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The relations among asset risk, product risk, and capital in the life insurance industry

Etti G. Baranoff [a,*,1], Thomas W. Sager [b,2]

[a] *Virginia Commonwealth University, School of Business, 1015 Floyd Avenue, Richmond, VA 23284-4000, USA*

[b] *Center for Statistical Sciences, Department of Management Science and Information Systems, The University of Texas at Austin, CBA 5.202, Austin, TX 78712-1175, USA*

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Abstract

This paper explores the relation between capital and risk in the life insurance industry in the period after the adoption of life risk-based capital (RBC) regulation. To examine this issue, we use a simultaneous-equation partial-adjustment model. Three equations express the interrelations among capital and two measures of risk: product risk and asset risk. The asset-risk measure used in this paper reflects credit or solvency risk as in RBC. Product risk assessment for life insurance products is rationalized by transaction-cost economics – contractual uncertainty. A significant finding is that for life insurers the relation between capital and asset risk is positive. This agrees with prior studies for the property/casualty insurance industry and some banking studies. But the relation between capital and product risk is negative. This is consistent with the hypothesized impact of guarantee funds in other studies. The contrast between the positive relation of capital to asset risk and the negative relation of capital to product risk underscores the importance of distinguishing these two components of risk. © 2002 Elsevier Science B.V. All rights reserved.

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* Corresponding author. Tel.: +1-512-345-7486; fax: +1-512-502-8561.
E-mail address: ebaranof@vcu.edu (E.G. Baranoff).
[1] Tel.: +1-804-828-3187.
[2] Tel.: +1-512-471-3322.

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1. Introduction

This is the first study to look at the simultaneous interrelation among capital, asset risk and product risk in the life insurance industry using the framework of Shrieves and Dahl (1992) and Cummins and Sommer (1996). For the life insurance industry, academic research in this area has concentrated mostly on the influence of the life risk-based capital (RBC) regulatory tool. Pottier and Sommer (1997) compared the life RBC results with those of the insurance industry's rating organizations and Ryan and Schellhorn (2000) examined the impact of the life RBC law on life insurer's efficiency.

The interrelation between capital and risk for the banking industry received attention from Shrieves and Dahl (1992) and Jacques and Nigro (1997), among others. Berger et al. (1995) provide a survey of capital structure studies in the banking industry. In the insurance industry, Cummins and Sommer (1996) examined the interrelation between capital and risk, but only for the property/casualty insurance industry. In this study, we apply the methods used by Shrieves and Dahl (1992) and Cummins and Sommer (1996) to the life insurance industry in the post-RBC era.

The banking literature presents somewhat inconsistent empirical results on the interrelation between the capital-to-asset ratio and asset risk. Shrieves and Dahl (1992) found a positive relation between the capital-to-asset ratio and asset risk for the period of 1983–1986, but Jacques and Nigro (1997) found a negative relation between capital and asset risk for 1991. Berger (1995) found that the level of capital to asset ratio was negatively related to the level of portfolio risk in a study of the relation between capital and earnings in banking for the period of 1983–1989. The asset risk measure of these studies was based on the 1988 Basle Accord RBC guidelines. For the property/casualty industry, Cummins and Sommer (1996) found a positive relation for capital and risk levels in 1979–1990. They aggregated asset and product risk into a single portfolio risk measure using a model based on option pricing.

A positive relation between capital, on the one hand, and asset risk or product risk, on the other hand, is consistent with agency theory, transaction-cost economics theory (Williamson, 1988) and insurers' preference to avoid bankruptcy costs (Cummins and Sommer, 1996; Shrieves and Dahl, 1992). Transaction-cost economics (Williamson, 1988) assumes that when the products sold by the firm are riskier, debt financing is harder to obtain because of greater uncertainty that the firm will fulfill its contractual obligation to repay. Thus, firms that sell products with greater risk such as health insurance are expected to hold more capital. Additional theoretical explanation for the positive relation between risk and capital (Shrieves and Dahl, 1992) is that a firm will adopt lower leverage levels because of regulatory costs, unintended effects of minimum capital standards, and bankruptcy cost avoidance considerations.

A negative relation between capital and risk is consistent with the hypothesis that deposit insurance for banks and guarantee funds for insurers induce greater risk taking at lower capital levels (Cummins, 1998). Lee et al. (1997) express this idea as the risk-subsidy hypothesis and show its applicability to stock insurers. Downs and Sommer (1999) also show that it holds for publicly traded insurers with some insider ownership.

In addition to systematic or macroeconomics risk, insurers face specific risks that arise from the written policy contracts and their invested assets. These are termed product risk and asset risk, respectively. Management of these two risks represents major aspects of an insurer's operations. For that reason, we focus only on the simultaneous influence of asset risk and product risk on the capital ratio of life insurers, although other risk types exist [3] (Santomero and Babbel, 1997; Gleason, 2000). For a capital measure, we take the adjusted book value of capital, as defined in the life RBC rules, divided by total firm assets. [4] The level of product risk is a measure of exposure to health insurance writings, which we rationalize by transaction-cost economic theory as applied to the life insurance industry. The product risk actually reflects the contractual risk of the relational and incomplete health insurance product as we interpret Williamson (1985) and as reflected in the life RBC. [5] We base our measure of asset risk on a modification and approximation of the "regulatory" definition given in the RBC rules for life insurance. [6] Thus our asset risk corresponds to the actuarial concept of credit/solvency risk as defined by Shrieves and Dahl (1992), Jacques and Nigro (1997), and Berger (1995) for the banking industry, and by Santomero and Babbel (1997) for the insurance industry. Our asset risk is not a measure of the *financial market* risk of assets, as defined by Cummins and Sommer (1996). Since this study focuses on the post-RBC era, a regulatory asset risk measure is selected for this study. This selection also allows us to compare our results for asset risk to those in the literature on the banking industry.

Using a simultaneous-equations model, we find a positive relation between capital ratio and regulatory asset risk, but a negative relation between the capital ratio and product risk. Caution must be exercised in comparing these results with those of other studies that do not separate the asset risk from the product risk, or that use different definitions of asset risk. Our results appear to be partly consistent with the results of Shrieves and Dahl (1992) for the banking industry. The comparison with the property/casualty study of Cummins and Sommer (1996) is less relevant since they used a different proxy of risk and did not separate the asset from the product risk.

The paper is organized as follows: Section 2 reviews hypotheses for relations between risk and capital, describes the life insurance industry's products and the definition of the endogenous variables – capital ratio, asset risk and product risk. Section 3

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[3] The Risk 2000 conference in Boston in June, 2000 dealt with various types of risks: credit, market and operational risks and their integration. The March, 2000 issue of *Risk* publication devotes various articles to the integration of financial risks faced by financial institutions.

[4] The book value is used since most life insurers are not publicly traded.

[5] It is part of the C-2 risk in the RBC formula as described in Footnote 13.

[6] It is a modification to the C-1 risk in the RBC formula as described in Footnotes 13 and 14.

explains the data and the model, while Section 4 presents the results. The paper concludes with a summary.

2. Product risk, asset risk and capital in the life insurance industry

2.1. Hypotheses

The literature entertains two conflicting hypotheses regarding the interrelation among asset risk, product risk and capital structure. The first hypothesis assumes a positive relation between asset risk and capital ratio and also between product risk and capital ratio, as noted in Section 1. This hypothesis is supported by agency theory (Lamm-Tennant and Starks, 1993; Mayers and Smith, 1981, 1986, 1988, 1994; Shrieves and Dahl, 1992; Cummins and Sommer, 1996; Pottier and Sommer, 1997), transaction-cost economics (Williamson, 1988) and bankruptcy-cost-avoidance arguments. In agency theory, risk taking is inversely related to the degree of separation between managers and owners. Cummins and Sommer (1996) cited agency theory to advance their argument about leverage and risk taking. They examined only public and private stock insurers and contended that a larger separation between the owners and the managers leads to lower overall risk taking. Therefore, managers of publicly traded insurers undertake lower levels of risk or adopt less risky strategies than do managers of privately held firms. Since there is greater separation between managers and the policyholders in mutual companies, managers of mutual insurers undertake even lower levels of risk than managers of stock companies.

Using transaction-cost economics theory, Williamson (1988) contends that the nature of a firm's products influences a firm's capital structure. If a firm deals in riskier and uncertain products, the firm is more likely to use equity capital than debt instruments. Product riskiness derives from product specificity, which is closely associated with the incompleteness of contracts involved with trading the product. Incomplete contracts create uncertainties that lead to conflicts among stakeholders.

Thus both transaction-cost economics and agency theories predict that greater conflicts, whether generated by divergence between managers and owners or by riskier products, lead to reduced leverage or increased capital to mitigate the uncertainties due to the conflicts. Shrieves and Dahl (1992) also add regulatory costs, unintended effects of minimum capital standards, and bankruptcy-cost-avoidance as reasons for a positive relation between risk and capital.

The second hypothesis posits a negative relation. Under this hypothesis deposit insurance for banks and guarantee funds for insurance provide incentives to increase the risk as capital decreases, as demonstrated by Merton (1977) for banks and Cummins (1998) for insurers. A theoretical explanation for this view equates deposit insurance and guarantee funds with the grant to firm owners of a put option that has strike price equal to the value of the guarantees. Risky behavior is encouraged because any shortfall between equity and liabilities can be covered by the guarantee fund through exercise of the put (Downs and Sommer, 1999). Lee et al. (1997) call it the risk-subsidy hypothesis. [7] They found that stock insurers shifted their asset distribution towards riskier allocation after the introduction of guarantee funds. Downs and Sommer (1999) also examined the risk-subsidy versus the monitoring hypotheses for the property/liability insurance industry and found evidence in favor of the risk-subsidy hypothesis. [8]

Thus, we examine here two opposing hypotheses for the life insurance industry.

H1. There is a positive relation between capital, on the one hand, and asset risk and product risk on the other hand.

H2. There is a negative relation between capital, on the one hand, and asset risk and product risk on the other hand.

To bring this argument into the realm of the life insurance industry and its products, we now provide a brief discussion of life insurance products and their relative risk levels. The objective of this exposition is to support our contention that health products pose greater risks than other products sold by life insurers. Therefore, the degree of concentration in health products may be taken as a (partial) measure of product risk.

2.2. Product risk

The life insurance industry provides an array of products – annuity, life, health, and reinsurance products. In 1997, the industry wrote a total of \$410.3 billion in written premiums and \$41.5 billion in reinsurance assumed, of which total 44.1% was in annuity coverages, 20.5% in health coverages, 25.8% in life coverages, and 9.2% in reinsurance. The industry also wrote \$151.6 billion in deposit-type (pension) funds. [9] Annuities and deposit type funds (pension funds) represent savings and are similar instruments to those used by non-insurance-type financial institutions except for the mortality element of the annuitants.

Each product sold by the life insurance industry is basically a contract. The insurance contract attempts to reduce to writing the risk exchanged between the insured and insurer; the contract attempts to specify accurately and precisely all of the conditions covered and the obligations of the parties to enforce execution. Transaction costs extend beyond the costs of contract drafting to include far more significantly,

[7] They examined the risk-subsidy hypothesis versus the monitoring hypothesis, which asserts that insurers lower their risk taking as competitors monitor their actions to detect especially risky behavior that would lead to increased guarantee fund assessments for all. Lee, Mayers and Smith find evidence in favor of the risk-subsidy hypothesis by studying asset mix changes before and after the introduction of guarantee funds.

[8] Their study focused on the risk-taking of property/liability insurers' managers who are also owners. They found that when managers become part owners, their incentives align with the owners and they take more risk.

[9] *Source*: annual statement of life insurers. Data from Exhibit 1 and Summary of Operations (p. 4).

the inability of the contract to express explicitly the obligations of the parties. The imperfections, incompleteness, and inability of the contracts to define explicitly all contingencies are the core of transaction costs theory (Williamson, 1985; Milgrom and Roberts, 1992) and the risk level embedded in the contract. The more explicit the contract, the less are the risks of conflicts among the stakeholders. Williamson (1985) provided a typology of contracts based on transaction costs: classical (low risk – or low asset specificity), neoclassical (medium risk), and relational (high risk). It is useful to interpret life insurance products in terms of this typology.

A classical contract is used for a product that is non-specific and occasionally traded. We suggest that the life insurance industry's product most closely fitting this category is the annuity product. Annuities or deposit-type funds can be considered financial intermediation products similar to various savings plans, but with mortality factors. Insurance companies are at risk should an annuitant live too long, but actuaries use mortality tables to project longevity and reduce the risk faced by insurers. When annuities are sold, there are no underwriting criteria to be met and annuity contracts are not specific to the individual annuitant but are uniform within age and sex cohort. In Williamson's terminology, the annuity contract is a classical contract since it is sold by insurers either occasionally (a single deposit type) or recurrently (on-going payments) without requirements of specific individual characteristics regarding health and life style factors.

A neoclassical contract, on the other hand, has mixed characteristics with an extended contractual term. We suggest that the life products most closely fit this category. Life insurance products sold by the industry include term life, whole life, universal life, and variable life, among others. [10] They require underwriting criteria relating to health and life style status of the policyholder. Because of the long duration of these products, they may pose some risk to the industry if the force of mortality changes dramatically, as when the AIDS epidemic erupted.

The third and most complex and risky contract is the relational contract. It is a contract with specific and mixed characteristics and is sold recurrently. We suggest that health insurance fits this category. The contract may explicitly exclude certain coverages, such as experimental drugs, but courts may rule otherwise, or may define exclusions such as "experimental" more narrowly than insurers had intended. As opposed to life insurance contracts that are sold for a predetermined death benefit amount, the actual sum to be paid under the medical expense insurance policies is not well defined. Despite the use of morbidity tables and commonly accepted actuarial methods, the vicissitudes of medical technology and regulatory intervention keep the contract more open-ended. Managed care attempts to limit costs, and thereby uncertainties. However, legislative efforts such the "Patients' Bill of Rights" [11]

[10] For a complete description of the types of life products available in the market place, see Rejda (2001, Chapters 16–19).

[11] For information about the "Patients' Bill of Rights" see, for example, some of the proposed legislation such as: "Patients' Bill of Rights Act of 1999 (Introduced in the Senate) [S.6.IS]" or "Patients' Bill of Rights Act of 1999 (Placed on the Calendar in the Senate) [S.1344.PCS]", or "Patients' Bill of Rights Act of 1999 (Introduced in the House) [H.R.358.IH]", etc.

create barriers to a more explicit health insurance contract. In addition, due to the dynamic developments in medical technology, new medicines and procedures frequently change the obligations of coverage or open new avenues for debate and litigation. [12] The de facto coverage of the contract changes as society, medical technology and courts change. The contracts are relational in terms of adapting to changes in the states of the world and pose greater risk of conflicts among the stakeholders. Greater conflict resulting from the sale of health products is evidenced by the relatively higher legal expenses of insurers that specialize in health contracts. During 1993–1997, the average annual legal expense as a percent of total assets for life insurers that write more than 70% of their business in health lines was 0.0984%, compared with 0.0185% for all other life insurers.

Insurance regulators also recognized the higher risk inherent in selling health products. In the life RBC formula, health writings receive a higher penalty weight than life writings. Annuity writings receive zero weight. [13] Thus, for our study we selected the ratio of health writings to total writings by an insurer as the product risk measure.

[12] An anecdotal example is provided by the new medication for impotency, Viagra, that was introduced by Pfizer in 1998. The Wall Street Journal (6-17-98, p. B7) reports that Aetna told the NY regulators it would not pay for the new medication. “Aetna is the only company so far that has refused to include Viagra as part of normal coverage, the state spokesman said”. Additional new media reports indicate that insurers limit coverage for Viagra in an attempt to curtail the escalating costs.

[13] Before 1996, four components comprised the Life RBC formula comprising four components. Each was related to different categories of risk: asset risk (C-1), insurance risk (C-2), interest rate risk (C-3), and business risk (C-4). Each of the four categories of risk is a dollar figure representing a minimum amount of capital required to cover the corresponding risk. In the Life Risk-Based Capital W.G, May 26, 2000, Draft copy, Interest Rate Risk Section LR022, interest risk is explained as “the risk of losses due to changes in interest rate levels. The factors chosen represent the surplus necessary to provide for a lack of synchronization of asset and liability cash flows”. When there is a mismatch in asset/liabilities for annuities, there are some corresponding factors for capital charge. This is the part which relates to annuities in the life RBC. In 1996, the National Association of Insurance Commissioners (NAIC) added changes to C-1 risk. Some of these changes relate to derivative instruments. Another significant change was the creation of C-0 risk for investment of affiliated companies. Affiliated stocks and off-balance sheet risk changes were moved from C-1 risk component into the new C-0 component. The RBC formula combines these five components into a single composite measure called RBC *authorized capital.*

$$\text{RBC authorized capital} = \left\{(\text{C-0}) + (\text{C-4}) + \sqrt{[(\text{C-1} + \text{C-3})^2 + (\text{C-2})^2]}\right\} \times 50\%.$$

The C-2 risk is the risk of under-estimating liabilities from business already written or of inadequately pricing business to be written in the coming year. The C-2 component is intended to reflect risk deriving from different product lines through differential loadings. Despite the life insurance industry’s multiple exposures in life, health, annuity and reinsurance products, the C-2 risk has risk loading on health and life writings only. Under this part of the RBC formula, health writing receives a loading in the range of 8–25% of premiums. The life insurance factors are chosen to “represent surplus needed to provide for excess claims over expected”. Evidently, lawmakers recognized the low specificity level of the annuity products. It is reported that most of the industry’s cumulative C-2 risk derives from the health writing of smaller insurers (Barth, 1995, 1996).

2.3. Asset risk

Although the life insurance industry is in the business of selling insurance coverages and annuities, it is also in the business of investing the funds entrusted to them and therefore is part of the financial institutions industry. Regulators assess the credit, or default, riskiness of each asset in the asset risk (C-1) component of the life RBC. In general, the C-1 risk is the sum of various risk loadings on the book value of a firm's assets, by value in dollars. [14] This asset risk measure represents an actuarial and regulatory perspective of asset risk. Such regulatory-based measures of asset risk were used by Shrieves and Dahl (1992), Jacques and Nigro (1997), and Berger (1995) for the banking studies. For the life industry, we adopt a similar proxy called regulatory asset risk that is based on publicly available data from the companies' annual statements. [15]

2.4. Capital-to-asset ratio

Because most life insurers are not publicly traded, market valuations of their capital are not readily available. Therefore, we measure capital by the adjusted book value of capital. [16] The median of the capital-to-asset ratio of insurers writing more than 70% of their premiums in annuities is close to the average of 7.2% shown in Shrieves and Dahl (1992) paper for the banking industry during 1984–1986. [17] The median for insurers writing more than 70% in health insurance is somewhat greater than the average capital to asset ratio of 33.9% shown by Cummins and Sommer (1996) for the Property/Casualty industry during 1979–1990. Thus, it appears that insurers specializing in annuities and financial intermediation-type instruments are closer in their capital structure to that of the banking industry, and insurers spe-

[14] C-1 risk includes a 30% risk loading for a company's lowest rated bonds, but zero risk loading for the highest rated bonds. The loading for mortgages depends on the delinquency potential of the mortgages. Unaffiliated preferred and common stocks receive a loading factor in the range of 2–30% of their value. Real estate has loadings of 10% and 15%, with foreclosed real estate receiving the higher loading. Other long-term assets also receive loadings up to 30% of value based on their credit ratings. Cash and short-term investments receive a 3% loading.

[15] Regulatory Asset Risk for each insurer for each year (1993, 1994, 1995, 1996, 1997) $= \sum$ {total low quality bonds $* (0.30 + 0.20 + 0.09)/3$, total high quality bonds $* (0.04 + 0.01 + 0.003)/3$, total stocks $* (0.30 + 0.023)/2$, total mortgages $* 0.03$ (an average between 0.001 and 0.06), total real estate $* (0.1 + 0.15 + 0.1)/3$, and total short term investments and cash $* 0.003$} – with the result then divided by total insurer assets.

[16] The adjusted capital formula is the sum of Capital and Surplus, asset valuation reserve (AVR), voluntary investment reserve, Dvidends apportioned for payment, Dividends not yet Apportioned, and the Life Subsidiaries AVR, Voluntary Investment Reserves and Dividend Liability less Property/Casualty Subsidiaries Non-Tabular Discount. *Source*: NAIC (1996, p. LR022).

[17] Also, in an overview by Berger et al. (1995) about the role of capital in financial institutions, the authors present a chart of the equity as a percent of assets for US commercial banks for the period 1840–1993. They show that since after the creation of the FDIC in 1933, the ratio settled at the 6–8% range from the mid-1940s to the 1990s.

cializing in health products appear to have a capital ratio level similar to that of the property/casualty industry.

3. Equation specification and variables

This section provides a brief specification of the partial-adjustment model used by Shrieves and Dahl (1992) and Cummins and Sommer (1996) and the variables used in the estimation model that is used in this study.

In single equation mode, the partial-adjustment model proposes the existence of an unobservable target (or desired, or equilibrium) level Y_t^* for an observable response Y_t. Over time, the actual response Y_t adjusts to the target by (partially) closing the gap according to the partial-adjustment hypothesis $Y_t - Y_{t-1} = \delta(Y_t^* - Y_{t-1})$, where $Y_t^* - Y_{t-1}$ is the desired change, $Y_t - Y_{t-1}$ is the actual change, and δ is the partial-adjustment coefficient. Although Y_t^* is not directly observable, it is a function $Y_t^* = f(X_{1t}, \dots, X_{kt})$ of observable predictors. Upon substitution of that function for Y_t^* and rewriting the partial-adjustment relation as $Y_t = \delta Y_t^* + (1-\delta)Y_{t-1} = \delta f(X_{1t}, \dots, X_{kt}) + (1-\delta)Y_{t-1}$, we have Y_t expressed more conventionally for estimation purposes as a function of the predictors and the lag of Y_t.

Both Shrieves and Dahl (1992) and Cummins and Sommer (1996) utilize the partial-adjustment model in simultaneous-equation mode. We follow their lead here. For our three response variables (capital-to-asset ratio [C], regulatory asset risk [A], and product risk [P]), we posit three unobservable target levels, C_t^*, A_t^*, and P_t^*, and the partial-adjustment mechanism [18]

$$\begin{aligned} C_t - C_{t-1} &= \delta_C(C_t^* - C_{t-1}) + \xi_t^C, \\ A_t - A_{t-1} &= \delta_A(A_t^* - A_{t-1}) + \xi_t^A, \\ P_t - P_{t-1} &= \delta_P(P_t^* - P_{t-1}) + \xi_t^P, \end{aligned} \tag{1}$$

in which ξ_t^C, ξ_t^A, and ξ_t^P represent randomly distributed disturbances (residual errors). In this model, insurers determine their desired capital, asset risk, and product risk adjustments ($C_t^* - C_{t-1}$, $A_t^* - A_{t-1}$, and $P_t^* - P_{t-1}$) endogenously, simultaneously, and interrelatedly. But each of the target levels (C_t^*, A_t^*, or P_t^*) is a function of exogenous predictors $X_{1t}, \dots, X_{kt}$, as well as of concurrent values of the other two observable responses (two of C_t, A_t, and P_t). We assume the target function has linear form and also includes an exogenous random disturbance. The targeting decisions of insurers for their capital and risk measures depend upon their preferences regarding matters

[18] At least in the case of capital, it may be the case that the partial-adjustment mechanism may not apply as we propose here. For publicly traded companies, there are fixed costs and economies of scale for stock offerings. Thus, such insurers may be inclined to overshoot their target capital levels. The resulting excess of capital may lead to spillover effects on other risk targets. Insurers may also reduce excess capital by stock buy-backs. However, we point out that most life insurers are not publicly traded. Moreover, the coefficient of partial adjustment is not mathematically constrained to be less than one. So, in principle, the empirical analysis could detect a tendency to overshoot if it is prevalent.

such as issuing additional stock, demutualization, retention of earnings, asset/liabilities matching, etc. Examples of exogenous disturbances for the life insurance industry include changes in medical technology, changes in the legal environment, economic downturn, and greater competition from other financial institutions. Following Cummins and Sommer (1996), we rewrite Eq. (1) in a form suitable for estimation by simultaneous-equation methods. We do this by substituting a linear function of the predictors and the other two observable responses for the target level in each equation, moving all terms but the response to the right-hand-side, and reparameterizing. For example, the first equation in Eq. (1) becomes

$$\begin{aligned} C_t &= \delta_C C_t^* + (1-\delta_C)C_{t-1} + \xi_t^C \\ &= \delta_C(L(X_{1t},\ldots,X_{kt},A_t,P_t) + \gamma_t) + (1-\delta_C)C_{t-1} + \xi_t^C, \end{aligned}$$

where L represents the linear form for C_t^* and γ_t is an exogenous disturbance. Upon the reparameterization, this equation becomes the first in Eq. (2):

$$\begin{aligned} C_t &= \beta_0^C + \beta_C^C C_{t-1} + \beta_A^C A_t + \beta_P^C P_t + \beta_1^C X_{1t} + \cdots + \beta_k^C X_{kt} + \varepsilon_t^C, \\ A_t &= \beta_0^A + \beta_C^A C_t + \beta_A^A A_{t-1} + \beta_P^A P_t + \beta_1^A X_{1t} + \cdots + \beta_k^A X_{kt} + \varepsilon_t^A, \\ P_t &= \beta_0^P + \beta_C^P C_t + \beta_A^P A_t + \beta_P^P P_{t-1} + \beta_1^P X_{1t} + \cdots + \beta_k^P X_{kt} + \varepsilon_t^P. \end{aligned} \tag{2}$$

We note for future reference that $\beta_C^C = 1-\delta_C$, $\beta_A^A = 1-\delta_A$, and $\beta_P^P = 1-\delta_P$. Forcing one or more of $\beta_1,\ldots,\beta_k$ to be zero in a given equation permits selective adjustment of the predictor set for each response.

Although OLS may be used to estimate the partial-adjustment model for cross-sectional data, [19] a correction for autocorrelation is required for our data, which are longitudinal. We have five consecutive years of values for each insurer. It is reasonable to expect that one insurer will be uncorrelated with another, but that successive years for the same insurer will be correlated. Moreover, even when the structural equations (Eq. (2)) are linear, the reduced-form parameter relations may be highly nonlinear. Recent concerns over the use in such contexts of efficient full-information estimation methods, such as three-stage least squares or maximum likelihood, led us to adapt the theoretically somewhat less efficient two-stage least squares method for the longitudinally autocorrelated context. [20] As in Cummins and Sommer (1996), we model the disturbances in Eq. (2) by a first-order autoregressive process, which results in a block-diagonal structure for the covariance matrix of the disturbances. [21] The autoregressive two-stage least squares procedure corrects for autocorrelation in simultaneous equations by means of instrumental variables, and iterates on the autocorrelation coefficient until convergence.

[19] Cf. Gujarati (1995, p. 603).

[20] If the model specification is correct, then 3SLS (or maximum likelihood, if normality obtains) is consistent and efficient; and 2SLS is consistent, but not efficient. However, 3SLS is not as robust as 2SLS to model misspecifications. Moreover, our data are rather numerous, so we are not too concerned about inefficiency.

[21] Theoretical details may be found in Kmenta (1986, pp. 704–710).

3.1. Explanatory variables

Among the explanatory variables are the following: An indicator for the governance structure (mutual or stock, NTYPE) is suggested by agency-theory-based studies (Lamm-Tennant and Starks, 1993; Mayers and Smith, 1981, 1986, 1988, 1994; Pottier and Sommer, 1997). As noted above, Cummins and Sommer (1996) consider agency theory to imply that risk taking is inversely related to the degree of separation of ownership from management. This implies that, in mutual insurance companies, managers will take less risk than in stock companies. Additionally, we added an indicator for whether the insurer is a member of a group of affiliated companies (NGROUP). Insurers who are part of a larger group may have superior access to capital and investment opportunities and may have different mechanisms for monitoring/controlling managerial performance (Shrieves and Dahl, 1992). Insurer size is an important determinant of insurer behavior according to the insurance literature on economy of scale and scope (Grace and Timme, 1992). Size is measured by the logarithm of total assets (LogAssets). Since a major source for increase in capital is the retained earnings, the return on capital (RETONCAP) is included in logarithmic form. Berger (1995) shows a significant positive relation between the return and capital-to-asset ratio.

Regulatory influences on risk and capital are the cornerstone of many of these studies of the regulated financial institutions. An additional explanatory variable signifies a significant degree of regulatory pressure (RBCratio). [22] Other control variables included YEAR95, YEAR96 and YEAR97 – binary indicators that capture general industry changes specific to the study years that are not otherwise incorporated explicitly into the model. [23]

From the perspective of the partial-adjustment model, it is reasonable to view the lagged variables C_{t-1}, A_{t-1}, and P_{t-1} as pre-determined quantities in setting targets for the next year. So these variables may be treated as exogenous. The five indicator variables may also be considered predetermined or exogenous – the three year indicators by definition, and NTYPE and NGROUP because once the structural choices are made to issue stock or not and to organize as an affiliated group or not, they are not likely to be changed easily. Compared with the indicator variables, return on capital, RBC ratio, and log(Assets) are more subject to year-to-year firm control. From the perspective of the partial-adjustment model, to treat these variables as predetermined or exogenous is to allow that they may affect the targeting decisions for capital, asset risk, and product risk but that either these decisions do not affect them more than minimally, or that we condition on them and view our Eqs. (1) and (2) as part of a larger process of firm decision-making and targeting. In fact, it is likely that the firm will have mechanisms for electing a desirable growth rate, optimizing return

[22] The Life RBC law specifies five trigger points for increasingly stringent regulatory intervention using the RBC ratio. The RBC ratio is calculated for each company by the formula RBC ratio = (total adjusted capital $*$ 100)/(2 $*$ authorized control level RBC), as prescribed by the life RBC law.

[23] There are only three year indicators because 1993 is lost on account of lagging, and inclusion of 1994 would induce a singularity due to multicollinearity with the other year indicators.

on capital, and attending to formulaic RBC especially if the latter is close to levels that would trigger regulatory scrutiny. One can also argue plausibly that the effects of our response variables on size, returns, and RBC may not be too direct. For example, the size of the firm usually does not vary dramatically, so may be taken as approximately a given value for our model. Return is a variable the firm attempts to maximize, but the firm's success is strongly mediated by market forces and structural constraints over which it has limited control. The RBC formula is determined by regulators, but the firm can allocate investments and favor business lines and asset mix that improve its score. So a plausible argument can be advanced for embedding our model in a larger decision-making context. On the other hand, our model is relatively simple and it is useful to isolate its three interrelated components from the larger context for the insights that it provides. Thus, for our purposes, we define the exogenous variables to include all variables except capital ratio, asset risk and product risk as noted above.

4. Data and empirical results

4.1. Data

Data were obtained from the NAIC database of insurers' annual statements for 1993–1997. Since the life RBC law was promulgated in 1993, the analysis therefore covered a period of fairly consistent regulation for life insurers. There were 1,022 life insurers with complete data for each of the five years that we were able to use in our analysis. Table 1 shows summary statistics for these insurers amalgamated over the five years (5,110 observations).

A few highlights are worth noting in comparison with prior banking (Shrieves and Dahl, 1992) and property/casualty insurance industry studies (Cummins and Sommer, 1996). The average capital-to-asset level for our life insurer database was about 32% for the period. This level of capital contrasts with 7.2% for the banking industry for the period 1984–1986, and compares with 34% for the property/casualty industry

Table 1
Summary statistics: 1993–1997 (1022 insurers in each year)

Variable	Mean	S.D.	Median
Capital/asset ratio	0.3221	0.2695	0.2247
Regulatory asset risk	0.0240	0.0411	0.0107
Product risk	0.2727	0.3722	0.0556
Total assets (in $ millions)	$2,032.6	$9,697.7	$91.805
Return on capital	1.9572	0.0424	1.9576
RBC ratio	3,296	87,320	371
Log(total assets)	18.4979	2.5199	18.3352
Indicator for group member	0.2626	0.4401	0
Indicator for stock(1) or mutual(0)	0.9025	0.2966	1

for the period 1979–1990. [24] For the risk measures, it appears that there are no precisely equivalent measures in the banking and property/casualty studies for either the product risk or the asset risk. The health writings constituted about 27% of the average firm's writings for our database, while the regulatory asset risk was 2.4% of insurer assets. Because of large variability in life insurer assets, we used the logarithm of assets as a predictor, rather than assets in original scale. About 26% of our database are members of affiliated groups; 90% are stock companies. Although not shown in Table 1, the investment portfolios of our life insurers differed from those of property/casualty insurers. [25]

4.2. Results of model estimation

Results for autoregressive two-stage least-squares estimation of the three equations in Eq. (2) are shown in Table 2. Parts (i), (ii) and (iii) of Table 2 correspond to the equations for the capital ratio, asset risk, and product risk, respectively.

In Parts (i), (ii) and (iii), we note that all three endogenous variables are significant as predictors. Moreover, the signs of the endogenous coefficients are consistent among the three equations. That is, the capital–asset risk relation is positive in Parts (i) and (ii); the capital–product risk relation is negative in Parts (i) and (iii); and the asset risk–product risk relation is positive in Parts (ii) and (iii). [26] The positive capital–asset risk relation is consistent with hypothesis H1, whereas the negative capital–product risk relation is consistent with hypothesis H2. We interpret these results as lending support to transaction-cost, agency, and bankruptcy-cost-avoidance theories for asset risk, but supporting risk-subsidy and other theories of negative relations for product risk. The contrast between the positive relation of capital to asset risk and the negative relation of capital to product risk underscores the importance of distinguishing these two components of risk.

These results raise questions for life insurance regulation, which treats each risk category as essentially additive. In RBC legislation, more capital is required as each type of risk increases, and trade-offs among types are not considered. Our structural

[24] As described in Section 2, the life insurance industry sells a heterogeneity of products that give it, in part, a blend of characteristics of other industries. Annuities and life products are similar in character to the products of the financial-intermediation industry, while health products are similar to those of the property/casualty industry. Thus it may not be surprising to find some of the statistics of the life industry to blend those of related industries.

[25] The investment portfolio of the life insurance industry for the period 1993–1997 consisted of 52.4% of high-quality bonds, 1.2% of low-quality bonds, 3.7% of common stocks, 0.5% of preferred stocks, 9.7% of mortgages, 0.2% of cash, 2.0% of short-term investments, 1.1% of real estate investment, 0.3 of occupied real estate and 0.4% properties acquired in satisfaction of debt. The rest of the portfolio was made up of separate accounts (22.3%), policy loans, aggregate write ins, etc. This portfolio was different from that of the property/casualty insurance industry as noted in Cummins and Sommer (1996).

[26] At industry median levels of all the endogenous variables, the estimated elasticity of capital with respect to product risk is −0.3827. The estimated elasticity of capital with respect to the regulatory asset risk is 0.6723. So, at industry median levels, a given percent change in regulatory asset risk is estimated to yield nearly twice the percentage change in capital as that produced by the same percentage change in product risk (in the opposite direction).

Table 2
Simultaneous equation estimates of the three-equation model (Eq. (2)) for capital-to-asset, product risk and regulatory asset risk (autoregressive two-stage least squares)

Variable	Estimate	S.E.	*T*-statistic	*P*-value
Part (i). Structural equation for capital-to-asset ratio				
Intercept	2.6155	0.1244	21.0197	0.0000
Regulatory asset risk	14.1178	3.1195	4.5256	0.0000
Product risk	−1.5467	0.2829	−5.4678	0.0000
Lag of capital ratio	−0.0700	0.0646	−1.0834	0.2787
Return on capital	0.2616	0.0356	7.3492	0.0000
RBC ratio	−0.0000	0.0000	−0.0640	0.9490
Log of total assets	−0.1432	0.0064	−22.2515	0.0000
In aff. group (1-0)	−0.0924	0.0117	−7.9102	0.0000
Stock company (1-0)	−0.0461	0.0142	−3.2579	0.0011
1995 (1-0)	0.0228	0.0037	6.1593	0.0000
1996 (1-0)	0.0292	0.0042	6.8884	0.0000
1997 (1-0)	0.0318	0.0048	6.5995	0.0000
$R^2 = 0.3741873$, Root MSE = 0.2132114				
Part (ii). Structural equation for regulatory asset risk				
Intercept	−0.1503	0.0975	−1.5423	0.1231
Capital ratio	0.0553	0.0364	1.5192	0.1288
Product risk	0.1041	0.0497	2.0952	0.0362
Lag of reg. asset risk	0.0974	0.5032	0.1935	0.8466
Return on capital	−0.0171	0.0070	−2.4506	0.0143
RBC ratio	−0.0000	0.0000	−0.1584	0.8742
Log of total assets	0.0085	0.0048	1.7678	0.0772
In aff. group (1-0)	0.0057	0.0029	1.9479	0.0515
Stock company (1-0)	0.0025	0.0029	0.8616	0.3890
1995 (1-0)	−0.0013	0.0014	−0.9808	0.3268
1996 (1-0)	−0.0017	0.0017	−0.9652	0.3345
1997 (1-0)	−0.0017	0.0021	−0.8200	0.4122
$R^2 = 0.0017921$, Root MSE = 0.0409973				
Part (iii). Structural equation for product risk				
Intercept	1.6721	0.6082	2.7492	0.0060
Capital ratio	−0.5603	0.1624	−3.4500	0.0006
Regulatory asset risk	10.5925	4.6671	2.2696	0.0233
Lag of product risk	−0.3131	0.5744	−0.5452	0.5857
Return on capital	0.1331	0.0730	1.8237	0.0683
RBC ratio	−0.0000	0.0000	−0.1887	0.8503
Log of total assets	−0.0862	0.0232	−3.7169	0.0002
In aff. group (1-0)	−0.0643	0.0250	−2.5755	0.0100
Stock company (1-0)	−0.0476	0.0351	−1.3590	0.1742
1995 (1-0) (YEAR95)	0.0107	0.0076	1.3967	0.1626
1996 (1-0) (YEAR96)	0.0158	0.0078	2.0262	0.0428
1997 (1-0) (YEAR97)	0.0156	0.0100	1.5563	0.1197
$R^2 = 0.0383358$, Root MSE = 0.370526				

equations suggest that firm behavior may be more complex than envisioned in current RBC formulas. Our results also emphasize the importance of disaggregating risk types.

Since our proxy for product risk is the percent of premiums written in health products, this result is significant for insurance regulators. Underwriting and liabilities are of great importance for insurance. In the risk loading for the C-2 component of the life RBC, health writings exact a large charge on capital. During the post-RBC period under study, our results indicate that life insurers with greater concentration in risky health writings have lower capital ratios and higher asset risk than life insurers with less exposure in health products, other factors being equal.

4.3. Other observations

In all three equations, we note the relatively small and statistically insignificant value of the coefficient of the lag of the response. Recall that this coefficient represents one minus the coefficient of partial adjustment in the partial-adjustment model. That is, the coefficient of partial adjustment is close to one for all three responses. This indicates a relatively rapid adjustment of the actual levels to the target levels set for the three responses.

The year variables, which proxy year-by-year developments not captured by other controls, are especially significant in the capital equation (Part (i)), but not in the asset risk equation. The asset risk would be expected to show less temporal variation than capital and product risk because the weights used to calculate asset risk do not vary by year. They are static factors. Size (log of total assets) is significant in all three equations and impacts capital and product risk negatively, but asset risk positively. Thus, it appears that smaller companies write more health insurance products and hold more capital while larger insurers take greater asset risk. Also, membership in a group (NGROUP) impacts asset risk positively as expected by companies that are part of a large affiliated group of companies that have access to larger pools of investments such as private placement. In the capital equation and the product risk equations in Parts (i) and (iii), LOGATOT, NGROUP, and NTYPE are negative influences. Thus, larger size, membership in a group, and being a stock company are all associated with a lower capital ratio and lower product risk, ceteris paribus. But higher returns on capital are associated with higher capital ratios and product risk.

5. Summary and conclusion

This study has explored the interrelations among capital to asset ratio, asset risk and product risk in the life insurance industry in the post-RBC era. As in the banking industry, arguments can be advanced in favor of either a negative or a positive relation between capital and risk. The existence of guarantee funds argues for greater risk taking at lower capital levels. This is articulated in the risk-subsidy hypothesis of Lee et al. (1997). Bankruptcy-cost-avoidance, agency theory, transaction-cost economics theory and other arguments favor a positive relation between capital and risk. Each hypothesis has found empirical support in the banking literature. But only the positive relation argument found support in the property/casualty study by Cummins and Sommer (1996).

In this study, we apply methods used both in the banking and property/casualty industries and found support for a positive relation between the regulatory asset risk and capital ratio, but a negative relation between product risk and capital ratio. In our structural equations, we see that at given levels of asset risk, firms with higher product risk are found to have lower capital ratios, ceteris paribus. But at given levels of product risk, firms with higher asset risk are found to have higher capital ratios. This result raises an issue for regulation. Regulators prefer that capital increase with rising levels of each type of risk. Yet the separate equation for capital describes behavior at variance with regulatory preference. It may be that firm behavior with respect to capital allocation is more complex than the simple and essentially additive risk model currently used in Life RBC regulation. It also underscores the importance of distinguishing different risk categories.

References

Barth, M.M., 1995. Life insurance companies' risk-based capital distributions by size groups. NAIC Research Quarterly 1 (1), 35–38.

Barth, M.M., 1996. Health insurance RBC underwriting risk measurement. NAIC Research Quarterly 2 (2), 12–30.

Berger, A.N., 1995. The relationship between capital and earnings in banking. Journal of Money, Credit, and Banking 27 (2), 432–456.

Berger, A.N., Herring, R.J., Szego, G.P., 1995. The role of capital in financial institutions. Journal of Banking and Finance 19, 393–430.

Cummins, J.D., 1998. Risk-based premiums for insurance guaranty funds. Journal of Finance 47, 1701–1730.

Cummins, J.D., Sommer, D.W., 1996. Capital and risk in property–liability insurance markets. Journal of Banking and Finance 20, 1069–1092.

Downs, D.H., Sommer, D.W., 1999. Monitoring, ownership, and risk-taking: The impact of guaranty funds. Journal of Risk and Insurance 66 (3), 477–497.

Gleason, J.T., 2000. Risk: The New Management Imperative in Finance. Bloomberg Press, Princeton, NJ.

Grace, M.F., Timme, S.G., 1992. An examination of cost economics in the US life insurance industry. Journal of Risk and Insurance 59, 72–103.

Gujarati, D.N., 1995. Basic Econometrics, third ed. McGraw-Hill, New York.

Jacques, K., Nigro, P., 1997. Risk-based capital, portfolio risk, and bank capital: A simultaneous equations approach. Journal of Economics and Business 49 (6), 533–548.

Kmenta, J., 1986. Elements of Econometrics, second ed. MacMillan, New York.

Lamm-Tennant, J., Starks, L., 1993. Stock versus mutual ownership structures: The risk implications. Journal of Business 66, 29–46.

Lee, S.-J., Mayers, D., Smith Jr., C, 1997. Guaranty funds and risk-taking: Evidence from the insurance industry. Journal of Financial Economics 44, 3–24.

Mayers, D., Smith, C.W., 1981. Contractual provisions, organizational structure, and conflict control in insurance markets. The Journal of Business 54, 407–434.

Mayers, D., Smith, C.W., 1986. Ownership structure and control, the mutualization of stock life insurance companies. Journal of Financial Economics 16, 73–98.

Mayers, D., Smith, C.W., 1988. Ownership structure across lines of property–casualty insurance. Journal of Law and Economics 31, 351–378.

Mayers, D., Smith, C.W., 1994. Managerial discretion and stock insurance company ownership structure. Journal of Risk and Insurance 61, 638–655.

Merton, R.C., 1977. An analytic derivation of the cost of deposit insurance and loan guarantees: An application of modern option pricing theory. Journal of Banking and Finance 1, 3–11.

Milgrom, P., Roberts, J., 1992. Economics, Organizations and Management. Prentice-Hall, Englewood Cliffs, NJ.

NAIC, 1996. Life Risk Based Capital Report Including Overview and Instructions for Companies.

Pottier, S.W., Sommer, D.W., 1997. Life insurer risk-based capital measures: Does the source matter? Journal of Insurance Regulation 16 (2), 179–196.

Rejda, G.E., 2001. Principles of Risk Management and Insurance, seventh ed. Addison-Wesley, New York.

Ryan Jr., H.E., Schellhorn, C.D., 2000. Life insurer cost efficiency before and after implementation of the NAIC risk-based capital standards. Journal of Insurance Regulation 18 (3), 362–384.

Santomero, A.M., Babbel, D.F., 1997. Financial risk management by insurer: An analysis of the process. Journal of Risk and Insurance 64 (2), 231–270.

Shrieves, R.E., Dahl, D., 1992. The relationship between risk and capital in commercial banks. Journal of Banking and Finance 16, 439–457.

Williamson, O.E., 1985. The Economic Institution of Capitalism. Free Press, New York.

Williamson, O.E., 1988. Corporate finance and corporate governance. The Journal of Finance XVIII (3), 567–591.