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 UK. We use a proprietary dataset from the Bank of England on stress-test submissions made by insurance firms to accurately measure firm-level regulatory constraints. We exploit the cross-sectional differences in constraints to show that regulatory frictions impacted the equilibrium product mix of the insurance sector. Insurance companies that are relatively more constrained substantially reduce 'traditional' insurance underwriting, products that provide life cover or guaranteed savings to policyholders. Unconstrained firms substantially increase 'linked' underwriting, products that are mainly investment vehicles (like mutual funds) which do not fulfill the economic function of standard insurance contracts. The marked shift in the insurance product mix led to a surge in linked liabilities from £345 billion in 2002 to more than £1 trillion in 2014, pointing to significant reduction in risk sharing in the economy.

Keywords: Risk-Based Capital Regulation, Portfolio Stress Tests, Life Insurance, Trends in Asset Management
1. Introduction

This paper examines the effect of the introduction of a new capital regulation regime on product market outcomes for the insurance industry in the UK. In 2002, the Financial Services Authority (FSA)\(^1\) announced the onset of a new prudential regulatory regime in which capital requirements became a function of balance-sheet risk exposures\(^2\) in sharp contrast to the old regime which 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 covers or guaranteed savings schemes (figure 1). Capital requirements, however, remained low for linked insurance products, which are mainly investment vehicles (like mutual funds) that do not provide traditional insurance. We document a marked shift in insurance product mix - from traditional to linked - after the new regime is 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 (figure 2). This trend is fueled by a slowdown in traditional new premium\(^3\) underwriting. For every £1 of traditional insurance, insurance companies underwrote £1.5 of linked insurance in 2002, which jumped up to £6.0 in 2014.

Standard models of capital structure (Miller-Modigliani (1958)) predict that change in capital requirements should have little impact on product mix of firms. In these models firms frictionlessly raise capital, thus their product mix remains unchanged. However, if firms cannot raise capital or can do so only at a sufficiently high cost\(^4\) then increase in capital requirements could lead to significant changes in equilibrium product mix\(^5\). Using a proprietary dataset from the Bank of England on stress-test submissions made by insurance firms that allows us to accurately measure firm-level regulatory constraints, we show that regulatory frictions impacted the equilibrium product mix of the insurance sector after 2002. A shift towards linked products, products that do not fulfill the economic function of standard insurance contracts, exposes households and businesses to increased amounts of idiosyncratic risk. Thus, our results point to reduced risk sharing and have confounding welfare consequences for the economy\(^6\). The implementation of Solvency II in January 2016 introduced risk-based capital requirements across all European Union countries. However,

\(^1\)The Financial Services Authority (FSA) supervised and regulated insurance companies in 2002, but has now been subsumed into the Bank of England.

\(^2\)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.

\(^3\)New premium refers to premium income from new policies net of reinsurance.

\(^4\)Raising equity could be expensive due to informational asymmetry (Myers and Majluf (1984)) or agency costs (Diamond and Rajan (2000)).

\(^5\)Kashyap and Stein (2004) argue that capital requirements could lead to decrease in lending for banks.

\(^6\)Koijen, Nieuwerburgh, Yogo (2015) show that welfare cost of sub-optimal insurance choice are significant.
despite the significant regulatory changes, we know very little about how insurance companies adjust to shifts in capital requirements. This is the first paper to address this subject and measure sensitivities of equilibrium product market outcomes to changes in capital requirements which can be helpful in guiding policy in the future.

We proceed in three steps. First, we develop a stylized insurance pricing model, following Koijen and Yogo (2014), in which insurance companies face heterogeneous regulatory capital requirements at the product level. The first order condition to the firm’s problem gives an optimal pricing model in which insurance prices depend on the firm’s constraints and the product’s regulatory risk weight. We derive predictions about equilibrium quantities in the cross-section of insurance companies due to a shift in the regulation of traditional products. 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 traditional and linked insurance. However, the effect is more pronounced for constrained firms for whom the regulatory costs are higher and for traditional products for which requirements increased. As traditional insurance becomes more expensive, households substitute into linked products, causing a shift in product mix towards linked products. Second, we show how we measure firm-level regulatory constraints when the new regime is announced in 2002 using a proprietary data on stress-test submissions made by firms to the Bank of England which allows us to measure capital requirements comprehensively across a range of balance-sheet risks. Third, we test the model’s cross-sectional implications on equilibrium quantities using a difference-in-differences identification strategy where we use unconstrained firms as a control for firms that are constrained by the new regulation, which helps overcome the identification challenge that the new regulation affected all firms. To make sure that the observed product market changes are unique to 2002, we conduct placebo tests with alternate event years.

We find that insurance companies that are relatively more constrained by regulation substantially reduce new traditional insurance underwriting, from £300 millions in 2002 to £115 millions in 2007 on an average. In contrast, unconstrained firms maintain relatively stable presence, going from £175 millions in 2002 to 230 millions in 2007 in the traditional market. Unconstrained firms substantially increase linked insurance underwriting from £220 millions in 2002 to £550 millions in 2007. However, constrained firms are unable to push up their linked insurance underwriting at a similar rate. We interpret these product market changes as an upward shift in the supply curve for constrained firms for whom the marginal cost

\footnote{We define a firm to be constrained if it has a \textit{capital buffer}, ratio of available capital to required capital, \textit{below one}, i.e. the firm does not have sufficient capital to meet the new requirements.}
of providing insurance goes up in the presence of regulatory frictions. This interpretation relies on three facts. First, firm level stress tests and new capital requirements remained undisclosed. Stress test disclosures produce new information previously not incorporated in prices by market participants (Petrella and Resti (2013)). Thus, shifts in demand that are correlated with our measure of constraints seem less plausible in the absence of this data in the public domain. Second, our identification strategy allows us to directly rule out alternate explanations where demand for traditional or linked insurance shifts in general, as any parallel shift in demand that affects both groups equally gets differenced out. Third, we show that the product market changes persist even after controlling for observable firm characteristics that drive cross-sectional variations in demand elasticities (Koijen and Yogo (2015)).

To provide evidence that our measure of financial constraints are indeed driven by changes in capital requirements, we compare the distribution of capital buffer in the old regime with the distribution of capital buffer in the new regime. We show a significant shift in the distribution i.e. a large fraction of previously unconstrained firms become constrained in the new regime (figure 3), which we interpret as a regulatory shock. Moreover, constrained firms adjusted their capital to assets ratios upwards, while unconstrained firms maintained a relatively stable capital to assets ratio during the five years window post 2002, thus corroborating the fact that the new capital requirements became a binding constraint and led to significant spill-overs in the product market. Finally, we conduct placebo tests to examine whether similar product market changes occurred in other years. We repeat the difference-in-differences regression in alternate years (1997, 1998, and 1999) and show that such large scale product market changes are unique to 2002 when the regulatory changes took place.

**Related Literature:** We contribute to the insurance literature documenting the effect of supply side frictions on insurance markets by providing evidence that regulatory capital requirements impacted the equilibrium product mix of the insurance sector after 2002. Our results complement the existing literature, for example, Koijen and Yogo (2014) who show that U.S. insurance companies alter their pricing behavior, selling products at deep discounts during the financial crisis, due to regulatory and product market frictions and Koijen and Yogo (2015) who examine the effect of curtailing shadow insurance, a widely used capital

---

8 Also see Goldstein and Sapra (2013).
9 Koijen and Yogo (2015) show that insurance demand is positively related to company size and A.M. Best rating for US insurance companies. We add several control variables to capture these firm characteristics.
10 See, Yaari (1965) and Rothschild and Stiglitz (1976) for an overview of traditional theories of insurance markets that assume that insurance companies operate in frictionless markets.
management tool, on insurance balance-sheets and market equilibrium. We add to this literature in two ways. First, we study the effect of capital requirements on equilibrium product mix, a topic not covered in the literature before. Second, we provide evidence on how insurance companies adjust to significant regulatory changes that permanently raised capital requirements. Another strand of the literature examines the effect of regulatory frictions on asset side of insurance balance-sheets (Ellul, Jotikasthira and Lundblad (2011); Merrill, Nadauld, Stulz, and Sherlund (2012); Ellul, Jotikasthira, Lundblad, and Wang (2015); and Becker & Ivashina (2014)). 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 insurance underwriting when confronted with higher regulatory requirements for such products.

We also contribute to the broader debate on the implications of financial regulation. Admati, DeMarzo, Hellwig, Pfleiderer (2013) support the Modigliani-Miller view that raising equity is not expensive and thus capital requirements are not costly for financial institutions. Since Peek and Rosengren (1997) and Khwaja and Mian (2008), the banking literature has found evidence that shocks to capital affect bank lending. Keeley (1988), Wall and Peterson (1987), 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 Wiedalek (2012) exploit time varying change in minimum capital requirements on bank credit supply. Our paper contributes to this larger debate by linking regulatory changes to shifts in the product market equilibrium and liability mix of insurance companies.

11Ellul, Jotikasthira and Lundblad (2011) and Merrill, Nadauld, Stulz, and Sherlund (2012), show that insurance firms sell downgraded bonds at fire-sale prices due to increased regulatory pressure. 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. Becker & Ivashina (2014) show that regulatory risk charges lead insurance firms to deviate from standard frictionless mean-variance portfolio compositions.

12Peek and Rosengren (1997) exploit changes in the Nikkei to identify the effect of changes in the capital of Japanese banks on the lending behavior of their US branches. Khwaja and Mian (2008) confirm the evidence on funding shocks using loan level data.
2. Institutional Background

2.1. Product Lines

Definitions: The long-term insurance industry[13] in the UK comprises of two major product lines: traditional and linked products. Traditional products provide policyholders with contracts that contain an insurance and a savings component. For example, with-profits[14] and annuity contracts typically offer a policyholder with a life cover or a guaranteed savings scheme. Thus, policyholders are provided with a fixed benefit and the insurance company assumes all or most of the investment and mortality risk. In contrast, linked products are mainly investment vehicles (like mutual funds) providing no life insurance or guaranteed savings to policyholders. These contracts are referred as unit-linked policies in the UK[15]. In these contracts, the benefit payable upon death, surrender, or maturity depends upon the market value of some underlying investment portfolio. Linked products are thus similar to mutual fund contracts as the insurance premium less expenses is invested in some underlying portfolio and at expiration pays the policyholder the market value of the underlying portfolio. Unlike traditional products, thus, the policyholder bears the full investment and mortality risk in linked contracts. This results in, as we will see a bit later, significantly lesser capital requirements for linked products.

2.2. The New Capital Regulation Regime

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[16]. To correct this, the FSA announced a new prudential regulatory regime for life insurers - the Individual Capital Adequacy Standards (ICAS) - in 2002[17]. The ICAS regime, commonly also known as Solvency I Pillar II regime, applied to all insurance companies doing business in the UK. In the new regime, minimum regulatory capital requirements for a firm were set based on its exposure to balance-sheet risks including market risk, credit risk, credit risk,

---

[13] Long-term insurance refers to the life insurance and pensions businesses.
[14] With-profits are insurance contracts with embedded guarantees.
[15] Variable annuities in the US offer similar product features with the key difference that variable annuities typically also offer guaranteed minimum benefits which unit-linked contracts do not.
[16] 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 done commonly in Banking.

6
interest rate risk, underwriting risk and other business risks. Thus, total minimum required capital $R$ was given by

$$R = R_M + R_C + R_I + R_U + R_O$$

where $R(_) \text{ denotes the pound value of capital requirement arising due to exposure to the following risk groups } M \text{ (market risk), } C \text{ (credit risk), } I \text{ (interest rate risk), } U \text{ (underwriting risk) and } O \text{ (other risks).}$

**2.2.1. Computation of Minimum 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 exercise yielded capital requirements for each risk exposure $R(_)\text{, which were then added together to arrive at the total minimum required capital for a firm as described in equation (1). The FSA provided guidelines on the types of risks and broad "scenarios" to be assessed by firms. The process was standardized and firms were required to calibrate their internal models such that they remained solvent with 99.5% probability over the next one year. Firm's stress test submissions were reviewed and validated by FSA supervisors to assess whether firm's submissions adequately reflected their risk exposures.}

The five risk groups captured a wide range of risk exposures faced by insurance companies. 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.
- Interest rate risk measured exposure to fluctuations in interest rate movements 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 persistence\textsuperscript{18} risks.
- Other risk included risks stemming from complex group and subsidiary structures, operational and diversification risks.

\textsuperscript{18}Persistence risk is the risk of early policy lapses.
2.2.2. Solvency

The FSA measured solvency of an insurance firm by assessing their capital buffer, defined as the ratio of actual available capital to required minimum capital, which measures the distance between a firm’s available capital position and the minimum capital it needs to hold. Thus, capital buffer $B_i$ for firm $i$ is defined as

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

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 new regulatory requirements\(^{19}\). 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 side and liability side risks are difficult to assess from typical regulatory filings made by firms (Koijen and Yogo (2016)). 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 disaggregated by risk groups.

3. Data and Key Facts

3.1. Data Sources

Our data comes from primarily two sources. (1) Regulatory Returns Data: We use FSA’s annual regulatory returns collected from Standard & Poor’s Synthesys database, which is a publicly available database. This database contains a wide range of information on insurance companies including (i) balance-sheets; (ii) asset allocation; (iii) liabilities by product lines; (iv) capital resources; (v) capital requirements for the old regulatory regime; (vi) revenue; (vii) premiums and policies sold; (viii) claims incurred; (ix) expenses; and (x) reinsurance ceded and accepted. We also constructed a record of firm’s mutual status\(^{20}\) using the Financial Conduct Authority’s register of mutual insurers, and historic data on mutual status available in Alzmezweq (2015). Importantly, the regulatory returns data from Synthesys are audited, making the information highly reliable. Synthesys covers nearly all insurance com-

---

\(^{19}\)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.

\(^{20}\)A mutual insurance company is a non-public company owned entirely by its policyholders.
panies in the UK\textsuperscript{21} The data are annual and cover the period from 1985 to 2014. We focus
our analysis on the long-term insurance sector which includes life insurance and pensions
markets. Our analysis is at the operating company level as capital requirements are set at
this level. Firms also report any major change to their businesses, including mergers and
business transfers, to the FSA in their financial notes that allowed us to construct variables
for transfers, mergers\textsuperscript{22} and reorganizations, and group structure. We hand-collect data on
mergers and transfers from firm’s regulatory filings and financial notes. We create dummy
variables for whenever a firm experiences a major transfer out, transfer in, or a merger.

(2) \textit{Capital Requirements Data}: We measure a firms’ capital requirements using a pro-
prietary database from the Bank of England used for the purpose of insurance supervision.
The database provides a detailed account of balance-sheet stress test submissions made by
insurance firms and the FSA’s review of these submissions, allowing us to measure capital
requirements comprehensively across all balance-sheet risks for each insurance firm in our
sample\textsuperscript{23} The stress-test review process typically lasted 3-6 months and involved multiple
actuaries (supervisors) who levied capital add-ons in case a firm inappropriately accounted
for any risks. The information on capital add-ons allows us to rule out concerns regarding
systematic under-reporting of capital requirements by firms. Behn, Haselman and Vig
(2014) provide evidence that risk models may be manipulated by banks to reduce their capi-
tal requirements. In the appendix, we show a comparison between pre FSA review and post
FSA review capital requirements. We find that capital add-ons levied on insurance firms
on top of internal assessments were small, which alleviates concerns regarding systematic
under-reporting of capital requirements.

In order to comply with the ICAS phasing-in, all insurance firms were required to pro-
vide 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, FSA could
only review few submissions at a point in time\textsuperscript{24} We focus attention on first-time stress
test submissions made between 2003 and 2006, which totaled to 131 submissions. We select

\textsuperscript{21}Non-Directive Friendly Societies are excluded from regulatory reporting requirements.
\textsuperscript{22}A transfer is different from a merger in the sense that it only involves partial sale of a firm’s assets
and there is no change in the legal entity of the firm. A transfer-out is sale of assets while a transfer-in is
purchase of assets of another firm.
\textsuperscript{23}In the U.S., insurance firms provide detailed filings on asset holdings but similar liability side disclosures
are absent (Koijen and Yogo (2016)), thus measurement of total capital requirements are problematic.
Moreover, the National Association of Insurance Companies (NAIC) does not disclose information on firms’
regulatory capital positions making it impossible to conduct a similar analysis on U.S. insurance firms.
\textsuperscript{24}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.
first-time submissions to ensure that we use data that closely resembles 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 will provide details on how we use our unique regulatory data to resolve this timing problem and measure firm level regulatory constraints as of 2002.

3.2. Key Facts

[A] Average Capital Requirement By Product Lines

We now present details on significant institutional changes that motivate our analysis. We first compare the average minimum required capital in the old regime with the new regime for each product line (figure 1). The old minimum required capital refers to the Pillar I requirements taken from Syntheses, while the new minimum required capital is from firms’ stress test submissions. Firms submit stress test results for their entire balance sheets and not for each product line separately. Thus, to understand the magnitude of average capital requirements for each product line, we have only focused on firms that have more than 90% of liabilities in a single product line. Two features of this data are important to note. First, capital requirement increased significantly for all firms as regulators adopted the new risk based regime. Second, the increase in requirements was significantly more pronounced for the traditional product line where the average required capital as a ratio of total assets went from 6.4% in the old regime to 13.7% in the new regime. Although, capital requirements also increased for linked products, these were relatively small in absolute levels underscoring the fact that insurance companies assume little risk in selling linked policies. In appendix A, we provide a breakdown of capital requirements by risk groups and show that linked products have lower risk exposures across all risk groups.

[B] Industry Transition: From Traditional Insurance to Mutual Fund

We also document a big shift in the UK insurance market - a transition from traditional to linked (or a mutual fund) - 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\(^25\) 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

\(^{25}\)Total net liabilities is the sum of gross liabilities arising in traditional and linked product lines minus reinsurance.
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 linked liabilities has been to a large extent fueled by a decline of traditional new premium underwritten (right panel)\textsuperscript{26}. The share of traditional new premium in total new premium underwritten has undergone a marked decline over the years. For every £1 of traditional new 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 in 2002 generated changes in the traditional and linked market equilibrium. 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 Bank of England. 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

Consider \( I \) insurance companies, indexed by \( i = 1, 2, ..., I \). Each company sells two products denoted \( j = 1, 2 \) where \( j = 1 \) are traditional and \( j = 2 \) are linked products. Each firm produces differentiated insurance products, where differentiation is along company characteristics. 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 also faces a regulatory cost \( C(B_i) \) (\( B_i \) defined below) which generates heterogeneity in cost of insurance supply across firms due to differences in regulatory capital positions.

Firm’s capital \( K_i \) after selling new policies is equal to

\[
K_i = \sum_{j=1}^{2} Q_{ij}(P_{ij} - V_j) + K^-_i
\]

\textsuperscript{26}We focus on direct premium income from new policies sold net of reinsurance
where \( K^−_i \) is the initial capital of firm \( i \). Minimum regulatory capital required for each firm \( R_i \) is given by

\[
R_i = \sum_{j=1}^{2} \phi_j (Q_{ij} V_j + \omega_j^− L_i^−)
\]

where \( \phi_j > 0 \) are the new regulatory risk weights for product \( j \). \( \omega_j^− × L_i^− \) are the liabilities for product \( j \) coming into the period. Here, we have assumed that total regulatory requirement is calculated based on proportion of liabilities in each product line.

The quantity \( B_i = K^−_i - R_i \) is the capital buffer over and above minimum required capital and generates heterogeneity in regulatory cost across firms. If capital buffer is high (low), regulatory cost is low (high). Thus, \( \frac{\partial C(B_i)}{\partial B_i} < 0 \). The change in regulation and all relevant comparative statics are with respect to a shift in \( \phi_1 \), which we think of as a shift in regulation of traditional products. \( \frac{\partial C(B_i)}{\partial \phi_1} > 0 \), thus, as increase in regulatory risk weight for traditional products results in an increase in regulatory cost.

Firm \( i \) maximizes profit subject to the downward sloping demand function for each product \( Q_{ij}(P_{ij}) \).

\[
\max_{P_{ij}} \sum_{j=1}^{2} Q_{ij} (P_{ij} - V_j) - C(B_i)
\]

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

\[
Q_{ij} + Q'_{ij}(P_{ij} - V_j) + c_i (Q_{ij} + Q'_{ij}(P_{ij} - V_j) - Q'_{ij} \phi_j V_j) = 0
\]

where \( c_i = -\frac{\partial C(B_i)}{\partial B_i} \). The solution to the FOC is

\[
P_{ij} = \left(1 - \frac{1}{\epsilon_{ij}} \right)^{-1} V_j \Phi_{ij}
\]

where \( \epsilon_{ij} = -\frac{\partial \log Q_{ij}}{\partial \log P_{ij}} \) is the demand elasticity, and

\[
\Phi_{ij} = \frac{1 + c_i (1 + \phi_j)}{1 + c_i}
\]

The pricing rule contains three components. The first term is the standard markup, which depends on the demand elasticity \( \epsilon_{ij} \). 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. $\Phi_{ij}$ depends on constraints $c_i$ which operates at the firm level and risk weights $\phi_j$ which operates at the product level. An increase in $\phi_j$ raises $\Phi_{ij}$ in general, but this effect is particularly pronounced for more constrained firms for which $c_i$ is higher, as with $\phi_j > 0$, $\frac{\partial \Phi_{ij}}{\partial c_i} > 0$.

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

\begin{equation}
    u_{ij}(n) = -\alpha P_{ij} + \beta' X_i + \gamma Z_j + \eta_{i,j}(n)
\end{equation}

where $(\alpha, \beta, \gamma)$ are preference parameters, $X_i$ are firm specific covariates, $Z_j = 1_{j=1}$ is an indicator variable for traditional products, and $\eta_{i,j}(n)$ are consumer specific demand shocks. Expected indirect utility from product $ij$ depends on price of product $ij$, characteristics of firm $i$, and whether product $j$ is a traditional or a linked product. Thus, the choice probabilities for consumer $n$ for product $ij$ becomes,

\begin{equation}
    Pr_{ij}(n) = \frac{\exp(\delta_{ij})}{1 + \sum_{j'=1}^{2} \sum_{i'=1}^{I} \exp(\delta_{i'j'})}
\end{equation}

where $\delta_{ij} = -\alpha P_{ij} + \beta' X_i + \gamma Z_j$.

Market share, $s_{ij}$, for product $ij$ equals $\frac{1}{N} Pr_{ij}(n, \theta) \times N$. Thus,

\begin{equation}
    s_{ij} = \frac{\exp(\delta_{ij})}{1 + \sum_{j'=1}^{2} \sum_{i'=1}^{I} \exp(\delta_{i'j'})}
\end{equation}

4.3. Comparative Statics

We want to evaluate the effect of a change in regulation of traditional products on the $i^{th}$ firm’s market share. We compute partial derivatives with respect to a change in risk weights $\phi_j$ below.

**Proposition [1]:** An increase in $\phi_j$ for firm $i$ decreases the share of product $j$ as

\begin{equation}
    \frac{\partial s_{ij}}{\partial \phi_j} < 0
\end{equation}
and, all else equal for two firms $i$ and $i'$, if $c_i > c_{i'}$ then

$$\frac{\partial s_{ij}}{\partial \phi_j} < \frac{\partial s_{i'j}}{\partial \phi_j}$$

As $\phi_j$ increases, the marginal cost of providing product $j$ increases. Thus, $P_{ij}$ increases, which combined with a downward sloping demand curve in (9), implies a fall in $s_{ij}$. Moreover, the effect of an increase in $\phi_j$ varies in the cross-section of firms. 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.

**Proposition [2]:**
An increase in $\phi_1$ for firm $i$ increases the share of linked products $s_{i2}$ as

$$\frac{\partial s_{i2}}{\partial \phi_1} > 0$$

We focus only on the within company cross product elasticity arising from an increase in $\phi_1$ as it is the dominant effect with $\phi_1$ significantly larger than $\phi_2$. If $\phi_1$ increases then $P_{i1}$ increases, which implies an increase in $s_{i2}$ as cross-price elasticities are positive. We test the product market predictions in proposition 1 and 2 using data on premium incomes for traditional and linked markets. 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 as a control for constrained firms to identify the effect of a 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 2005. We do this for two reasons. First, it ensures what we capture is the unexpected regulatory shock. Second, it helps prevent under-estimation of firms response to the regulatory change. As the new requirements stemmed from firms own risk assessments, it is a reasonable assumption that firms know their capital shortfall and make adjustments much before the new regulation is implemented. Firms are also under pressure from supervisors to start making changes to their balance-sheets much ahead of the deadline, particularly if supervisors deem a firm unlikely to meet the new capital requirements. By measuring changes from the date of implementation
therefore may result in significant under-estimation of firm’s responses by missing 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 requirements in 2002. We observe firm’s requirements from 2003 to 2006 when they make their stress-test submissions. To mitigate this issue, we recover the capital requirement models by linking risk exposures (requirements) from 2003 to 2006 to observable firm characteristics and use these models to predict capital requirements in 2002.

5.1. Capital Requirement Models

We use capital requirements from stress-test submissions for each risk group along with observable firm characteristics including 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 $t$ and $X_{rit}$ denote a vector of relevant firm specific covariates at time $t$, and $\tau_{rt}$ are time fixed effects to account for staggered submissions between 2003 and 2006. We estimate

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

for each risk group $r \in \{\text{Market, Credit, Interest Rate, Underwriting, Others}\}$. We select the explanatory variables on the basis of FSA guidelines on portfolio stress tests.\footnote{See ‘FSA Enhanced Capital Requirements and Individual Capital Assessments for Life Insurers (2003) Consultation Paper 195’.

Thus, our requirement models are likely to closely match firms own assessments of capital requirements, as is also evident from the good model-fit we achieve overall. Table 1 presents our requirement models. In specification I under each risk group, we show the final model that we use to predict capital requirements in 2002. All other specifications are provided for robustness.

**Market Risk**: Market risk is positively related to 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. Our market risk model accounts for 64% of the total cross-sectional variation in market risk across firms.

**Credit Risk:** Credit risk is positively related to the amount of non-government bonds, mortgages and loans on the balance-sheet of firms. We interact non-government bond yields with proportion of total assets in non-government bonds to measure the credit risk of insurance bond portfolios. As we do not observe credit ratings of the bonds held on insurance-balance-sheets during our sample period, we use bond yields as a proxy of ratings. Unlike non-government bonds, mortgages and loans are not interacted with their respective prices as the data on mortgage and loan rates are not available. Our model explains over 74% of the cross-sectional variation in credit risk across firms.

**Underwriting Risk:** Underwriting risk accounts for a large share of insurance capital requirements (32%). This risk group is mainly associated with the types of policies being written and their underlying risk profiles including their mortality and morbidity experience. We use death and disability claims experienced by firms as a proportion of total net liabilities to account for underwriting related requirements. Our model explains 63% of the total variation in underwriting risk.

**Other Risks:** Other risks include risks stemming from complex group and subsidiary structures, operational and diversification risks. We use subsidiary assets as a proportion of total assets to proxy for size and complexity of a firm’s group structure. This 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. However, our results are overall weak. This could be because net interest rate risk exposures also depend on duration of insurance liabilities, which we do not observe. We also do not observe derivative holdings which is commonly used to hedge interest rate risk exposures. Despite the weaker results, this is unlikely to cause significant mis-measurement of capital requirements as interest rate risk contributes only 12% to total capital requirements on an average. In addition, predicted total requirements and actual total requirements closely align with each other, with an implied $R^2 = 68\%$ (see appendix).

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

$$
\hat{R}_{i,02} = \sum_r \hat{R}_{r,i,02}
$$
where as before \( r \in \{ \text{Market, Credit, Interest Rate, Underwriting, Others} \} \). The crucial assumption is that the requirement models recovered from 2003 to 2006 well represent the requirement model in 2002\(^{28}\). 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 non-trivial 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 give 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 assessment procedure described in section (2). Capital buffer for each firm \( \hat{B}_{i,02} \) in 2002 is

\[
\hat{B}_{i,02} = \frac{\bar{K}_{i,02}}{\hat{R}_{i,02}}
\]

where \( \hat{R}_{i,02} \) is the total predicted required capital to asset ratio derived from (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 \( C_i \) if it has a capital buffer below one, i.e. the firm does not have sufficient capital to meet the new regulatory requirements. Thus,

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

\(^{28}\)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.
6. Empirical Strategy

6.1. Identification

We now describe our empirical strategy. The model implies that an increase in regulatory risk weight for traditional insurance leads to an increase in marginal cost of providing insurance for all firms. However, the effect is more pronounced for constrained firms for whom the regulatory costs are higher implying a greater increase in prices for such firms. 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 as a control for constrained firms. 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. As described in the previous section, we define a firm to be constrained if it has a capital buffer below one. For robustness, we also use an alternate cutoff of 1.2, as firms with a buffer below 1.2 could also experience greater regulatory oversight. Firms that have a capital buffer above 1.2 are treated as unconstrained in all our specifications.

Our empirical specification is,

\[ Y_{it} = \alpha + \alpha_i + \alpha_t + \beta(C_i \times P_t) + \delta X_{it} + \epsilon_{it} \]

where \( Y_{it} \) is the outcome variable of interest, \( C_i \) 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, \( \alpha_i \) are firm fixed effects, and \( \alpha_t \) are time fixed effects. The outcome variables are total premium incomes in traditional and linked product lines. We only consider direct premium income (net of reinsurance) to account for actual policies sold in the insurance market. 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 change in capital requirements mainly affected traditional products, we focus on firms that primarily underwrite traditional products. An insurance company may have multiple product lines or may specialize in a single product. 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\textsuperscript{29}. We define a firm to be traditional if the firm has more than 50\% of its liabilities in traditional products in 2002 i.e. 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. Another approach could have been to represent the counter-factual using linked firms\textsuperscript{30} who are unaffected by the new regulation. However, these firms are unlikely to provide a good counter-factual as they are inherently different firms. Thus, the analysis sample is the population of all traditional firms in 2002. A total of 206 firms filed regulatory returns in 2002\textsuperscript{31}, 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 new premiums being written in traditional products.

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

We present the distribution of capital buffers for all traditional firms in our sample in figure 3. The red line shows the capital buffer under the new regime calculated as in equation (17). The dotted blue line shows the distribution of capital buffer calculated using the old capital requirements. The magnitude of changes due to the new regime can be seen from the shift in the distribution of capital buffer under the new requirements. The shaded area to the left of 1 denotes the mass of constrained firms under either regime. As is evident, almost all the 101 firms in our sample were unconstrained under the old regime. However, a large fraction of these previously unconstrained firms become constrained under the new regime, reflecting the fact that the change in requirements were significant.

6.3. Properties of Constrained and Unconstrained Firms

To show that the unconstrained firms well represent the counter-factual outcomes for the constrained firms, we present a basic profile of the two groups. Table 2 presents key firm characteristics for the two groups in 2002. The two groups contain roughly an even split of firms, of the 101 traditional firms in our sample, a total of 49 firms are constrained and 52 are unconstrained. Average total assets for constrained firms is £7.5Bn and unconstrained firms is £3.8Bn. Although, the constrained firms are larger, this difference is not statistically significant. Despite that, we control for firm size using logarithm of total assets in all our regressions. As the dependent variable is also in logs, the model specification also accounts

\textsuperscript{29}This information is taken from publicly available regulatory returns of these firms.

\textsuperscript{30}Firms with more than 50\% liabilities in linked product lines.

\textsuperscript{31}Only firms with non-zero assets and liabilities are considered valid filings.
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. We also evaluated difference in firm’s key financial characteristics such as (i) proportion of invested assets in risky securities including equities, non-government bonds and mortgages (asset risk); (ii) total insurance claims as a proportion of net liabilities (claims); (iii) return on assets (ROA); and (iv) reinsurance ceded (reinsurance). Across all these dimensions, the difference between the two groups are statistically insignificant. We also examine whether the two groups have meaningful differences in their organizational structures and find no significant differences. Both groups also have similar proportion of mutual and stock companies.

7. Results - Product Market Changes

7.1. Graphical Results

We first present our results graphically. In figure 4, we plot total new premium income in traditional and linked product lines from firm’s regulatory filings in Synthesys. Premium income for traditional products is the number of policies sold multiplied by the premium charged, while for linked products it is the amount invested in the reference portfolio by policyholders. We consider direct premium income to ensure we focus on actual policies sold to households in the insurance market excluding any reinsurance accepted by firms. In the left panel, we show traditional new premium underwritten by constrained and unconstrained firms from 1997 to 2007. Before 2002, both groups exhibit similar trends in traditional underwriting, however, the two groups display striking differences after the new regulation is announced. Insurance companies that are relatively more constrained by the regulation substantially reduce new traditional insurance underwriting. On an average, the constrained group underwrote £300 millions of traditional products in 2002, which falls to £115 millions in 2007. In contrast, unconstrained firms maintain relatively stable presence in the traditional market, underwriting £175 millions of traditional products in 2002 which goes up to £230 millions in 2007.

The right panel shows linked new premium underwritten by constrained and unconstrained groups from 1997 to 2007. Similar to the evidence in traditional market, the two groups display large differences in linked underwriting after the new regulation is announced. Unconstrained insurance firms substantially increase linked insurance underwriting after 2002, however, constrained firms are unable to push up their linked insurance underwrit-
ing at a similar rate. On an average, the unconstrained group underwrote £220 millions of linked products in 2002, which rises to £550 millions in 2007. In contrast, constrained firms maintain relatively stable presence, underwriting £170 millions of linked products in 2002 which goes to £150 millions in 2007. Figure 4 also shows that most of the insurance underwriting is driven by increases in linked underwriting between 2002 and 2007. This trend is fueled by unconstrained firms who have the balance-sheet capacity to underwrite insurance in the new regulatory climate. Thus, as traditional insurance becomes more expensive, households substitute into linked products, causing a shift in product mix towards linked products consistent with proposition [2].

7.2. Difference-in-Differences Model

Table 3 reports the results of the difference-in-differences regression. The table is divided into two panels, the left panel shows results for the traditional market and the right panel shows results for the linked market. $C \times P$ is the main independent variable of interest where $C$ is an indicator variable that takes a value of 1 if a firm is constrained\(^{32}\) and $P$ is the post regulation dummy variable that takes a value of 1 after 2002. The dependent variable is the log transformation of premium income. Specification I shows the baseline results and specification II provides results with demand controls. 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 -0.84 for the traditional market and -0.76 for the linked market after adding demand controls. Thus, on an average, the difference in traditional premium underwritten between constrained and unconstrained firms shrinks by approximately 84% after 2002. There is a similar reduction of 76% in the linked market between the two groups.

The results validate proposition [1]. As capital requirements increase for traditional products, the marginal cost of providing traditional insurance goes up resulting in higher optimal price and lower demand for traditional insurance, assuming a downward sloping demand schedule. However, as the coefficient on $C \times P$ indicates, this increase is significantly more pronounced for constrained firms who experience higher regulatory costs and thus significantly higher loss in market shares in the traditional market. However, these changes are not just restricted to the traditional market. As we analyze firms with large share of traditional liabilities, the increase in regulatory risk weight for traditional products results in a large numbers of firms becoming constrained. Because constraints operate at the firm level, not

\(^{32}\)Firms are constrained if they have a capital buffer of less than 1, i.e. their current capital level is less than their minimum required capital.
only price of traditional insurance goes up, but also price of linked insurance goes up. Thus, as with traditional products, the parameter estimate on $C \times P$ is negative and statistically significant for linked market across all our specifications, showing that constrained firms experience significantly higher regulatory costs as predicted by our equilibrium model of the insurance sector.

We interpret these results as an upward shift in the supply curve for constrained firms for whom the marginal cost of providing insurance goes up in the presence of regulatory frictions. Our interpretation of a supply-side story (as opposed to a shift in insurance demand) is due to the following reasons. First, 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, making shifts in demand that are correlated with our measure of constraints seem unlikely. 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. To the extent that this is true more generally, an alternate explanation where households willingly substitute away from constrained firms as they know these firms could be less solvent from a regulatory stand-point is less plausible in the absence of this data in the public domain.

Second, our identification strategy allows us to directly rule out alternate explanations where demand for traditional or linked insurance shifts in general, as any parallel shift in demand that affects both groups equally, gets 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, would affect all firms writing traditional products. As our estimations are restricted to firms that primarily underwrite traditional products, it is not clear why only constrained firms experience a slowdown, while unconstrained firms experience a rise in traditional insurance underwriting between 2002 and 2007. 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, such changes should affect all firms. 89% of liabilities for constrained firms and 93% for unconstrained firms are within traditional products, thus it is not clear why only unconstrained firms increase linked underwriting between 2002 and 2007.

\[33\] Also see Goldstein and Sapra (2013) who discuss the costs and benefits associated with stress test disclosures.
Third, we control for observable firm characteristics that are known to drive variations in demand elasticities across firms. Insurance firms produce differentiated products, where differentiation is along company characteristics. Market shares depend on firm characteristics, thus product market changes could also be due to changes in firm characteristics over time. Thus, to account for changes in insurance underwriting beyond regulatory constraints, we add demand controls in specification II. Koijen and Yogo (2015) show that demand is positively related to both company size and A.M. Best rating for US insurance companies. In addition, Koijen and Yogo (2015) show that credit rating is largely explained by firm characteristics, including size of liabilities, leverage ratio, liquidity, return on assets, risk based capital (RBC), and mutual status of a firm. Since RBC is not directly available for UK firms, we use explicit asset and liability risk proxies. A full list of demand controls included are provided in table notes. As our results show, the product market changes persist even after controlling for observed firm characteristics that drive cross-sectional variations in demand elasticities across the two groups, making an alternate demand side explanation of our results less likely.

8. Robustness

8.1. 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) from 1997 to 2007. Figure 5 presents the results. Constrained firms adjusted their capital to assets ratios upwards, while unconstrained firms maintained a relatively stable capital to assets ratio during the five years window post 2002. Before 2002, the trend in capital ratio for both groups is roughly similar. We formalize these trends using the difference-in-differences regression described in section 6 with capital ratio as the dependent variable (table 4). The change in average difference between the two groups after 2002 is statistically significant and economically large. On an average, the constrained group increased their capital ratio by 4.8 percentage points as compared to the unconstrained group, supporting the fact that the new capital requirements became binding constraint for firms.

A firm’s choice of optimal capital is not independent of its choice of other asset and

34This makes sense as insurance is a complicated financial product that is largely sold through financial advisors who possess the ability to conduct sophisticated firm specific analysis, even though households may not do so directly.
liability risks. In particular, a firm with a higher than average allocation to equities or a firm that sells higher than average amount of risky annuities 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 by changes in capital requirements. We control for these market based incentives that also drive a firm’s capital choice differentially across the two groups. In specification II, we control for 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). We also control for a firm’s changing liability mix across products. As the linked businesses require substantially lower capital to operate, we include share of liability in linked products as an additional explanatory variable. As our results show, the differential evolution of capital ratio across the two groups persist even after controlling for observed firm characteristics that could drive changes in capital ratio, implying that the new capital requirements became binding and could lead to significant spill-overs in the product market.

8.2. Placebo Tests

We conduct placebo tests with alternate event years to examine whether similar product market changes occurred in other years. The tests exactly mirror 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 buffers. We repeat the difference-in-differences regression. Table 5 presents these results. The table shows the coefficient and standard errors for the independent variable of interest $C \times P$ for the full model specification with demand controls. The parameter estimates are insignificant across all years, implying that large scale product market changes are unique to 2002 when the regulatory changes took place.

8.3. Additional Tests

To provide additional robustness, we examine the following other issues. In table 6, we include a number of explanatory variables related to market re-organizations that have been described in section 3. Firm re-organizations, such as transfers or mergers, could have a significant effect on product market outcomes. If the constrained group experiences a differential rate of reorganizations relative to the unconstrained group, then this could explain
the substantial slowdown in premium income for constrained firms. Similarly, a merger or a transfer could also have a significant effect on the capital ratio of firms. To the extent that the constrained group experiences a differential rate of mergers or transfers, then this could explain the subsequent increase in capital ratio of constrained firms. However, as we show, the product market shifts and capital ratio changes persist even after controlling for re-organizational changes. As firms with capital buffer less than 1.2 also experience increased regulatory oversight, we run all our cross-sectional tests using this alternate definition of regulatory constraints. Table 7 provides these results for traditional and linked new premium, and capital to assets ratio. As the table shows, most of our results are statistically significant and economically large in magnitude, however as can be expected, the magnitudes of our results are stronger with the original definition of regulatory constraints. For additional robustness, we also use number of policies sold as an alternate dependent variable and show that our findings are robust to this specification.35

9. Conclusion

This paper examines whether the introduction of a risk-based capital regulation regime led to changes in product market outcomes for the insurance industry in the U.K.. We document a marked shift in the liability mix of insurance companies in the UK after a new regulatory regime was introduced in 2002. Proportion of net linked liabilities (products that are mainly investment vehicles like mutual funds providing little or no traditional life insurance) increased to 72% in 2014 from about 43% in 2002. Using a difference-in-differences identification strategy, we show that insurance companies that are relatively more constrained by regulation substantially reduce traditional insurance underwriting, a product that attracted higher capital charges in the new regime. In contrast, unconstrained firms substantially increase linked insurance underwriting. Thus, we show that changes in capital regulation led to marked changes in the equilibrium in both traditional and linked markets and impacted the equilibrium product mix of the insurance sector after 2002. A shift towards linked products, products that do not fulfill the economic function of standard insurance contracts, exposes households and businesses to increased amounts of idiosyncratic risk. This implies that capital regulation may have confounding implications for welfare as the welfare cost of sub-optimal insurance choices are significant (Koijen, Nieuwerburgh, Yogo (2015)). The implementation of Solvency II in January 2016 introduced risk-based capital requirements across the European Union. Our analysis could be relevant to understand the consequences of these regulatory changes on insurance markets in Europe.

35Results available on request.
References


The chart shows average minimum capital requirement in the old regime as compared to the new regime for reporting firms between 2003 and 2006. Data are as described in section 4. Since firms submit stress test results for their entire balance sheet (and not by each product line separately), we only focus on firms that have more than 90% of liabilities in each product line to understand the magnitude of average capital requirements for each product line separately. There are 31 firms with more than 90% traditional liabilities and 38 firms with more than 90% linked liabilities. New capital requirements refer to the post FSA review requirements.
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 UK long-term insurance industry as a whole from 1985 to 2014. The right panel shows the ratio of linked to traditional direct new premium written. Direct new premium refers to premium income from new policies net of reinsurance. The blue lines indicate average values of the ratio of linked to traditional direct new premium from 1985 to 2002 and from 2003 to 2014. The vertical line corresponds to the announcement of the new regulation in 2002.
Table 1: Capital Requirement Models

Table shows the results of the capital requirement models where capital requirements ratio across firms are regressed on their observable characteristics. Dependent variables are capital requirements to total assets ratio for each risk group. 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. Table reports parameter estimates, standard errors in parentheses, R-sq and adjusted R-sq. Data pertain to stress-test submissions between 2003 and 2006 for firms with more than £500 million in total assets.

<table>
<thead>
<tr>
<th>Contribution</th>
<th>Market (30%)</th>
<th>Credit (11%)</th>
<th>Interest Rate (12%)</th>
<th>Underwriting (32%)</th>
<th>Other (15%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity*FTSE(vol)</td>
<td>0.03*** (0.002)</td>
<td>0.03*** (0.002)</td>
<td>0.04*** (0.009)</td>
<td>0.05*** (0.001)</td>
<td>0.006 (0.005)</td>
</tr>
<tr>
<td>Non-Gov Bonds*Yield</td>
<td>0.01*** (0.001)</td>
<td>0.01*** (0.001)</td>
<td>0.06*** (0.015)</td>
<td>0.001 (0.001)</td>
<td>0.92*** (0.080)</td>
</tr>
<tr>
<td>Mortgages &amp; Loans</td>
<td>0.04*** (0.009)</td>
<td>0.06*** (0.015)</td>
<td>0.001 (0.001)</td>
<td>0.002** (0.001)</td>
<td>0.94*** (0.078)</td>
</tr>
<tr>
<td>All Bonds*Yield</td>
<td>0.001 (0.001)</td>
<td>0.002** (0.001)</td>
<td>0.001 (0.001)</td>
<td>0.002** (0.001)</td>
<td>0.006 (0.001)</td>
</tr>
<tr>
<td>Death &amp; Disability</td>
<td></td>
<td></td>
<td>0.92*** (0.080)</td>
<td>0.94*** (0.078)</td>
<td></td>
</tr>
<tr>
<td>Subsidiaries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.48*** (0.170)</td>
</tr>
<tr>
<td>Intercepts</td>
<td>0.006 (0.005)</td>
<td>0.003* (0.002)</td>
<td>-0.005** (0.002)</td>
<td>0.007 (0.004)</td>
<td>0.011* (0.006)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.000 (0.001)</td>
<td>0.004*** (0.001)</td>
<td>0.003* (0.002)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.005*** (0.001)</td>
<td>0.006*** (0.001)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.006 (0.002)</td>
</tr>
<tr>
<td>Time Fixed Effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.48 (0.06)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.45 (0.06)</td>
</tr>
<tr>
<td>R-sq</td>
<td>0.64</td>
<td>0.63</td>
<td>0.74</td>
<td>0.64</td>
<td>0.13</td>
</tr>
<tr>
<td>Adj R-sq</td>
<td>0.62</td>
<td>0.63</td>
<td>0.72</td>
<td>0.64</td>
<td>0.12</td>
</tr>
</tbody>
</table>
| N | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91
Figure 3: Distribution of Capital Buffer - Old vs. New Regimes

Chart provides a distribution of capital buffers for our sample of traditional firms in 2002. Data description is provided in section 4. The red line shows the capital buffer under the new regime, where capital requirements are calculated using the predicted values from the capital requirement models. The dotted blue line shows the distribution of capital buffer under the old capital requirement regime. The shaded area to the left of 1 denotes the mass of constrained firms under either regime.
Table 2: Characteristics of Constrained and Unconstrained Traditional Firms

The table shows basic firm characteristics such as assets, liabilities, financials, and group structures for our sample of constrained and unconstrained traditional firms in 2002. Data description is provided in section 4. Mean values are reported and standard errors are in parentheses. A test of difference in sample means across the two groups are reported in the last column.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Unconstrained</th>
<th>Constrained</th>
<th>Difference (t-stat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Firms</td>
<td>52</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Average Assets (£Billions)</td>
<td>3.80</td>
<td>7.53</td>
<td>-1.57</td>
</tr>
<tr>
<td></td>
<td>(1.09)</td>
<td>(2.15)</td>
<td></td>
</tr>
<tr>
<td>% Traditional Liabilities</td>
<td>0.929</td>
<td>0.890</td>
<td>1.62</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.018)</td>
<td></td>
</tr>
<tr>
<td>Asset Risk</td>
<td>0.471</td>
<td>0.551</td>
<td>-1.53</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.036)</td>
<td></td>
</tr>
<tr>
<td>Claims</td>
<td>0.131</td>
<td>0.156</td>
<td>-0.72</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.024)</td>
<td></td>
</tr>
<tr>
<td>ROA</td>
<td>-0.019</td>
<td>-0.014</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.018)</td>
<td></td>
</tr>
<tr>
<td>Reinsurance</td>
<td>0.127</td>
<td>0.117</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td>(0.030)</td>
<td></td>
</tr>
<tr>
<td>Mutual Status</td>
<td>0.539</td>
<td>0.510</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>(0.069)</td>
<td>(0.072)</td>
<td></td>
</tr>
<tr>
<td>Subsidiaries</td>
<td>0.135</td>
<td>0.204</td>
<td>-0.93</td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
<td>(0.058)</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4: Product Market Changes - Graphical Results

The chart shows average direct new premium underwritten by constrained and unconstrained groups from 1997 to 2007. Data description is provided in section 4. The left panel shows traditional new premium and the right panel shows linked new premium. Direct new premium refers to premium income from new policies net of reinsurance. The vertical line corresponds to the announcement of the new regulation in 2002.
Table 3: Product Market Changes - Difference-in-Differences Results

Table reports results of the difference-in-differences regression described in section 4. The left panel shows results for the traditional market and the right panel shows results for the linked market. $C \times P$ 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. Constrained firms are defined to have a capital buffer of less than 1. The dependent variable is $\log(PremiumIncome)$. 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%. Demand Controls: Log(assets), Capital to Asset Ratio, ROA, Liquidity Ratio, Asset Risk; Death & Disability, Annuity, and Surrender Claims; Reinsurance; Subsidiaries; and Mutual status.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Traditional</th>
<th>Linked</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>$C \times P$</td>
<td>-1.014**</td>
<td>-0.843**</td>
</tr>
<tr>
<td></td>
<td>(0.457)</td>
<td>(0.343)</td>
</tr>
<tr>
<td>Constant</td>
<td>9.867***</td>
<td>-1.330</td>
</tr>
<tr>
<td></td>
<td>(0.264)</td>
<td>(3.417)</td>
</tr>
<tr>
<td>Demand Controls</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>1,037</td>
<td>1,018</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.815</td>
<td>0.873</td>
</tr>
<tr>
<td>Cluster</td>
<td>Firm</td>
<td>Firm</td>
</tr>
</tbody>
</table>
Figure 5: Capital to Assets Ratio - Graphical Results

The chart shows the evolution of total capital to assets ratio from 1997 to 2007 for constrained and unconstrained groups in our sample. Data description is provided in section 4. The vertical line corresponds to the announcement of the new regulation in 2002.
Table 4: Capital to Assets Ratio - Difference-in-Differences Results

Table reports results of the difference-in-differences regression described in section 4. The dependent variable is the total 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 and $P$ is the post regulation dummy variable that takes a value of 1 after 2002. Constrained firms are defined to have a capital buffer of less than 1. 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%. Balance-sheet Controls: Asset Risk; Death & Disability, Annuity, and Surrender Claims; Reinsurance; Subsidiaries; Mutual status; % linked liabilities.

<table>
<thead>
<tr>
<th>Variables</th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C \times P$</td>
<td>0.048**</td>
<td>0.048**</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.192***</td>
<td>0.315***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.052)</td>
</tr>
<tr>
<td>Balance-sheet Controls</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>1,020</td>
<td>1,020</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.528</td>
<td>0.596</td>
</tr>
<tr>
<td>Cluster</td>
<td>Firm</td>
<td>Firm</td>
</tr>
</tbody>
</table>
Table 5: Placebo Tests - Alternate Event Years

The table shows the coefficient and standard errors for the independent variable of interest $C \times P$ for the full model specification with demand controls for a difference-in-differences regression estimated using data on traditional firms in 1997, 1998, and 1999. The procedure exactly mirrors what we followed in 2002 and is described in section 4. Constrained firms are defined to have a capital buffer of less than 1. Standard errors in parentheses are robust to heteroscedasticity and correlation at the firm level. Significance: * 10%; ** 5%; *** 1%. Demand Controls: Log(assets), Capital to Asset Ratio, ROA, Liquidity Ratio, Asset Risk; Death & Disability, Annuity, and Surrender Claims; Reinsurance; Subsidiaries; and Mutual status.

<table>
<thead>
<tr>
<th>Year</th>
<th>Capital Ratio</th>
<th>Traditional</th>
<th>Linked</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>0.033</td>
<td>0.120</td>
<td>-0.188</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.442)</td>
<td>(0.419)</td>
</tr>
<tr>
<td>1998</td>
<td>0.034</td>
<td>-0.512</td>
<td>0.792</td>
</tr>
<tr>
<td></td>
<td>(0.032)</td>
<td>(0.360)</td>
<td>(0.550)</td>
</tr>
<tr>
<td>1997</td>
<td>0.010</td>
<td>-0.266</td>
<td>0.643</td>
</tr>
<tr>
<td></td>
<td>(0.032)</td>
<td>(0.418)</td>
<td>(0.840)</td>
</tr>
</tbody>
</table>
Table 6: Robustness: Re-organizational Controls

Table reports results of the difference-in differences regression with re-organizational controls. Dependent variables $\log(Premium\ Income)$ and total capital to assets ratio are denoted at the top of each column. $C \times P$ 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. Constrained firms are defined to have a capital buffer of less than 1. 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%. Demand Controls: Log(assets), Capital to Asset Ratio, ROA, Liquidity Ratio, Asset Risk; Death & Disability, Annuity, and Surrender Claims; Reinsurance; Subsidiaries; and Mutual status.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Traditional</th>
<th>Linked</th>
<th>Capital Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C \times P$</td>
<td>-0.884***</td>
<td>-0.782*</td>
<td>0.043**</td>
</tr>
<tr>
<td></td>
<td>(0.333)</td>
<td>(0.397)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.775</td>
<td>-1.705</td>
<td>0.246***</td>
</tr>
<tr>
<td></td>
<td>(3.859)</td>
<td>(4.922)</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Demand Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Reorganization Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>1,018</td>
<td>1,018</td>
<td>1,020</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.874</td>
<td>0.911</td>
<td>0.620</td>
</tr>
<tr>
<td>Cluster</td>
<td>Firm</td>
<td>Firm</td>
<td>Firm</td>
</tr>
</tbody>
</table>
Table 7: Robustness: Alternate Definition for Constrained Firms (Capital Buffer < 1.2)

Table reports results of the difference-in differences regression described in section 4. Dependent variables log(PremiumIncome) and total capital to assets ratio are denoted at the top of each panel. $C \times P$ 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. Constrained firms are defined to have a capital buffer of less than 1.2. 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%.

Demand Controls: Log(assets), Capital to Asset Ratio, ROA, Liquidity Ratio, Asset Risk; Death & Disability, Annuity, and Surrender Claims; Reinsurance; Subsidiaries; and Mutual status.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Traditional</th>
<th>Linked</th>
<th>Capital Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>$C \times P$</td>
<td>-1.057**</td>
<td>-0.740**</td>
<td>-0.759**</td>
</tr>
<tr>
<td></td>
<td>(0.490)</td>
<td>(0.334)</td>
<td>(0.327)</td>
</tr>
<tr>
<td>Constant</td>
<td>10.21***</td>
<td>-0.810</td>
<td>-2.151</td>
</tr>
<tr>
<td></td>
<td>(0.230)</td>
<td>(3.423)</td>
<td>(3.879)</td>
</tr>
<tr>
<td>Demand Controls</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Reorganization Controls</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>1,037</td>
<td>1,018</td>
<td>1,018</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.815</td>
<td>0.872</td>
<td>0.873</td>
</tr>
</tbody>
</table>
APPENDIX A

Figure 6: Post FSA Review vs. Pre FSA Review Minimum Capital Requirements

The table shows the post FSA review relative to the pre FSA review minimum capital requirements by risk groups for reporting firms between 2003 and 2006. Data are as described in section 4. Requirements are in £billions. Except for the other risk group, firms did not receive significant capital add-ons in any other risk group, implying that systematic under-reporting of capital requirements is unlikely.
Figure 7: Average Minimum Required Capital to Total Assets Ratio by Risk Groups

The chart shows average minimum capital requirement from each risk group for reporting firms between 2003 and 2006. Data are as described in section 4. Chart provides a more detailed breakdown of economic capital requirement coming from each risk group. Since firms submit stress test results for their entire balance sheet (and not by each product line separately), we only focus on firms that have more than 90% of liabilities in each product line to understand the magnitude of average capital requirements for each product line separately. There are 31 firms with more than 90% traditional liabilities and 38 firms with more than 90% linked liabilities. We also show average capital requirements for firms with 100% linked liabilities (20 firms). New capital requirements refer to the post FSA review requirements.
The chart shows a scatter plot between actual total requirements and predicted total requirements. The capital requirement models estimated before (see section 4) are used to predict total capital requirement for each risk group, which are added together to compute total predicted requirements. The implied $R^2 = 68\%$. The results are in-sample.