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Capital regulation and product market outcomes

Ishita Sen and David Humphry

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Ishita Sen[(1)] and David Humphry[(2)]

Abstract

This paper examines the impact of the introduction of a risk-based capital regulation regime in 2002 on product market outcomes for the insurance industry in the United Kingdom. Using proprietary data on stress-test submissions from the Bank of England, we develop a measure of firm-level shocks to regulatory constraints that is plausibly exogenous to shifts in insurance demand. We find that constrained firms reduced underwriting relative to unconstrained firms, particularly for traditional insurance products which became more capital intensive in the new regulatory regime. The reduction in underwriting was not as pronounced for linked products, products that are mainly investment vehicles like mutual funds, implying a shift in the equilibrium product mix from traditional to linked. We also show that a higher proportion of constrained firms restructured their balance sheets by transferring assets and liabilities and went through reorganizations ie a change in legal owner of the firm.

Key words: Risk-based capital regulation, stress testing, life insurance, trends in asset management.

JEL classification: G22, G28, G32.

(1) London Business School. Email: isen@london.edu
(2) Bank of England. Email: david.humphry@bankofengland.co.uk

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Publications and Design Team, Bank of England, Threadneedle Street, London, EC2R 8AH
Telephone +44 (0)20 7601 4030 email publications@bankofengland.co.uk

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1. Introduction

This paper examines the effect of the introduction of a new risk-based capital regulation regime on product market outcomes for the insurance industry in the UK[1]. In 2002, the Financial Services Authority (FSA) announced the onset of a new prudential regulatory regime[2]. In the new regime, capital requirements became a function of risk exposures measured by stress-testing insurance balance sheets, in contrast to the old regime that was largely risk insensitive. The new regime led to a significant increase in capital requirements for *traditional* insurance products, products that typically provide policyholders with life cover or guaranteed savings. Capital requirements, however, remained low for *linked* products, which are mainly investment vehicles similar to mutual funds. We document a marked shift in insurance product mix - from traditional to linked - after the new regime was introduced, leading to a surge in linked liabilities from £345 billion in 2002 to more than £1 trillion in 2014 or 72% of total insurance liabilities. This trend was fueled by a slowdown in traditional underwriting. For every *£*1 of traditional products, insurance companies underwrote *£*1.5 of linked products in 2002, which jumped up to *£*6.0 in 2014.

Standard models of capital structure (Miller-Modigliani (1958)), where firms can frictionlessly raise capital, predict that changes in capital requirements should have no impact on equilibrium product market outcomes. However, if firms cannot raise capital or can do so only at a sufficiently high cost[3], then increases in capital requirements could lead to significant changes in equilibrium outcomes[4]. In this paper, we show that regulatory frictions affected the equilibrium product mix of the insurance sector and led to significant balance sheet restructuring and firm reorganizations. The main contribution of our paper is that we can accurately measure regulatory constraints using proprietary data on stress-test submissions of insurance firms from the Bank of England. Moreover, as the stress-test submissions remained non-public, our setting allows us to construct a measure of regulatory shock that is plausibly exogenous to shifts in demand and helps rule out potential demand side explanations of our results.

We proceed in three steps. First, we develop a stylized model of insurance pricing based

[1]UK was the third largest insurance market (by premiums) after United States and Japan in 2014 (see OECD Global Insurance Market Trends (2014)).

[2]The Individual Capital Adequacy Standards (ICAS), also known as Solvency I Pillar II regime, was announced in 2002. See, Individual Capital Adequacy Standards Consultation Paper 136 for details.

[3]Raising equity could be expensive, e.g. due to informational asymmetry (Myers and Majluf (1984)) or agency costs (Diamond and Rajan (2000)).

[4]Kashyap and Stein (2004) argue that capital requirements could lead to decrease in lending for banks.

on a structural model of the insurance sector (Koijen and Yogo (2015)) to understand the impact of shifts in capital regulation. Our model yields predictions about equilibrium quantities in the cross-section of insurance firms due to a shift in the regulation of traditional products. An increase in capital requirement for traditional products leads to an increase in marginal cost of supplying insurance, resulting in higher prices and lower demand for all products. However, the effect is more pronounced for constrained firms for whom the regulatory costs are higher and for traditional products which became more capital intensive in the new regime. Second, we provide a framework to measure firm-level regulatory constraints at the time of announcement of the new regime using proprietary stress-test submissions from firms, which allows us to measure capital requirements comprehensively across a range of balance sheet risks. We then compute capital buffers, defined as the ratio of available capital to required capital, to measure solvency for each firm. Firms that are *constrained* have capital buffers under one and must either reduce balance sheet risks or raise more capital to avoid regulatory intervention. Third, we test the model's predictions by difference-in-differences identification using unconstrained firms, firms already meeting the new requirements in 2002, as a control for constrained firms, firms that have a capital shortfall in 2002, which helps overcome the identification challenge that the new regulation affected all firms.

We find significant differences in underwriting between constrained and unconstrained firms, after the regulatory changes were announced in 2002. Firms that are constrained by the new regulation reduce underwriting relative to firms that are unconstrained. Moreover, the reduction in underwriting for constrained firms relative to unconstrained firms is more pronounced for traditional products, which became more capital intensive in the new regime. The economic magnitudes of the differences are large: for example, conditional on underwriting at all (intensive margin), we find 51% lower traditional underwriting and 9% lower linked underwriting for constrained firms relative to unconstrained firms. Furthermore, we find that the propensity to underwrite (extensive margin) declines by 2.8 percentage points for traditional products and by 8.2 percentage points for linked products for constrained firms relative to unconstrained firms.

We also find significant differences in balance sheet restructuring and firm reorganizations. A significantly higher proportion of constrained firms undertake net transfers (partial or complete sale of their assets and liabilities), and undergo a change in parent after 2002, compared to unconstrained firms. On an average, the constrained group is 5.8 times more likely to have a major sale of assets and liabilities, 97% less likely to buy another firms' assets and liabilities and 3.5 times more likely to have a change in parent after 2002 vis-a-vis before 2002, as compared to the unconstrained group during the same period.

To provide evidence that our measure of financial constraints is indeed driven by changes in capital requirements, we compare the distribution of capital buffers in the old regime relative to the new regime. As the regulatory changes applied to a firm's entire balance sheet, including its legacy liabilities and not just new products, we find a significant shift in the distribution i.e. a large fraction (47%) of previously unconstrained firms become constrained in the new regime. Thus, the new regulatory regime resulted in a large shock to firms' regulatory capital positions and marginal costs of supplying insurance. We also show that relative to unconstrained firms who maintained a stable capital to asset ratio, constrained firms increased their capital to asset ratio by 4.3 percentage points on an average during the five years window post 2002. This supports the finding that the new capital requirements became binding for constrained firms and led to significant product market changes and balance sheet adjustments. Finally, we conduct placebo tests to examine whether similar product market changes occurred in "alternate event years" and show that such large scale changes are unique to 2002 when the regulatory changes took place.

We interpret these product market changes as a shock to insurance supply for constrained firms for whom the marginal cost of providing insurance goes up in the presence of regulatory frictions. Our interpretation relies on the following facts. First, stress test disclosures typically produce new information previously not incorporated in prices by market participants (Petrella and Resti (2013))[5]. Second, firm level stress test outcomes and the new capital requirements remained undisclosed to the larger public. In fact even aggregate statistics on the new requirements and solvency of insurance firms have not been published by the FSA. These two facts imply that our measure of shocks to regulatory constraints (and insurance supply) is plausibly exogenous to shifts in insurance demand i.e. an alternate explanation where households substitute away from constrained firms as such firms are perceived to be less solvent is less plausible in the absence of this data in the public domain. Although the stress test outcomes per se were not disclosed, public signals of this information, e.g. credit ratings were widely available. In our empirical analysis, we show that the observed product market changes are robust to the inclusion of credit ratings. Finally, using hand-collected price quotes, we show that the price trend for traditional products was upwards, while for linked products remained flat, consistent with a supply side explanation of our results.

[5]Also see Goldstein and Sapra (2013) who discuss the costs and benefits associated with stress test disclosures.

Related Literature: Traditional theories of insurance markets assume that insurance companies operate in frictionless markets (Yaari (1965) and Rothschild and Stiglitz (1976)). More recently, number of papers have documented the effect of supply side frictions: for example, Koijen and Yogo (2015) show that US insurance companies altered pricing behavior, selling products at deep discounts during the financial crisis, due to regulatory and product market frictions; Koijen and Yogo (2015) examined the effect of curtailing shadow insurance, a widely used capital management tool, on insurance balance sheets and market equilibrium; Ge (2016) shows that firms that suffer losses within their P&C affiliates change the pricing behavior in their life insurance subsidiaries. We add to this literature in the following ways. First, we exploit a plausibly exogenous shock to insurance supply due to a large-scale regulatory change and document subsequent product market changes. Second, unlike previous studies that focused primarily on pricing behavior, we provide direct evidence on quantity and mix of underwriting and show that regulatory changes affected the equilibrium product mix of the insurance sector. Finally, we measure sensitivities of equilibrium outcomes to changes in capital requirements and inform the literature on the costs of capital regulation and various margins of adjustment for insurance companies.

Another strand of the literature documents the effect of regulatory frictions on the asset side of insurance balance sheets. For example, Ellul, Jotikasthira and Lundblad (2011) show that insurance firms sell downgraded bonds at fire-sale prices due to increased regulatory pressure[6]; Ellul, Jotikasthira, Lundblad, and Wang (2015) show that constrained insurance firms sell bonds with the highest unrealized capital gains to improve their regulatory capital positions; and Becker and Ivashina (2015) show that regulatory risk charges lead insurance firms to deviate from standard mean-variance portfolio compositions. We add to this literature on regulatory pressures by providing evidence from the liability side of insurance balance sheets. In particular, we show that constrained companies in the UK sharply reduced traditional underwriting when confronted with higher regulatory requirements for such products.

We also contribute to the broader debate on the implications of capital regulation. Admati, DeMarzo, Hellwig, Pfleiderer (2013) support the Modigliani-Miller view that raising equity is not expensive and thus capital requirements do not affect lending outcomes for banks. However, since Peek and Rosengren (1997), Kashyap and Stein (2000), Ashcraft (2005), Paravisini (2008), and Khwaja and Mian (2008), the banking literature has found evidence that shocks to capital affect bank lending. Keeley (1988), Wall and Peterson (1987),

[6] Also see Merrill, Nadauld, Stulz, and Sherlund (2012).

Avery and Berger (1991), and Ashcraft (2001) are some early studies that examined whether bank capital regulation led to changes in banking balance sheets and capital positions. Aiyar, Calomiris, and Wieladek (2012) exploit time varying change in minimum capital requirements on bank credit supply[7]. Our paper contributes to this larger debate by providing evidence from outside the banking sector. We link regulatory changes to shifts in the product market equilibrium and changes in product mix of insurance companies, which could potentially have long-term welfare consequences for households.

2. Institutional Background

2.1. Product Lines

Life insurance products in the UK can be broken into two broad groups to reflect where the risk of the product resides: traditional and linked products. Traditional products (with-profits and non-profit) are products where policyholder receives some form of insurance (e.g. life cover) and protection (e.g. guaranteed savings) from market fluctuations. Benefits are either fixed at the outset or vary due to discretionary bonuses which depend on investment performance. Thus, in these products, the insurance company assumes all or most of the investment and mortality risk. In contrast, linked products are mainly investment vehicles (like mutual funds) that provide no insurance or protection to policyholders. In these products, the benefit payable at contract expiration due to death, surrender, or maturity are linked to the market value of some underlying investment portfolio. Thus, unlike traditional products, the policyholder bears the entire investment and mortality risk in linked products. This results in, as we will see a bit later, significantly lower capital requirements for linked products.

2.2. The New Capital Regulation Regime Introduced in 2002

Prior to 2002, insurance capital requirements in the UK were guided by the Solvency I Pillar I regime. Pillar I was largely risk insensitive and did not depend on the actual risks that an insurer assumed on its balance sheet, posing requirements as a fixed percentage of liabilities[8]. To correct this, the FSA announced a new prudential regulatory regime for life insurers - the

[7] Also see Francis and Osborne (2009).

[8] For example, Pillar I Minimum Capital Requirements (MCR) were computed as the sum of Resilience Capital Requirement (RCR) and Long Term Insurance Capital Requirement (LTICR), which was equal to 4% of the firm's liabilities. The computations did not make use of risk weights for different balance sheet items as was common in Banking regulation.

Individual Capital Adequacy Standards (ICAS) - in 2002[9]. The ICAS regime, commonly also known as Solvency I Pillar II regime, applied to all insurance companies in the UK. In the new regime, regulatory required capital depended on a firm's exposure to balance sheet risks including market risk, credit risk, interest rate risk, underwriting risk and other business risks. Total required capital R was thus given by

$$R = R_M + R_C + R_I + R_U + R_O \tag{1}$$

where $R_{(.)}$ denotes the pound value of required capital due to exposure to risk groups M (market), C (credit), I (interest rate), U (underwriting) and O (others).

The five risk groups captured a wide range of risk exposures. For example:

- Market risk included exposure to shocks in equity, exchange rate, and property markets;
- Credit risk included exposure to decline in credit quality of bonds and counter-party risk arising from reinsurance partners;
- Interest rate risk measured exposure to fluctuations in interest rate and inflation;
- Underwriting risk is the core risk faced on the liability side of the balance sheet and included exposure to longevity, mortality, morbidity, and policy lapse risks;
- Other risk included risks stemming from complex group and subsidiary structures, and operational risks.

2.2.1. Computation of Required Capital by Portfolio Stress Testing

Insurance firms were required to conduct "scenario" based simulations or stress-tests on their portfolios. The portfolio stress test exercises yielded capital requirements for each risk exposure $R_{(.)}$, which were then added together to arrive at the total required capital for a firm as described in equation 1. The FSA provided guidelines on the types of risks to be assessed by firms. Firms were required to calibrate their internal models such that they remained solvent with 99.5% probability over the next one year. Firms' stress test submissions were reviewed and validated by FSA supervisors to assess whether submissions adequately reflected their risk exposures.

[9]See 'FSA Individual Capital Adequacy Standards (2002) Consultation Paper 136' and 'FSA Enhanced Capital Requirements and Individual Capital Assessments for Life Insurers (2003) Consultation Paper 195'.

Two additional points are worth noting. (1) Firm level stress test outcomes and the new capital requirements remained undisclosed to the larger public. In fact even aggregate statistics on the new requirements and solvency of insurance firms were not published by the FSA. A recent literature examines the reaction of financial markets to disclosures of bank stress test results. For example, Petrella and Resti (2013) find significant market responses to the European Banking Authority stress test in 2011, implying that stress test disclosures produce new information previously not incorporated in prices by market participants. This, if more generally true, along with the fact that the stress test outcomes were non-public helps alleviate the concern that our measure of regulatory constraints might be correlated with shifts in insurance demand. Thus, our setting provides us a measure of shocks to regulatory constraints (and insurance supply) that is plausibly exogenous to shifts in demand. (2) Firms were required to stress-test their *entire* balance sheets, which implies that the new requirements applied retroactively, i.e. also to policies that were underwritten in the past. This is unlike what happens in the US where typically regulatory changes apply to new underwriting only. This implies that the shock to regulatory constraints in our case was relatively big and could have a large impact on subsequent product market outcomes.

2.2.2. Solvency

The FSA measured solvency of insurance firms by assessing their capital buffer, defined as the ratio of available capital to required capital, i.e. capital buffer measures the distance between a firm's available capital and the required capital it needs to hold. Thus, capital buffer B_i for firm i is

$$B_i = \frac{K_i}{R_i} \tag{2}$$

where the numerator K_i is the available capital and the denominator R_i is the required capital measured using equation 1. A firm faced increased risk of regulatory intervention if it had a capital buffer below one, i.e. the firm did not have sufficient capital to meet the regulatory requirements[10]. While information on capital resources (numerator) is relatively easy to assess from firms' balance sheets, measuring their capital requirements (denominator) is not straightforward as detailed information on asset and liability risk exposures are difficult to assess from typical regulatory filings made by firms (Koijen and Yogo (2016)). The US adopted a risk-based regulatory regime in 1994. However, the National Association of

[10]See 'FSA Enhanced Capital Requirements and Individual Capital Assessments for Life Insurers (2003) Consultation Paper 195' pages 45-49, which sets out the FSA's view on adequate financial resources and provides guidelines on regulatory oversight.

Insurance Commissioners (NAIC) does not publicly disclose information on firm's regulatory capital positions, which makes it difficult to measure firm-level regulatory constraints. The unique feature of our setting is that we are able to accurately measure capital requirements using a proprietary database from the Bank of England that contains information on firm-level stress test submissions undisclosed to the larger public.

3. Data and Key Facts

3.1. Data

We use three types of data: (1) Regulatory returns and credit ratings data; (2) Capital requirements data; and (3) Insurance pricing data.

(1) *Regulatory Returns and Credit Ratings Data*: We use FSA's annual regulatory returns collected from Standard & Poor Global Market Intelligence Synthesys database, which is a publicly available database. The sample consists of firms in the long-term insurance sector (life and pensions markets), covering nearly all insurance companies in the UK[11]. The data are annual and cover the period from 1985 to 2014. Our analysis is at the operating company level as capital requirements are set at this level. Synthesys provides product level information on premium income and policies sold, which are our main dependent variables of interest. In addition, the database covers a wide range of other information on insurance companies, such as (i) balance sheet; (ii) asset allocation; (iii) liabilities by product lines; (iv) capital resources; (v) capital requirements for the old regulatory regime; (vi) claims incurred; and (vii) reinsurance ceded and accepted, which are useful control variables for our study. Importantly, the regulatory returns data from Synthesys are audited, making the information highly reliable. Appendix A provides variable descriptions.

Firms also report any major change to their businesses, including transfers and reorganizations, in their financial notes. We define reorganizations as a change in legal owner of a firm, typically following change in the firm's parent. A transfer involves partial or complete sale of a firm's assets and liabilities with no change to the legal owner of the firm. A 'transfer-out' is sale of assets and liabilities while a 'transfer-in' is purchase of assets and liabilities of another firm. Unlike reinsurance, where the firm ceding reinsurance remains ultimately liable, in a transfer, there is a reallocation of legal ownership of liabilities to the firm accepting the transfer. We hand-collect data on transfers and reorganizations from firms' regulatory filings and financial notes. We create dummy variables for whenever a firm

[11] Non-Directive Friendly Societies are excluded from regulatory reporting requirements.

experiences a major transfer out, transfer in, or a change in parent. We also construct a record of firms' mutual status[12] using the Financial Conduct Authority's register of mutual insurers, and historic data on mutual status available in Alzmezweq (2015).

Data on credit ratings are from S&P Global Market Intelligence. In less than 10% of cases where S&P's ratings data was unavailable, we used credit rating from Moodys, A.M.Best or Fitch. Where the credit rating of the operating company was not available, we imputed the rating of the parent company. We converted the letter ratings into a cardinal scale such that the highest rating grade AAA corresponded to a rating score of 10. We reduced the score of each subsequent rating grade by 0.5. For example, AA+ corresponded to a rating score of 9.5, BBB+ corresponded to a rating score of 6.5 and CCC- corresponded to a rating score of 1.0. For robustness, we also use an alternate rating score where we convert letter ratings into a non-linear scale by imputing historical default probabilities taken from Standard and Poor's Rating Direct (2014).

(2) *Capital Requirements Data*: Capital requirements for the new regulatory regime are from a Bank of England proprietary database used for the purpose of insurance supervision. The database provides balance sheet stress test submissions of insurance firms and the FSA's review of these submissions, allowing us to measure capital requirements comprehensively across risk groups for each insurance firm[13]. The stress-test review process typically lasted 3-6 months and involved multiple actuaries (supervisors). The FSA levied capital add-ons in case a firm's assessment of requirements were inappropriate. Behn, Haselman and Vig (2014) show that risk models may be manipulated by banks to reduce their capital requirements. The data on capital add-ons allow us to rule out this concern on systematic under-reporting of capital requirements by insurance firms. We show a comparison between pre-review and post-review capital requirements in table A.2. We find that capital add-ons levied by the FSA, over and above firm's internal assessments, were relatively small, which alleviates concerns regarding under-reporting of capital requirements.

In order to comply with the new regulatory regime, all insurance firms were required to provide internal assessments of their capital requirements by 2006. Stress-test submissions and reviews took place in a staggered manner as due to limited supervisor time, the FSA could not review all submissions at once[14]. We focused attention on first-time stress test

[12]A mutual insurance company is a non-public company owned entirely by its policyholders.

[13]See table A.2 for descriptive statistics on this data.

[14]After the first wave of submissions and reviews, firms were reviewed again roughly every three years or if they went through major changes in their business or risk profiles.

submissions made between 2003 and 2006, which totaled to 131 submissions. We select first-time submissions to ensure that we use data that closely resemble what firms would have done in 2002, when the regulation was first announced, and not be contaminated by any potential learning from future FSA reviews and interaction with supervisors. However, as the submissions only started in 2003, we do not directly observe solvency of firms in 2002 when the regulation is announced. In section 5, we provide a framework on how we used our unique regulatory data to resolve this timing problem and measure firm level regulatory constraints as of 2002.

(3) *Insurance Pricing Data*: We get data on insurance prices from Investment Life and Pensions Moneyfacts, which provides price quotes on investment, retirement and protection products from some of the larger insurance providers in the UK. The data are hand-collected from the December issue every year between 1997 and 2007. The majority of traditional liabilities are within pension and annuity contracts and linked liabilities are entirely pension contracts. Each product follows a different convention for reporting price quotes. In section 8, we describe our methodology to standardize these quotes and estimate the overall price for a product.

3.2. Key Facts

Average Capital Requirement By Product Lines

We now discuss the significant institutional changes that motivate our analysis. Figure 1 presents a comparison of the minimum required capital between the old regime and the new regime for each product line. The old regime refers to capital requirements under Solvency I Pillar I, while the new regime refers to capital requirements under ICAS computed from firms' stress test submissions. Firms submit stress test results for their entire balance sheet and not for each product line separately. Thus, to measure the magnitude of required capital for each product line, we only focused on firms that have more than 95% of liabilities in a single product line. Two key points are worth noting. First, capital requirement increased significantly for all firms as regulators adopted the new risk based regime. Second, the increase in requirement was significantly more pronounced for the traditional product line where the average required capital as a ratio of total assets went from about 6% in the old regime to about 13% in the new regime. Thus, for every £1 of traditional liabilities, while in the old regime insurance companies were required to hold £0.06 in capital, in the new regime they were required to hold £0.15 in capital. Although, capital requirement also increased for the linked product line, it was relatively small in absolute levels underscoring the fact that insurance companies assume little risk in selling linked products. In Appendix A.2, we provide a breakdown of capital requirements by risk groups and show that linked products have lower risk exposures across all risk groups.

Industry Transition: From Traditional to Linked

We also document a big shift in the UK insurance market - a transition from traditional to linked - after the new regulatory regime was introduced in 2002. In figure 2 (left panel) we show the long-term trend in linked liabilities as a proportion of total net liabilities[15] for the insurance industry as a whole. As is evident, there was a marked shift in the liability mix of insurance companies after 2002. Linked liabilities as a proportion of total net liabilities went up from about 43% in 2002 to 72% in 2014. The largest increase came in immediately after 2002 when the share of linked products went up from 43% to 66% in just 5 years. The increase in share of linked liabilities has been to a large extent fueled by a decline of traditional underwriting relative to linked underwriting over the years (right panel). For every £1 of traditional insurance, insurance companies underwrote £1.5 of linked insurance on an average between 1985 and 2002, which jumped up to £4.5 between 2003 and 2014.

In this paper, we attempt to understand whether the shift in the regulation of traditional products generated changes in the market equilibrium of traditional and linked products. We proceed in three steps. First, we present a stylized insurance pricing model and derive testable cross-sectional implications on equilibrium quantities, where the cross-sectional differences in firm outcomes arise from differences in their regulatory constraints. Second, we show how we measure firm-level regulatory constraints when the new regime is announced in 2002 using data on stress-test submissions made by firms to the FSA. Finally, we test the model's predictions using a difference-in-differences identification strategy where we use unconstrained firms as a control for firms that are constrained by the new regulation. In the next three sections, we will describe each of these steps in more detail.

4. Model

4.1. Insurance Firms

We develop a stylized model of insurance pricing, following Koijen and Yogo (2015), in which insurance companies face heterogeneous capital requirements at the product level. Consider I insurance companies, indexed by $i = 1, 2, ..., I$. Each company sells two products denoted

[15] Total net liabilities is the sum of gross liabilities arising in traditional and linked product lines minus reinsurance.

$j = 1, 2$ where $j = 1$ are traditional and $j = 2$ are linked products. Firms face marginal cost V_j for each product. We think of V_j as the fair actuarial value of selling policies which is same across all firms. Each firm faces regulatory cost $C(B_i)$, where B_i is firm $i's$ capital buffer, which generates heterogeneity in the cost of insurance supply across firms due to differences in regulatory capital positions.

Firm $i's$ capital K_i after selling new policies is equal to

$$K_i = \sum_{j=1}^{2} Q_{ij}(P_{ij} - V_j) + K_i^- \tag{3}$$

where Q_{ij} and P_{ij} are quantity and price of product ij respectively and K_i^- is the initial capital of firm i. Regulatory required capital for each firm R_i is given by

$$R_i = \sum_{j=1}^{2} \phi_j(Q_{ij}V_j + \omega_{ij}^- L_i^-) \tag{4}$$

where $\phi_j > 0$ is the regulatory risk weight for product j. $\omega_{ij}^- \times L_i^-$ is total liability for product j coming into the period. Thus, total regulatory required capital depends on total liability in each product line and the associated regulatory risk weight[16].

Firm $i's$ capital buffer B_i is thus

$$B_i = K_i - R_i \tag{5}$$

Capital buffer of firm i generates heterogeneity in regulatory cost $C(B_i)$ across firms. $C'(B_i) < 0$ and $C''(B_i) \geq 0$. Thus, if the capital buffer is high (low), regulatory cost is low (high).

Firm i maximizes profit subject to a downward sloping demand function for each product, $Q_{ij}(P_{ij})$,

$$\max_{P_{ij}} \quad \sum_{j=1}^{2} Q_{ij}(P_{ij} - V_j) - C(B_i) \tag{6}$$

[16]We have assumed required capital only depends upon proportion of liability in each product line, i.e. it is independent of the asset mix, as we aim to focus on the differences between the two product lines.

The first order condition (FOC), for each product j is

$$Q_{ij} \;+\; Q'_{ij}(P_{ij} - V_j) \;+\; c_i(Q_{ij} + Q'_{ij}(P_{ij} - V_j) - Q'_{ij}\phi_j V_j) = 0 \tag{7}$$

where $c_i = -C'(B_i)$. The solution to the FOC is

$$P_{ij} \;=\; \left(1 - \frac{1}{\epsilon_{ij}}\right)^{-1} \; V_j \; \Phi_{ij} \tag{8}$$

where $\epsilon_{ij} = -\frac{\partial logQ_{ij}}{\partial logP_{ij}}$ is the demand elasticity, and

$$\Phi_{ij} = \frac{1 + c_i(1 + \phi_j)}{1 + c_i} \tag{9}$$

The pricing rule contains three components. The first term is the standard markup, which depends on the demand elasticity ϵ_{ij}. The second term is the marginal cost. The first two terms together is the price of insurance in a model without regulatory frictions. The third term connects prices and quantities in the presence of regulatory constraints. Φ_{ij} depends on regulatory constraints c_i which operates at the firm level and risk weights ϕ_j which operates at the product level.

4.2. Demand

Demand is determined from a discrete choice problem (McFadden (1974)). There are N consumers, indexed $n = 1, 2, ..., N$ with indirect utility function given by

$$u_{ij}(n) = -\alpha P_{ij} + \beta' X_i + \eta_{i,j}(n) \tag{10}$$

where (α, β) are preference parameters, P_{ij} are prices, X_i are firm specific covariates and $\eta_{i,j}(n)$ are consumer specific demand shocks. Insurance firms produce differentiated products, where differentiation is due to company characteristics. Thus, expected indirect utility from product ij depends on the price of the product and characteristics of firm i. Market share, s_{ij}, for product ij becomes,

$$s_{ij} = \frac{e^{\delta_{ij}}}{1 + \sum_{j'=1}^{2} \sum_{i'=1}^{I} e^{\delta_{i'j'}}} \tag{11}$$

where $\delta_{ij} = -\alpha P_{ij} + \beta' X_i$ and e denotes the exponential operator.

4.3. *Comparative Statics*

We want to evaluate the effect of a change in regulation on the amount of underwriting and market share of the i^{th} firm. The change in regulation and all relevant comparative statics are with respect to a shift in ϕ_1, which we think of as a shift in regulation of traditional products.

Proposition [1]: An increase in ϕ_1 decreases firm $i's$ market share if firm i is *relatively* constrained enough as

$$\frac{\partial s_{ij}}{\partial \phi_1} < 0 \tag{12}$$

if $c_i > c_{i'}$ for sufficient number of $i' \in I$.

We prove proposition 1 in Appendix B. An increase in ϕ_1 raises marginal costs and insurance prices for all firms. However, the effect is more pronounced for constrained firms for which the regulatory costs c_i are higher, implying a greater increase in prices for such firms. Firm $i's$ market share is determined by not only its own price elasticity, but also relative differences in cross price elasticities which depend on how constrained other firms are relative to firm i. Equation 12 says that if firm i is relatively more constrained, i.e. a sufficient number of firms are less constrained than firm i, then its market share reduces as (i) firm $i's$ price increases; and (ii) relative to other firms, this increase is higher, implying a substitution away from firm i. Conversely, if firm i is relatively unconstrained, then despite an increase in its own price, it could gain market share due to relative increase in prices of other more constrained firms.

Proposition [2]: An increase in ϕ_1 for firm i decreases traditional underwriting relative to linked underwriting as

$$\frac{\partial (s_{i1}/s_{i2})}{\partial \phi_1} < 0 \tag{13}$$

All else equal for two firms i and i', if $c_i > c_{i'}$ then

$$\frac{\partial (s_{i1}/s_{i2})}{\partial \phi_1} < \frac{\partial (s_{i'1}/s_{i'2})}{\partial \phi_1} \tag{14}$$

We prove proposition 2 in Appendix B. Equation 13 implies that, all else equal, an increase in ϕ_1 decreases traditional underwriting more than linked underwriting resulting in a change in product mix towards linked products. Moreover, the effect is more pronounced for constrained firms i.e. constrained firms have a greater reduction in traditional underwriting than linked underwriting, as compared to unconstrained firms.

We test the product market predictions using data on premium income for traditional and linked products. The model has differential predictions in the cross-section of insurance firms which motivates a difference-in-differences identification strategy where we can use unconstrained firms, firms already meeting the new requirements in 2002, as a control for constrained firms, firms that have a capital shortfall in 2002, to identify the effect of the change in regulation of traditional products. In the sections that follow, we describe how we measure firm level regulatory constraints and our empirical strategy in more detail.

5. Measuring Regulatory Constraints

We measure the effect of the new regulation on firm outcomes when the regulation is announced in 2002 as opposed to when it is implemented in 2006. We do this for two reasons. First, it ensures what we capture is likely to be the unexpected regulatory shock. Second, it helps prevent under-estimation of a firm's response to the regulatory change[17]. As the new requirements stemmed from firms own risk assessments, it is a reasonable assumption that firms knew the magnitude of capital shortfall and made adjustments much before the new regulation was implemented. Firms might also have been under pressure from supervisors to start making changes to their balance sheets ahead of the deadline, particularly if supervisors deemed a firm unlikely to meet the new capital requirements. Measuring changes only at the date of implementation, therefore, may result in significant under-estimation of firm's responses as it misses out on the run-up adjustment effect.

However, measuring the regulatory shock in 2002 implies the following timing issue. We would like to assess solvency of firms in 2002 when the regulation is announced, however, we do not observe the new capital requirements in 2002. We instead observe firm's capital requirements from 2003 to 2006 when they make their stress-test submissions. To mitigate this issue, we proceed as follows: we recover the capital requirement models by linking risk exposures (requirements) from 2003 to 2006 to observable firm characteristics. We then use these capital requirement models to predict the new risk based required capital in 2002.

[17] Eber and Minoiu (2016) find that European banks made balance sheet adjustments ahead of the European Central Bank's Comprehensive Assessments in 2014.

5.1. Capital Requirement Models

We use capital requirements from stress-test submissions for each risk group along with observable firm characteristics, such as asset allocation, asset yield, claims, and group structure, to recover the capital requirement models for the average firm. The process helps identify factors that explain a firm's exposure to various types of risks. We assume a linear relationship between risk exposures and firm characteristics and use a least squares models to explain the cross-sectional variation in risk exposures across firms. Let $\bar{R}_{rit}$ denote the requirement to total asset ratio for risk group r, firm i at time t, X_{rit} denotes a vector of relevant firm-specific covariates at time t, and τ_{rt} denote time fixed effects to account for staggered submissions between 2003 and 2006. We estimate,

$$\bar{R}_{rit} = \alpha_r + \beta_r X_{rit} + \tau_{rt} + \epsilon_{rit} \tag{15}$$

for each risk group $r \in$ {Market, Credit, Interest Rate, Underwriting, Others}. The sample consists of stress test submissions made between 2003 and 2006 by firms with more than £500 millions in total assets. Explanatory variables are selected based on the FSA's guidelines on conducting portfolio stress tests[18]. Thus, our requirement models are likely to closely match firms' own assessments, as is also evident from the good model-fit we achieve overall. Table 1 presents the requirement models. In specification I under each risk group, we show the final model that was used to predict the new capital requirements in 2002. All other specifications are provided for robustness[19].

- Market Risk: Market risk accounts for one of the largest shares (30%) of total capital requirements. It is positively related to the proportion of equities on a firm's balance sheet. We use equities as a proportion of total assets interacted with past 10 years volatility of FTSE100 to explain the cross-sectional variation in market risk. 10 years volatility on FTSE100 is included to account for the fact that the inherent riskiness of an equity portfolio varies from year to year. The coefficient is positive and statistically significant at the 1% level. Our market risk model accounts for 64% of the total cross-sectional variation in market risk across firms.

- Credit Risk: Credit risk accounts for 12% of the total capital requirements. Credit risk is positively related to the amount of non-government bonds, mortgages and loans on the balance sheet of firms. As we do not observe credit ratings of the bonds held on

[18]See 'FSA Enhanced Capital Requirements and Individual Capital Assessments for Life Insurers (2003) Consultation Paper 195'.

[19]To show model fit due to observable firm characteristics only, we also present R^2 without the time fixed effects.

insurance balance sheets during our sample period, we use bond yields as a proxy for ratings. We interact non-government bond yields with the proportion of total assets in non-government bonds to measure the credit risk of an insurance bond portfolio. As the data on mortgage and loan rates are not available, unlike non-government bonds, mortgages and loans are not interacted with their respective prices. Both variables are statistically significant at the 1% level and explain over 74% of the cross-sectional variation in credit risk across firms.

- Underwriting Risk: Underwriting risk accounts for the largest share of total capital requirements (32%). This risk group is mainly associated with the inherent riskiness of the policies being underwritten, such as the portfolio's mortality and morbidity experience. We use death and disability claims experienced by firms as a proportion of total net liabilities to account for cross-sectional variation in underwriting requirements. Our model explains 63% of the total variation in underwriting risk across firms.

- Other Risk: Other risks include risks stemming from complex group and subsidiary structures, and operational risks. We use subsidiary assets as a proportion of total assets to proxy for size and complexity of a firm's group structure. The variable explains 48% of the total variation of other risks across firms.

- Interest Rate Risk: Interest rate risk is positively related to the amount of fixed income securities on firm's balance sheets. We use proportion of all bonds - government and non-government - interacted with the portfolio's composite yields, which proxies for duration, to account for interest rate risk exposure. The model fit is weaker in the absence of two other factors that affect net interest rate risk exposures - duration of insurance liabilities and derivative holdings which is commonly used to hedge interest rate risk exposures - both of which we do not observe (see Domanski, Shin, and Sushko (2015)). The weaker results are less likely to cause significant mis-measurement of capital requirements as interest rate risk contributes only 11% to total required capital on an average.

Moreover, the predicted total required capital ratio and actual total required capital ratio closely align with each other, with an implied $R^2 = 68\%$ (see Appendix C.1), lending further credibility to the overall fit achieved by the baseline models. For robustness, we change the specification of the baseline model, where each risk is modelled separately, to an alternate specification where all risks are modelled jointly ('One Risk Model'). Appendix C.1 describes the results. The risk factors that explain cross-sectional variation in individual risk groups turn out to be statistically significant and similar in magnitude when all risk groups are considered together. In particular, our concern regarding the interest rate risk model is mitigated to an extent as the variation in interest rate risk appears to be well captured by the other risk factors, with the 'One Risk Model' explaining 74% of the total cross-sectional variation in capital requirements.

We use the capital requirement models estimated above to predict the total required capital to asset ratio for firm i in 2002 as follows

$$\hat{\bar{R}}_{i,02} = \sum_{r} \hat{\bar{R}}_{r,i,02} \tag{16}$$

where as before $r \in$ {Market, Credit, Interest Rate, Underwriting, Others}. The key assumption is that the requirement models recovered from 2003 to 2006 well represent the requirement model in 2002[20]. Although the assumption is not completely innocuous, it is necessary to analyze the effect of the regulatory shock as of announcement. This is because the FSA did not formally prescribe risk weights for each risk group which would have made measurement of requirements in 2002 straightforward. Nevertheless, our approach provides some important benefits. (1) Using the submitted risk exposures between 2003-2006 as a proxy for risk exposure in 2002 would be problematic as it does not provide an ex-ante measure of regulatory shock and likely already incorporates all adjustments firms had made. Our approach instead delivers an ex-ante measure of capital requirements. (2) Firms submit their stress-test results in a staggered manner between 2003 and 2006. A firm's choice about when to submit is endogenous, our approach helps avoid this issue. (3) Restricting our sample to firms who eventually have their ICAS assessments and report capital requirements between 2003 and 2006 could introduce survivorship bias to our results. Our approach allows us to consider all firms that existed in 2002 as we are able to predict requirements based on observable balance sheet characteristics for all firms.

5.2. Definition of Constrained Firms

To assess the solvency of firms in 2002, we compute capital buffers using actual available capital and predicted required capital in 2002, exactly following the FSA's assessment procedure described in section 2. The capital buffer for each firm $\hat{B}_{i,02}$ in 2002 is

$$\hat{B}_{i,02} = \frac{\bar{K}_{i,02}}{\hat{\bar{R}}_{i,02}} \tag{17}$$

[20] In the empirical specification, we add time dummies in equation 15 for 2004-2006 implying that in the absence of time dummies the model captures the situation in 2003, the year closest to 2002.

where $\hat{\hat{R}}_{i,02}$ is the total predicted required capital to asset ratio derived from equation 16 and $\bar{K}_{i,02}$ is the actual capital to asset ratio in 2002. As described in section 2, we define a firm to be constrained, $C_i = 1$, if it has a capital buffer below one, i.e. the firm does not have sufficient capital to meet the new regulatory requirements. Thus,

$$C_i = \begin{cases} 1 & \text{if} \quad \hat{B}_{i,02} < 1 \\ 0 & \text{if} \quad \hat{B}_{i,02} \geq 1 \end{cases}$$

6. Empirical Strategy

6.1. *Identification*

We now describe our empirical strategy. The model implies that an increase in regulatory risk weight for traditional products, leads to an increase in regulatory constraint for firms, which increases the marginal cost of providing all types of insurance products - traditional and linked. However, the effect is more pronounced for constrained firms for whom the regulatory costs are higher and for traditional products for which requirements increased. Thus, the model has differential predictions in the cross-section of insurance firms depending on how large their regulatory constraints are, which measures the size of the regulatory shock and thus the level of the treatment effect.

This motivates a difference-in-differences identification strategy where we can use unconstrained firms, firms already meeting the new requirements in 2002, as a control for constrained firms, firms that have a capital shortfall in 2002. As described in the previous section, we define a firm to be constrained if it has a capital buffer, ratio of actual available capital to predicted required capital, below one[21]. This helps us overcome the identification challenge that the new regulation affected all firms and thus the counter-factual outcome - behavior of firms if the new regime was not implemented - is not observed i.e., there is no true control group. Thus, our empirical specification is,

$$log(Y_{it}) = \alpha + \alpha_i + \alpha_t + \beta(C_i \times P_t) + \delta D_{it-1} + \epsilon_{it} \tag{18}$$

where Y_{it} is total new premium income in traditional or linked product line for firm i at time t. C_i is an indicator variable that takes a value of 1 if a firm is constrained, P_t is the post regulation dummy variable that takes a value of 1 after 2002, D_{it-1} are additional firm

[21] As firms with a buffer between 1.0 and 1.2 are also perceived to be thinly capitalized by the FSA and experience increased regulatory oversight, we also use the alternate cutoff definition of 1.2 to test the robustness of our results (see section 7).

characteristics that also explain equilibrium product demand, α_i are firm fixed effects, and α_t are time fixed effects. C_i and P_t are not included directly as they are absorbed by the fixed effects. We select a 5 year window before 2002 to capture pre-dynamics and a 5 year window after 2002 to identify the effect of the change in regulation.

As the new regulatory regime mainly affected traditional products, we focus on firms that primarily underwrite traditional products. An insurance company can either have multiple product lines or specialize in a single product line. For example, Prudential Assurance underwrote 92% of total net liabilities in traditional products in 2002. In contrast, Sun Life Canada had a split of 52:48 and Legal and General Pension Management had a split of 0:100 in traditional and linked products respectively[22]. We define a firm to be traditional if the firm had more than 50% of its total liabilities in traditional products in 2002, thus we focus on firms like Prudential Assurance and Sun Life Canada. We then sort firms into constrained and unconstrained, following the procedure described in the previous section.

As we restrict our identification to firms that primarily underwrite traditional products, we can directly rule out alternate explanations where demand for a particular product line shifts in general. This is because shocks to demand in a particular product line are likely to affect both constrained and unconstrained firms similarly and get differenced out. For example, concerns about traditional products experiencing bad press during Equitable Life's near failure in 2001, a firm specializing in traditional products, should not affect constrained firms more than unconstrained firms as both groups have similar market power in the traditional market. Similarly, if demand for linked insurance rose in general due to increased popularity of these products or due to shocks to the mutual fund sector, then firms with similar market power in the linked market should not be differentially affected.

As linked firms (firms with more than 50% of total liabilities in the linked product line) were unaffected by the new regulation, an alternate approach could be to represent the counter-factual using linked firms. However, this is less suitable for the following other reasons. (1) Traditional and linked products are inherently different, particularly with respect to regulatory and institutional aspects. As we focus within traditional firms, we are able to control for these unobservable differences. (2) Linked firms have limited presence in the traditional market. More than 70% of linked firms underwrite less than £5 million of new traditional business annually, implying linked firms are unlikely to provide a good counter-factual.

[22]This information is taken from publicly available regulatory returns of these firms.

Thus, the analysis sample is the population of all traditional firms in 2002. A total of 206 firms filed regulatory returns in 2002[23], of which 115 are traditional. We excluded 2 firms as their last filings occur in 2002. We also excluded 12 firms as they sell no direct insurance throughout our sample from 1997 to 2007 as they mainly do reinsurance. Our final sample contains 101 firms which account for over 90% of the new premium underwritten in traditional products in 2002.

6.2. Distribution of Capital Buffer - Old vs. New Regimes

We present the distribution of capital buffer, ratio of available capital to predicted required capital, for all traditional firms in our sample in figure 3. The black bars show the distribution of capital buffer under the new regime calculated as in equation 17. The gray bars show the distribution of capital buffer calculated using the old capital requirements. The shaded area to the left of 1 denotes the mass of constrained firms. The magnitude of the regulatory shock due to the new regime can be seen from the shift in the distribution of capital buffer under the new regime. Of the 101 traditional firms in our sample, a total of 49 firms are constrained and 52 are unconstrained in the new regime. However, under the old regime, 98 firms out of the 101 firms in our sample were unconstrained. Thus, a large fraction of firms, 46 firms out of the 98 previously unconstrained firms (or 47% of the firms), become constrained under the new regime[24], implying that the change in capital requirements under the new regime turned out to be large in magnitude.

6.3. Properties of Constrained and Unconstrained Firms

Table 2 presents key firm characteristics for the constrained and unconstrained firms in 2002. By construction, the two groups are different in solvency measures (panel A). The average unconstrained firm has a capital buffer of 1.8, whereas the average constrained firm has a capital buffer of 0.7. This difference is largely driven by differences in capital to asset ratio, which is 16.5% for unconstrained and 8.6% for constrained firms on an average. Moreover, constrained firms have a higher required capital ratio at 12.4%, compared to 9.6% for unconstrained firms. However, this difference is not statistically significant.

To show that constrained and unconstrained firms are similar along many other dimensions, we evaluate a number of other firm characteristics (panel B). Average total assets

[23]Only firms with non-zero assets and liabilities are considered valid filings.

[24]Note that the 3 firms that were constrained under the old regime were also constrained under the new regime.

for constrained firms is £7.5 billion and unconstrained firms is £3.8 billion, although, the difference is not statistically significant. We control for firm size using logarithm of total assets in all our specifications. As the dependent variable is in logs, the model specification also accounts for non-linear relationship between product market outcome variables and firm size. By construction, both groups have high proportion of traditional liabilities, 93% and 89% for the unconstrained and constrained groups respectively. Both groups are similar in terms of the profitability metric, return on assets (ROA). Unconstrained firms have a higher proportion of liquid assets than constrained firms, a measure that is highly correlated with capital to asset ratio.

We also evaluated the two groups with respect to their asset and liability risk profiles: (i) proportion of invested assets in risky securities including equities, non-government bonds and mortgages (asset risk); (ii) total death and disability, annuity, and surrender related claims as a proportion of net liabilities (death and disability, annuity, and surrender); and (iii) reinsurance ceded (reinsurance). Across all these dimensions, the difference between the two groups are statistically insignificant. The two groups have similar average rating score of about 7.5, corresponding to a letter grade of 'A'. We also examine whether the two groups have meaningful differences in their organizational structures. Over 50% of firms within each group are mutual companies. Constrained and unconstrained groups also have similar subsidiary structures as seen from similar share of subsidiary assets to total assets.

7. Main Empirical Results

7.1. Evolution of the Product Market

7.1.1. Graphical Results

We first present the main results of the paper graphically. In figure 4, we plot direct new premium income in traditional and linked product lines. Premium income is the amount of insurance underwritten. The majority of insurance liabilities are within pension and annuity contracts, where premium income is the amount of money invested by a policyholder in a contract. For products such as term assurance, which account for a small portion of total liabilities, premium income equals the number of policies sold multiplied by the premium charged. We consider *direct* premium income, excluding premium income arising due to reinsurance accepted by firms, to ensure that we focus on policies sold directly to households and to avoid double counting. We exclusively focus on *new* underwriting, which excludes regular premium received from policies underwritten in the past.

The left panel shows traditional premium underwritten by constrained and unconstrained firms from 1997 to 2007. Up until 2002, both groups exhibit similar trends, with increasing amounts of traditional products underwritten between 1997 and 2002. However, the two groups display striking differences immediately after the new regulation is announced. Insurance companies that are relatively more constrained by the regulation substantially reduce traditional underwriting. On an average, the constrained group underwrote £300 million of traditional products in 2002, which falls to £115 million by 2007. In contrast, unconstrained firms maintain a relatively stable presence in the traditional market, underwriting £175 million of traditional products in 2002 which goes up to £230 million by 2007.

In the linked market (right panel), similar to the evidence in the traditional market, the two groups display differences in underwriting after 2002. Unconstrained insurance firms substantially increase linked underwriting, however, constrained firms are unable to push up their linked underwriting at a similar rate. On average, the unconstrained group underwrote £220 million of linked products in 2002, which rises to £550 million by 2007. In contrast, constrained firms are unable to maintain a similar pace, underwriting £170 million of linked products in 2002 which goes to £150 million by 2007.

Two additional comments are in order. In the linked market, the differences between the two groups become apparent after 2005, whereas in the traditional market these differences immediately follow the regulatory announcement in 2002. One interpretation could be that the constrained firms first pull back from the market that is significantly more capital intensive. Second, although unconstrained firms do not fully pull back from the traditional market, they underwrite largely linked products. Constrained firms, on the other hand, slow down in both markets, however, relative to linked products, traditional underwriting is curtailed significantly more. Thus, most of the new insurance underwriting is driven by increases in linked underwriting between 2002 and 2007, a trend fueled by unconstrained firms who have the balance sheet capacity to underwrite in the new regulatory environment.

7.1.2. Difference-in-Differences Model

Intensive Margin: We first analyze the effect of the change in regulation on the intensive margin of underwriting i.e. the amount underwritten by firms conditional on any underwriting at all. Table 3 reports the results of the difference-in-differences regressions. Panel A shows the results for the traditional market and panel B shows the same for the linked market. $C \times P$ is the main independent variable of interest where C and P are as defined in section 6[25]. The dependent variable is the log transformation of premium income.

Specification I shows results without any demand controls. As equilibrium product market outcomes could also be driven by variations in demand elasticities across firms, in specifications II to V, we account for observable firm characteristics that are known to drive insurance demand. Insurance firms produce differentiated products, where differentiation is due to company characteristics. Market shares depend on firm characteristics, thus product market changes could also be due to changes in firm characteristics over time. Koijen and Yogo (2015) show that insurance demand is largely explained by company size and A.M. Best rating (credit rating) for US insurance companies. In specification II, we add log(assets) and credit rating of firms. We convert the letter ratings into a rating score, which is a cardinal measure using both a linear scale and by imputing historical default probabilities (as described in the data section). Where a rating was not available in case a firm was unrated, we imputed a score using a rating regression (see Appendix C.2).

In specification III, we add additional demand controls[26] to proxy for a firm's financial strength[27] and market power. Our proxies for financial strength include capital to asset ratio, return on assets, liquidity ratio (proportion of assets invested in liquid securities), asset risk (proportion of assets held in equities, non government bonds, and mortgages), liability risk (claims resulting from death, disability, and annuities as a proportion of net liabilities), reinsurance (proportion of liabilities ceded to re-insurers), complex group structure (whether a firm has a subsidiary), and mutual (whether a firm is a mutual or a public entity). We proxy for market power using proportion of liabilities in the linked product line[28] and total surrenders as a proportion of net liabilities. To show that our results are robust to measurement error due to the use of rating regressions, we present results only on the population of rated firms in specification IV. Finally, to compare results on exactly the same set of firms, in specification V, we restrict the sample to firms that underwrite in both markets in both sub-periods (1997-2002 and 2003-2007).

The table mirrors the results seen in the charts. The coefficient on the interaction term $C \times P$ is negative, statistically significant and economically large in magnitude for traditional market across specifications. In the specification after adding demand controls (specifica-

[25]Note that we have suppressed the firm and time subscripts for ease of notation.

[26]The exact list of demand controls are provided in table notes.

[27]Insurance is a complicated financial product that is largely sold through financial advisors who can conduct firm level financial analysis, even though households may not do so directly.

[28]This is equivalent to using proportion of liabilities in traditional products as both variables sum to one.

tion III), the coefficient on the interaction term is -0.51 for the traditional market, implying that the difference in traditional underwriting between constrained and unconstrained firms shrinks by 51% between 2003 and 2007 relative to the difference between the two groups between 1997 and 2002. In other words, relative to unconstrained firms, constrained firms reduce underwriting by 51% post 2002 compared to pre 2002. Thus, our results show that the product market changes are significant and large in magnitude even after controlling for observed firm characteristics that drive cross-sectional variations in demand elasticities across the two groups. Similarly, there is a reduction of 9% in the linked market between the two groups, however, the estimated coefficient is statistically insignificant. Amongst rated firms, the reduction in traditional underwriting is close to 80% and linked underwriting is 20% (specification IV). Among firms that underwrite in both markets in both sub-periods (specification V), the decline in traditional underwriting is even stronger at 85%. Thus, constrained group reduces underwriting in both traditional and linked markets after 2002 compared to before 2002. However, compared to the unconstrained group, the reduction is higher in the more capital intensive traditional market.

Extensive Margin: We next analyze the effect of the change in regulation on the extensive margin of underwriting i.e. the choice of whether to underwrite or not. Table 4 presents the average propensities to underwrite for constrained and unconstrained firms in the two periods (1997-2002 and 2003-2007). Constrained firms have a lower propensity to underwrite both traditional and linked products in the period after 2002. For example, propensity to underwrite traditional products falls from 0.96 to 0.88, while linked products falls from 0.58 to 0.53. In contrast, unconstrained firms have a relatively stable presence in traditional products and experience an increase in the propensity to underwrite linked products from 0.51 before 2002 to 0.56 after 2002. We analyze these trends more formally using a difference-in-differences regression[29]. The propensity to underwrite traditional products declines by 2.8 percentage points (specification III) for constrained firms relative to unconstrained firms. However, this difference is statistically insignificant. In contrast, there is a statistically significant and large decline in the propensity to underwrite linked products of 8.2 percentage points. This is a result of both constrained firms curtailing underwriting and unconstrained firms, who have the balance sheet capacity to underwrite in the new regulatory environment, increasing underwriting of linked products.

Overall, the results are consistent with the predictions of our model of insurance pric-

[29]Table reports estimations of a linear probability model. For robustness, we also estimate a logit specification and find similar results.

ing with regulatory frictions. A shift in the regulatory capital requirement for traditional products leads to an increase in marginal cost, higher prices and thus lower demand for *all* insurance. Our results show that this is indeed true and in fact the increase is significantly more pronounced for constrained firms who experience higher regulatory costs and thus suffer significantly higher loss in market share across all product lines. As we analyze firms that have large share of legacy traditional liabilities, an increase in capital requirements for traditional products results in a large numbers of these firms becoming constrained. Because constraints operate at the firm level, marginal cost of providing both types of insurance - traditional and linked - goes up. Thus, these changes are not just restricted to the traditional market. However, the reduction in underwriting for constrained firms relative to unconstrained firms is more pronounced for traditional products, which attracted a higher capital charge under the new regulatory regime, implying a shift in the product mix towards linked products.

7.1.3. Robustness

Placebo tests on cut-off choices: We have, so far, defined a firm to be unconstrained if its capital buffer (ratio of available capital to required capital) is greater than one. We now relax this assumption and test the sensitivity of our results by varying the threshold capital buffer cut-off that identifies a firm to be unconstrained. We consider four alternate cut-off choices: 0.8, 1.2, 1.5, and 1.8. In the first specification, we consider a firm to be constrained (unconstrained) if it has a buffer below (above) 0.8. In the next three specifications, a firm is considered constrained if it has a buffer below one and unconstrained if the firm has a buffer greater than the alternate threshold. For example, when we choose the alternate threshold to be 1.2, firms with buffer above 1.2 are unconstrained and firms below buffer of 1.0 are constrained. Firms in between (1.0 and 1.2) are ignored. Moreover, as firms with buffer between 1.0 and 1.2 are also perceived to be thinly capitalized and experience increased regulatory oversight, the alternate cutoff of 1.2 is particularly useful to check the robustness of our empirical findings.

Table 5 reports the coefficient on the interaction term $C \times P$ for specification III with all demand controls. Three key results stand-out. First, the cutoff choice of 0.8 produces weaker results, implying that firms with buffer between 0.8 and 1.0 behave differently from firms above 1.0. Thus, tagging them as unconstrained is inappropriate. Second, the results are not sensitive to the choice of how an unconstrained firm is defined. Our results, with alternate cut-offs (1.2, 1.5, and 1.8), are statistically significant and economically similar in magnitude when compared to the main specifications for intensive and extensive margins (tables 3 and 4), implying that our results are valid across the distribution of unconstrained firms and not just in a particular buffer segment. Finally, our results remain robust in the alternate specification where only firms above the buffer of 1.2 are considered unconstrained, lending further credibility to the main findings.

Other robustness checks: We conduct a number of other robustness checks (table 6). First, we consider alternate measures of the dependent variable: (i) number of policies underwritten, a variable only available for traditional products; (ii) market share, computed as the ratio of firm's premium income in product j at time t divided by the total premium income across all firms in product j at time t. Our results for traditional products remain economically large and statistically significant for both dependent variable definitions. For the linked market, differences, although directionally correct, are statistically insignificant when market share is used as an alternate definition, which is consistent with the overall finding that the difference between the two groups is relatively less stark in the linked product line.

Second, we consider alternate specifications of the capital requirement model. To ensure that our results are robust to any error in how capital buffer is measured, we exclude firms that have a capital buffer between 0.9 and 1.1, which amounts to about 20% of firms. Our results remain robust and in line with the main specifications for intensive (table 3) and extensive (table 4) margins, with constrained firms exhibiting a higher (and statistically more robust) decline in traditional underwriting than linked underwriting. We also change the capital requirement model from the baseline model, where each risk is modeled separately, to the 'One Risk Model', where all risks are modeled jointly. See Appendix C.1 for details on the 'One Risk Model'. All our results remain economically large and highly robust in this alternate specification where capital requirements across risk categories are jointly predicted.

7.2. Balance sheet Restructuring and Firm Reorganizations

To provide evidence of the extent of financial constraints, we evaluate major balance sheet restructuring (transfers) and reorganizations by firms. A transfer involves sale (transfer-out) or purchase (transfer-in) of another firm's assets and liabilities. We show that a higher proportion of constrained firms undertake net transfers of their assets after 2002, compared to unconstrained firms. We also find that a higher proportion of constrained firms undergo reorganizations, a change in legal owner typically following change in the firm's parent company. Transfers and reorganizations are indeed yet another mode of adjustment to meet the new regulatory requirements. By selling a major portion of their portfolio or by slowing down on planned purchase of new assets, firms were able to effectively reduce their future risk-based capital requirements. On the other hand, a reorganization could be a means to raise fresh capital from a new parent firm. Transfers and reorganizations, therefore, help alleviate regulatory constraints by either reducing capital requirements or increasing available capital.

Table 7 provides a comparison of transfers and reorganizations in the two sub-samples between unconstrained and constrained firms. 29% of constrained firms sell a major portion of their portfolio after 2002, compared to only 4% until 2002. In contrast, the percentage of unconstrained firms that sell a portion of their portfolios increases from 10% before 2002 to only 17% after 2002. Further, only 2% of constrained firms purchase other firms' assets and liabilities after 2002, compared to 20% of firms until 2002. The percentage of unconstrained firms that purchase other firms' assets and liabilities jumps up from 8% before 2002 to 12% after 2002. In addition, 39% of constrained firms undergo a change in parent after 2002, up from 16% until 2002, while unconstrained firms do not undergo a significant change.

We analyze these trends more formally using a difference-in-differences logit regression with transfers and reorganizations as the dependent variable. Our empirical specification is,

$$T_{it} = \Phi(\alpha + \beta(C_i \times P_t) + \delta X_{it-1} + \alpha_t + \epsilon_{it}) \tag{19}$$

where T_{it} is a dummy variable for transfer-out, transfer-in, or reorganization, C_i is an indicator variable that takes a value of 1 if a firm is constrained, P_t is the post regulation dummy variable that takes a value of 1 after 2002, X_{it-1} are firm specific control variables, and α_t are time fixed effects.

Table 8 shows the results. On an average, the constrained group is 5 times more likely to have a major sale of assets and liabilities, 95% less likely to buy another firms' assets and liabilities and 4 times more likely to have a change in parent after 2002 vis-a-vis before 2002, as compared to the unconstrained group during the same period (specification I). Following Cremers, Nair and John (2009), we control for a number of balance sheet characteristics that are known to drive takeover propensity in firms. These factors include firm size, leverage, liquidity and ROA. In addition, we also control for asset and liability risk profile, group structure and mutual status in specification II. The results remain statistically significant and similar in magnitude, implying that regulatory constraints were indeed binding and led firms to adjust on multiple fronts to make sure they met the new regulatory requirements.

7.3. *Evolution of Capital to Assets Ratio*

To provide evidence that our measure of financial constraints is indeed driven by changes in capital requirements, we examine the evolution of capital to assets ratio (capital ratio) for constrained and unconstrained firms from 1997 to 2007. Figure 5 presents the results. The following comments are in order. Firm's choice of capital ratio is endogenous. As capital ratio is a key determinant of our measure of regulatory constraints, there could be a concern that level of regulatory constraints is correlated with the event itself i.e. the announcement of the new regulatory regime. We show that the choice of capital ratio appears to have been made much before the new regulatory regime was announced in 2002. Constrained firms consistently have a lower capital ratio compared to unconstrained firms throughout 1997 to 2002, which mitigates concerns that the choice of capital ratio itself is endogenous.

Second, both groups share similar dynamics in their capital ratios before the new regulation is announced in 2002. The difference between the two groups is highly stable and persistent before 2002. Third, the dynamics between the two groups changed after 2002. Constrained firms adjusted their capital ratios upwards, while unconstrained firms maintained a relatively stable capital ratio during the five years window post 2002. We formalize these trends using a difference-in-differences regression with capital ratio as the dependent variable. Our empirical specification is,

$$\bar{K}_{it} = \alpha + \alpha_i + \alpha_t + \beta(C_i \times P_t) + \delta X_{it} + \epsilon_{it} \tag{20}$$

where $\bar{K}_{it}$ is the capital to assets ratio, C_i is an indicator variable that takes a value of 1 if a firm is constrained, P_t is the post regulation dummy variable and takes a value of 1 after 2002, X_{it} are firm specific control variables, α_i are firm fixed effects, and α_t are time fixed effects. As before, we select a 5 year window before 2002 to capture pre-dynamics and a 5 year window after 2002 to identify the effect of the change in regulation. Table 9 shows the results. The average difference between the groups after 2002 compared to average difference between the groups before 2002 is statistically significant and economically large in magnitude. On average, the constrained group increased their capital ratio by 4.8 percentage points (specification I) as compared to the unconstrained group during the five years window after 2002, supporting the hypothesis that the new capital requirements became a binding constraint for the constrained firms.

In specifications II and III, we account for reasons other than capital requirements that may also drive a firm's capital ratio. We first control for balance sheet factors that could drive capital ratio differentially across the two groups, including various asset and liability risks on an insurance firm's balance sheet. In particular, an insurance firm with a higher than average allocation to equities or a firm that sells riskier products, for example, may optimally choose a different level of capital to reflect this higher risk. If the constrained group contains a greater proportion of such firms, then our results could be driven by this difference in characteristics and not just by changes in capital requirements. In specification II, we add a number of these characteristics including asset risk (proportion of assets held in equities, non government bonds, and mortgages), liability risk (claims resulting from death, disability, annuity, and surrenders as a proportion of net liabilities), reinsurance (proportion of liabilities ceded to re-insurers), group structure (whether a firm has a subsidiary), and mutuals (whether a firm is a mutual or a public entity). In addition, we control for change in liability mix over time. As linked products require substantially lower amount of capital, we include share of liability in linked products as an additional explanatory variable. However, the coefficient on the interaction term $C \times P$ remains large (0.048) and statistically significant, implying that constrained firms had a higher increase in capital ratio compared to unconstrained firms after 2002.

In specification III, we include a number of other explanatory variables related to firm re-organizations. In particular, we include dummy variables for any instances of transfers and reorganizations, which could also have a significant impact on a firm's capital ratio. If the constrained group experiences a differential rate of reorganizations relative to the unconstrained group, then this could explain the subsequent increase in capital ratio for constrained firms. However, as we show, the differential capital ratio evolution between the constrained and unconstrained firms persists after controlling for both balance sheet characteristics and re-organizational factors, implying that the new capital requirements became binding and could lead to significant spill-overs in the product market.

8. Placebo Test and Alternative Explanations

8.1. Placebo Tests

To provide evidence that the observed product market changes are due to changes in capital requirements, we conduct placebo tests with "alternate event years". The test exactly mirrors the procedure followed in 2002. We sort the population of existing traditional firms in alternate years - 1997, 1998, and 1999 - into two groups - constrained and unconstrained - depending on their capital buffer and repeat the difference-in-differences regression. Table 10 presents these results. The first four columns show the results for product market changes and the last column shows results for capital to asset ratio. We report the coefficient and standard errors for the main independent variable of interest, the interaction between constrained firms and post 2002 dummy ($C \times P$), for the third specification with all demand controls for product market regressions and all balance sheet controls for capital ratio regression. The parameter estimates are insignificant or have the opposite sign for all the alternate years that we consider, implying that the observed product market changes are unique to 2002 when the regulatory changes took place. This helps substantiate the results in the previous section that the new capital regulation regime led to a significant shift in the product market equilibrium of the insurance sector.

8.2. Insurance Prices

The paper primarily focuses on the following margins: amount of underwriting, balance sheet restructuring and firm reorganizations. We now present evidence on insurance prices. The data are hand collected from Moneyfacts Life and Pensions, which reports price quotes for some of the larger firms in the industry[30]. However, the price quotes are noisy. Insurance products are typically heterogeneous and small differences in contract features could matter for pricing, a source of variation not reported in Moneyfacts. Moreover, the coverage of this database is rather limited as not all firms are required to report. Thus, although the data does not allow for a more comprehensive analysis by splitting the sample into constrained and unconstrained firms, for completeness, we show that the broad price trends were upwards for traditional products and remained flat for linked products, consistent with these firms being constrained and a supply side interpretation of our results.

We focus on price quotes on pensions and annuities products, which account for majority of traditional and linked liabilities in the UK.

- Pensions: Pension contracts have an upfront and ongoing annual management fees. As different companies load up differently across upfront and ongoing charges, to standardize and ascertain the overall magnitude, we compute "reduction in yield ratio" (RIYR)[31], which is the ratio of investment yield without fees to investment yield after taking account of fees. Appendix D.1 describes these calculations. The higher (lower) the ratio, the higher (lower) is the effective price of the pension contract. We consider single premium contracts with investment horizons of 20, 25 and 30 years. Pensions are of both types: traditional and linked.

[30]Total assets of the average firm reporting price of traditional products is £16Bn and linked products is £11Bn.

[31]See FCA Handbook Conduct of Business Sourcebook 13, Annex 4.

- Annuities: Annuities are quoted as an annual annuity income to the policyholder for an initial investment of £10,000. To ascertain "price" of the contract, we compute "annuity ratio" (AR)[32], ratio of the initial investment to the expected present value of the annuity income over a fixed horizon. Thus, annuity ratio provides a measure for the money's worth of a contract. The lower (higher) the annuity ratio, the greater (smaller) are the benefits to the policyholder. We show pricing evidence for females aged 65 years for various annuity contracts[33]. Only traditional products are annuitized.

Figure 6 shows the RIYR and AR graphically and table 11 reports average price quotes, RIYR, and AR for the two sub-samples: 1997 to 2002 and 2003 to 2007. To be included, we require firms to report prices in each sub-sample. For traditional products, annuities and pensions, we see an increase in average prices post 2002. Average annuity ratio for the contract with no mortality guarantee increased from 1.08 to 1.23, stemming from a decline in annuity amount from £779 to £649 on an average. Average RIYR for traditional pension contracts increased from 1.008 to 1.011 for an investment horizon of 25 years. This is also evident from the increase in average annual management fees from 65 bps to 104 bps post 2002. On the other hand, linked pensions did not go through a big change, where the increase in average annual management fees from 82 bps to 96 bps seems to be offset by a proportional decline in upfront fees. However, it is important to caveat this by saying that the price estimates are noisy, perhaps due to subtle differences in contracts across firms, a feature we cannot control for as it is not reported in Moneyfacts. To absorb firm specific variation in contract features, we estimate the price trends with firm fixed effects and find similar results. Nevertheless, the differential price trends for traditional and linked products provide evidence consistent with supply side interpretation of our findings.

8.3. Dot-Com Crash

As the new regulatory regime followed on the heels of the dot-com crash, one concern could be that our measure of regulatory constraints coincides with firms that were most affected by the dot-com crash. Thus, financial constraints due to the dot-com crisis, and not regulatory constraints per se, could be driving the subsequent product market behavior that we document. There are two factors that determine constraints due to the dot-com crash: (i) losses suffered on invested assets; and (ii) payments due to be paid to policyholders from

[32] See FCA Occasional-Papers-5.

[33] Annuities can be with or without mortality guarantee. In products without mortality guarantee, payment stops when the policyholder dies, whereas products with a mortality guarantee provide payments for the length of the guarantee. Contracts can also be fixed or escalating. In a fixed annuity contract, payments are fixed over the life of the policy, while benefits grow at a specified rate for escalating contracts.

guaranteed bonuses declared in the past. Thus, firms that suffered the biggest investment losses and offered the most onerous guarantees were likely to be most constrained due to the dot-com crash. In our empirical analysis, we focus on the first measure as data on level of guarantees is not available.

We construct two alternate ways to measure the extent of losses suffered on the asset side of the balance sheet: (i) change in the market value of equity portfolio between 1999 and 2002 (equity portfolio growth); (ii) investment income between 1999 and 2002 as a proportion of total assets in 1999 (investment income ratio). We sort firms into two groups - affected and unaffected - depending on whether they have below median (affected) or above median (unaffected) investment income ratio or equity portfolio growth. Table 12 shows results of the difference-in-differences regression with the alternate measures of constraints. To see that our measure of constraints due to the dot-com crash are indeed valid, first note that firms that are more affected by the dot-com crash have a higher propensity to do net transfers and have a change in parent relative to firms that are less affected (panel B). In contrast, the parameter estimates for the product market and capital ratio regressions are insignificant for both measures, implying that firms that were most affected by the crash did not alter their underwriting behavior, as compared to firms that were less affected by the crash. Thus, the product market behavior we document does not seem to be driven, as much by the dot-com crash, as by the regulatory changes that took place in 2002.

9. Conclusion

How do insurance companies adjust to changes in capital regulation? This paper informs the literature on various margins of adjustment and costs of capital regulation for insurance companies. We document a marked shift in the product mix of the UK insurance sector after a risk based capital regulation regime was introduced in 2002. Linked products, which are mainly investment vehicles similar to mutual funds, increased from £345 billion in total liabilities in 2002 to more than £1 trillion in 2014. In the cross-section of firms, we show that these product market changes are driven by firms that are constrained, i.e. have a shortfall in their regulatory capital positions in the new regime. We also show that a higher proportion of constrained firms undertake net sale (transfer) of assets and liabilities and undergo reorganizations, which are potentially other modes of adjustment to meet the new regulatory requirements.

The implementation of Solvency II[34] in 2016 introduced risk-based capital requirements across the European Union. By adding to the limited existing knowledge about how insurance companies adjust to shifts in capital regulation, our analysis could be relevant to understand the consequences of these regulatory changes on insurance markets in Europe. Our paper could also be relevant for understanding the effects of the introduction of risk-based capital requirements more widely. Traditional products, products that became more capital intensive in the new regime, require insurance companies to assume higher risks on their balance sheets as these products are designed to protect policyholders from idiosyncratic and market risks. A shift towards linked products, products that do not fulfill the economic function of traditional products, could imply reduced risk transformation and risk sharing thus leaving households more exposed. Although a comprehensive welfare analysis of the regulatory change is beyond the scope of this paper[35], our results indicate that the benefits in terms of policyholder protection should be weighed against the decrease in traditional insurance activity as the welfare cost of sub-optimal insurance choices are significant (Koijen, Nieuwerburgh, Yogo (2015)).

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Figure 1: Required Capital to Total Assets Ratio by Product Lines

The chart shows average required capital to total assets ratio in the old regime as compared to the new regime for reporting firms between 2003 and 2006. Since firms submit stress test results for their entire balance sheets (and not by each product line separately), we focus on firms that have more than 95% liabilities in a particular product line to compute the average required capital ratio for that product line. The vertical error bars denote the associated 95% confidence intervals. Required capital includes any add-ons that FSA levied after reviewing firms' stress test submissions.

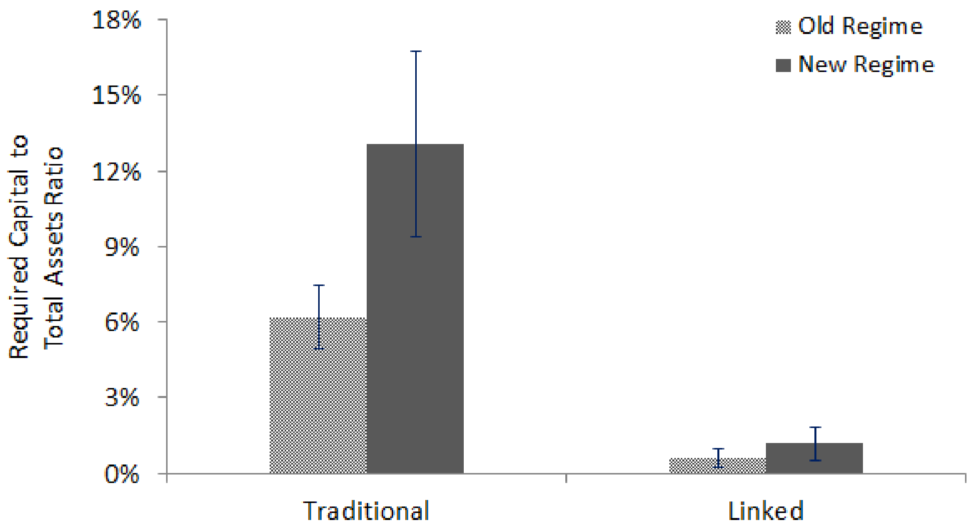


Figure 2: Long Term Trends in Product Mix

The left panel shows a plot of net linked liabilities as a proportion of total net liabilities for the UK insurance industry as a whole from 1985 to 2014. The right panel shows the ratio of linked underwriting to traditional underwriting. Only data for direct new premium income, i.e. premium income from new policies net of reinsurance excluding premium arising from policies underwritten in the past, are included. The horizontal blue lines indicate average values from 1985 to 2002 and from 2003 to 2014. The vertical line corresponds to the announcement of the new regulation in 2002.

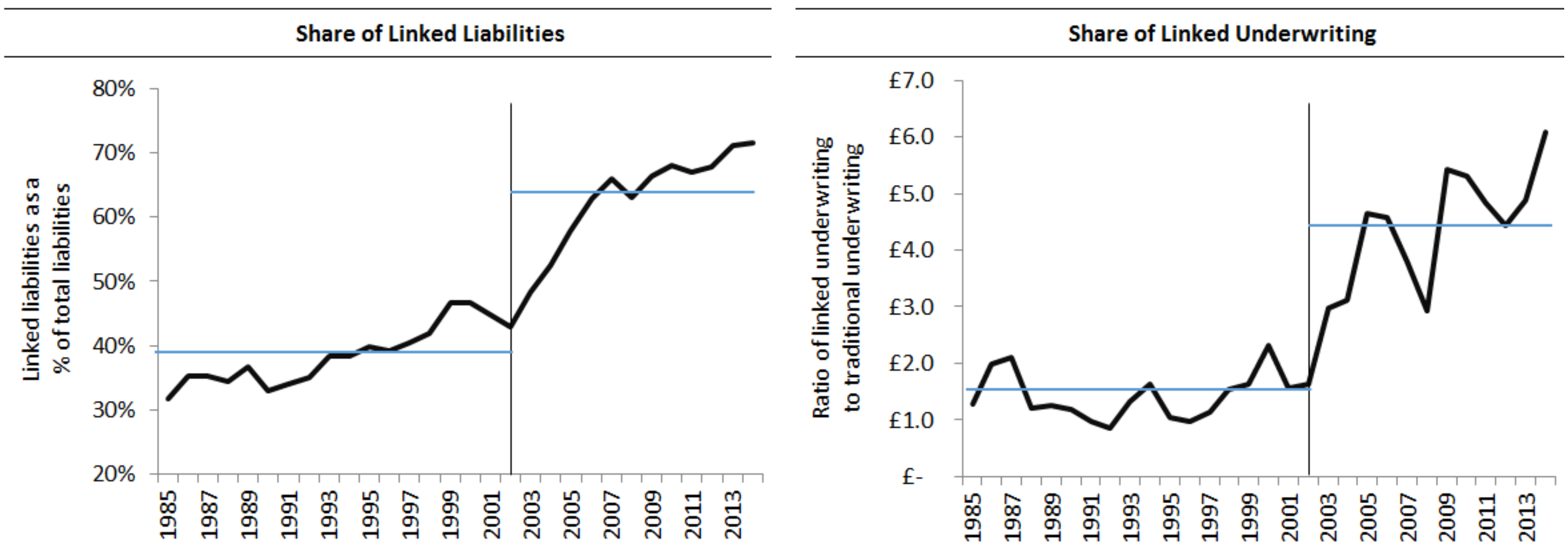


Figure 3: Distribution of Capital Buffers - Old vs. New Regimes

Chart provides a distribution of capital buffers for our sample of traditional firms in 2002. The black bars show the distribution of capital buffers under the new regime, where capital requirements are predicted using the baseline capital requirement models. The gray bars show the distribution of capital buffers under the old regime. The shaded area to the left of *one* denotes the mass of constrained firms, firms with available capital less than required capital.

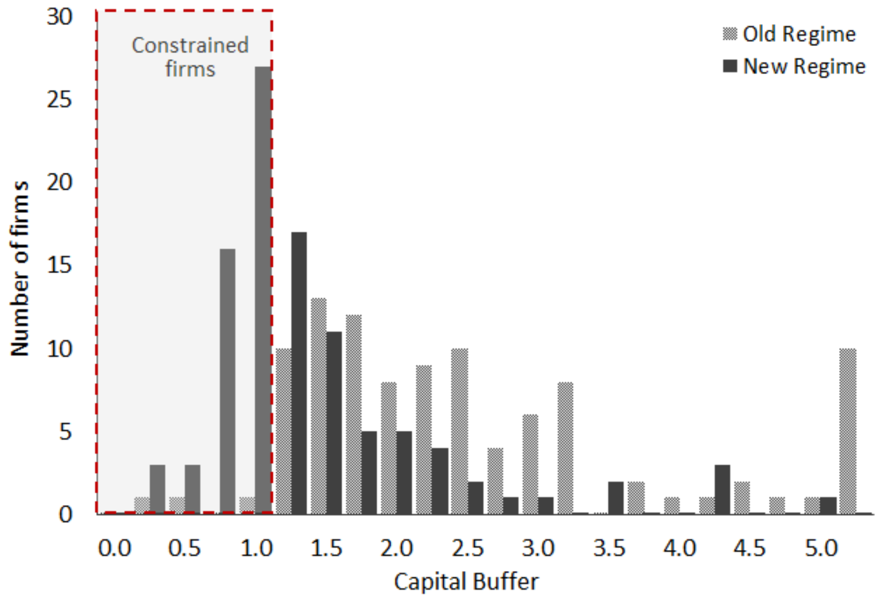


Figure 4: Product Market - Graphical Results

The chart shows average underwriting by constrained and unconstrained firms from 1997 to 2007. The left panel shows traditional premium underwritten and the right panel shows linked premium underwritten in £million. Only data for direct new premium income, i.e. premium income from new policies net of reinsurance excluding premium arising from policies underwritten in the past, are included. The vertical line corresponds to the announcement of the new regulation in 2002.

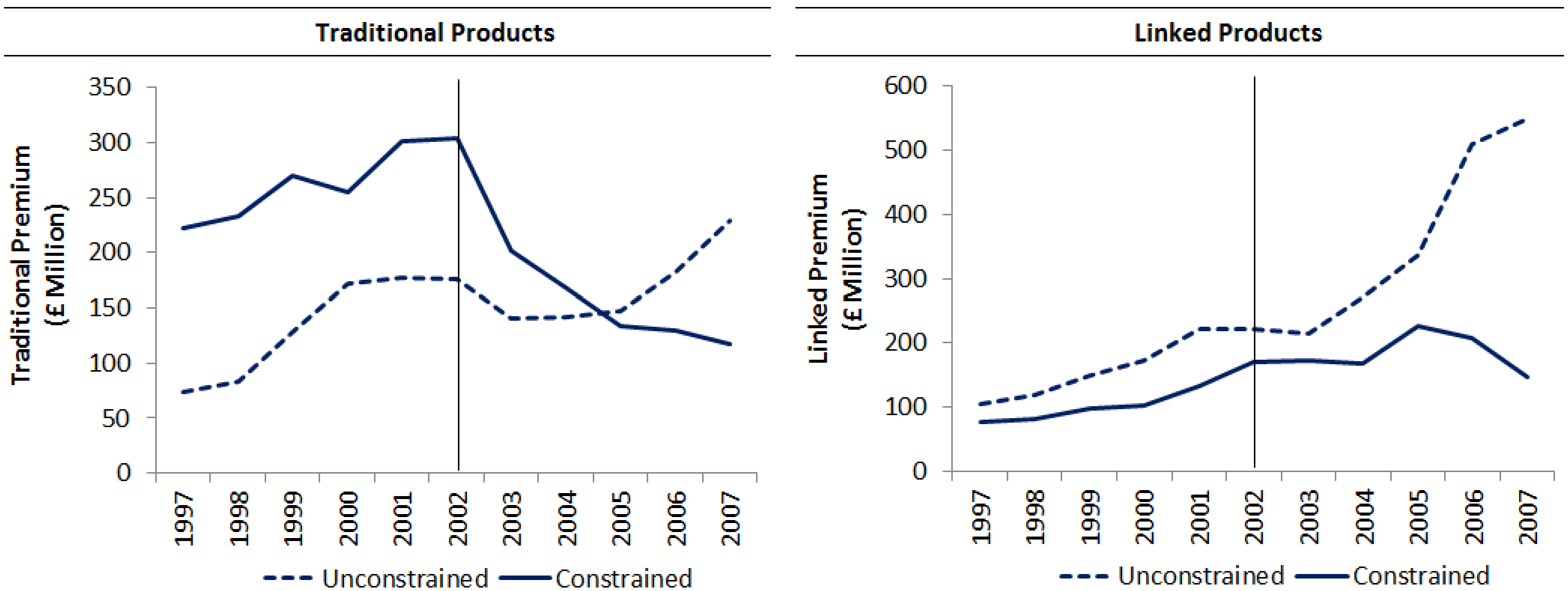


Figure 5: Available Capital to Total Assets Ratio - Graphical Results

The chart shows the evolution of available capital to total assets ratio from 1997 to 2007 for constrained and unconstrained firms. The vertical line corresponds to the announcement of the new regulation in 2002.

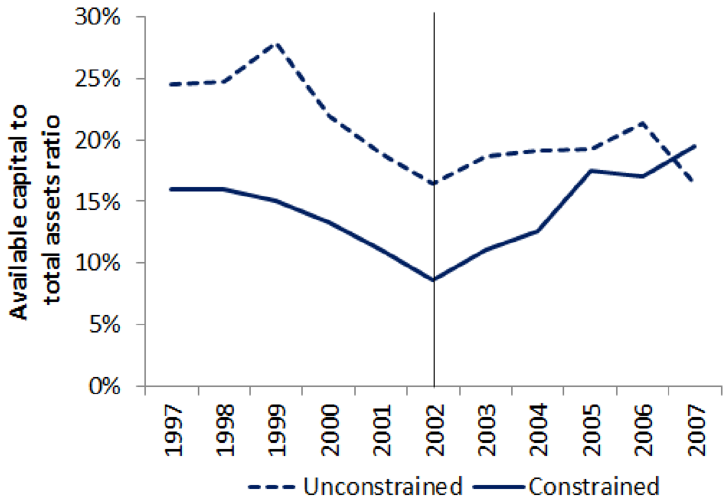


Figure 6: Insurance Pricing

Figure shows annuity ratio and reduction in yield ratio (RIYR) graphically from 1997 to 2007 for annuity, traditional pensions, and linked pensions. Dotted gray line shows average values and large dark points show data for individual firms. To be included, we require firms to report prices in both sub-periods (1997-2002 and 2003-2007). The data are from Moneyfacts Life and Pensions, which collects price quotes from insurance providers in the UK.

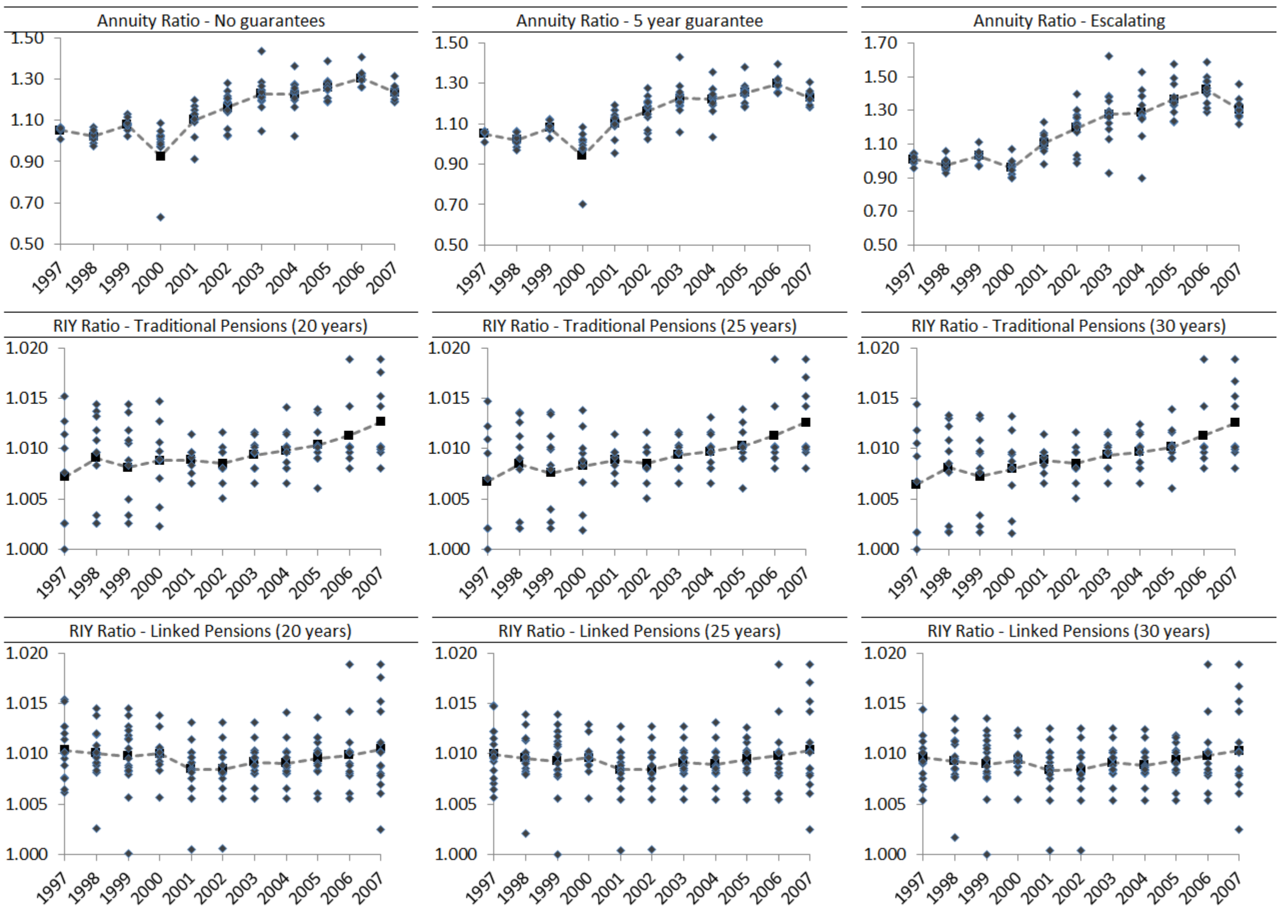


Table 1: Capital Requirement Models

Table shows the baseline capital requirement models. Dependent variables are the ratio of required capital in risk group r to total assets. Columns depict results by risk groups. In specification I under a risk group, we show the final model that we use to predict capital requirements in 2002. All other specifications are provided to show robustness of the variables used and model fit without time fixed effects. Table reports parameter estimates, standard errors in parentheses, and R-squared. Data pertain to stress-test submissions between 2003 and 2006 for firms with more than £500 million in total assets.

Contribution	Market (30%)		Credit (12%)			Interest Rate (12%)		Underwriting (32%)		Other (15%)	
Characteristics	I	II	I	II	III	I	II	I	II	I	II
Equity*FTSE(vol)	0.03***	0.03***									
	(0.002)	(0.002)									
Non-Gov Bonds*Yield			0.01***	0.01***							
			(0.001)	(0.001)							
Mortgages & Loans			0.04***		0.06***						
			(0.009)		(0.015)						
All Bonds*Yield						0.001	0.002**				
						(0.001)	(0.001)				
Death & Disability								0.92***	0.94***		
								(0.080)	(0.078)		
Subsidiaries										1.48***	1.43***
										(0.170)	(0.167)
Intercept	0.006	0.003*	-0.005**	0.000	0.005***	0.007	0.004***	0.006	0.006***	0.011*	0.003*
	(0.005)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.001)	(0.007)	(0.002)	(0.006)	(0.002)
Time Fixed Effects	Y	N	Y	N	N	Y	N	Y	N	Y	N
R-squared	0.64	0.63	0.74	0.64	0.13	0.10	0.06	0.63	0.62	0.48	0.45
N	91	91	91	91	91	91	91	91	91	91	91

Table 2: Descriptive Statistics: Characteristics of Constrained and Unconstrained Firms

Panel A shows solvency profile and panel B shows other balance sheet characteristics of *traditional* constrained and *traditional* unconstrained firms in 2002. Table reports sample means and standard errors are in parentheses. A test of difference in sample means across the two groups are reported in the last column.

Characteristics	Unconstrained	Constrained	Difference (t-stat)
Number of Firms	52	49	
Panel A: Solvency			
Capital Buffer $\hat{B}_{i,02}$	1.81	0.73	7.87
	(0.13)	(0.03)	
Capital-Asset Ratio $\bar{K}_{i,02}$ (%)	16.5	8.6	3.72
	(1.57)	(1.40)	
Capital Requirement $\bar{R}_{i,02}$ (%)	9.66	12.42	-1.39
	(0.98)	(1.77)	
Panel B: Other Characteristics			
Average Assets (£Billion)	3.80	7.53	-1.57
	(1.09)	(2.15)	
Traditional Liabilities (%)	92.9	89.0	1.62
	(1.59)	(1.85)	
ROA (%)	-1.85	-1.38	-0.16
	(2.26)	(1.78)	
Liquidity Ratio (%)	40.5	28.3	3.03
	(3.14)	(2.49)	
Asset Risk (%)	47.1	55.1	-1.53
	(3.83)	(3.58)	
Death & Disability (%)	3.59	6.58	-1.31
	(1.12)	(2.03)	
Annuity (%)	1.09	1.25	-0.38
	(0.35)	(0.30)	
Surrenders (%)	2.52	2.56	-0.07
	(0.47)	(0.47)	
Reinsurance (%)	12.7	11.7	0.26
	(2.70)	(2.97)	
Mutual Status (%)	53.9	51.0	0.28
	(6.98)	(7.22)	
Subsidiaries (%)	13.46	20.41	-0.93
	(4.78)	(5.82)	
Rating Score	7.55	7.27	0.52
	(0.39)	(0.37)	

Table 3: Product Market Changes - Intensive Margin

Table reports results of the difference-in-differences regression. Panel A shows results for the traditional market and panel B for the linked market. The dependent variable is $log(NewPremium)$. $C \times P$ is the main independent variable of interest where C is an indicator variable that takes a value of 1 if a firm is constrained (firms with capital buffer less than 1) and P is the post regulation dummy variable that takes a value of 1 after 2002. Fixed effects are denoted at the bottom of each panel. Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%. Controls: *(1) Rating & Size*: Log(assets) and Credit Rating; *(2) Financial strength*: Capital to Asset Ratio, ROA, Liquidity Ratio, Asset Risk; Death & Disability; Annuity claims; Reinsurance; Subsidiaries; and Mutual status; *(3) Market Power*: % liabilities in linked market, Surrender claims. Population: *(1) All*: all firms; *(2) Rated*: firms that have a credit rating; *(3) Both*: firms that underwrite in both traditional and linked markets in both sub-periods (1997-2002 and 2003-2007).

	Panel A: Traditional					Panel B: Linked				
Variables	I	II	III	IV	V	I	II	III	IV	V
C × P	-0.644**	-0.615**	-0.512**	-0.796**	-0.846**	-0.385	-0.296	-0.093	-0.203	0.035
	(0.289)	(0.265)	(0.245)	(0.320)	(0.329)	(0.505)	(0.467)	(0.430)	(0.465)	(0.419)
Demand Controls										
(1) Rating and size	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
(2) Financial strength	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
(3) Market power	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Population	All	All	All	Rated	Both	All	All	All	Rated	Both
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	971	958	956	554	561	566	560	558	421	531
R-squared	0.909	0.918	0.921	0.877	0.860	0.849	0.865	0.880	0.859	0.875
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm

Table 4: Product Market Changes - Extensive Margin

Panel A reports the average propensities to underwrite traditional and linked products for constrained and unconstrained firms for the two sub-samples. Panel B reports results of the difference-in-differences regression. The dependent variable is a dummy variable that takes a value of 1 if firms underwrite positive quantities of insurance and 0 otherwise. $C \times P$ is the main independent variable of interest where C is an indicator variable that takes a value of 1 if a firm is constrained (firms with capital buffer less than 1) and P is the post regulation dummy variable that takes a value of 1 after 2002. Fixed effects are denoted at the bottom of each panel. Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%. Controls: *(1) Rating & Size*: Log(assets) and Credit Rating; *(2) Financial strength*: Capital to Asset Ratio, ROA, Liquidity Ratio, Asset Risk; Death & Disability; Annuity claims; Reinsurance; Subsidiaries; and Mutual status; *(3) Market Power*: % liabilities in linked market, Surrender claims.

Panel A: Descriptive Statistics						
	Traditional			Linked		
	1997-2002	2003-2007	Diff (t-stat)	1997-2002	2003-2007	Diff (t-stat)
Unconstrained (%)	95.4	94.1	0.66	51.3	55.9	-1.06
	(1.21)	(1.53)		(2.88)	(3.24)	
Constrained (%)	95.6	88.3	3.09	58.2	53.4	1.08
	(1.23)	(2.16)		(2.98)	(3.35)	

Panel B: Regression Results						
	Traditional			Linked		
Variables	I	II	III	I	II	III
C × P	-0.055	-0.042	-0.028	-0.096**	-0.099**	-0.082**
	(0.044)	(0.041)	(0.034)	(0.044)	(0.043)	(0.038)
Demand Controls						
(1) Rating and size	No	Yes	Yes	No	Yes	Yes
(2) Financial strength	No	No	Yes	No	No	Yes
(3) Market power	No	No	Yes	No	No	Yes
Population	All	All	All	All	All	All
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,036	1,018	1,007	1,036	1,018	1,007
R-squared	0.531	0.615	0.647	0.863	0.873	0.882
Cluster	Firm	Firm	Firm	Firm	Firm	Firm

Table 5: Product Market Changes - Cutoff Sensitivities

Table reports results of the difference-in-differences regression for both intensive and extensive margin of underwriting. We report the coefficient and standard errors for the main independent variable of interest, $C \times P$, for the third specification with all demand controls (rating & size, financial strength, and market power). N_U denotes number of unconstrained firms that satisfy the cutoff criteria in column one. Fixed effects are denoted at the bottom of each panel. Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%.

		Traditional		Linked	
Cutoffs	N_U	Intensive	Extensive	Intensive	Extensive
Unconstrained = Buffer $\geq$ 0.8	71	-0.035	-0.023	0.304	-0.019
		(0.237)	(0.043)	(0.443)	(0.041)
Unconstrained = Buffer $\geq$ 1.0	52	-0.512**	-0.028	-0.093	-0.082**
		(0.245)	(0.034)	(0.430)	(0.038)
Unconstrained = Buffer $\geq$ 1.2	36	-0.496*	-0.025	0.042	-0.084**
		(0.273)	(0.036)	(0.480)	(0.042)
Unconstrained = Buffer $\geq$ 1.5	24	-0.547**	0.001	-0.321	-0.092*
		(0.273)	(0.040)	(0.552)	(0.052)
Unconstrained = Buffer $\geq$ 1.8	18	-0.661*	0.018	-0.378	-0.099
		(0.332)	(0.047)	(0.712)	(0.064)
Demand Controls					
(1) Rating and size		Yes	Yes	Yes	Yes
(2) Financial strength		Yes	Yes	Yes	Yes
(3) Market power		Yes	Yes	Yes	Yes
Population		All	All	All	All
Firm & Time Fixed Effects		Yes	Yes	Yes	Yes
Cluster		Firm	Firm	Firm	Firm

Table 6: Product Market Changes - Additional Robustness Tests

Table reports results of the difference-in-differences regression with alternate dependent variables, under alternate specifications of the capital requirement model, and alternate buffer cut-off choices. We report the coefficient and standard errors for the main independent variable of interest, $C \times P$, for the third specification with all demand controls (rating & size, financial strength, and market power). Fixed effects are denoted at the bottom of each panel. Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%.

	Traditional		Linked	
	Intensive	Extensive	Intensive	Extensive
Dependent Variable				
(1) Log(number of policies)	-0.872**			
	(0.393)			
(2) Market Share	-0.007***		-0.000	
	(0.002)		(0.003)	
Capital Requirement Model				
(3) Exclude firms Buffer $\in [0.9, 1.1]$	-0.424*	-0.030	0.045	-0.084*
	(0.238)	(0.041)	(0.491)	(0.047)
(4) One Risk Model	-0.672**	-0.039	-0.557	-0.085*
	(0.267)	(0.037)	(0.429)	(0.043)
Demand Controls				
(1) Rating and size	Yes	Yes	Yes	Yes
(2) Financial strength	Yes	Yes	Yes	Yes
(3) Market power	Yes	Yes	Yes	Yes
Population	All	All	All	All
Firm & Time Fixed Effects	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm

Table 7: Balance sheet Restructuring and Firm Reorganizations - Descriptive Statistics

Table reports descriptive statistics, sample means and standard errors in parentheses, on transfers and reorganizations. A comparison between unconstrained and constrained firms before and after 2002 is shown. The column 'Diff (t-stat)' reports t-statistic for a test of difference in sample means across the two sub-samples.

	Unconstrained			Constrained		
	1997-2002	2003-2007	Diff (t-stat)	1997-2002	2003-2007	Diff (t-stat)
Transfer-out (%)	9.62	17.31	-1.15	4.08	28.57	-3.44
	(4.13)	(5.30)		(2.86)	(6.52)	
Transfer-in (%)	7.69	11.54	-0.66	20.41	2.04	2.98
	(3.73)	(4.47)		(5.82)	(2.04)	
Reorganizations (%)	23.08	25.00	-0.23	16.33	38.78	-2.54
	(5.90)	(6.06)		(5.33)	(7.03)	

Table 8: Balance sheet Restructuring and Firm Reorganizations - Regression Results

Table reports the difference-in-differences logit regression results. Dependent variables are dummy variables for transfer-out, transfer-in and reorganizations. $C \times P$ is the main independent variable of interest where C is an indicator variable that takes a value of 1 if a firm is constrained and P is the post regulation dummy variable that takes a value of 1 after 2002. Fixed effects are denoted at the bottom of each panel. Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%.

	Transfer-out		Transfer-in		Reorganizations	
Variables	I	II	I	II	I	II
C × P	1.591*	1.755*	-3.060**	-3.498**	1.311**	1.262*
	(0.918)	(1.066)	(1.326)	(1.553)	(0.662)	(0.757)
Odds Ratio	4.91	5.79	0.05	0.03	3.71	3.53
Balance sheet Controls	No	Yes	No	Yes	No	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,111	1,027	1,111	1,027	1,111	1,027
Cluster	Firm	Firm	Firm	Firm	Firm	Firm

Table 9: Capital to Assets Ratio - Regression Results

Table reports the difference-in-differences regression result. The dependent variable is capital to assets ratio. $C \times P$ is the main independent variable of interest where C is an indicator variable that takes a value of 1 if a firm is constrained (firms with capital buffer less than 1) and P is the post regulation dummy variable that takes a value of 1 after 2002. Fixed effects are denoted at the bottom of each panel. Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%. Controls: *(1) Balance sheet*: Asset Risk; Death & Disability, Annuity, and Surrender Claims; Reinsurance; Subsidiaries; Mutual status; % linked liabilities in linked market; *(2) Re-organization*: Dummy variables to identify reorganizations, transfer-out, and transfer-in.

Variables	I	II	III
C × P	0.048**	0.048**	0.043**
	(0.020)	(0.019)	(0.019)
Controls			
Balance sheet	No	Yes	Yes
Reorganization	No	No	Yes
Firm Fixed Effects	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes
Observations	1,020	1,020	1,020
R-squared	0.528	0.596	0.620
Cluster	Firm	Firm	Firm

Table 10: Placebo Tests - Alternate Event Years

Table reports the difference-in-differences regression results using three alternate event years. Coefficient and standard errors for the main independent variable of interest, $C \times P$, is reported with all demand controls for product market regressions and with balance sheet controls for the capital ratio regression (specification III). Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%.

	Traditional		Linked		Capital Ratio
Year	Intensive	Extensive	Intensive	Extensive	
1997	0.036	-0.063	0.641	0.060	0.012
	(0.368)	(0.038)	(0.470)	(0.089)	(0.036)
1998	-0.199	-0.071	-0.428	0.095*	0.027
	(0.332)	(0.044)	(0.342)	(0.055)	(0.034)
1999	-0.165	0.035	-0.500	-0.007	0.031
	(0.326)	(0.059)	(0.625)	(0.038)	(0.023)
Controls	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm

Table 11: Insurance Prices

Panel A reports average actual price quotes, annuity ratio, and reduction in yield ratio (RIYR) for the two sub-periods. The column 'Diff (t-stat)' reports t-statistic for a test of difference in sample means across the two sub-periods. Panel B provides a comparison between unconstrained and constrained firms before and after 2002. To be included, we require firms to report prices in both sub-periods. The data are from Moneyfacts Life and Pensions, which collects price quotes insurance providers in the UK.

	Panel A			Panel B			
	1997-2002	2003-2007	Diff (t-stat)	1997-2002	2003-2007	1997-2002	2003-2007
Annuities	All (N=13)			Unconstrained (N=8)		Constrained (N=5)	
Annuity Ratio							
No guarantees	1.08	1.23	4.12	1.12	1.26	1.01	1.19
5 year guarantee	1.08	1.23	4.39	1.12	1.25	1.02	1.19
Escalating	1.09	1.30	3.97	1.12	1.36	1.03	1.20
Annuity Amount							
No guarantees (£)	779	649	-3.61	739	632	844	677
5 year guarantee (£)	764	645	-4.23	733	629	813	670
Escalating (£)	441	360	-4.17	431	338	458	394
Traditional Pensions	All (N=12)			Unconstrained (N=9)		Constrained (N=3)	
Reduction in Yield Ratio (RIYR)							
20 years	1.008	1.011	2.01	1.009	1.010	1.008	1.014
25 years	1.008	1.011	2.27	1.008	1.010	1.007	1.013
30 years	1.008	1.011	2.45	1.008	1.010	1.007	1.013
Fees							
Upfront Charges (%)	3.50	0.75	-3.85	3.27	0.44	4.18	1.67
Annual Charges (%)	0.65	1.04	3.25	0.68	0.96	0.56	1.26
Linked Pensions	All (N=19)			Unconstrained (N=15)		Constrained (N=4)	
Reduction in Yield Ratio (RIYR)							
20 years	1.010	1.010	0.52	1.010	1.010	1.009	1.012
25 years	1.009	1.010	0.82	1.010	1.010	1.009	1.012
30 years	1.009	1.010	1.03	1.009	1.010	1.009	1.011
Fees							
Upfront Charges (%)	2.86	0.89	-3.75	2.84	0.71	2.93	1.56
Annual Charges (%)	0.82	0.96	2.20	0.83	0.92	0.77	1.08

Table 12: Dot-com Crash

Table reports the difference-in-differences regression results with alternate measures of financial constraints due to the dot-com crash. Coefficient and standard errors for the main independent variable of interest, $Aff \times P$, is reported where Aff takes a value of 1 if the firm has below median investment income ratio or equity portfolio growth. All demand controls are included for the product market regressions and all balance sheet controls are included for the capital ratio, transfers and re-organization regressions. Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%.

	Panel A				Panel B			
	Traditional		Linked		Capital Ratio	Transfer-out	Transfer-in	Re-organizations
Measure	Intensive	Extensive	Intensive	Extensive				
Investment income	0.018	-0.023	-0.141	-0.005	0.017	0.743	-2.837*	0.279
	(0.278)	(0.034)	(0.429)	(0.046)	(0.021)	(0.508)	(1.624)	(0.430)
Equity portfolio	-0.089	-0.035	-0.708	0.041	-0.033	1.064*	0.276	1.156**
	(0.300)	(0.033)	(0.501)	(0.048)	(0.022)	(0.606)	(0.971)	(0.486)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	No	No	No
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm

A. Appendix A: Data

A.1. Variable Description

Table A.1: Variable Description

Variable	Description
Capital Buffer	Ratio of available capital to required capital
Capital-Asset Ratio	Ratio of available capital to total assets
New Capital Requirement Ratio	Ratio of required capital to total assets, where required capital are *risk-based* from firm's stress test submissions (ICAS Regime)
Old Capital Requirement Ratio	Ratio of required capital to total assets, where required capital are *non risk-based* from Solvency I Pillar I regime
Premium Income	Premium income is "quantity" of insurance underwritten. We consider direct premium income, which excludes premium arising due to reinsurance accepted by firms and new underwriting only, which excludes regular premium received from policies underwritten in the past
Traditional Liabilities	Total liabilities stemming from traditional products such as with-profit contracts, annuities etc.
Linked Liabilities	Total liabilities stemming from unit-linked contracts
ROA	Total income minus total expenditure scaled by total assets
Liquidity Ratio	Ratio of liquid assets to total assets. Liquid assets include government bonds, bank deposits, and cash
Asset Risk	Ratio of assets held in equities, non government bonds, and mortgages to total assets
Death & Disability	Total death and disability claims divided by net liabilities
Annuity	Total claims from annuities divided by net liabilities
Surrenders	Total surrender related claims divided by net liabilities
Reinsurance	Total reinsurance ceded divided by total gross liabilities
Subsidiaries	Ratio of total subsidiary asset to total asset of a firm
Mutual status	A flag variable to indicate whether a firm is a mutual or a public entity
Rating Score	A cardinal measure that converts letter ratings from Standard and Poor's into a linear scale (from 10 (AAA) to 1.0 (CCC-)) and a non-linear scale where rating score equals historical default probabilities
Transfer-out	Major sale of a firm's assets and liabilities
Transfer-in	Major purchase of another firm's assets and liabilities
Reorganizations	Change in a firm's parent company

A.2. *Capital Requirement Data*

This section provides additional details on the capital requirement data. We first provide descriptive statistics and a comparison between pre FSA review and post FSA review stress test submissions. Table A.2 shows that firms did not receive significantly higher capital add-ons in any risk group, as seen from small differences between pre vs. post review required capital to total assets ratios.

Table A.2: Capital Requirement Data - Descriptive Statistics

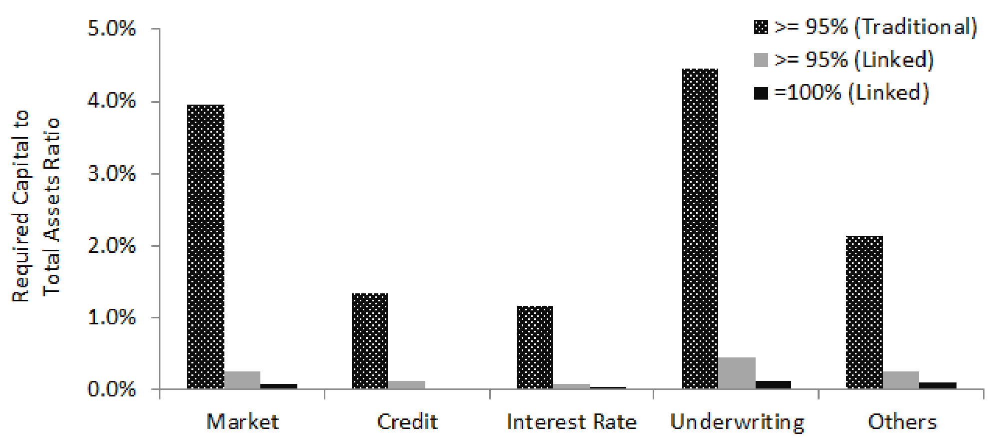
The table shows pre review relative to post review required capital to total assets ratio by risk groups for reporting firms between 2003 and 2006. Table reports sample means and standard errors in parentheses. A test of difference in means between pre and post review requirements are reported in the last column.

Risk Groups	Pre-Review	Post-Review	Diff (t-stat)
Market (%)	1.95	1.93	0.04
	(0.26)	(0.26)	
Credit (%)	0.81	0.84	-0.18
	(0.13)	(0.13)	
Interest Rate (%)	0.93	0.94	-0.06
	(0.19)	(0.19)	
Underwriting (%)	2.33	2.77	-0.91
	(0.30)	(0.38)	
Other (%)	1.00	1.35	-1.34
	(0.18)	(0.18)	
Total (%)	7.02	7.84	-0.84
	(0.63)	(0.74)	

We next provide a breakdown of total capital requirements by risk groups. We show that linked products have lower risk exposure across all risk groups - as seen from lower required capital ratio for firms that have 95% liabilities in linked products as compared to firms that have 95% liabilities in traditional products.

Figure A.1: Average Required Capital to Total Assets Ratio by Risk Groups

The chart shows a break-down of average required capital ratio by risk groups for reporting firms between 2003 and 2006. Required capital includes any add-ons that FSA levied after reviewing firms' stress test submissions.



B. Appendix B: Proofs

Proof of Proposition 1

The partial derivative $\frac{\partial s_{ij}}{\partial \phi_1}$ equals

$$\frac{\partial s_{ij}}{\partial \phi_1} = [-\alpha e^{\delta_{ij}} \underbrace{\frac{\partial P_{ij}}{\partial \phi_1}}_{\text{A}} - \sum_{i'=1}^{I} \sum_{j'=1}^{2} \alpha e^{(\delta_{ij}+\delta_{i'j'})} \underbrace{(\frac{\partial P_{ij}}{\partial \phi_1} - \frac{\partial P_{i'j'}}{\partial \phi_1})}_{\text{B}}] \frac{1}{D^2} \tag{21}$$

where $D = (1 + \sum_{j'=1}^{2} \sum_{i'=1}^{I} e^{\delta_{i'j'}})$.

The sign of equation 21 depends on the two terms A and B. The first term captures own price elasticity and the second term captures relative differences in cross price elasticities which depend on how constrained other firms are relative to firm i. Sign of A and B depend upon the change in regulatory cost Φ_{ij} due to a shift in ϕ_1. Notice,

$$\frac{\partial \Phi_{i1}}{\partial \phi_1} = \frac{1}{(1+c_i)^2}(c_i(1+c_i) + \phi_1 \frac{\partial c_i}{\partial \phi_1}) > 0 \tag{22}$$

$$\frac{\partial \Phi_{i2}}{\partial \phi_1} = \frac{1}{(1+c_i)^2}(\phi_2 \frac{\partial c_i}{\partial \phi_1}) > 0 \tag{23}$$

Equations 22 and 23 say that an increase in regulatory risk weight ϕ_1 raises regulatory cost Φ_{ij} i.e., $\frac{\partial \Phi_{ij}}{\partial \phi_1} > 0$ as $c_i > 0$ and $C''(B_i) \geq 0$. This implies that $\frac{\partial P_{ij}}{\partial \phi_1} > 0$ and thus $A > 0$.

Moreover, the increase in Φ_{ij} is particularly more pronounced for constrained firms for which c_i are higher, as with $\phi_j > 0$,

$$\frac{\partial \Phi_{ij}}{\partial c_i} = \frac{\phi_j}{(1+c_i)^2} > 0 \tag{24}$$

This implies that if firm i is more constrained than firm i', then as ϕ_1 increases price of firm i rises more than firm i', i.e. $B > 0$. Thus, $\frac{\partial s_{ij}}{\partial \phi_1} < 0$ if sufficient number of firms are less constrained than firm i, so that the terms inside the sum, $B > 0$.

Proof of Proposition 2

The partial derivative $\frac{\partial(s_{i1}/s_{i2})}{\partial\phi_1}$ equals

$$\frac{\partial(s_{i1}/s_{i2})}{\partial\phi_1} = [-\alpha e^{(\delta_{i1}+\delta_{i2})}\underbrace{(\frac{\partial P_{i1}}{\partial\phi_1} - \frac{\partial P_{i2}}{\partial\phi_1})}_{\text{C}}]\frac{1}{D^2} \tag{25}$$

where $D = (1 + \sum_{j'=1}^{2}\sum_{i'=1}^{I} e^{\delta_{i'j'}})$.

The sign of equation 25 depends on the sign of C which captures the relative change in the prices of the two products for the same firm due to a shift in the regulatory risk weight of traditional products. Define,

$$\Delta\Phi_i = \Phi_{i1} - \Phi_{i2} = \frac{c_i(\phi_1 - \phi_2)}{1 + c_i} \tag{26}$$

$\Delta\Phi_i$ captures the relative differences in the marginal cost of the two products due to regulatory constraints. Notice with $\phi_1 > \phi_2$,

$$\frac{\partial\Delta\Phi_i}{\partial\phi_1} = \frac{1}{(1 + c_i)^2}(c_i(1 + c_i) + (\phi_1 - \phi_2)\frac{\partial c_i}{\partial\phi_1}) > 0 \tag{27}$$

Equation 27 implies that the relative increase in marginal cost (and hence price) is greater for traditional products than linked products following an increase in ϕ_1. Thus, $C > 0$. Moreover,

$$\frac{\partial\Delta\Phi_i}{\partial c_i} = \frac{\phi_1 - \phi_2}{(1 + c_i)^2} > 0 \tag{28}$$

This implies that the effect is particularly pronounced for more constrained firms for which c_i are higher. Thus, constrained firms have a greater reduction in traditional underwriting than linked underwriting, as compared to unconstrained firms.

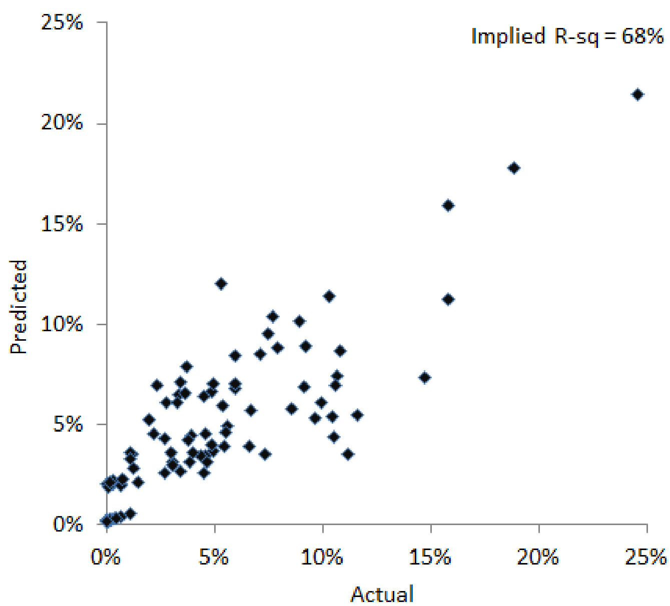
C. Appendix C: Additional Results

C.1. Capital Requirement Model

In this section, we provide additional results on the capital requirements models. We first show the overall model fit of the baseline models and then discuss the 'One Risk Model'.

Baseline Models: The chart shows a scatter plot between actual total required capital to asset ratio and predicted total required capital to asset ratio. The individual capital requirement models (see section 5 *Measuring Regulatory Constraints*) are used to predict required capital to asset ratio for each risk group, which we add together to compute total predicted required capital to asset ratio. The implied $R^2 = 68\%$.

Figure C.1: Capital Requirement Models - Baseline Results - Robustness



One Risk Model: The table shows the alternate capital requirement model where all risks groups are modeled jointly. The dependent variable is the sum of required capital to total asset ratio across all risk groups: market, credit, interest rate, underwriting and others. We use the risk factors that explain the cross-sectional variation of individual risk groups, which turn out to be statistically significant and similar in magnitude when all risk groups are considered together. As before, specification I with time fixed effects, shows the final model that was used to predict capital requirements in 2002 for the robustness exercise in section

7. Specification II shows model fit without time fixed effects. The 'One Risk Model' explains 74% of the total cross-sectional variation in capital requirements.

Table C.1: Capital Requirement Models - One Risk Model

Table reports parameter estimates, standard errors, and R-squared. Data pertains to stress-test submissions between 2003 and 2006 for firms with more than £500 million in total assets.

	One Risk Model	
Characteristics	I	II
Equity*FTSE(vol)	0.02***	0.02***
	(0.005)	(0.005)
Non-Gov Bonds*Yield	0.02**	0.02**
	(0.008)	(0.008)
Mortgages & Loans	0.09*	0.09*
	(0.047)	(0.046)
All Bonds*Yield	0.001	0.001
	(0.007)	(0.006)
Death & Disability	0.99***	1.03***
	(0.129)	(0.127)
Subsidiaries	1.45***	1.44***
	(0.292)	(0.292)
Intercept	0.013	0.012***
	(0.012)	(0.004)
Time Fixed Effects	Y	N
R-squared	0.74	0.73
N	91	91

C.2. Rating Regressions

As a large fraction of firms (40%) are unrated, a credit rating is only available for a subset of firms. Koijen and Yogo (2015) show that credit rating is largely explained by firm characteristics such as size of liabilities, leverage ratio, liquidity, return on assets, risk based capital (RBC), and mutual status of a firm using data on US life insurance companies. We use observable firm characteristics to explain the cross-sectional variation in credit ratings using an OLS regression. More specifically, we collapse the data for each firm across the time dimension by taking time series average of each variable:

$$\bar{S}_i = \bar{\alpha} + \bar{\beta}\bar{X}_i + \bar{\epsilon}_i \quad (29)$$

where S_i is the rating score, cardinal measure of credit rating, constructed using the methodology described in the Data section, X_i are firm specific co-variates and bar above a variable denotes average over time. The sample consists of rated firms from 1997 to 2007. Since data on RBC is unavailable for UK firms, we use explicit asset and liability risk proxies such as data on firm's asset allocation and claims profile.

Table C.2: Rating Regressions

Table reports parameter estimates, standard errors, and R-squared. The sample consists of rated firms from 1997 to 2007. *Linear scale*: letter ratings are converted into a cardinal scale such that the highest rating grade AAA corresponded to a rating score of 10. We reduced the score of each subsequent rating grade by 0.5. *Non-linear scale*: letter ratings are converted into a non-linear scale by imputing historical default probabilities from Standard and Poor's Rating Direct (2014).

	Linear Scale	Non-Linear Scale
Log(assets)	0.08	0.35
	(0.17)	(0.24)
Capital-asset Ratio	6.25**	-0.89
	(2.77)	(3.90)
ROA	0.04	0.05
	(0.07)	(0.09)
Liquidity Ratio	-3.06	4.33
	(2.54)	(3.57)
Asset Risk	-1.22	-0.02
	(1.73)	(2.43)
Death & Disability	-2.13	0.84
	(2.94	(4.13
Annuity	25.86*	-6.21
	(13.32)	(18.74)
Surrender	1.95	-1.14
	(1.53)	(2.15)
Reinsurance	0.95	0.23
	(1.46)	(2.06)
Subsidiaries	1.37*	-1.78*
	(0.74)	(1.04)
Mutual Status	-1.28	0.67
	(0.59)	(0.84)
Share Net Traditional Liabilities	0.55	-3.25
	(1.71)	(2.41)
Intercept	5.88	-2.46
	(2.23)	(3.14)
R-squared	0.28	0.11
N	60	60

D. Appendix D: Insurance Pricing

This section describes the computation of reduction in yield ratio and annuity ratio, which were used to standardize the price quotes for pension and annuity contracts.

D.1. Reduction in Yield Ratio

Let I denote an policyholder's initial investment. Investment earns constant annual return of r. Let $(1 + r) = R$. Compounding is annual. Investment is locked in up to T periods i.e. policyholder cannot withdraw before T. Upfront fees are denoted as F_0 and annual management fee are denoted f[36]. To be precise, both F_0 and f are in percentages.

Then, at $t = 0$, an amount $I(1 - F_0)$ after initial fees is invested in the fund. Value of investment to the policyholder at the end of the following periods is

$$\text{t} = 1 : V_1 = I(1 - F_0)R(1 - f) \tag{30}$$

$$\text{t} = 2 : V_2 = I(1 - F_0)R^2(1 - f)^2 \tag{31}$$

$$\text{t} = \text{T} : V_T = I(1 - F_0)R^T(1 - f)^T \tag{32}$$

The investment yield after fees Y_F is

$$Y_F = (\frac{V_T}{I})^{\frac{1}{T}} = (\frac{I(1 - F_0)R^T(1 - f)^T}{I})^{\frac{1}{T}} = (1 - F_0)^{\frac{1}{T}}R(1 - f) \tag{33}$$

The investment yield without fees Y is

$$Y = R \tag{34}$$

Thus, reduction in yield ratio (RIYR) equals

$$RIYR = \frac{Y}{Y_F} = \frac{1}{(1 - F_0)^{\frac{1}{T}}(1 - f)} \tag{35}$$

[36]Upfront fees include allocation, initial charges, and bid-offer rates. Ongoing fees include annual management charges.

D.2. Annuity Ratio

Let A denote the annual annuity amount for an initial investment of I. Assume the contract offers no mortality guarantee i.e. the payment stops on policyholder's death. We use mortality rates μ_t from Office for National Statistics (English Life Tables) and the UK gilt term structure Δ_t for discounting, where Δ_t are discount factors. Annuity ratio equals the ratio of the initial investment to the expected present value $PV(.)$ of the annuity income over a fixed horizon T. Thus, annuity ratio (AR) equals

$$AR = \frac{I}{PV(A, \Delta_t, \mu_t, T)} = \frac{I}{A \sum_1^T (1 - \mu_t) \Delta_t} \tag{36}$$

D.3. Equivalence between Reduction in Yield Ratio and Annuity Ratio

Let $\bar{A}$ denote the annuity amount that puts the annuity contract at par i.e. $AR(\bar{A}) = 1$.

$$AR(\bar{A}) = \frac{I}{\bar{A} \sum_1^T (1 - \mu_t) \Delta_t} = 1 \tag{37}$$

Notice, $\bar{A}$ is the level of annuity payment that is consistent with zero fees. In contrast, the actual annuity amount $A < \bar{A}$ incorporates a positive fee. We assume the policyholder gets paid a fixed fraction of $\bar{A}$ after fees. Thus,

$$(1 - \tilde{f}) \bar{A} = A \tag{38}$$

where $\tilde{f}$ is the implied fee of the annuity contract. Using (37) and (38) we get

$$\tilde{f} = 1 - \frac{A \sum_1^T (1 - \mu_t) \Delta_t}{I} = 1 - \frac{1}{AR} \tag{39}$$

Substituting the expression for the implied fee in (35) yields $RIYR = AR$, where the upfront fee $F_0 = 0$.

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