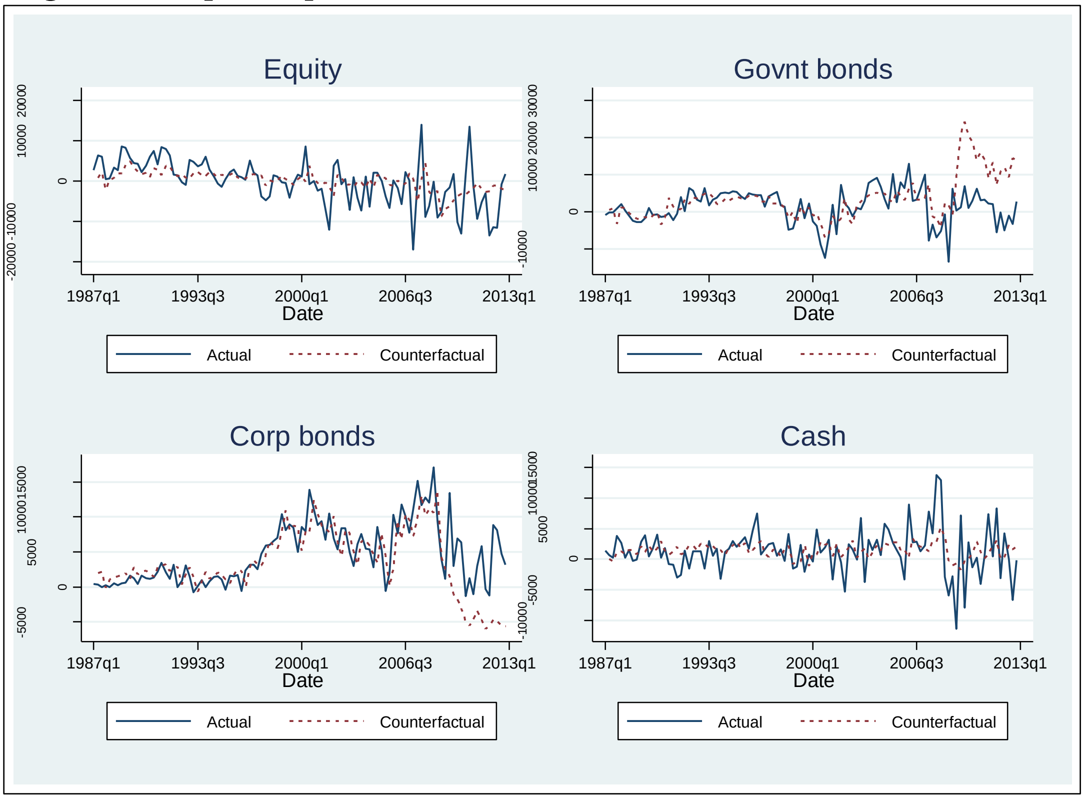


Figure 5: Impact of QE on ICPFs: financial accounts data, ex-ante and ex-post QE effects

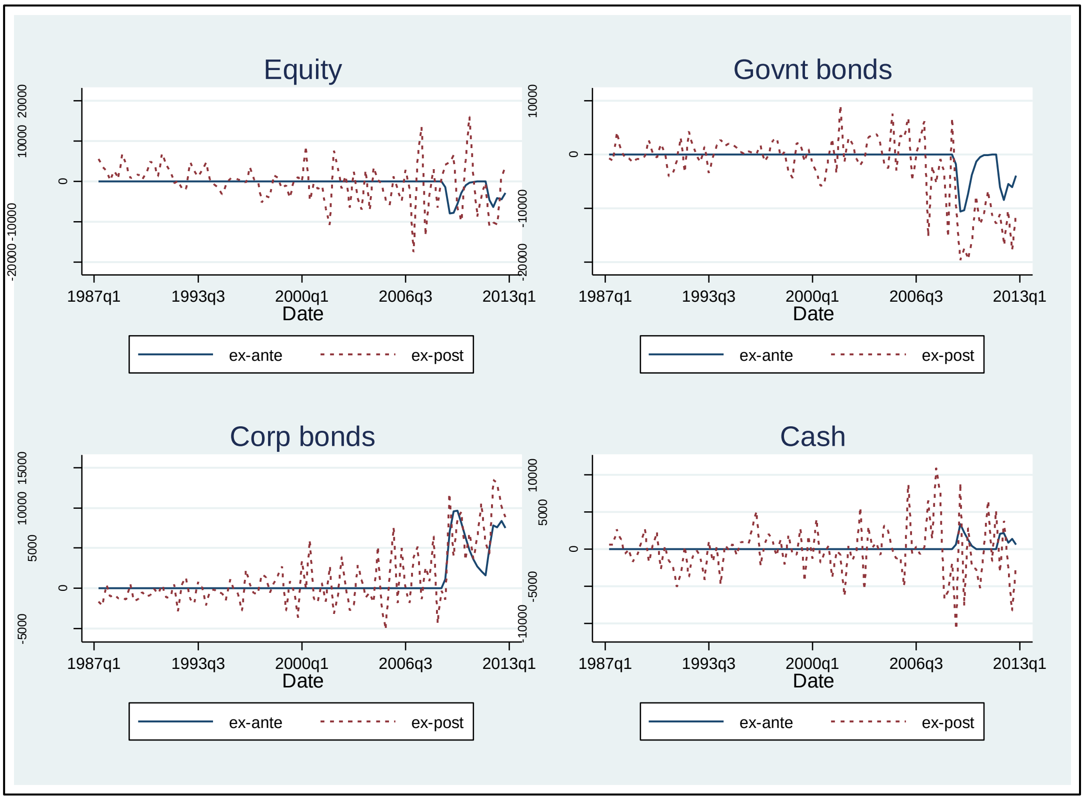


Figure 6: Impact of QE: MQ5 Life Companies, ex-ante and ex-post QE effects

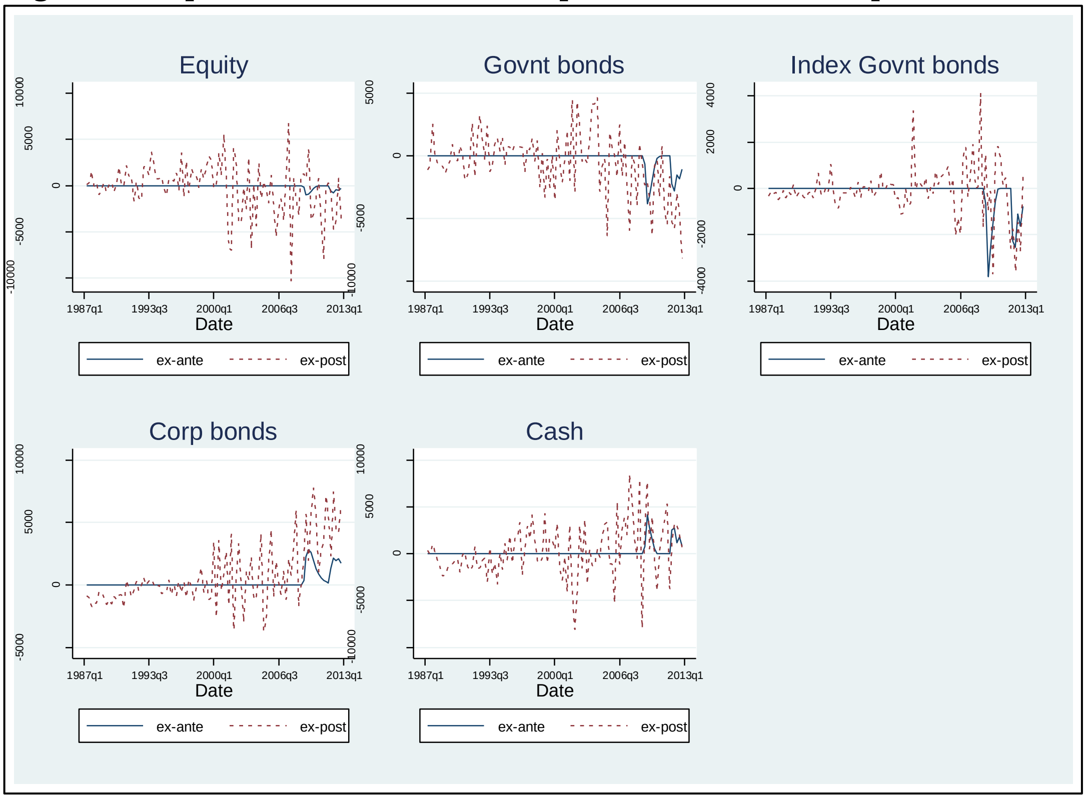


Figure 7: Impact of QE: MQ5 pension fund data, ex-ante and ex-post QE effects

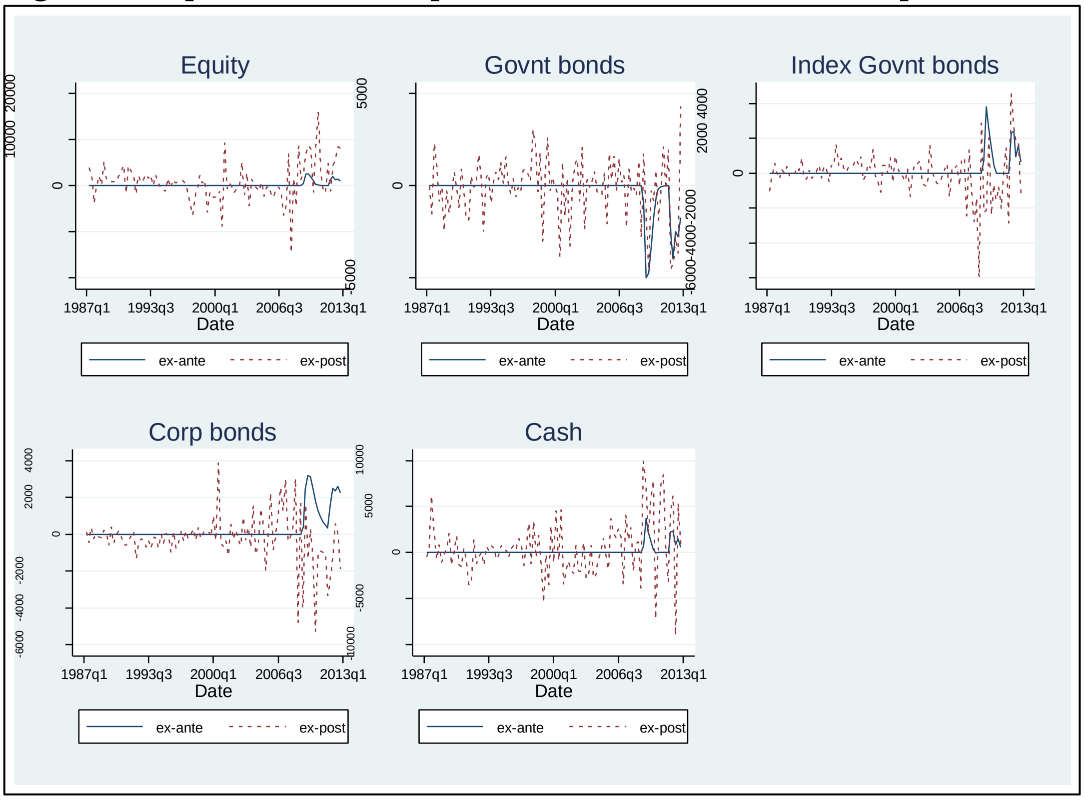


Figure 6 show the ex-ante and ex-post QE effects for life insurance companies utilising the MQ5 data which also allow us to examine net investments into index-linked bonds. The chart shows that the impact of QE on investment flows into conventional and index-linked gilts was negative following QE, suggesting that net investment would have been higher in the absence of QE. In contrast, the impact of QE on net investment into corporate bonds and cash is positive, suggesting there was some reallocation towards these assets. Again we find the QE impact on equities was negative.

Figure 7 reports the ex-ante and ex-post QE effects for pension funds. We can see that for MQ5 pension fund data there is conflicting evidence on the QE effects depending on whether the counterfactual is based on the ex-ante or the ex-post criterion. For example, in the case of corporate bonds the ex-ante effect is positive, but the ex-post effect is negative. So according to the ex-ante QE effect, investment flows into corporate bonds would have been lower in the absence of QE, but according to the ex-post criterion net investment flows into corporates would have been higher without QE. This may be due to the fact that the subsample (from 1987 -2008) used for estimating the ex-post counterfactual includes a positive trend for corporate bond net investment, which may lead to an overestimate of the out-of-sample ex-post counterfactual for corporate bond net investment. There is also conflicting evidence for the other assets classes, with the exception of investment in conventional gilts, which would have been higher in the no-QE counterfactual case according to both the ex-ante and ex-post measures.

6 Micro-level results for insurers

6.1 Regression results

We now move on to report estimates for the dynamic panel models described in equations (3) and (4) for life insurers, using the annual financial information provided by the SynThesys database from 1985-2012. Table 9 reports the results based on Arellano-Bond estimation, which allows for the presence of the lagged dependent variable for a panel dataset. In addition to the financial controls used previously, the regressions also include individual controls relating to the characteristics of the insurance fund, including: firm size (firm_size), which enters as the log change in total admissible assets; the free asset ratio (FAR); the ratio of business premiums to assets (premium_ratio); and the fraction of assets linked to liabilities (Assets_matched_ratio). In interpreting the results, it should be borne in mind that, as described in the footnotes to Table 1, the SynThesys data for nominal and index-linked government bonds include both UK and overseas government bonds. Again this is not ideal, but it seems very likely that UK government bonds dominate. Note also that the data we use for equities and corporate bonds combines UK and overseas securities and that cash includes cash in hand and deposits.

The coefficient on the QE purchases variable (BoE_QE) in the second column relates to the effect of the QE programme on asset allocation to nominal government bonds. The estimated value of this coefficient, -0.01397, should be interpreted as -0.01397%. Using the 2012 figure for total life insurer assets, this would imply that £375 billion of QE purchases reduced the value of life insurers' holdings of nominal gilts by around £39 billion.[32] The estimates in the table also suggest that the QE impact on the allocation to index-linked government bonds and equities was negative, but there was a positive impact on the asset allocation towards corporate bonds. So these results broadly confirm the earlier sectoral results.

[32] This estimate is derived from 0.01397% * 1,292 * 0.58 * 375 = £39.3 billion, where £1,292 billion is the total assets of all the life insurers which were invested in gilts in 2012, according to SynThesys. The asset share percentages are not share percentages against total admissible assets; they are shares against the subtotal, which excludes assets held to match linked liabilities. So 0.58 is the ratio of the assets not linked to liabilities (ie the subtotal) against total admissible assets. The total amount of QE is £375 billion.

Table 9 Asset allocation regressions for life companies: individual company level (1985-2012)

	Equities	Nominal Govt Bonds	Indexed Govt Bonds	Corp Bonds	Cash
BoE_QE (x)	-0.01697***	-0.01397**	-0.00388	0.02364***	0.00581
	(-2.85)	(-2.26)	(-0.98)	(4.79)	(0.68)
DMO control	16.20141**	13.12418*	10.48642**	-19.60156***	-42.57982***
	(2.28)	(1.86)	(2.10)	(-3.25)	(-4.01)
Financial Controls					
US_long_yield	0.79140***	-0.95602***	0.09578	-0.81513***	-0.55179**
	(3.85)	(-5.01)	(0.74)	(-5.19)	(-2.03)
US_corp_spread	0.45601***	-0.32298***	0.15870**	-0.32445***	0.15170
	(4.37)	(-3.27)	(2.29)	(-4.04)	(1.07)
US_SP_Return	0.09478***	-0.00660	0.02012*	-0.05748***	0.01215
	(6.24)	(-0.46)	(1.95)	(-4.72)	(0.58)
US_SP_Vol	-0.08442***	0.12400***	0.02337	-0.04768**	-0.01792
	(-2.94)	(4.48)	(1.22)	(-2.02)	(-0.44)
Firm Controls					
Firm_size	1.00247*	-2.96462***	-1.83692***	-0.14971	-1.60587***
	(1.83)	(-5.41)	(-4.80)	(-0.33)	(-2.90)
FAR	24.31380***	2.06682	6.03459**	0.61376	-2.93678
	(6.33)	(0.54)	(2.24)	(0.18)	(-0.73)
premium_ratio	0.80667	1.79175*	0.02654	4.66459***	-0.76718
	(0.79)	(1.73)	(0.05)	(2.66)	(-1.01)
Assets_matched_ratio	-9.07154***	11.92764***	2.72630*	-0.38355	-8.87655***
	(-3.26)	(4.58)	(1.88)	(-0.20)	(-2.75)
LDV	0.56199***	0.64371***	0.63929***	0.55400***	0.51716***
	(20.87)	(26.72)	(25.93)	(19.88)	(24.21)
Constant	15.35744***	3.81198***	-0.72022	11.05576***	15.80726***
	(10.31)	(2.77)	(-1.12)	(9.85)	(8.96)
Obs	3048	3742	1312	2793	4654

Note:
Significance level: ***1%; **5%; *10%. Models are estimated using PRA/FSA returns data.

As we mentioned in Section 3, rather than returns being submitted at the parent level, the individual subsidiaries of parent insurance companies submit life company returns to the regulator. In Table 10 we repeat the same panel regressions as Table 9 using each parent (ie group level) insurance company as the cross-sectional unit, rather than each subsidiary. The response to QE at the parent level is similar to the results for the subsidiaries, however. The share of portfolios allocated to nominal government bonds and equities fell after the introduction of QE, but the allocation to corporate bonds increased.

Table 10 Asset allocation regressions for life companies: parent company level (1985-2012)

	Equities	Nominal Govt Bonds	Indexed Govt Bonds	Corp Bonds	Cash
BoE_QE (x)	-0.01721***	-0.01721***	0.00088	0.02838***	-0.00845
	(-2.71)	(-2.66)	(0.34)	(5.51)	(-1.05)
DMO control	20.51959***	15.59620**	8.00706**	-13.31846**	-35.86279***
	(2.75)	(2.11)	(2.50)	(-2.10)	(-3.52)
Financial Controls					
US_long_yield	0.83647***	-0.95462***	0.03690	-0.73276***	-0.24587
	(3.83)	(-4.68)	(0.44)	(-4.37)	(-0.94)
US_corp_spread	0.32563***	-0.25923**	0.05686	-0.31564***	0.16670
	(2.93)	(-2.47)	(1.28)	(-3.69)	(1.24)
US_SP_Return	0.10181***	-0.01913	0.00227	-0.05853***	0.00565
	(6.41)	(-1.24)	(0.34)	(-4.51)	(0.29)
US_SP_Vol	-0.10194***	0.12412***	0.00905	-0.01656	0.02217
	(-3.34)	(4.22)	(0.74)	(-0.66)	(0.57)
Firm Controls					
Firm_size	0.09243***	-0.08520***	-0.00235	-0.03988**	-0.04639
	(3.68)	(-3.57)	(-0.36)	(-2.37)	(-1.50)
FAR	13.01042***	8.65527**	5.57293***	0.51753	-13.17535***
	(2.90)	(2.02)	(2.65)	(0.12)	(-3.53)
premium_ratio	-10.76729**	-0.14057	0.47175	0.39249	-7.30797***
	(-2.18)	(-0.09)	(0.22)	(0.18)	(-3.83)
Assets_matched_ratio	-11.87795***	0.01456	-2.63884**	0.83690	3.68846
	(-4.04)	(0.01)	(-2.49)	(0.40)	(1.20)
LDV	0.58520***	0.60737***	0.40849***	0.70166***	0.59557***
	(20.20)	(24.61)	(12.55)	(27.37)	(24.00)
Constant	17.58094***	7.83694***	1.60509***	6.83683***	9.12193***
	(11.01)	(5.98)	(3.29)	(6.08)	(6.09)
Obs	2183	2506	1047	1972	2873

Note: Significance level: ***1%; **5%; *10%. Models are estimated using PRA/FSA returns data.

In Table 11, we report the panel results for life insurer subsidiaries when we separate out the effects of QE1 and QE2. It can be seen that the negative QE1 impact on the allocation of nominal bonds and equities is stronger than for QE2, although the increased allocation to corporate bonds is larger with respect to the QE2 programme. This pattern differs slightly to the sectoral results on net investment flows, though of course the data are rather different, so they are not necessarily inconsistent.

Table 11 Asset allocation regressions for life companies (individual company level): comparison of QE1 vs QE2 (1985-2012)

	Equities	Nominal Govt Bonds	Indexed Govt Bonds	Corp Bonds	Cash
BOE_QE_1 (x1)	-0.02042***	-0.01467**	-0.00452	0.02270***	0.01928**
	(-3.09)	(-2.16)	(-1.03)	(4.18)	(2.05)
BOE_QE_2 (x2)	-0.00855	-0.01146	-0.00224	0.02642***	-0.02815**
	(-0.95)	(-1.17)	(-0.37)	(3.40)	(-2.11)
DMO control	17.84122**	13.36756*	10.86370**	-19.10974***	-51.13142***
	(2.46)	(1.87)	(2.12)	(-3.10)	(-4.72)
Financial Controls					
US_long_yield	0.83565***	-0.94910***	0.10294	-0.80392***	-0.69589**
	(4.00)	(-4.92)	(0.79)	(-5.05)	(-2.53)
US_corp_spread	0.46138***	-0.32195***	0.16033**	-0.32227***	0.12741
	(4.42)	(-3.25)	(2.31)	(-4.00)	(0.90)
US_SP_Return	0.09868***	-0.00602	0.02089**	-0.05639***	-0.00323
	(6.35)	(-0.41)	(1.97)	(-4.53)	(-0.15)
US_SP_Vol	-0.07405**	0.12545***	0.02516	-0.04528*	-0.05783
	(-2.47)	(4.39)	(1.26)	(-1.86)	(-1.38)
Firm Controls					
Firm_size	1.04388*	-2.96047***	-1.83209***	-0.15039	-1.65379***
	(1.91)	(-5.40)	(-4.78)	(-0.33)	(-3.00)
FAR	23.87940***	2.02660	5.99573**	0.48080	-2.40763
	(6.19)	(0.52)	(2.22)	(0.14)	(-0.60)
premium_ratio	0.79379	1.80054*	0.02659	4.74586***	-0.75078
	(0.78)	(1.73)	(0.05)	(2.69)	(-0.99)
Assets_matched_ratio	-9.47897***	11.90004***	2.68299*	-0.45688	-8.41922***
	(-3.38)	(4.56)	(1.85)	(-0.24)	(-2.62)
LDV	0.56101***	0.64373***	0.63909***	0.55358***	0.51005***
	(20.85)	(26.72)	(25.91)	(19.85)	(23.85)
Constant	15.30989***	3.78588***	-0.75143	-0.75143	11.03167***
	(10.28)	(2.74)	(-1.15)	(-1.15)	(9.82)
Obs	3048	3742	1312	2793	4654

Note: Significance level: ***1%; **5%; *10%. Models are estimated using PRA/FSA returns data.

6.2 Heterogeneities in the response to QE

In order to examine potential heterogeneities across insurance companies, we tried interacting the QE purchase variable with a range of other control variables. Table 12 provides a summary of the results from six separate sets of regression that each included a different QE interaction term, as described in equation (4).

The first row shows the effect of interacting QE purchases with whether the life insurer has a high or low risk-appetite. In order to construct this variable, we separated life insurance companies into those which were high or low risk, according to whether the percentage of the life-insurer's assets allocated to equities was above or below the median of the cross-sectional distribution.[33] We computed similar interactions for life company firm size (another proxy for

[33] The volatility of equity returns is typically much higher than for returns on government bonds, corporate bonds or cash. So it is more likely that a higher portfolio share of equity will be associated with companies that have a higher tolerance for risk.

risk aversion), the free asset ratio (which identifies the extent to which the firm is constrained by regulations on capital), the business premium ratio (an indicator of how budget constrained the firm is), assets linked to liabilities (the larger the share of linked assets the less constrained the scheme is by its liabilities and the more likely to invest in riskier assets), and the amount of with-profit business (another indicator likely to be correlated with a greater risk preference).

From the second row in Table 12, it can be seen that those life insurers with a higher risk appetite (above the median equity investment share) are those who reduced their portfolio weight in nominal government bonds the most, and would therefore appear to be the institutions who were the biggest net sellers of government bonds. The main sellers also appear to be the larger firms, those with higher free-asset ratios, those with lower business premium ratios, and those with more assets linked to liabilities.

With respect to the allocation to equities (column 1), the insurers who were more likely to reduce their equity allocations following QE were those funds who: were more risk averse (with lower portfolio shares of equity), those with lower free asset ratios (so those who were facing greater regulatory capital constraints), those with lower business premium ratios (those receiving relatively less premium income) and those with fewer assets linked to their liabilities (and so less constrained by their liabilities).

But while these results suggest some heterogeneity in the response of life insurers to QE, the fourth column shows a remarkable lack of heterogeneity with respect to the increased allocation to corporate bonds. In almost every case there is a significant increase in the holdings of corporate bonds and the size of the effect is similar irrespective of which firm characteristic is chosen.

Table 12 Asset allocation regressions for life companies (individual company level): summary of interaction effects with firm characteristics (1985-2012)

Dummy Variables	Equities	Nominal Govt Bonds	Indexed Govt Bonds	Corp Bonds	Cash
QE Dummy: less equity investment	-0.03415***	-0.00731	-0.00589	0.02567***	0.00243
	(-4.30)	(-0.87)	(-1.19)	(4.17)	(0.20)
QE Dummy: more equity investment	-0.00236	-0.02505***	-0.01067**	0.02893***	0.01239
	(-0.31)	(-2.74)	(-1.98)	(3.96)	(1.02)
QE Dummy: smaller firms	-0.01968**	-0.01104	-0.00903*	0.01632**	0.01044
	(-2.52)	(-1.34)	(-1.67)	(2.47)	(0.94)
QE Dummy: larger firms	-0.01441*	-0.01690**	-0.00017	0.02981***	0.00101
	(-1.86)	(-2.08)	(-0.04)	(4.80)	(0.09)
QE Dummy: lower Free asset ratio	-0.02678***	-0.01266	-0.00734	0.02119***	0.01239
	(-3.42)	(-1.57)	(-1.57)	(3.33)	(1.12)
QE Dummy: higher Free asset ratio	-0.00770	-0.01542*	0.00149	0.02621***	-0.00106
	(-1.01)	(-1.86)	(0.27)	(4.04)	(-0.09)
QE Dummy: less policy premium ratio	-0.02534***	-0.02118**	-0.00747	0.02009***	0.01686
	(-3.17)	(-2.48)	(-1.26)	(2.63)	(1.52)
QE Dummy: more policy premium ratio	-0.00968	-0.00830	-0.00192	0.02539***	-0.00590
	(-1.28)	(-1.07)	(-0.42)	(4.44)	(-0.52)
QE Dummy: less assets linked to liabilities	-0.02829***	-0.01110	-0.00416	0.02136***	0.00376
	(-3.73)	(-1.39)	(-0.82)	(3.58)	(0.33)
QE Dummy: more assets linked to liabilities	-0.00441	-0.01716**	-0.00357	0.02709***	0.00786
	(-0.56)	(-2.06)	(-0.72)	(3.86)	(0.71)
QE Dummy: Non-profits	-0.01888**	-0.01223	-0.00038	0.02674***	0.00377
	(-2.53)	(-1.62)	(-0.08)	(4.39)	(0.36)
QE Dummy: With-profits	-0.01399*	-0.01597*	-0.00758	0.02243***	0.00888
	(-1.75)	(-1.78)	(-1.46)	(3.31)	(0.71)

Note: Significance level: ***1%; **5%; *10%. Models are estimated using PRA/FSA returns data.

7 Micro-level results for pension funds

7.1 Regression results

We now turn to the panel regression analysis for defined benefit pension schemes, where we estimated the dynamic panel model in equation (3) using the annual data provided to us by the Pension Protection Fund for the years 2005-2010. The results from this analysis are presented in Table 13.

The models estimated include only one financial control variable (the change in US Treasury yields) given the short sample size,[34] but various fund-specific controls. These controls include: the size of the pension scheme measured by the log of the number of members (Fund_size); the maturity of the scheme, measured by the ratio of pensioners in payment to the total number of members in the scheme including active and deferred (Pen_ratio); the size of the Risk-Based Levy (RBL); and the funding ratio, measured by the value of assets as a percentage of liabilities

[34] When this control is excluded the main change is that the QE purchase variable becomes positive and statistically significant in the equity share equation. The full results are available on request.

(Funding_ratio). The RBL variable is the annual premium that the fund has to pay to the PPF, and is partly based on the insolvency risk of the sponsor and the underfunding risk of the scheme, but it also includes a scheme-based element (around 10% of the total) which depends on the size of the scheme. The Funding_ratio variable shows the extent to which the scheme is adequately funded; if substantially underfunded, the Pensions Regulator may require the scheme sponsor to make additional contributions into the scheme to reduce the deficit.[35] In interpreting the results, note that, as described in the footnote to Table 1, the PPF data for nominal and index-linked government bonds include both the UK and overseas government bonds, though the former is likely to dominate. Note also that equities and corporate bonds include both UK and overseas securities and that cash includes cash in hand and deposits.

From the results in Table 13, it can be seen that the allocation to nominal government bonds is estimated to have fallen in response to QE. The change in the portfolio share of pension funds' holdings of nominal government bonds in response to £1 bn of QE is 0.00577%, which would suggest a reduction of around £22 bn over the whole QE period (assuming the impact of QE2 is the same as QE1 and noting that our analysis only incorporates data up to the end of QE1).[36] We also see that QE is associated with an increased allocation to both index-linked and corporate bonds. As with the life companies, these results are consistent with the earlier sectoral dataset results.

One unsatisfactory feature of the estimation results in Table 13 is the coefficient on the lagged dependent variable which exceeds unity for some asset classes, perhaps reflecting the short sample period used for the estimation. To check robustness, we also estimated the same asset share equations in difference form (see Table 14) using fixed effects. We find that the response to QE is similar to the dynamic panel regression in Table 13 for both nominal gilts and corporate bonds. The main difference is for equities equation, where the effect of QE becomes negative and statistically significant. However, the lagged dependent variable in the dynamic panel regression for equities in Table 13 does not display the same instability problem as some of the other assets classes, so the difference specification might not be preferred.

[35] Webb (2007) applies agency theory to predict that when pension funds are in deficit the incentives for the corporate sponsors are to risk-shift, and move the asset allocation into equities in order to go-for-broke to try and rescue the pension scheme. However, in a paper that tests this proposition directly using a large sample of pension schemes, Rauh (2009) finds that in fact pension schemes in deficit invest a greater percentage of their assets in safe investments (government bonds and cash), and it is well-funded pension schemes that invest a greater percentage in equities. For a sample of US firms, Rauh (2006) allows for the endogeneity between the pension funding ratio and corporate investments, and finds a negative relation even after controlling for the correlations between the pension funding ratio and the firm's unobserved investment opportunities. Liu and Tonks (2013) use the funding ratio to identify a company's mandatory pension contributions, and they examine the effect of these mandatory contributions on a company's dividend payments and investment spending, for a panel of FTSE350 companies. They report that the effect of pension contributions on investments is weaker than the evidence for US companies, suggesting that pension regulations in the UK allow firms sufficient discretion to maintain investment spending, and that in the UK the response of balance sheet adjustments to financial pressures takes place through dividends rather than real investments.

[36] This estimate is derived from 0.00577% * 1,026.80 *375 = £22.2 bn, where £1,026.80bn is the total assets of all DB pension funds as reported in the PPF's 2012 Purple Book and £375bn is the total amount of QE.

Table 13 Asset allocation regressions for pension funds - Arellano-Bond estimation (2005-2010)

	Equities	Nominal Govt Bonds	Indexed Govt Bonds	Corp Bonds	Cash
BoE_QE (x)	-0.00008	-0.00577***	0.00349*	0.01142***	-0.00159
	(-0.06)	(-3.29)	(1.89)	(4.57)	(-0.82)
DMO control	0.00001***	-0.00001*	-0.00002***	-0.00001**	-0.00001***
	(2.78)	(-1.89)	(-4.84)	(-2.47)	(-2.86)
Financial Controls					
US_long_yield	3.04692***	0.00378	-0.61801**	-1.74430***	-0.32057
	(16.74)	(0.02)	(-2.20)	(-6.42)	(-1.33)
Fund Controls					
Fund_size	-0.14692	0.02625	0.76516	1.57630**	1.35401**
	(-0.32)	(0.04)	(1.03)	(2.06)	(2.19)
Pen_ratio	0.01427	-0.01741	0.00029	0.00586	0.01128
	(1.04)	(-0.99)	(0.01)	(0.28)	(0.59)
RBL	-0.06978	-0.01119	-0.04596	0.06606	0.01023
	(-1.11)	(-0.13)	(-0.73)	(0.95)	(0.14)
Funding_ratio	1.71594***	-2.01028**	0.01706	-1.60184*	0.48390
	(2.83)	(-2.41)	(0.02)	(-1.71)	(0.62)
LDV	0.77444***	1.03791***	1.43311***	1.14434***	0.67409***
	(25.01)	(22.00)	(10.17)	(11.61)	(26.10)
Constant	9.22658**	2.01014	-8.65430	-8.84198*	-4.99002
	(2.44)	(0.50)	(-1.63)	(-1.71)	(-1.28)
Obs	13891	6017	4513	6694	8402

Note: Significance level: ***1%; **5%; *10%. Models are estimated using PPF data.

Table 14 Asset allocation regressions for pension funds – fixed effect estimation on the changes in asset allocation (2005-2010)

	D_Equities	D_Nominal Govt Bonds	D_Indexed Govt Bonds	D_Corp Bonds	D_Cash
BoE_QE (x)	-0.00329**	-0.00430***	0.00124	0.00940***	-0.00400*
	(-2.22)	(-2.85)	(0.85)	(6.24)	(-1.88)
DMO control	0.00003***	-0.00001***	-0.00001***	-0.00001***	-0.00001***
	(16.01)	(-3.95)	(-3.72)	(-4.06)	(-2.86)
Financial Controls					
US_long_yield	2.66163***	0.06029	-0.66813***	-1.56170***	0.10957
	(15.42)	(0.27)	(-3.03)	(-6.62)	(0.42)
Fund Controls					
Fund_size	-0.44219	-0.32104	0.57797	1.21570**	1.81585***
	(-1.08)	(-0.59)	(1.09)	(1.98)	(3.14)
Pen_ratio	0.01465	-0.01357	0.00386	0.00400	0.03380*
	(1.22)	(-0.92)	(0.25)	(0.24)	(1.92)
RBL	-0.05105	-0.03665	-0.03386	0.05706	-0.01278
	(-0.84)	(-0.47)	(-0.64)	(0.86)	(-0.17)
Funding_ratio	1.52458***	-1.97072***	-0.15014	-1.42887**	0.60748
	(2.83)	(-2.79)	(-0.22)	(-1.98)	(0.81)
Constant	-4.15912	4.93624	-2.00441	-4.29125	-10.92971***
	(-1.59)	(1.43)	(-0.57)	(-1.08)	(-3.03)
Obs	17587	8727	6646	9752	11527

Note: Significance level: ***1%; **5%; *10%. Models are estimated using PPF data.

7.2 Heterogeneities in the response to QE

We also interacted QE purchases with various pension fund characteristics, in order to investigate heterogeneities across funds.

Table 15 provides a summary of the separate regression results based on equation (4). We computed interactions for fund risk-appetite (again measured by being above or below the cross-sectional median allocation to equities); pension fund size, as measured by number of members in the scheme; the maturity of pension scheme, measured by the ratio of pensioners to all members; the size of the risk-based levy (RBL), which measures the riskiness of the fund's sponsor; whether the fund is in surplus or deficit, as measured by the funding ratio; and whether the pension scheme was open or closed.

Table 15 shows that, as with the life company data, although there is some heterogeneity in the response to QE across different types of funds there are also similarities. The main heterogeneities are with respect to index-linked bonds, where increased holdings were more apparent (statistically significant) in funds that exhibited a higher risk appetite (as shown in the size of their equity holdings), where schemes were more mature, smaller or less well funded, with a higher RBL ratio and where funds were closed.[37] Reduced allocations to conventional gilts and increased allocations to corporate bonds seem to have been similar across most fund types. One factor relevant to the amount of disinvestment from gilts seems to have been the funding ratio, with funds that were better funded showing a larger negative effect.

Table 15 Asset allocation regressions for pension funds: summary of interaction effects with fund characteristics (2005-2010)

Dummy Variables	Equities	Nominal Govt Bonds	Indexed Govt Bonds	Corp Bonds	Cash
QE Dummy: less equity investment	0.00065	-0.00552***	0.00231	0.01036***	-0.00234
	(0.40)	(-2.81)	(1.11)	(4.14)	(-1.01)
QE Dummy: more equity investment	-0.00048	-0.00577***	0.00481**	0.00926***	-0.00586**
	(-0.30)	(-2.87)	(2.08)	(3.66)	(-2.50)
QE Dummy: smaller funds	-0.00063	-0.00573***	0.00464**	0.00905***	-0.00255
	(-0.38)	(-2.86)	(1.99)	(3.37)	(-1.13)
QE Dummy: larger funds	0.00040	-0.00579***	0.00274	0.01314***	-0.00061
	(0.25)	(-2.93)	(1.35)	(4.89)	(-0.27)
QE Dummy: lower ratio of pensioners	0.00023	-0.00662***	0.00238	0.01043***	-0.00426*
	(0.14)	(-3.24)	(1.10)	(3.93)	(-1.87)
QE Dummy: higher ratio of pensioners	-0.00042	-0.00508***	0.00441**	0.01248***	0.00105
	(-0.25)	(-2.61)	(2.08)	(4.55)	(0.46)
QE Dummy: lower RBL ratio	0.00184	-0.00585***	0.00319	0.01028***	0.00071
	(1.13)	(-2.94)	(1.54)	(3.86)	(0.31)
QE Dummy: higher RBL ratio	-0.00196	-0.00569***	0.00389*	0.01264***	-0.00391*
	(-1.19)	(-2.86)	(1.73)	(4.63)	(-1.72)
QE Dummy: lower funding ratio	-0.00159	-0.00475**	0.00427*	0.01183***	-0.00329
	(-0.99)	(-2.37)	(1.90)	(4.43)	(-1.45)
QE Dummy: higher funding ratio	0.00165	-0.00670***	0.00290	0.01097***	0.00015
	(1.00)	(-3.39)	(1.39)	(4.04)	(0.07)
QE Dummy: Close funds	-0.00070	-0.00582***	0.00417**	0.01222***	-0.00153
	(-0.48)	(-3.23)	(2.16)	(4.78)	(-0.76)
QE Dummy: Open funds	0.00286	-0.00551**	0.00081	0.00786**	-0.00185
	(1.21)	(-2.01)	(0.29)	(2.38)	(-0.57)

Note: Significance level: ***1%; **5%; *10%. Models are estimated using PPF data.

[37] When we repeat the analysis in Table 15 using the difference equation specification, the main changes are with respect to equities in line with the different results shown in Table 14.

8 Summary and conclusions

In this paper we examined how the Bank of England's quantitative easing (QE) policy during the financial crisis affected the investment behaviour of insurance companies and pension funds and, more specifically, looked for evidence of the operation of the so-called 'portfolio balance channel' that has been emphasised by UK and US monetary policy makers as a key channel through which QE works.

More specifically, we hoped to shed light on the following four questions:

(1) Did a significant fraction of the Bank's asset purchases come from institutional investors?
(2) Did institutional investors increase their net investment in risky assets more than they would otherwise have done as a result of QE?
(3) Did institutional investors increase their asset allocation towards risky assets more than they would otherwise have done as a result of QE?
(4) To what extent were any resultant changes in portfolio allocation uniform across different types of institutional investor?

In order to answer these questions, we examined institutional investors' portfolio behaviour over the global crisis relative to a counterfactual constructed, following Pesaran and Smith (2012), by conditioning on variables that explain portfolio allocation but are invariant to the QE policy itself. These variables included gilt issuance by the Debt Management Office and overseas financial variables. To the extent the data allow, we also constructed both ex-ante and ex-post estimates of the effect of QE. We examined a range of data sources, including sectoral net investment data and micro-level data on individual life insurance companies and pension funds that allowed us to examine possible heterogeneities across institutions with different characteristics. All of our analysis is nevertheless subject to a number of limitations and caveats, including the fact that we cannot directly control for recent and prospective accounting and regulatory changes that may also have had an important bearing on portfolio allocation behaviour of institutional investors over the same period.

Our answers to the first two questions are largely based on analysis of the sectoral data. Here we found that about a fifth of the Bank of England's QE gilt purchases appeared to have come from institutional investors (question (1)), although we argued that this was likely to be an underestimate. We also found that, at the same time as reducing their net investment in gilts, institutional investors increased their net investment in corporate bonds, consistent with the expected portfolio substitution away from gilts into riskier assets – although this result was less compelling when we looked at the MQ5 data which allows us to examine insurer and pension funds separately. The impact of the Bank's purchases on disinvestment from gilts appeared larger for QE2, but switching into corporate bonds was stronger for QE1 (at least for pension funds), which might suggest the rebalancing effects of QE1 was larger. There is no clear evidence, however, to suggest that ICPFs increased their net investment in equities in response to QE (in QE1 or QE2), with our results suggesting the opposite. While pension funds appeared to increase their net investment in index-linked bonds (particularly during QE2), insurance companies reduced it. And, according to the MQ5 sectoral data, there was some switching into cash, particularly by insurance companies.

Our answers to the last two questions are based on our panel regression analysis of the micro-data. Here we found strong evidence that both insurers and pension funds reduced their asset allocation in gilts and increased their allocation in corporate bonds, again consistent with them switching from gilts into corporate bonds (although we cannot exclude the possibility that this portfolio shift reflected revaluation effects that had nothing to do with portfolio rebalancing, as discussed earlier in Section 2). The switch into corporate bonds was remarkably similar across different types of insurance companies and pension funds, but in the case of insurers (who appear to exhibit more heterogeneity) the switch away from gilts was more pronounced for schemes that showed less risk aversion (ie were larger than average and more heavily weighted in equities), were under more financial constraints (ie had a lower than average ratio of business premiums to assets) and those less constrained on average by their liabilities (ie with a larger share of assets linked directly to liabilities). For pension funds, the switch out of gilts was more pronounced for those funds that were better funded (ie had a higher than average funding ratio). Consistent with the sectoral data analysis, we found no evidence to suggest there was switching out of gilts into equities for either life insurers or pension funds as a result of QE. Pension funds increased their asset allocation in index-linked bonds but life insurers did not, which is again consistent with the sectoral data analysis.

Overall the balance of evidence seems consistent with the hypothesis that the Bank of England's QE policy resulted in some portfolio rebalancing behaviour by institutional investors, who appear to have reduced their gilt holdings and reinvested some of the proceeds into riskier corporate bonds relative to the counterfactual. But it appears that portfolio rebalancing was limited to corporate bonds, with most of the evidence suggesting that institutional investors moved out of equities during the period of QE purchases. Of course, this does not necessarily imply equity prices were not supported by portfolio reallocation behaviour, still less from QE, as our analysis only considers insurers and pension funds and we do not investigate the behaviour of other financial institutions, something we leave for further work.

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