Efficiency of Insurance Firms with Endogenous Risk Management and Financial Intermediation Activities

By

J. David Cummins*
Temple University
1301 Cecil B. Moore Avenue
Philadelphia, PA 19122
Phone: (215) 204-8468
Fax: (610) 520-9790
Email: cummins@temple.edu

Georges Dionne
HEC Montréal
3000, Chemin de la Côte-Sainte-Catherine
Montreal (Qc)
Canada, H3T 2A7
Phone: (514) 340-6596
Fax: (514) 340-5019
E-mail: georges.dionne@hec.ca.

Robert Gagné
HEC Montréal
3000, Chemin de la Côte-Sainte-Catherine
Montreal (Qc)
Canada, H3T 2A7
Phone: (514) 340-6435
Fax: (514) 340-6469
E-mail: robert.gagne@hec.ca

Abdelhakim Nouira
HEC Montréal
3000, Chemin de la Côte-Sainte-Catherine
Montreal (Qc)
Canada, H3T 2A7
Phone: (514) 340-7158
Fax: (514) 340-5019
E-mail: abdelhakim.nouira@hec.ca

October 15, 2007

*Corresponding author.

Efficiency of Insurance Firms with Endogenous Risk Management and Financial Intermediation Activities

Abstract

Risk management is now present in many economic sectors. We investigate the role of risk management and financial intermediation in creating value for financial institutions by analyzing U.S. property-liability insurers. Our main goal is to test how risk management and financial intermediation activities create value for insurers by enhancing economic efficiency through cost reductions. We consider these two activities as intermediate outputs and estimate their shadow prices. Insurer cost efficiency is measured using an econometric cost function. The econometric results show that both activities significantly increase the efficiency of the property-liability insurance industry.

Efficiency of Insurance Firms with Endogenous Risk Management and Financial Intermediation Activities

1. Introduction

Risk management is now present in many economic sectors. Although perfect markets finance theory provides little rationale for widely held firms to expand resources to hedge unsystematic risk, various market imperfections create opportunities for such firms to maximize market value through hedging. The principal market imperfections that motivate corporate hedging are corporate income taxation (Graham and Rogers, 2002), financial distress costs (Smith and Stulz, 1985), investment opportunity costs (Froot, Scharfstein, and Stein, 1993), information asymmetries (DeMarzo and Duffie, 1991), and corporate governance considerations (Dionne and Triki, 2005). Firms also engage in hedging for non-value-maximizing reasons such as managerial risk aversion (Tufano, 1996).

For financial firms, matters are more complicated because the customers are also concerned about risk exposure. Policyholders and depositors cannot diversify their risk by using many insurers or banks because this is costly, and they do not perfectly monitor the managers of these institutions because monitoring is also costly and requires specialized expertise. Moreover, the existence of government deposit insurance and insurance guaranty funds reduce incentives for monitoring and create moral hazard. This form of moral hazard may explain the risk taking behavior of managers in both industries. Monitoring by customers is also impeded by the opacity of key financial statement items such as bank loans and insurance loss reserves. Risk capital is another form of protection, but capital is costly and a role for risk management is to reduce risk capital.

Insurers are financial intermediaries who borrow money from their policyholders in the form of premium payments and invest the funds raised in financial assets. Thus, financial intermediation is one important activity that generates value for insurers. An equally important economic function of property-liability insurers is to provide risk pooling (diversification) and risk bearing services to their policyholders, and these services are a primary driver of the need for risk management. Moreover, both insurer assets generated by the intermediation function and liabilities generated from the risk pooling function are sensitive to inflation and interest rates, creating the need for asset-liability (interest rate risk) management.

In this paper, we test how risk management and financial intermediation activities create value for insurers by enhancing economic efficiency. We argue that risk management and financial intermediation are two activities that may be used by insurers to improve efficiency, where efficiency is gauged by the capacity to reduce the costs of providing insurance. We measure insurer efficiency by estimating a parametric cost function. Risk management and financial intermediation are key activities for insurers and are treated as endogenous in our econometric model. However, because the prices of risk management and financial intermediation services are not observable, we consider these two activities as intermediate outputs and estimate their shadow prices. The shadow prices are then used to isolate the contributions of risk management and financial intermediation to insurer cost efficiency, as measured by their capacity to reduce costs. We use data from the U.S. property-liability insurance industry.

Another contribution of the paper is to develop a theoretical model of value-added in the property-liability insurance industry. This is important because output estimation for financial services firms has been based primarily on the value-added approach in the recent literature. Our model represents a significant extension and generalization of prior models of value-added in the insurance industry by including insolvency risk and explicitly adding risk management as part of value added. The final important contribution of this paper is related to the econometric estimation of the cost function. Our econometric methodology, borrowed from the exhaustible resources literature (Halvorsen and Smith, 1991; Chermak and Patrick, 2001), enables us to estimate the shadow prices of risk management and financial intermediation. To our knowledge it is the first paper that applies this econometric methodology to the financial institutions literature.

The remainder of the paper is organized as follows. Section 2 reviews the literature on risk management and performance measures in property-liability insurance. Section 3 analyses outputs of insurers related to risk-pooling, financial intermediation and risk management as components of the insurance industry value-added. Section 4 proposes the econometric model and estimation method, while Section 5 presents the data and variables. Section 6 analyses the main results and Section 7 concludes.

2. Background and Literature Review

The primary function of property-liability insurers is to diversify specific types of risks faced by consumers and business firms. Although insurers can reduce risk significantly by diversifying, significant residual risk remains, and insurer claim payments are highly stochastic. Insurers have several mechanisms available to manage the residual risk of insured losses. The most important tool for managing insurance claims risk is reinsurance (Culp, 2002). Insurers can also manage underwriting risk through securitization using innovative financial instruments such as catastrophe (CAT) bonds and options (Froot, 2001, Mocklow, DeCarro, and McKenna, 2002). CAT bonds are usually issued through special purpose vehicles (SPV), which raise funds by issuing bonds to investors and provide reinsurance to the sponsoring insurer by writing an option contract.

There is also a large and growing market for industry loss warranties (ILWs), which are hedging contracts that are hybrids of financial contracts and reinsurance (McDonnell, 2002). Typical ILWs are dual trigger contracts that pay off on when a specified industry-wide loss index exceeds a particular threshold at the same time that the issuing insurer's losses from the event equal or exceed a specified amount. Other multiple trigger contracts are available that payoff on the joint occurrence of a defined loss event such as a Florida hurricane and an economic event such as an increase in market-wide interest rates that would cause insurers to incur capital losses when liquidating bonds to pay claims. During the past decade, insurers have dramatically improved their databases, data mining techniques, and the computer models used to underwrite and price insurance. Insurers also manage claims risk through increasingly detailed exposure mapping to avoid excessive exposure to loss in specific geographical regions or industries. They use models that incorporate actuarial and statistical data as well as scientific models from fields such as seismology and meteorology (Grossi and Kunreuther, 2005).

Insurers must come to the market with equity capital to satisfy regulatory requirements and to back their promise to pay claims if losses are larger than expected. They also accumulate assets because premiums are collected in advance of claims payments. Investing in assets generates significant revenues for insurers but also exposes them to additional risks. Such risks include market value risk, credit risk from investing in bonds and other debt instruments, and foreign exchange rate risk resulting from investment in international capital markets. Insurers operating internationally are also subject to foreign exchange rate risk on their insurance premium receipts and claim payments. The market values of insurers' assets and liabilities are sensitive to interest rates, exposing insurers to interest rate risk.

Insurers engage in a variety of risk management strategies to manage their asset risks, foreign exchange business risks, interest rate risk, and capital allocation (Santomero and Babbel, 1997; Froot, 2007). Insurers manage credit risk by holding well-diversified portfolios of debt securities and by trading credit risk derivative instruments. A subset of insurers also use derivatives such as options to hedge market value risk in their stock portfolios and foreign exchange rate risk (Cummins, Phillips, and Smith, 2001). Insurers employ sophisticated asset-liability management techniques to manage their exposure to interest rate risk (Staking and Babbel, 1995). In particular, they engage in asset trading strategies to manage the duration and convexity of the market value of their equity capital. Thus, in terms of their insurance underwriting operations and their asset and liability portfolios, risk management is the most important core competency of any property-liability insurer.

Given the importance of risk management in the insurance industry, it is perhaps surprising that there have been few studies that have attempted to measure the impact of risk management on firm performance. The lack of prior research in this area is partially due to data limitations – the detailed data needed to measure risk management activities with any precision are not yet available to researchers studying European or Asian insurance companies. Although more detailed data are available on U.S. insurers, some of this information was not available electronically until very recently. We take advantage of the more detailed U.S. data, including the recently released electronic databases on certain types of insurer risk management activities, to measure the effects of risk management on firm performance. Our database is described in more detail below.

An extensive literature has developed on the efficiency of financial institutions. A review of the literature a decade ago identified 130 financial institution efficiency studies (Berger and Humphrey, 1997), and the literature has continued to grow. Cummins and Weiss (2000) review twenty-one insurance efficiency studies over the period 1983-1999, and there have been an approximately equal number of studies since that time. Most of the existing insurance efficiency studies utilize the estimated efficiencies to test economic hypotheses. Insurance efficiency studies have been conducted to test for economies of scope (Berger, et al., 2000) and to measure the relative efficiency of product distribution systems (Klumpes, 2004). Other studies have considered deregulation and consolidation (Mahlberg and Url, 2003; Cummins and Rubio-Misas, 2006) and organizational form (Greene and Segal, 2004). There have been approximately an equal number of studies on the life and property-casualty insurance industries.

None of the existing insurance efficiency studies considers risk management as a potential determinant of firm performance, although some studies have considered the importance of solvency risk and capitalization (e.g., Cummins and Nini, 2002). Several papers have analyzed insurer risk management using other methodologies. Staking and Babbel (1995) analyze the relationship between capital structure, interest rate risk, and market value for U.S. property-liability insurers. They find that insurers manage interest rate risk to protect their franchise values. Cummins, Phillips, and Smith (2001) analyze the use of derivatives by insurers and find that some of the more sophisticated insurers use derivatives in risk management. However, they do not test the relationship between risk management and insurer financial performance. Thus, an important contribution of the present study is the explicit consideration of risk management as a determinant of firm performance using cost structure analysis. Likewise, although most of the prior literature treats insurers as financial intermediaries, none of the prior studies has attempted to estimate the shadow price of the financial intermediation function.

Several studies have analyzed the risk management-performance relationship for non-financial firms. Allayannis and Weston (2001) find a positive relationship between firm value and the use of foreign currency derivatives. Nelson, Moffitt, and Affleck-Graves (2005) find evidence that non-financial firms that hedge using derivatives outperform non-hedgers, and Dionne and Triki (2006) find that risk management in the gold mining industry increases returns on assets. However, this set of papers does not focus on the relationship between risk management and efficiency.

3. Insurer Value-Added

We treat risk management as an answer to policyholders' demand for reducing solvency risk related to insurance contracts. We do not consider other determinants of risk management such as taxes, financial distress costs, investment financing or managers' risk aversion. In other words, in our model only the clients' risk aversion explains risk management. If we introduce the possibility of insurer insolvency to the insurance contracting problem (Doherty and Schlesinger, 1990; Doherty and Dionne, 1993) and assume that the insured buys full coverage for the insurable loss when he is compensated by the insurer and receives no coverage when a solvency problem occurs, the corresponding total risk premium for both solvency risk and risk pooling (π_S) solves the following equation:

$$p\int_0^{\bar{L}} U\left(W_0 - L - P_S\right) f\left(L\right) dL + \left(1-p\right) U\left(W_0 - P_S\right) = U\left(W_0 - P_S - \pi_S\right) \quad (1)$$

where W_0 is initial wealth of the insurance buyer, *L* measures a given loss for the insured, $f\left(L\right)$ is the corresponding density, and $\bar{L}$ is the maximum possible value of loss. The left hand side of (1) is the insurance situation in presence of solvency risk and the right hand side corresponds to the full security situation. P_S is the actuarial insurance premium for the risk-pooling activity in presence of solvency risk, and *p* is the probability of the non-solvency state. Consequently, the insured is willing to pay π_S above P_S to get full insurance and full security against solvency risk.

There are different types of output measures in the insurance literature. In this study, we use the value-added approach (Berger and Humphrey, 1992), which is the most widely accepted approach in the financial institutions literature. Under this approach, the insurance output measure has three components – risk pooling and risk-bearing, real financial services (such as safety management), and intermediation (Cummins and Weiss, 2000). If we limit the discussion, for the moment, to the risk-pooling/risk-bearing component without solvency risk and intermediation, we can measure the corresponding value-added by the difference between the insurance premium and the insurance output.

We can write the competitive insurance premium $\left(P_P\right)$ as:

$$P_P = \frac{Q\left(1+e_q\right)+r_e E}{1+r_0} \tag{2}$$

where Q is the expected insurance compensation, under full insurance above a deductible, $Q=\left(E\left(L\right)-D\right)\big|_{L>D}$, where D is a deductible, e_q is the insurer expenses as a proportion of expected insurance compensation, E is total equity, r_e is the return required by equity holders to invest in the insurance industry, and r_0 is the risk-free interest rate required by policyholders. Therefore, using (2), the corresponding value-added can be written as:

$$V_p = P_p + \left(P_p + E\right)r_0 - Q - r_e E = e_q Q + r_0 E \tag{3}$$

which corresponds to the fraction of the risk premium available to the insurance industry under competition. It is equal to the insurer expenses for direct insurance plus the investment return on equity. We may add the intermediation component by defining $\left(1+r_a\right)=\left(1+r_p\right)\left(1+m\right)$ where m is the net interest margin received by the insurer for performing the intermediation function, r_p is the required interest rate by policyholders under market risk $\left(r_p > r_0\right)$, and r_a is the investment return obtained from the financial intermediation function. We still assume here that there is no solvency risk and, to simplify the notation, the financial intermediation expenses are included in $e_q Q$. The corresponding total value-added for risk pooling and financial intermediation can be written as:

$$V_{PF} = m\left(Q\left(1+e_q\right)+r_e E\right)+\left(e_q Q + r_a E\right). \tag{4}$$

The intermediation function creates additional added value via two effects: $r_a > r_0$ and when $m > 0$ or when the required return by policyholders r_p is smaller than the investment return r_a.

If we now assume that the policyholders value the security offered by insurers that hold capital to cushion unexpected losses and investment shocks due to random interest rates, for example, this means that the value-added of insurance should contain an extra source. We can introduce this extra source by supposing that the expected compensation is random without risk management activities by the insurer. For example, the expected compensation can be written as $(1-p)Q$, where *p* is the probability of the non-solvency state, which implies that the expected loss due to insolvency is *pQ*. For a risk averse insured, this supplementary random variable represents an additional risk with respect to his loss net of insurance coverage and, as shown in (1), he is willing to pay a total premium $P_S + \pi_S$ to reduce or eliminate this additional risk along with the insurable risk.

For simplicity, we define *h* as the hedging ratio of the additional risk $(0 \le h \le 1)$. When $h=1$, the insurer has eliminated the extra risk and when $h=0$, the insurer does not hedge at all this additional risk. We suppose that *h* is observable in the market and that e_h is the additional proportional cost related to risk management. Consequently, equation (2) becomes:

$$P_{PFM} = \frac{(Q+r_e E)(1-p+ph)+e_{hq}Q}{(1+r_h)}, \qquad (5)$$

where e_{hq} is insurer expenses including the risk-management activity $(e_{hq} = e_q + he_h)$ and r_h is the required interest rate by policyholders under market and solvency risk. We implicitly assume that it is optimal for the equity holders to manage this additional risk on security markets (so r_e is not modified). Insurer expenses are not subject to solvency risk, i.e., the solvency risk occurs at the end of the contracting period after all expenses $(e_{hq}Q)$ have been paid. However, both the equity holders' income and the policyholders' loss recoveries are subject to the solvency risk. When $h=1$, $r_h = r_p$ (only the market risk remains) and when $h<1$, $r_h > r_p$. Solvency risk also affects the value of the net interest margin received by the insurer for performing the intermediation function, when $r_h > r_p$. So

$\left(1+r_a\right)=\left(1+r_h\right)\left(1+m_r\right)$, where r_a is the investment return and m_r is the net interest margin under market and solvency risk. The total value-added then becomes equal to:

$$V_{PFM}=m_r\left(e_{hq}Q+\left(1-p+ph\right)\left(Q+r_eE\right)\right)+\left(e_qQ+r_aE\right)+e_hhQ-c\left(h\right) \tag{6}$$

which is the value added from intermediation, plus the value added from risk-pooling, plus the value added from risk management. $c\left(h\right)$ measures cash outflows that can be paid for some risk management activities such as consultant services. In Appendix 1, we derive explicitly equation (6).

For property-liability insurers, it is usually possible to measure the risk-pooling insurance output and its corresponding price. Matters are more difficult for the financial intermediation and risk management activities. To solve this problem, we propose to treat these two activities as intermediate outputs that have separable quantities of inputs from those used in the risk-pooling activity. Therefore, we can estimate the shadow prices of both the financial intermediation and the risk management activities. We now test whether these activities improve the efficiency of insurance-pooling and reduces its costs.

4. Econometric Model and Estimation Method

We assume that insurance services (Q) are produced using a vector of inputs $\left(X^A\right)$ and two intermediate outputs – financial intermediation and risk management – according to the following production function:

$$Y\left(Q;R,F,X^A,Z,T\right)=0\,, \tag{7}$$

where Z is a vector of control variables which may contain quasi-fixed inputs, and T represents time (for simplicity, we omit the time and firm subscripts). *R* and *F* are the intermediate outputs representing risk management and financial intermediation activities. The technology associated with the production of risk management is defined as:

$$R=R\left(X^R,Z,T\right), \tag{8}$$

where X^R are inputs used in the production of risk management. Similarly, the technology associated with financial intermediation is:

$$F = F(X^F, Z, T), \tag{9}$$

where X^F are inputs used in the production of financial intermediation. Under the assumption that insurance firms are cost minimizers, and that Q, R, and F are pre-determined, the restricted cost function associated with the technology described by (7), (8) and (9) is:

$$CR = CR\left(Q, R, F, P^A, P^R, P^F, Z, T\right), \tag{10}$$

where CR are total costs, and P^A, P^R, and P^F are, respectively, the prices of inputs X^A, X^R and X^F. The restricted cost function defined by (10) gives the minimum cost of producing the level of insurance services (Q), given the levels of risk management and financial intermediation undertaken by the firm (*R* and *F*), the different input prices (P^A, P^R, and P^F), the state of the control variables (Z), and time (T), which is included to take into account of technical change. Following Halvorsen and Smith (1991), we obtain the implicit (or shadow) prices of risk management (μ) and financial intermediation (λ) using the partial derivatives of the restricted cost function with respect to R and F:

$$\mu = -\frac{\partial CR}{\partial R} \text{ and } \lambda = -\frac{\partial CR}{\partial F}. \tag{11}$$

Since the exact functional form of the restricted cost function defined by (10) is unknown, we use the well known translog approximation which is given by:

$$\begin{aligned} \ln CR_{it} = {} & \alpha_i + \sum_v \beta_v^Q \ln Q_{vit} + \beta_i^R \ln R_{it} + \beta_i^F \ln F_{it} \\ & + \sum_s \beta_s^A \ln P_{sit}^A + \sum_j \beta_j^R \ln P_{jit}^R + \sum_k \beta_k^F \ln P_{kit}^F \\ & + \beta^Z \ln Z_{it} + second - order\ terms + \sum_t \beta^t D_t + u_{it}, \end{aligned} \tag{12}$$

where subscripts i and t, represent, respectively, firms and time, and D_t are time dummy variables (the sample first year being the omitted category). The coefficients associated with the time dummy variables can be used to compute industry-level technical change. The intercept (α_i) and the coefficients associated with the risk management and financial intermediation variables $(\beta_i^R$ and $\beta_i^F)$ are firm-specific, allowing, among other things, for firm-specific estimates of the risk management and financial intermediation shadow prices. α_i will also be used for the analysis of insurance-pooling efficiency. For the estimation, we treat these three parameters as random variables which follow a normal distribution with means α, β^R, β^F and variance-covariance Ω. Finally, u_{it} are i.i.d. random disturbances. Linear homogeneity of degree one in input prices is imposed prior to estimation by dividing total costs and all input prices but one by this last price. Finally, all continuous variables on the right-hand side of (12) are divided by their sample mean (the point of approximation).

The risk management (R) and financial intermediation (F) variables are likely to be endogenous. Endogeneity is taken into account by first instrumenting these two variables. The set of instruments used includes the log of the insurance output prices, input prices, time dummy variables and other dummy variables measuring insurer's characteristics: ownership structure, group membership, distribution system and head office state. Output and input prices are determined, respectively, on the insurance and labour markets. Also, ownership structure, group membership, distribution system and head office state are most of the times once and for all decisions unaffected by the current situation of the firm (in fact, in our sample, these characteristics are constant over time for almost all firms). It is therefore very unlikely that unobserved variables affecting risk management and financial intermediation would also affect this type of variables. The predicted values of each endogenous variable are obtained from OLS regressions on the set of instruments and are substituted to the actual values in equation (12). Equation (12) is then estimated by restricted/residual maximum likelihood (REML) as it is implemented in the *Mixed Model* procedure of *SAS*. The proper test statistics of the different estimated parameters of the model are obtained by running 5,000 simulations (see Appendix 2 for the details on estimation and simulations).[1]

Shadow prices for risk management (μ_{it}) and financial intermediation (λ_{it}) outputs are computed from (12) using the following equations:

$$\mu_{it} = -\frac{\partial \ln CR}{\partial \ln R_{it}} \frac{CR_{it}}{R_{it}} \text{ and } \lambda_{it} = -\frac{\partial \ln CR}{\partial \ln F_{it}} \frac{CR_{it}}{F_{it}} . \tag{13}$$

It is possible to compute the shadow prices for each observation (i, t) in the sample only because they are functions of variables specific to each observation. However, recall that the translog approximation of the restricted cost function includes firm-specific coefficients associated with the risk management and financial intermediation variables. Their estimated values are used to compute $\partial \ln CR / \partial \ln R_{it}$ and $\partial \ln CR / \partial \ln F_{it}$. A higher shadow price for a specific insurer (compared to other insurers) indicates the potential cost reductions that could be realised by increasing risk management or financial intermediation activities. A shadow price near zero indicates that an insurer has already internalized the benefits of risk management and financial intermediation into its cost structure. A negative shadow price would be an indication of an over production of risk management or financial intermediation activities.

Finally, the relative residual efficiency of each firm in the sample can be computed using the stochastic part of the cost function. This is the efficiency that cannot be attributable to any specific input or intermediate output. Two efficiency measures are used:

$$Efficiency(1)_i = \exp\left(\alpha_{\min} - \alpha_i\right) \tag{14a}$$

$$Efficiency(2)_i = 1 - \exp\left(\alpha_i - \alpha_{\max}\right) \tag{14b}$$

where $\alpha_{\min}$ = the smallest estimated value of α_i in the sample and $\alpha_{\max}$ = the largest estimated value of α_i in the sample. The first efficiency measure (*Efficiency* (1)) is analogous to the measure proposed by Berger (1993). It defines relative efficiency as the ratio of the minimum cost needed (costs of the fully efficient firm) to the actual costs expended. The second efficiency measure (*Efficiency* (2)) considers the relative inefficiency defined as the ratio of the actual costs expended to the maximum cost needed (costs of the fully inefficient firm).

5. Data and Variables

5.1. Data

The primary data for our analysis are the regulatory annual statements filed by U.S. property-liability insurers with the National Association of Insurance Commissioners (NAIC). We include data for all property-liability insurance firms reporting to the NAIC for the period 1995 through 2003. However, we eliminate reporting firms showing negative surplus, assets, losses or expenses. Such firms are not viable operating entities but are retained in the database by the NAIC for regulatory purposes such as the resolution of insolvencies. Because insurers formulate investment and risk management strategies at the overall corporate level, our analysis focuses on groups of insurers under common ownership and unaffiliated single insurance firms. Data for insurance groups are obtained by aggregating the data for affiliated insurance firms which are members of the group. The resulting sample is an unbalanced panel containing 9,854 observations for the 9-year period.

Our primary analysis focuses on multiple line insurance firms reporting strictly positive output in each of the four lines of insurance business: long-tail personal, short-tail personal, long-tail commercial and short-tail commercial, where the length of the tail refers to the length of the claims payout period for the line of business. However, for robustness and industry representation results, we also consider larger samples of firms obtained from the aggregation of the four outputs into only one. In that case, only insurance firms with non-strictly positive total output are dropped. Also, insurers reporting negative input prices or surplus duration are deleted as well.

Our final samples include 3,320 observations (613 firms) when we use outputs from four lines (Sample 1), 5,612 observations (1,021 firms) when we use a single total output and two output attributes (Sample 2),[2] and 9,206 observations (1,652 firms) when we use a single total output without output attributes (Sample 3). Although the restriction of the smaller sample to insurers with strictly positive outputs in all four lines reduces the sample size, most of the firms eliminated are small specialized firms. In fact, Sample 1 accounts for about 90 percent of total industry premium volume in 2003, while Sample 3 accounts for nearly 100 percent of total premiums. Thus, because the use of four outputs is likely to give more reliable results and because most of the firms eliminated by the strictly positive output criterion are small specialized insurers, our preferred results are based on the smaller sample of firms active in all four major output categories.

5.2. Variables

5.2.1. Intermediate Outputs

The insurer receives the premium payments from policyholders at the beginning of the period. When a claim occurs, the insurer pays the amount of the claim at some time in the future. The period between the date of the claim occurrence and the date of the claim payment depends on the type of insurance policy. Financial intermediation activities consist in investing the amount of premiums received until the claim payment date. We measure the quantity of financial intermediation activities by the value of total assets under management which is equal to invested assets (*Invested assets*). This measure of intermediation output has been used in several insurance efficiency studies (Cummins and Weiss 2000) and is equivalent to measures used in bank efficiency studies under the intermediation approach (Berger and Humphrey, 1997). Property-liability insurers tend to be relatively homogeneous in their investment activities, with more than 95 percent of assets invested in tradable bonds, stocks, and short-term securities. This differentiates these firms from life insurers, who tend to invest more actively in privately placed bonds. Hence, we consider invested assets to be the best available measure of the quantity of financial intermediation by property-liability insurers.

One particularity of insurers is that the amount of invested assets may depend to some degree on the type of insurance risks underwritten. Invested assets may tend to be somewhat higher for insurers specialized in underwriting long-tail business because they invest unpaid losses for a long time before paying claims. Nevertheless, the correlation between *invested assets* and the proportion of premium revenues in long-tail lines is very low, about 2 percent during the period 1995-2003; and the correlation between long-tail premium revenues and invested assets is about the same as the correlation between short-tail premium revenues and invested assets (92 percent). An explanation for this is that expected future losses tend to be heavily discounted in calculating premiums for long-tail lines due to the length of the loss payout period. Consequently, long-tail lines tend to generate underwriting losses (i.e., loss and expense payments usually exceed premium receipts), thus reducing invested assets. Short-tail lines tend to generate underwriting profits or smaller underwriting losses and underwriting results on these lines do not adversely affect invested assets. Hence, the value of invested assets remains a good proxy for the quantity of financial intermediation activities. It measures assets under management for which investment decisions must be taken.

Although we consider invested assets a good proxy for the level of financial intermediation activities, it is possible that insurers with similar quantities of invested assets could exhibit different intensities of investment management. Consequently, to test the robustness of the measure of output associated with financial intermediation activities, we also estimate our cost model using two alternative financial intermediation variables. The first one is asset turnover, defined as the value of assets acquired and sold during the year. The total dollars traded (*Turnover*) reveals whether the insurer's financial management strategy adopted is active or passive. In case of an active investment strategy, insurer's size being equal, the insurer will have a larger *Turnover;* whereas in case of a passive investment strategy, the insurer will have a lower *Turnover.* Thus, *Turnover* measures the quantity of trading and hence may be an alternative measure of financial intermediation activities than *Invested assets*. Although both *Invested assets* and *Turnover* are measures of quantity rather than outcomes, this is not an issue for our analysis because the efficiency of the financial intermediation activities will be assessed through shadow prices.

The second alternative measure of financial intermediation is investment return (*Investment return*). In fact, this is not a measure of the quantity but rather a measure of the quality of the financial intermediation activities. A small insurer with a passive investment strategy has relatively small *Invested assets* and a small *Turnover* but could gain, for a given level of risk, a relatively high *Investment return* because of the ability of its financial managers. A large insurer with an active investment strategy has relatively large *Invested assets* and a large *Turnover* but could gain, for a given level of risk, a relatively low *Investment return* because of fees associated with the active strategy or because of a weak performance of its financial managers.

The other intermediate output is risk management. Reducing the insurer's risk could create value through, among other things, reducing the market discount in insurance premiums for insolvency risk. Insurers face many risks. During the 1995-2003 period, U.S. property-liability insurers invested on average 62 percent in bonds, 14 percent in common stocks, 2 percent in preferred stocks and 20 percent in cash and short-term investments. Thus, the two main risks that affect the value of assets of property-liability insurers are interest rate risk and credit risk. In this study we focus on interest rate risk.[3]

Life insurers tend to have liabilities with a large variety of embedded interest rate options, such as minimum interest rate guarantees and renewal options, which significantly complicate the analysis of duration. However, non-life insurance policies do not contain these types of options. Rather, non-life policies represent promises to pay loss cash flows in response to loss events occurring during the policy period. While such promised cash flows are stochastic, they do not have non-linear optionality features that can be exercised by the claimants or be triggered by movements in interest rates. For example, when a property-liability insurer writes a block of commercial liability insurance policies, it becomes liable to make claim payments in response to liability lawsuits. The timing and amount of the payments are determined through negotiation with the claimants or by the courts. The payment of claims represents a linear stream of cash flows that are tracked in schedule P of the insurer's regulatory annual statement.

The linearity of the loss cash flow streams greatly facilitates the measurement of liability duration for property-liability insurers. However, liabilities are sensitive to inflation because claims are paid at prices of the year in which the value of losses is fixed. Since inflation and interest rates are correlated, liabilities are subject to interest rate risk.[4] As a result, managing the impact of interest rate movements on both assets and liabilities is crucial for insurers (see also Staking and Babbel, 1995, and Santomero and Babbel 1997).

The dollar duration of the surplus (*Asset-liability risk*) is used as a proxy for the quantity of output associated with risk management activities.[5] The dollar duration of the surplus is defined as: $SD_S = AD_A - PV(L)D_L$, where D_S is the duration of surplus, D_A is the duration of assets, D_L is the effective duration of liabilities, A is the market value of invested assets, $PV(L)$ is the present value of liabilities. The surplus of the firm is immunized ($D_S = 0$) when the effect of the interest rate changes on assets is equal to the effect of interest rate changes on liabilities. The dollar duration of the surplus is a measure of the quantity of risk that remains after the firm conducts its risk management activities. We assume that insurers undertaking more risk management activities will have smaller dollar surplus durations, which contribute to increasing the insurer's value-added for the policyholders.

When the security's cash flows are independent of the interest rate movements, as it is the case for bonds, we calculate the Macaulay duration. When the security's cash flows can change with interest rate movements, as it is the case with insurance liabilities, we calculate the effective duration. To estimate the effective duration of a cash flow, Ahlgrim, D'Arcy and Gorvett (2004) calculate the present value of the expected cash flow in three ways. The first present value PV_o is based on the original term structure. The second present value PV_{up} is based on a new term structure that is generated if the observed interest rates increase by a specific amount (Δr). The third present value PV_{down} is based on another term structure that is generated if observed interest rates decrease by the same specific amount (Δr). The effective duration ED is then obtained as: $ED = \frac{PV_{down} - PV_{up}}{2 PV_o \, \Delta r}$.

We use data from schedule D of the *NAIC* insurance regulatory statements to compute the duration of each security owned by the insurance firm as of December 31. For each bond, we estimate the implied yield to maturity from the reported statement value and then we calculate the duration. We consider preferred stocks as perpetual bonds to calculate their duration. We also assume that the duration of common stocks is equal to the duration of S&P 500 (Staking and Babel, 1995). The duration of the S&P 500 is computed as the duration of perpetual bonds. Finally, we measure the duration of invested assets as the value weighted duration of all securities, including cash with nil duration.[6]

In order to compute the effective duration of liabilities, we proceed in four steps. In the first step we use the cumulative paid losses and allocated expenses from schedule P, part 3, of the *NAIC* insurance regulatory statements to estimate the cash flows patterns by the chain ladder method.[7] In the second step, we calculate the real value of the future payments. The third step consists in an inflation adjustment of the future payments to take account of the fact that insurers hold reserves in nominal value. In the last step, we discount the future payments using the interest rates term structure corresponding to the insurer's credit quality and we calculate the effective duration. See Appendix 3 for details on the computation of liabilities' effective duration.

5.2.2. Output Quantities and Output Prices

Consistent with most of the prior insurance efficiency literature, output is defined as incurred losses in the four principal property-liability insurance business lines: *Long-tail personal, Short-tail personal, Long-tail commercial* and *Short-tail commercial*. We also use a measure of aggregated output (*Total output*) which is the sum of the four outputs.[8] The output quantity for a given year is defined as the present value of incurred losses arising only from the exposure related to the premiums earned during that year. Losses paid during that year but arising from exposures related to the premiums written during previous years are not included in that year's output quantity. [9] To compute the present value of incurred losses we use the chain ladder parameters and the interest rates term structure obtained for the estimation of liabilities' effective duration.

Output prices are calculated as the difference between premiums earned and the output quantity, expressed as a ratio to the output quantity: $Output\ price_{ikt} = [Premium_{ikt} - Q_{ikt}]/Q_{ikt}$, where *Premium* is premium earned, *Q* is the output quantity, and subscripts *i*, *k*, and *t* refer to insurer *i*, output *k* and year *t*, respectively. Thus, for each insurer we obtain four different prices: *Price of long-tail personal, Price of short-tail personal, Price of long-tail commercial* and *Price of short-tail commercial*. The *Price of total output* is computed similarly.

5.2.3. Inputs

Insurers use three primary inputs – labour, materials and business services, and capital. In order to better measure the effects of risk management activities, we utilize three labour inputs – administrative labour services, agent labour services, and risk management labour services. Prior insurance efficiency papers have lumped together administrative and risk management labour into a single category. Separating administrative and risk management labour allows us to measure variations in the intensity of risk management across insurers. The other inputs, which are standard in insurance efficiency research, are materials and business services, debt capital, and equity capital. Administrative labour and materials/business services are used for the insurance, risk management, and financial intermediation activities and, therefore, prices are the same for these activities. Agent labour services are only used for insurance activities. Risk management labour services are used only for the risk management activities. Debt capital and equity capital are inputs used for financial intermediation and also support the insurance activities through their impact on insolvency risk.

The price of administrative labour services (*Administrative labour)* is the average weekly wage in the U.S. state where the head office of the firm is located for *SIC* code 6331- Fire, Marine, and Casualty Insurers. The price of agent labour services (*Agent labour)* is a weighted average of the average weekly wages in each U.S. state where the firm operates for *SIC* code 6411- Insurance agents and brokers. In that case, the weight is the share of premiums written in each state by the insurance firm. The price of risk management input (*Risk labour)* is the average weekly wage in each U.S. state where the head office of the firm is located for the North American Industry Classification System (*NAICS*) code 52392- Portfolio management. The price of materials/business services (*Material/Business*) is the average weekly wage also in the U.S. state where the head office is located for *SIC* code 7300 - Business services. The *SIC* and *NAICS* average weekly wages used to compute prices are obtained from the U.S. Department of Labor's Bureau of Labor Statistics.

The price associated with debt capital (*Debt price)* is defined as the required return by policyholders. This required return is a function of the credit quality of the insurer and the expected waiting time between accident occurrence and claim payment. We compute *Debt price* for each insurance firm as the annualized interest rate equivalent to the rate on the term structure corresponding to the firm's credit quality and with maturity equal to the effective duration of the insurer's liabilities. This produces a different price for each insurance firm varying by its credit quality and its liability's effective duration.[10]

The price associated with equity capital (*Equity price)* is defined as the required return by equity holders. We use the Fama-French three-factor model to estimate the required returns for listed insurance firms on financial markets.[11] We assume that listed and unlisted insurers that have the same credit quality also have the same required return on equity. In other words, we categorize insurers by debt quality and take an average within each debt rating of the Fama-French cost of capital.

Total costs (*Costs*) are computed as the sum of total expenses (net of loss adjustment expenses, which are part of the incurred loss outputs) and the cost of capital. The cost of capital is the sum of the cost of equity capital and the cost of debt capital.[12] The equity capital (*Equity*) is defined as the sum of policyholders' surplus and the redundant statutory liabilities (excess of statutory over statement reserves plus provision for reinsurance). The debt capital (*Debt*), i.e., liabilities, is defined as the sum of losses and loss adjustment expenses reserves, unearned premium reserves, and borrowed money.

5.2.4. Other Variables

Yearly dummy variables (*Year96-Year03*) are used to take into account of time. A set of additional dummy variables is used to account for the insurer's characteristics. The *Stock ownership* dummy is equal to 1 for stock insurers and equal to 0 otherwise. The *Group* dummy is equal to 1 if the firm is an insurance group (i.e., consists of multiple insurers under common ownership) and equal to 0 otherwise (i.e., if the firm is an unaffiliated single insurer). *Distribution* dummy is equal to 1 if the insurer uses independent agents; and *States* dummy equals 1 if the head office of the insurer is in state *s*. The omitted state is New York State.

5.3. Summary Statistics

[Table 1]

Summary statistics for all variables are presented in Table 1 for the three different samples of insurers. Insurers in Sample 1 had on average about $1.81 billion of invested assets and generated on average an annual return of 5.8 percent during the period 1995-2003. The average total output produced by insurers in sample 1 was about $484 million. These insurers produced more personal insurance than commercial insurance, and they produced more long-tail insurance than short-tail insurance. When we look at size variables such as *Equity* and *Debt*, we observe that insurers in Sample 1 are about twice the size of those in the total available population composed of 1,652 insurers and 9,206 observations (Sample 3). The unweighted average share of business in personal lines is about 55 percent in Sample 1 and about 38 percent in Sample 3. Thus, large insurers are more active in personal lines while small insurers are more specialized in commercial lines. However, large and small insurers have a comparative share of business in long-tail lines. Table 1 also indicates that large firms are more likely to be a group of insurers and are more likely to use independent agents to sell their policies.

6. Empirical Results

[Table 2]

Table 2 presents the estimation results for the first stage regressions of the intermediate outputs. Except for *Investment return*, the adjusted R^2 are high. Several coefficients associated with the instruments are statistically significant. Some interesting results show up from these regressions. For instance, insurer groups have significantly higher *Turnover*, *Invested assets* and *Investment returns* than unaffiliated single insurers, and they have also higher *Asset-liability risk*. This is consistent with insurance groups being larger and more sophisticated than unaffiliated single insurers. Insurers that use independent agents have lower *Invested assets* and lower *Turnover* than direct insurers, and they have also lower *Asset-liability risk*. Thus, insurers that use independent agents are more active in risk management and less active in financial intermediation than insurers using direct marketing or exclusive agents. Stock insurers have significantly higher *Turnover* than mutual insurers, but they have lower *Asset-liability risk.* This would suggest that stock insurers are more active in both financial intermediation and risk management than mutual insurers, consistent with agency theoretic arguments that stock insurers have stronger profit motives than mutuals.[13]

[Table 3]

Table 3, Panel A, presents our main results for Equation (12) specified with four outputs and with random coefficients associated with the two intermediate outputs. The difference between Model 1.1, Model 2.1 and Model 3.1 is the measure for financial intermediation output. Model 1.1 is specified with *Invested assets*, Model 2.1 is specified with *Turnover*, and Model 3.1 is specified with *Investment return*. Table 3 shows the results for the three models estimated with Sample 1. The coefficients of *Invested assets* and *Investment return* are negative and significant at the one percent level. The coefficient of *Turnover* is also negative but significant only at the 10 percent level. A negative coefficient means that the financial intermediation activities decrease the insurance activity costs. This result is in line with the theoretical model (Equation 6) where it is shown that financial intermediation may create additional value added when some conditions are satisfied.

The coefficient for *Asset-liability risk* is positive and significant at one percent level in the three models. A positive coefficient for *Asset-liability risk* is also in line with the theoretical model (Equation 6) where it is shown that risk management may have a positive effect on the insurer's value added since it reduces the solvency risk. A positive coefficient means that higher equity durations have higher insolvency risk and higher insurance costs, primarily due to higher costs of debt and equity capital. The results for the insurance output quantities and input prices are also as expected. The coefficients for output quantities are positive and statistically significant in the different model specifications. The coefficients for input prices are positive when they are statistically significant.

Table A1 and Table A2 (in Appendix 4) present results with larger samples using a more aggregated output measure. These results confirm that higher financial intermediation and risk management activities reduce insurers' costs.

[Figure 1] [Figure 2]

One particularity of our econometric model is related to the shadow prices of the intermediate outputs. Since these two outputs are not traded on markets but inside the firms, they are not directly observable but can be estimated. Estimated shadow prices are illustrated in Figure 1 for risk management and in Figure 2 for financial intermediation using the parameter estimates of Model 1.1 (with 613 insurers in Sample 1).[14] In both cases, the average shadow price is positive indicating that, on average, insurance firms in the sample could reduce their costs further by increasing their level of risk and financial intermediation activities. This observation is, of course, consistent with the empirical results presented in Table 3, panel A, where the fixed parts of the coefficients associated with the two intermediate outputs are statistically significant. Figures 1 and 2 also reveal that several insurers are quite far from optimal levels of risk management and financial intermediation activities and could further reduce their costs significantly by increasing these activities. The figures also show that a few firms are over-producing risk management and financial intermediation activities (negative shadow price values) and could therefore reduce their costs by reducing the level of these activities.

Panel B of Table 3, Table A1, and Table A2 presents the descriptive statistics of shadow prices for financial intermediation and risk management that are obtained with different model specifications and with different samples. We observe in these results that the mean of the shadow prices for risk management increases when the sample size increases. This would suggest that small insurers have higher shadow prices for risk management and hence have a larger potential to reduce costs by improving risk management.

Insurance-pooling efficiency results are presented in Panel C of Table 3, Table A1, and Table A2. We look at the efficiency measures (equations (14a) and (14b)) computed from the estimates of the nine empirical models considered in our analysis. For all models, the results are quite consistent. In Sample 1, cost efficiency averages between 48 and 50 percent compared to the most efficient firms, and cost efficiency averages between 55 and 57 percent compared to the least efficient firm. Results obtained with Sample 2 and Sample 3 are similar. Interpreting the results from our preferred model (Model 1.1), we can see that, on average, firms in Sample 1 have costs which are approximately twice as high on average as the costs of the most efficient firm in the sample, everything else being equal. Alternatively, we also see that, on average, firms in the Sample 1 have costs which are about 57 percent of the costs of the least efficient firm in the sample (613 observations) again, everything else being equal. The magnitude of the efficiencies is generally consistent with prior insurance efficiency studies (Cummins and Weiss, 2000). These efficiency measurements must be interpreted as overall insurance pooling activity efficiency.

7. Conclusion

This paper tests the role of risk management and financial intermediation activities in value creation by analyzing three samples of U.S. property-liability insurers over the period 1995-2003. We argue that risk management and financial intermediation are activities that may be used by insurers to improve efficiency, where efficiency is gauged by the capacity to reduce the costs of providing insurance.

We measure insurer efficiency by estimating an econometric cost function. Risk management and financial intermediation are key activities for insurers and are treated as endogenous variables. Also, because the prices of risk management and financial intermediation activities are not observable, we consider these two activities as intermediate outputs and estimate their shadow prices. The shadow prices are then used to isolate the contributions of risk management and financial intermediation to insurer cost efficiency, as measured by their capacity to reduce costs. The article also contributes to the prior literature by developing a theoretical model of value-added in the property-liability insurance industry.

An important contribution of this article is to utilize a new approach for the estimation of efficiency for financial institutions. The econometric methodology enables us to estimate the shadow prices of risk management and financial intermediation and thereby to show their contribution to insurer cost efficiency. The estimation of shadow prices is particularly important for financial institutions because many of the services provided by such firms are intangible and not explicitly priced.

The empirical results clearly indicate that risk management and financial intermediation contribute significantly to enhancing efficiency for property-liability insurers. The average shadow price for both services is positive, indicating that, on average, insurance firms in the sample could reduce their costs further by increasing their level of risk management and financial intermediation activities. The results also reveal that several insurers are quite far from an optimal level of risk management and financial intermediation activities and could reduce their costs significantly by increasing these activities. However, a few firms are over-producing these intermediate outputs and could therefore improve their efficiency by reducing the level of these activities. Finally, the results indicate that smaller insurers have higher shadow prices for risk management and suggest that they may have difficulty competing with larger firms in the long-run due to resource constraints and scale economies of risk management activities and systems. Thus, the results could suggest that there should be further consolidation of the property-liability insurance industry.

References

Ahlgrim, K.C., D'Arcy, S.P., and Gorvett, R.W., 2004. The Effective Duration and Convexity of Liabilities for Property-Liability Insurers Under Stochastic Interest Rates. *Geneva Papers on Risk and Insurance Theory* 29, 75-108.

Allayannis, G. and Weston, J.P., 2001. The Use of Foreign Currency Derivatives and Firm Value. *The Review of Financial Studies* 14, 243-276.

Berger, A.N., 1993. "Distribution Free" Estimates of Efficiency in the U.S. Banking Industry and Tests of the Standard Distributional Assumptions. *Journal of Productivity Analysis* 4, 261-292.

Berger, A.N., Cummins, J.D., Weiss, M.A., and Zi, H., 2000. Conglomeration vs. Strategic Focus: Evidence From the Insurance Industry. *Journal of Financial Intermediation* 9, 323-362.

Berger, Allen N. and David B. Humphrey, 1992. Measurement and Efficiency Issues in Commercial Banking. In: Griliches, Zvi., ed. Output Measurement in the Service Sector, University of Chicago Press, Chicago, IL, 245-279.

Berger, Allen N. and David B. Humphrey, 1997. Efficiency of Financial Institutions: International Survey and Directions for Future Research. *European Journal of Operational Research* 98, 175-212.

Chermak, J.M. and Patrick, R.H., 2001. A Microeconomic Test of the Theory of Exhaustible Resources. *Journal of Environmental Economics and Management* 42, 82-103.

Culp, Christopher L., 2002, The ART of Risk Management. New York: John Wiley & Sons.

Cummins, J.D., Phillips, R.D., and Smith, S.D., 2001. Derivatives and Corporate Risk Management: Participation and Volume Decisions in the Insurance Industry. *Journal of Risk and Insurance* 68, 51-91.

Cummins, J.D. and Nini, G., 2002. Optimal Capital Utilization by Financial Firms: Evidence From the Property-Liability Insurance Industry. *Journal of Financial Services Research* 21, 15-53.

Cummins, J.D. and M. Rubio-Misas, 2006, "Deregulation, Consolidation, and Efficiency: Evidence from the Spanish Insurance Industry," *Journal of Money, Credit, and Banking* 38 (no. 2): 323-356.

Cummins, J.D. and Weiss, M.A., 2000. Analyzing Firm Performance in the Insurance Industry Using Frontier Efficiency Methods, in: G. Dionne, (Ed.), Handbook of Insurance. Kluwer Academic Publishers, Boston, 767-829.

DeMarzo, P. and Duffie, D., 1991. Corporate Financial Hedging with Proprietary Information. *Journal of Economic Theory* 53, 2, 261-286.

Dionne, G., Gagné, R., and Vanasse, C., 1998, Inferring Technological Parameters from Incomplete Panel Data. *Journal of Econometrics* 87, 303-327.

Dionne, G. and Triki, T., 2005. Risk Management and Corporate Governance: The Importance of Independence and Financial Knowledge for the Board and the Audit Committee. Working Paper 05-03, Canada Research Chair in Risk Management, HEC Montréal.

Doherty, N. and Dionne, G., 1993. Insurance with Undiversifiable Risk: Contract Structure and Organizational Form of Insurance Firms. *Journal of Risk and Uncertainty* 6, 2, 187-203.

Doherty, N. and Schlesinger, H., 1990. Rational Insurance Purchasing: Consideration of Contract Nonperformance. *Quarterly Journal of Economics* 105, 143-153.

Froot, K., 2001. The Market for Catastrophe Risk: A Clinical Examination. *Journal of Financial Economics* 60, 529-571.

Froot, K., 2007. Risk Management, Capital Budgeting, and Capital Structure Policy for Insurers and Reinsurers. *Journal of Risk and Insurance* 74, 273-299.

Froot, K., Scharfstein, D., and Stein, J., 1993. Risk Management: Coordinating Corporate Investment and Financing Policies. *The Journal of Finance* 48, 5, 1629-1658.

Graham, J. and Rogers, D., 2002. Do Firms Hedge in Response to Tax Incentives? *The Journal of Finance* 57, 2, 815-839.

Greene, W.H. and Segal, D., 2004. Profitability and Efficiency in the U.S. Life Insurance Industry. *Journal of Productivity Analysis* 21, 229-247.

Grossi, P. and Kunreuther, K., 2005. Catastrophe Modeling: A New Approach to Managing Risk. New York: Springer Science.

Halvorsen, R. and Smith, T.R., 1991. A Test of the Theory of Exhaustible Resources. *The Quarterly Journal of Economics* 106, 1, 123-140.

Hull, J. and and White, A., 1990. Pricing Interest-rate-derivative Securities. Review of Financial Studies 3, 573-592.

Klumpes, P.J.M., 2004. Performance Benchmarking in Financial Services: Evidence from the U.K. Life Insurance Industry. *Journal of Business* 77, 257-273.

Mahlberg, B. and Url, T., 2003. Effects of the Single Market on the Austrian Insurance Industry. *Empirical Economics* 28, 813-838.

McDonnell, E., 2002. Industry Loss Warranties. In Morton Lane, ed., Alternative Risk Strategies (London: Risk Books).

Mocklow, D, DeCaro, J. and McKenna, M., 2002. Catastrophe Bonds. In Morton Lane, ed., Alternative Risk Strategies (London: Risk Books).

Nelson, J.M., Moffitt, J.S., and Affleck-Graves, J., 2005. The Impact of Hedging on the Market Value of Equity. *Journal of Corporate Finance* 11, 851-881.

Santomero, A.M. and Babbel, D.F., 1997. Financial Risk Management by Insurers: An Analysis of the Process. *Journal of Risk and Insurance* 64, 231-270.

Smith, C. and Stulz, R., 1985. The Determinants of Firms' Hedging Policies. *Journal of Financial and Quantitative Analysis* 20, 4, 391-405.

Staking, K.B. and Babbel, D.F., 1995. The Relation Between Capital Structure, Interest Rate Sensitivity, and Market Value in the Property-Liability Insurance Industry. *Journal of Risk and Insurance* 62, 690-718.

Taylor, Greg, 2000, *Loss Reserving: An Actuarial Perspective* (Boston: Kluwer Academic Publishers).

Tufano, P., 1996. Who Manages Risk? An Empirical Examination of Risk Management Practices in the Gold Mining Industry. *The Journal of Finance* 51, 4, 1097-1137.

TABLE 1

Summary Statistics for Variables Used in Cost Function Estimation: 1995–2003

	Sample 1		Sample 2		Sample 3	
Variables	**Mean**	**Standard**	**Mean**	**Standard**	**Mean**	**Standard**
Intermediate Outputs						
Invested assets	1813.58	6548.19	1109.80	5111.08	738.38	4036.51
Turnover	887.16	3598.91	547.12	2805.47	370.88	2217.61
Investment return	0.0580	0.0296	0.0555	0.0354	0.0546	0.0348
Dollars surplus duration	16916.52	71020.06	10321.64	55240.82	6738.69	43476.92
Output Quantities and Output Prices						
Long-tail personal	190.58	1025.40	114.77	794.05	69.97	622.47
Short-tail personal	86.26	470.07	52.45	364.32	32.39	285.71
Long-tail commercial	164.53	532.58	101.12	417.32	68.11	330.13
Short-tail commercial	42.70	139.25	29.31	125.41	20.89	110.30
Total output	484.06	1847.50	297.65	1441.15	191.36	1134.93
Share of Personnel	0.5505	0.3211	0.5748	0.3353	0.3782	0.3908
Share of long-tail	0.7163	0.1714	0.7152	0.2111	0.6857	0.3301
Price of long-tail personal	0.4387	1.0480	0.4724	1.2506	0.2884	1.0031
Price of short-tail personal	0.5575	1.2972	0.4996	2.1345	0.4053	2.0466
Price of long-tail commercial	1.3635	7.5635	1.7296	10.5514	1.3114	8.7574
Price of Short-tail commercial	0.9534	2.8103	1.3722	10.5489	4.0258	161.9372
Price of Total output	0.4925	0.4159	0.5594	0.7064	3.5220	161.7207
Inputs Prices						
Administrative labour	947.70	172.29	949.72	162.94	943.31	164.02
Agent labour	801.30	151.88	810.52	159.68	809.99	157.40
Risk labour	2069.18	1126.89	2061.32	1070.10	2029.56	1061.32
Material/Business	613.12	197.32	610.21	190.14	603.18	183.60
Debt Price	0.0576	0.0181	0.0573	0.0185	0.0586	0.0185
Equity Price	0.1688	0.0641	0.1746	0.0695	0.1782	0.0724
Others						
Equity	920.80	3767.25	568.03	2933.44	373.56	2310.63
Debt	1236.97	4062.78	754.49	3180.90	497.43	2513.66
Total Costs	437.45	1525.49	268.69	1191.93	174.61	939.33
Dummy variables						
Group dummy	0.6675	0.4712	0.5061	0.5000	0.4097	0.4918
Stock ownership dummy	0.5232	0.4995	0.5055	0.5000	0.5413	0.4983
Distribution dummy	0.6578	0.4745	0.6397	0.4801	0.5084	0.5000
Number of observations	3320		5612		9206	
Number of insurers	613		1021		1652	

Note: Quantities of intermediate outputs, quantities of outputs and assets are in millions of real 1995 dollars. Equity, Debt and Total costs are in million of current dollars.

Table 2
Results for first stage regressions with Sample 1

Variable	Invested assets		Turnover		Investment return		Asset-liability risk	
	Estimate	**Estimated P-value**	**Estimate**	**Estimated P-value**	**Estimate**	**Estimated P-value**	**Estimate**	**Estimated P-value**
Intercept	-2.37	<.0001	-3.03	<.0001	-0.05	0.274	-2.98	<.0001
Price of long-tail personal	0.01	0.3534	0.01	0.4306	-0.02	<.0001	0.04	0.0178
Price of short-tail personal	0.14	<.0001	0.13	<.0001	0.01	0.0732	0.14	<.0001
Price of long-tail commercial	0.01	0.399	-0.01	0.3605	-0.01	0.0001	0.03	0.0619
Price of Short-tail commercial	0.05	0.0081	0.05	0.0187	0.00	0.3375	0.06	0.0049
Price of administrative labour	0.55	0.4652	0.01	0.9875	-0.09	0.6405	0.57	0.5102
Price of agent labour	0.96	0.008	0.26	0.5213	0.05	0.6097	0.81	0.0541
Price of risk labour	-0.40	0.1312	-0.32	0.2797	0.11	0.1121	-0.54	0.0754
Price of Material/Business	0.42	0.3911	0.35	0.5321	0.38	0.0033	0.30	0.6034
Debt Price	1.80	<.0001	2.01	<.0001	0.03	0.7366	1.02	0.0078
Equity Price	-0.86	<.0001	-0.62	0.0011	-0.05	0.2981	-1.04	<.0001
Distribution dummy	-0.77	<.0001	-0.81	<.0001	0.01	0.6316	-0.85	<.0001
Group dummy	2.29	<.0001	2.38	<.0001	0.04	0.0213	2.61	<.0001
Stock ownership dummy	0.04	0.5468	0.32	<.0001	0.02	0.1675	-0.12	0.0828
Number of observations	3320		3313		3297		3320	
Number of insurers	613		612		612		613	
Adjusted R-sq	0.4981		0.4813		0.1935		0.4747	

Note: Results for time dummy variables and state dummy variables are available upon request. Results with sample 2 and sample 3 are not presented but are also available.

Table 3

Models specified with four outputs and estimated with Sample 1

Model 1.1: *Invested assets* is the measure of financial intermediation output

Model 2.1: *Turnover* is the measure of financial intermediation output

Model 3.1: *Investment return* is the measure of financial intermediation output

Panel A: Results for the Cost Function Estimation

	Model 1.1		Model 2.1		Model 3.1	
	Estimate	**Simulated P-value**	**Estimate**	**Simulated P-value**	**Estimate**	**Simulated P-value**
Intercept	13.2682	<.0001	13.1209	<.0001	13.3000	<.0001
Financial intermediation	-0.6273	0.0016	-0.1504	0.0864	-0.8051	<.0001
Asset-liability risk	0.8049	<.0001	0.4046	<.0001	0.2353	<.0001
Long-tail personal	0.2123	<.0001	0.1981	<.0001	0.2271	<.0001
Short-tail personal	0.1370	<.0001	0.1566	<.0001	0.1389	<.0001
Long-tail commercial	0.2856	<.0001	0.2768	<.0001	0.2634	<.0001
Short-tail commercial	0.1321	<.0001	0.1246	<.0001	0.1516	<.0001
Agent labour	0.0638	0.3988	-0.1642	0.2554	0.1411	0.2454
Risk labour	0.1725	0.0063	0.1600	0.0234	0.2012	0.0018
Material/Business	0.0756	0.2759	0.1511	0.1582	0.1469	0.1195
Debt Price	0.2540	0.0079	0.2299	0.0304	-0.0053	0.4848
Equity Price	0.4242	<.0001	0.4451	<.0001	0.3770	<.0001
-2 Log Likelihood	485.2		510.2		352.8	

Panel B: Shadow Prices for Intermediate Outputs

	Model 1.1		Model 2.1		Model 3.1	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Risk management	0.07	0.24	0.05	0.12	0.02	0.08
Financial intermediation	0.18	0.24	0.57	3.11		

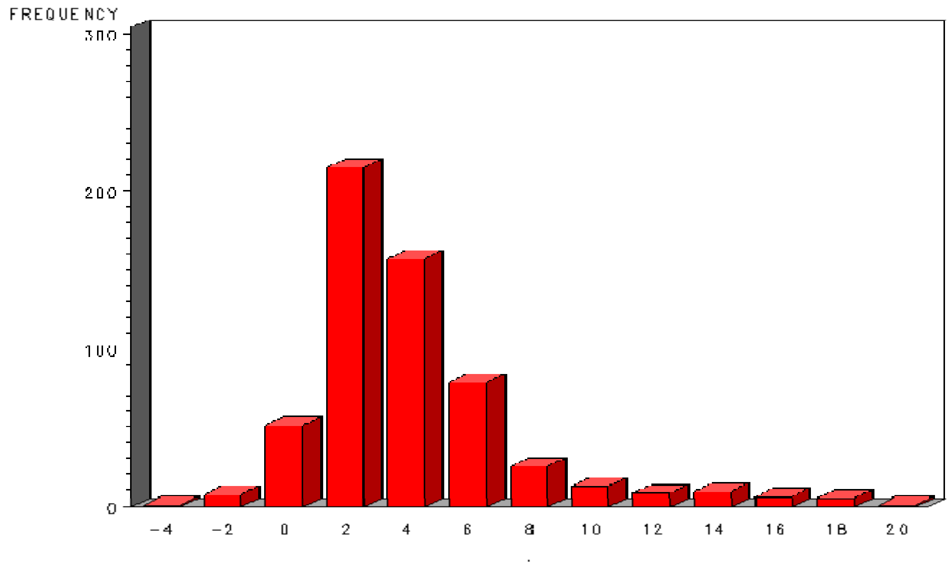
Panel C: Insurance-pooling Efficiency Results

	Model 1.1		Model 2.1		Model 3.1	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Efficiency (1)	0.48	0.22	0.49	0.22	0.50	0.21
Efficiency (2)	0.57	0.21	0.56	0.21	0.55	0.21
Number of observations	3320		3313		3297	
Number of insurers	613		612		612	

Notes for Panel A: Results for time dummy variables and second-order terms are available. The number of observations and the number of insurers in Sample 1 change because the variable that measures financial intermediation changes.

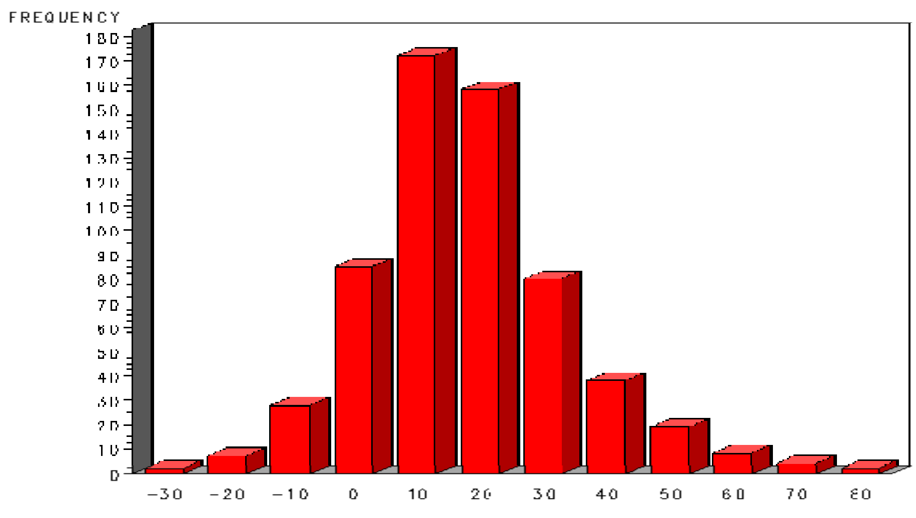
Notes for Panel B: Shadow price for risk management and shadow price for financial intermediation are obtained from equation (13). We did not calculate the shadow prices for financial intermediation when we use Investment return as a measure for financial intermediation because Investment return is a quality and not a quantity of the output of financial intermediation.

Notes for Panel C: Efficiency(1) and Efficiency(2) are obtained from equation (14). The results are obtained from truncated measures, as in Berger (1993). We set the top and bottom 5% to the 5^{th} and 95^{th} percentiles, respectively, of their distribution.



Shadow prices for risk management (10^{-2})

Figure 1. The shadow prices for risk management. These prices are obtained from equation (13) applied to Model 1.1. The mean of the shadow prices for risk management is 0.0701.



Shadow prices for financial intermediation (10^{-2})

Figure 2. The shadow prices for financial intermediation. These prices are obtained from equation (13) applied to Model 1.1. The mean of the shadow prices for financial intermediation is 0.1768.

Appendixes

Appendix 1

In a first step, we assume that there is a solvency risk but the insurer does not use any risk management activity. We propose the following notation:

p is the probability of the solvency risk;

r_e is the required return by equity holders;

r is the required return by policyholders;

r_a is the investment return;

e_q is the insurer expenses for risk pooling and financial management as proportion of expected insurance coverage Q; it is paid even when the insurer is insolvent.

So, the premium can be written as:

$$P = \frac{(1-p)\left(Q + r_e E\right) + e_q Q}{(1+r)} .$$

The corresponding value added is:

$$V = \frac{(1+r_a)}{(1+r)}\left((1-p)\left(Q + r_e E\right) + e_q Q\right) + r_a E - (1-p)\, Q - (1-p)\, r_e E ,$$

or equivalently to:

$$V = m\left[(1-p)(Q + r_e E) + e_q Q\right] + e_q Q + r_a E ,$$

where $1 + m = \frac{1+r_a}{1+r}$; $m > 0$ when $r_a > r$.

We now assume that the insurer uses risk management to reduce the solvency risk. We define:

h as the hedging ratio;

$p\left(1-h\right)$ as the new default probability of solvency risk;

e_h measures expenses for hedging; it is proportional to hedging ratio and expected insurance coverage;

$e_{qh} = e_q + he_h$;

r_e is the required return by equity holders. r_e is the same as before because equity holders diversify their solvency risk in financial markets. In other words, they can diversify the specific risk by themselves;

r_h is the new required return by policyholders. When $h > 0$ then $r_h < r$.

When the default risk decreases, policyholders reduce their required return because they are less exposed to the solvency risk.

$$1 + r_h = \frac{1 + r}{1 + m_p}$$

Since $r_h \leq r$ then $m_p \geq 0$ (when $h = 0$ we get $m_p = 0$).

The insurance premium becomes:

$$P_{PFM} = \frac{\left(1 - p + ph\right)\left(Q + r_e E\right) + e_{qh} Q}{(1 + r_h)}$$

$$P_{PFM} = (1 + m_p)\frac{\left(1 - p\right)\left(Q + r_e E\right) + e_q Q}{(1 + r)} + \frac{Qhe_h + ph\left(Q + r_e E\right)}{(1 + r_h)}$$

$$P_{PFM} = P + m_p P + \frac{he_h Q + ph\left(Q + r_e E\right)}{(1 + r_h)}$$

As a result policyholders are ready to pay an extra premium to reduce the solvency risk. The value added becomes:

$$V_{PFM} = \frac{(1 + r_a)}{(1 + r_h)}\left[(1 - p + ph)(Q + r_e E) + e_{qh} Q\right] + r_a E - (1 - p + ph)(Q + r_e E).$$

We can write:

$$\frac{1 + r_a}{1 + r_h} = (1 + m_r) = \frac{1 + r_a}{1 + r} \times \frac{1 + r}{1 + r_h} = (1 + m)(1 + m_p).$$

Setting:

$$W = Q(1 + e_{qh}) + r_e E,$$

we obtain:

$$V_{PFM} = m_r \left[(1 - p + ph) W + e_{qh} Q \right] + e_{qh} Q + r_a E$$

$$V_{PFM} = m_r \left[(1 - p) W + e_q Q \right] + m_r [phW + he_h Q] + e_{hq} Q + r_a E$$

$$V_{PFM} = m \left[(1 - p) W + e_q Q \right] + e_q Q + r_a E + m_p (1 + m)[(1 - p) W + e_q Q] + m_r [phW + he_h Q] + he_h Q$$

$$V_{PFM} = V + m_p (1 + m)[(1 - p) W + e_q Q] + m_r [phW + he_h Q] + he_h Q$$

So the net value added of risk management is equal to:

$$V_{PFM} - V = m_p (1 + m)[(1 - p) W + e_h Q] + m_r [phW + he_h Q] + he_h Q > 0$$

when $m_r > 0$ since $m_p > 0$ when $h > 0$.

Appendix 2

Details on estimation and simulation procedures

Random effects are preferred to fixed effects because the number of observations on each firm is not large enough (maximum 9 observations per firm for three firm-specific parameters to be estimated). With the random effect approach, only the distribution parameters of the firm-specific effects are estimated at the sample level (α, β^R, β^F and 6 parameters in Ω). The random parameters α_i , β_i^R and β_i^F are then calculated for each firm using the estimated variance-covariance matrices and fixed effect parameters. For more details about the estimation techniques, see the *Mixed Model* documentation in *SAS*.

Because the specification of the cost function includes the random variables *R* and *F*, the estimated standard errors of the fixed parameters α *and* β in (12) are no longer appropriate. We present here the simulation procedure which allows us to replace the usual *t* statistics provided by the estimation procedure with simulated ones.

1) From the OLS estimates of the instrumental equations, 5,000 samples are generated for the intermediate outputs *R* and *F*.

2) Similarly, 5,000 samples are generated for *C* (the total costs) using the estimated distributions of $u_{it}, \alpha_i, \beta_i^R, \beta_i^F$ obtained from the estimation of the cost function (12) by restricted/residual maximum likelihood (REML).

3) For each generated sample of *C, R* and *F,* equation (12) is estimated again by REML.

4) From the 5,000 estimations of (12), we obtain the *simulated* distribution of the *t* statistic for each estimated parameter of the cost function.

5) To test for the statistical significance of each parameter of the cost function, we compute the *simulated p* value from the *simulated* distribution of the *t* statistics.

Appendix 3

Details on the computation of liabilities' effective duration

We proceed in four steps to compute the effective duration of liabilities:

1- We use the cumulative paid losses and allocated expenses from schedule P, part 3, of the *NAIC* insurance regulatory statements to estimate the cash flows patterns. We deflate the paid losses each year to the real 1995 values based on the consumer price index (CPI). We adopt the chain ladder method to estimate the percentage of ultimate losses that is paid in each development year (Taylor, 2000). Because the payout pattern differ between the principal types of insurance's business, we estimate a different chain ladder parameter for personal lines long-tail losses, personal lines short-tail losses, commercial lines long-tail losses and for commercial lines short-tail losses. In each year, we estimate the same chain ladder parameters for the whole property-liability insurance industry.

2- We determine the real values of incurred losses by accident year as the sum of the real values of unpaid losses and the real value of paid losses. Then we applied the chain ladder parameters found in the first step to calculate the real value of losses that will be paid in the future development years.

3- We adjust the future payments for inflation to take account of the fact that insurers hold reserves in nominal value. We assume that inflation and risk free interest rates are linearly correlated. Thus, the future movement of interest rates will affect the future claim payouts. We use the U.S. Treasury yield curves obtained from the Federal Reserve Economic Database (FRED) as the risk free interest rate term structure. We use Hull and White (1990) term structure model to simulate 1000 paths of interest rates movement. We utilize inflation paths to calculate the inflation adjusted value of future losses. The chain ladder method allows us to determine the loss cash flow patterns for ten years. If the sum of all the inflation adjusted future payments is less than the real value of unpaid losses, we assume that the rest will be paid during the eleventh year.

4- To determine the effective duration in a last step we need to calculate the present value of future payments in three ways as in Ahlgrim, D'Arcy and Gorvett (2004). The interest rate term structures by insurer's credit quality are obtained from Bloomberg. Actually, these term structures are available only since May 2000 for three different credit qualities AA, A and BBB. The insurer credit rating is obtained from Best's Key Rating Guide (A.M. Best Co). We use the table of correspondence between A.M Best rating scale and Bloomberg rating scale to split insurers in three different pools. Each pool has a different term structure. We estimate then the average spread between each interest rate term structure and the risk free interest rates term structure during the period 2000-2005 where data are available. We applied these average spreads for the missing period 1995-2000 to find out an equivalent interest term structure for each credit quality. Hence, for each insurer, we use the interest rates term structure corresponding to its credit quality to discount the future payments and to calculate the effective duration.

Appendix 4

TABLE A1

Models specified with aggregated output and estimated with Sample 2

Model 1.2: *Invested assets* is the measure of financial intermediation output

Model 2.2: *Turnover* is the measure of financial intermediation output

Model 3.2: *Investment return* is the measure of financial intermediation output

	Model 1.2		**Model 2.2**		**Model 3.2**	
Panel A: Results for the Cost Function Estimation						
	Estimate	**Simulated P-value**	**Estimate**	**Simulated P-value**	**Estimate**	**Simulated P-value**
Intercept	12.4699	<.0001	12.3665	<.0001	12.7964	<.0001
Financial intermediation	-0.4817	0.0095	-0.1741	0.0708	-2.8367	<.0001
Asset-liability risk	0.6107	0.0007	0.3632	0.0008	0.3007	<.0001
Total output	0.9081	<.0001	0.8946	<.0001	0.8779	<.0001
Share of personal	-0.0881	<.0001	-0.0827	0.0006	-0.0848	<.0001
Share of long-tail	0.0481	0.1428	0.0322	0.2984	0.0689	0.0207
Agent labour	0.0033	0.4488	-0.0392	0.4374	-0.0917	0.3050
Risk labour	0.0617	0.1816	0.0775	0.1692	0.0652	0.1197
Material/Business	0.1655	0.0871	0.1494	0.1678	0.4159	<.0001
Debt Price	0.2768	0.0029	0.1965	0.0442	0.1406	0.0217
Equity Price	0.6159	<.0001	0.5836	<.0001	0.6741	<.0001
Year96	-0.0746	<.0001	-0.0832	<.0001	-0.0107	0.0953
Year97	-0.0061	0.3192	0.0108	0.1936	0.0512	<.0001
Year98	-0.0099	0.2994	0.0418	0.0336	0.0519	<.0001
Year99	0.1164	<.0001	0.1249	<.0001	0.0390	0.0190
Year00	0.0667	0.0022	0.0172	0.281	-0.0585	0.0033
Year01	0.2126	0.0015	0.2010	0.0222	-0.5110	<.0001
Year02	0.5854	<.0001	0.5053	0.0002	-1.0338	<.0001
Year03	1.0430	<.0001	0.8920	<.0001	-0.8296	<.0001
-2 Log Likelihood	1907.3		1899.1		811.8	
Panel B: Shadow Prices for Intermediate Outputs						
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Risk management	0.14	1.20	0.09	0.89	0.08	0.81
Financial intermediation	0.17	0.39	4.30	117.86		
Panel C: Insurance-pooling Efficiency Results						
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Efficiency (1)	0.48	0.20	0.49	0.20	0.52	0.19
Efficiency (2)	0.47	0.21	0.44	0.20	0.41	0.20
Number of observations	5612		5578		5546	
Number of insurers	1021		1017		1020	

TABLE A2

Models specified with aggregated output and estimated with Sample 3

Model 1.3: *Invested assets* is the measure of financial intermediation output

Model 2.3: *Turnover* is the measure of financial intermediation output

Model 3.3: *Investment return* is the measure of financial intermediation output

	Model 1.3		**Model 2.3**		**Model 3.3**	
Panel A: Results for the Cost Function Estimation						
	Estimate	**Simulated P-value**	**Estimate**	**Simulated P-value**	**Estimate**	**Simulated P-value**
Intercept	11.5843	<.0001	11.5370	<.0001	12.4139	<.0001
Financial intermediation	-0.3891	0.0085	-0.3658	<.0001	-2.9717	<.0001
Asset-liability risk	0.4269	0.0025	0.4924	<.0001	0.3535	<.0001
Total output	0.8234	<.0001	0.8010	<.0001	0.8031	<.0001
Agent labour	-0.1023	0.2815	-0.1344	0.2314	0.3883	0.0133
Risk labour	0.0618	0.1415	0.1165	0.0296	0.1297	0.0080
Material/Business	0.1611	0.0655	0.1354	0.1036	0.2881	0.0005
Debt Price	0.5501	<.0001	0.6265	<.0001	-0.0201	0.3728
Equity Price	0.2892	<.0001	0.3905	<.0001	0.5706	<.0001
Year96	-0.0381	<.0001	-0.0673	<.0001	0.0171	0.0053
Year97	0.0052	0.3220	0.0212	0.0083	0.0695	<.0001
Year98	-0.0104	0.2710	0.1241	<.0001	0.0708	<.0001
Year99	-0.0346	0.0655	0.0176	0.2130	-0.0246	0.0773
Year00	0.0546	0.0080	0.0066	0.3959	-0.1091	<.0001
Year01	0.2184	<.0001	0.4442	<.0001	-0.6449	<.0001
Year02	0.4185	<.0001	0.7138	<.0001	-1.4577	<.0001
Year03	0.6676	<.0001	1.0149	<.0001	-1.4413	<.0001
-2 Log Likelihood	4964.8		4755.4		3682.9	
Panel B: Shadow Prices for Intermediate Outputs						
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Risk management	0.34	4.55	0.28	3.95	0.10	1.13
Financial intermediation	0.29	0.44	62.76	2306.87		
Panel C: Insurance-pooling Efficiency Results						
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Efficiency (1)	0.35	0.24	0.36	0.23	0.47	0.22
Efficiency (2)	0.61	0.25	0.60	0.24	0.52	0.22
Number of observations	9206		9117		9084	
Number of insurers	1652		1644		1648	

As already discussed in the paper, in Table 3 we used only insurers which have strictly positive outputs in the four lines of business. This reduced considerably the numbers of observations. Therefore, both for robustness and market representation, we extended the analysis to a higher number of insurers by summing up the four output variables into a single one. This enables us to include insurers that have positive total output but zero output for one or more of the four insurance lines. In Table A1, the results are obtained with this larger sample, referred to as Sample 2. Model 1.2 is specified with *Invested assets*, Model 2.2 is specified with *Turnover*, and Model 3.2 is specified with *Investment return* as the measure for financial intermediation output. In these specifications, there is a single aggregated output along with two output attribute variables (*Share of personal* and *Share of long- tail*). It is interesting to observe that the coefficients associated with the two intermediate outputs variables keep the same signs as in Table 3 although their magnitudes change. These results confirm that higher financial management and risk management activities reduce insurers' costs. The coefficient for *Share of personal* is negative and statistically significant. Thus, insurers more involved in personal lines have lower costs. This is consistent with the commercial lines of insurance being more complex and hence requiring higher levels of underwriting and claims settlement labour. The coefficient for *Share of long-tail* is positive but statistically significant only in Model 3.2 which means that insurers more involved in long tail lines tend to have higher costs.

In Table A2, Models are specified with a single aggregated output but without attribute variables because many insurers are not present in personal or long tail lines. Hence, the results are obtained with our largest sample (Sample 3). Again the results are quite robust. The coefficient associated with financial intermediation activities is negative and statistically significant at the one percent level whichever the proxy used: *Invested assets*, *Turnover* or *Investment return*. The coefficient for *Asset-liability risk* is positive and statistically significant at one percent level in the three different models. The results confirm again that higher financial intermediation and risk management activities reduce insurers' costs.

Panel B of Table 3, Table A1 and Table A2 present the descriptive statistics of shadow prices for risk and financial management that are obtained with different model specifications and with different samples. We can observe also that the mean of the shadow prices for risk management increases when the sample size increases. This would suggest that small insurers have higher shadow prices for risk management and hence have a larger potential to reduce costs through a better risk management. This is consistent with the argument that larger insurers are more sophisticated and better able to take advantage of scale economies in the design of information systems and other risk management practices. Larger insurers also have the resources to compete more effectively in hiring highly qualified risk managers. The findings suggest that smaller insurers may not be financially viable in the long-run and hence that consolidation of the industry is likely to continue.

Notes

[1] Alternatively, we obtained similar results using a bootstrapping approach.

[2] Because multiple outputs are aggregated into a single measure in Sample 2, we add to the specification of the cost function the *Share of personal insurance* and the *Share of long-tail insurance* as output attributes.

[3] The credit risk of property-liability insurer investment portfolios tends to be very low. For example, in 2005, 91 percent of the industry's bonds fell in the NAIC's top quality class and 97 percent fell in the top two (of six) quality classes. A.M. Best Company, Best's Aggregates and Averages: 2006 Edition (Oldwick, NJ).

[4] In our empirical work, we use a correlation of 0.74 between monthly risk free interest rate and monthly inflation.

[5] Surplus is the term used for the book-value of equity capital in the insurance industry.

[6] Insurers could use interest rate derivatives to hedge the interest rate risk. However, during the 2001-2003 period there is, on average, less than 3% of groups and less than 1% of unaffiliated insurers usingused derivatives. In the present study, we did not account for derivatives mainly because we have detailed data on derivatives only since 2001.

[7] The chain ladder method is a widely accepted actuarial methodology for estimating liability cash flows. See Taylor (2000).

[8] As mentioned above, we add to this specification of the cost function the *Share of personal insurance* and the *Share of long-tail insurance* as output attributes. This procedure has often been used in models for inferring technological parameters in the transportation industry (see, for instance, Dionne, Gagné and Vanasse, 1998).

[9] Alternatively, we also estimated our models with the output quantities defined as the total incurred losses during the year plus the *loss reserve adjustment*, which includes in the current year output the adjustment in reserves for prior years. The inclusion of the reserve adjustment has been used in most of the prior literature (see Cummins and Weiss, 2000). The estimates of cost function, shadow prices and efficiencies remain qualitatively the same.

[10] The credit quality term structures are obtained from Bloomberg, and the insurer's credit quality is obtained from Best's Key Rating Guide (A.M. Best Co).

[11] We split listed insurers into three groups based on their A.M. Best's rating. In every year, we estimate the cost of equity capital for each group. The prices of the Fama-French three risk factors were obtained from Kenneth French's website.

[12] The cost of equity capital is the average quantity of equity capital hold by the insurer during the year multiplied by *Equity price.* The cost of debt capital is the average quantity of debt capital hold by the insurer during the year multiplied by *Debt price*.

[13] Head office state dummy variables control the effect of the state insurance regulations. Regulation could limit managerial discretion in investment and risk management decisions. Many of these dummy variables are statistically significant. Results for the 50 head office state dummies are available.

[14] Even if shadow prices are computed for each observation in the Sample 1 (3,320 observations), Figures 1 and 2 report the firm-average shadow prices (613 firms). For risk management activities, the results correspond to negative value obtained from Equation 15 because increasing risk management decreases asset-liability risk.