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Trois Essais en Gestion des Risques et Efficience des Assureurs: Application à l'Industrie d'Assurance Responsabilité Américaine

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Résumé

Les assureurs émettent les polices d'assurance et collectent les primes en contre partie de leur promesse de payer les réclamations en cas d'accidents. Pour plusieurs types d'assurance, l'écart entre la date de l'accident et la date du règlement peut atteindre plusieurs années. Durant cette période, les assureurs investissent les fonds accumulés dans des actifs financiers. Si un assureur fait défaut à cause d'un choc financier ou à cause d'une perte majeure suite à une catastrophe, les assurés risquent de perdre une partie de leurs réclamations. Ainsi, l'intérêt ultime des assurés et des régulateurs est la continuelle fiabilité financière des compagnies d'assurance. L'un des outils les plus importants pour gérer les risques financiers est l'appariement entre l'actif et le passif. De même, l'un des outils les plus importants pour gérer le risque de souscription est la réassurance. Pourtant, aucune des études existantes n'a considéré la gestion des risques comme un déterminant potentiel de la performance des entreprises.

Dans le premier essai, nous analysons le rôle de la gestion des risques et de l'intermédiation financière dans la création de la valeur économique des institutions financières en considérant l'industrie de l'assurance responsabilité américaine. Notre objectif principal est de tester comment la gestion des risques et l'intermédiation financière créent de la valeur pour les assureurs en augmentant leur efficacité économique et en réduisant leurs coûts. Nous considérons ces deux activités comme deux outputs intermédiaires et nous estimons leurs prix implicites. L'efficacité des assureurs est mesurée en utilisant une fonction de coût économétrique. Les résultats économétriques montrent que les deux activités augmentent significativement l'efficacité de l'industrie étudiée. La moyenne des prix implicites pour ces deux activités est positive indiquant que les compagnies d'assurance peuvent réduire davantage leurs coûts en intensifiant leurs activités de gestion des risques et d'intermédiation financière.

Dans le deuxième essai, nous analysons les coûts et les bénéfices de la réassurance pour l'industrie de l'assurance responsabilité américaine. L'achat de la réassurance réduit le risque

d'insolvabilité des assureurs en stabilisant les pertes réalisées, en augmentant la capacité d'offre d'assurance, en limitant l'exposition à certains risques, et/ou en limitant les pertes en cas de catastrophes. En conséquence, l'achat de réassurance devrait réduire le coût du capital. Toutefois, transférer les risques aux réassureurs est coûteux. Le prix de la réassurance peut être beaucoup plus élevé que le prix actuariel du risque transféré. Les résultats empiriques montrent que l'achat de la réassurance augmente significativement les coûts des assureurs mais réduit significativement la volatilité de leur ratio de perte. En achetant de la réassurance, les assureurs acceptent de supporter un coût de production plus élevé afin de réduire leur risque de souscription.

Dans le troisième essai, nous analysons les déterminants de la performance des assureurs dans ses différentes activités. La finance corporative prédit que certaines caractéristiques des entreprises, telles que l'endettement, la forme organisationnelle et le système de distribution, affectent les coûts d'agence et ainsi l'efficacité des entreprises. Dans le premier essai, nous avons proposé une spécification de la fonction de coûts des assureurs qui mesure séparément l'efficacité de l'offre d'assurance, de gestion des risques et d'intermédiation financière. Dans le troisième essai, nous analysons les caractéristiques des assureurs qui déterminent les différentes efficacités. Nos résultats empiriques montrent que les mutuelles dominent les assureurs à capital action dans les trois activités. Les assureurs utilisant des agents indépendants et à forte capitalisation ont des coûts plus élevés d'offre d'assurance. D'autres caractéristiques, comme le fait d'être un groupe d'assureurs affiliés, d'avoir un plus grand volume d'assurance commerciale, de gérer davantage de réassurance ou d'investir une plus grande proportion des actifs dans des obligations, augmentent l'efficacité des assureurs dans leurs activités de gestion des risques et d'intermédiation financière.

Mots clés : Gestion des risques, intermédiation financière, output intermédiaire, prix implicite, efficience, coûts d'agence, appariement actif passif, réassurance, risque d'insolvabilité, assurance responsabilité américaine et données panel.

Abstract

Insurers issue policies and collect premiums against the promise of paying claims when accidents occur. For many types of insurance, the gap between the time of the accident and the time of the settlement could reach several years. During that period, insurers invest the funds raised in financial assets. If an insurer is defaulting because of a financial shock or a catastrophic loss, policyholders could lose part of their claims. Therefore, the ultimate interest of policyholders and regulators is the continued financial viability of the insurance company. In addition, policyholders accept to pay higher premium for insurers with lower insolvency risk. One of the most important tools for managing financial risks is the asset-liability management and one of the most important tools for managing insurance claim risk is reinsurance. However, none of existing studies consider risk management as a potential determinant of firm performance.

In the first essay, 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. 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.

In the second essay, we analyze the costs and benefits of reinsurance purchase. Purchasing reinsurance reduces insurers' insolvency risk by stabilizing loss experience,

increasing capacity, limiting liability on specific risks, and/or protecting against catastrophes. Consequently, reinsurance purchase should reduce capital costs. However, transferring risk to reinsurers is expensive. The cost of reinsurance for an insurer can be much larger than the actuarial price of the risk transferred. In this article, we analyze empirically the costs and the benefits of reinsurance for a sample of U.S. property-liability insurers. The results show that reinsurance purchase increases significantly the insurers' costs but also reduces significantly the volatility of the loss ratio. With purchasing reinsurance, insurers accept to pay higher costs of insurance production to reduce their underwriting risk.

In the third essay, we investigate the determinants of insurers' performance in risk pooling, risk management, and financial intermediation activities. Corporate finance theory predicts that firm characteristics such as leverage, organizational forms, and distribution systems will affect agency costs and hence their efficiency. In the first essay we proposed a cost function specification that measures separately insurer efficiency in handling risk pooling, risk management, and financial intermediation functions. In this study, we investigate the insurer characteristics that determine these efficiencies. Our empirical results show that mutuals outperform stock insurers in handling the three functions. Independent agents and high capitalization reduce the cost efficiency of risk pooling without significantly increasing the efficiency with which risk management and financial intermediation activities are handled. However, certain characteristics, such as being a group of affiliated insurers, a higher volume of business in commercial lines, a larger assumed reinsurance, or a higher proportion of assets invested in bonds, do significantly increase insurers' efficiency in risk management and financial intermediation.

Keywords: Risk management, financial intermediation, intermediate output, shadow price, efficiency, cost function, agency costs, asset-liability management, reinsurance, insolvency risk, property-liability insurance, and panel data.

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À ma famille si lointaine et pourtant si proche de mon cœur.

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Introduction Générale

La théorie financière classique prévoit, dans le cadre d'un marché financier parfait, que les grandes entreprises n'ont pas besoin de se couvrir puisque les actionnaires peuvent eux-mêmes diversifier les risques spécifiques à l'intérieur de leurs portefeuilles. Pourtant, la gestion des risques est reconnue actuellement dans plusieurs secteurs d'activité comme une fonction principale qui permet de créer de la valeur ajoutée. Plusieurs études ont montré que la gestion des risques est pertinente en présence des imperfections du marché, telles que une structure convexe des taxes, coûts des difficultés financières, coûts d'opportunités d'investissement, ou présence d'asymétrie d'information. Toutefois, aucune étude n'a cherché à montrer si l'activité de gestion des risques permette d'améliorer l'efficacité globale des entreprises. Dans cette thèse, nous utilisons les données de l'industrie d'assurance responsabilité pour montrer comment la gestion des risques peut créer de la valeur ajoutée.

Les assureurs émettent les polices d'assurance et collectent les primes en contre partie de leur promesse de payer les réclamations en cas d'accidents. Pour plusieurs types d'assurance, l'écart entre la date de l'accident et la date du règlement peut atteindre plusieurs années. Durant cette période, les assureurs investissent les fonds accumulés dans des actifs financiers. Si un assureur fait défaut à cause d'un choc financier ou à cause d'une perte majeure suite à une catastrophe, les assurés risquent de perdre une partie de leurs réclamations. Ainsi, l'intérêt ultime des assurés et des régulateurs est la continuelle fiabilité financière des compagnies d'assurance. L'un des outils les plus importants pour gérer les risques financiers est l'appariement entre l'actif et le passif. De même, l'un des outils les plus importants pour gérer le risque de souscription est la réassurance. Pourtant, aucune des études existantes n'a considéré la gestion des risques comme un déterminant potentiel de la performance des entreprises.

Nous analysons d'abord le rôle de la gestion des risques et de l'intermédiation financière dans la création de la valeur économique des institutions financières en considérant l'industrie de l'assurance responsabilité américaine. Nous considérons ces deux activités comme deux outputs intermédiaires et nous estimons leurs prix implicites. Les résultats économétriques montrent que les deux activités augmentent significativement l'efficacité de l'industrie étudiée. La moyenne des prix implicites pour ces deux activités est positive indiquant que les compagnies d'assurance peuvent réduire davantage leurs coûts en intensifiant leurs activités de gestion des risques et d'intermédiation financière.

Nous analysons ensuite les coûts et les bénéfices de la réassurance pour l'industrie de l'assurance responsabilité américaine. L'achat de la réassurance réduit le risque d'insolvabilité des assureurs en stabilisant les pertes réalisées, en augmentant la capacité d'offre d'assurance, en limitant l'exposition à certains risques, et/ou en limitant les pertes en cas de catastrophes. Toutefois, transférer les risques aux réassureurs est coûteux. Le prix de la réassurance peut être beaucoup plus élevé que le prix actuariel du risque transféré. Les résultats empiriques montrent que l'achat de la réassurance augmente significativement les coûts des assureurs mais réduit significativement la volatilité de leur ratio de perte. En achetant de la réassurance, les assureurs acceptent de supporter un coût de production plus élevé afin de réduire leur risque de souscription.

Enfin, nous analysons les déterminants de la performance des assureurs dans ses différentes activités. Nous étudions les caractéristiques des assureurs qui déterminent différemment l'efficacité de l'offre d'assurance, de gestion des risques et d'intermédiation financière. Nos résultats empiriques montrent que les mutuelles dominent les assureurs à capital action dans les trois activités. Les assureurs utilisant des agents indépendants et à forte capitalisation ont des coûts plus élevés d'offre d'assurance. D'autres caractéristiques, comme le fait d'être un groupe d'assureurs affiliés, d'avoir un plus grand volume d'assurance commerciale, de gérer davantage de réassurance ou d'investir une plus grande proportion des actifs dans des obligations, augmentent l'efficacité des assureurs dans leurs activités de gestion des risques et d'intermédiation financière.

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

David Cummins, Georges Dionne, Robert Gagné,

and Abdelhakim Nouira

Abstract

Risk management is now present in many economic sectors. However, none of existing studies consider risk management as a potential determinant of firm performance. In this paper, 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.

Keywords: Risk management, financial intermediation, intermediate output, shadow price, efficiency, cost function.

1. Introduction

Risk management is now present in many economic sectors. Although perfect markets finance theory provides little rationale for widely held firms to expend 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 may 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 (Cummins, 1988). 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 an 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.

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. We take advantage of the more detailed data that are available on U.S. insurers to measure the effects of risk management on firm performance. Our database is described in more detail below.

One 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. 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. To our knowledge it is the first paper that applies this econometric methodology to the analysis of financial institutions. We use data from the U.S. property-liability insurance industry.

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 proposes the econometric model and estimation method, while Section 4 presents the data and variables. Section 5 analyses the main results and Section 6 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 (Mayers and Smith, 1990). 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 pay off 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 equity risk, foreign exchange business risk, interest rate risk, spread risk and volatility risk (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 uses 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.

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 (2005) 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. Econometric Model and Estimation Method

The property-liability insurers' primary function is risk pooling and risk bearing. They sell different types of insurance policies to a large pool of policyholders against the commitment of paying claims when accidents occur and they hold equity capital as a cushion for the risk assumed. Insurers invest received premiums and equity capital in financial assets to earn returns and they manage the resulting risks to reduce the costs of capital.

An important step in cost analysis is the definition of output quantities and input prices. There are different approaches to measuring insurance outputs in the 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, outputs are assigned to the functions which are creating significant value-added as measured by operating cost allocations. Most of the existing studies recognize that the risk pooling and risk-bearing function and the financial intermediation function create value added (Cummins and Weiss, 2000). However, none of them considers that risk management activities could create value. In this study, we test whether these activities improve the efficiency of insurance-pooling and reduce its costs.

For property-liability insurers, it is usually possible to measure the risk-pooling insurance outputs and their corresponding prices. Matters are more difficult for the financial intermediation and risk management activities because their prices are not observable. 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 activities. Therefore, we can estimate the shadow prices of both the financial intermediation and risk management activities.

We assume that insurance outputs (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:

$$Y\left(Q;R,F,X^{A},Z,T\right)=0\,, \tag{1}$$

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:

$$R=R\left(X^{R},Z,T\right), \tag{2}$$

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

$$F=F(X^{F},Z,T)\,, \tag{3}$$

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 (1), (2) and (3) is:

$$CR=CR\left(Q,R,F,P^{A},P^{R},P^{F},Z,T\right), \tag{4}$$

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 (4) 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.

Halvorsen and Smith (1991), use duality theory to derive the shadow price of the output of an intermediate function in the case of a vertically integrated firm. Applying their methodology,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 :

$$\mu = -\frac{\partial CR}{\partial R} \text{ and } \lambda = -\frac{\partial CR}{\partial F}. \tag{5}$$

Since the exact functional form of the restricted cost function defined by (4) is unknown, we use the well known translog approximation which is given by:

$$\begin{aligned} \ln CR_{it} &= \alpha_i + \sum_v \beta_v^Q \ln Q_{vit} + \beta_i^R \ln R_{it} + \beta_i^F \ln F_{it} \\ &+ \sum_s \beta_s^A \ln P_{sit}^A + \sum_j \beta_j^R \ln P_{jit}^R + \sum_k \beta_k^F \ln P_{kit}^F \\ &+ \beta^Z \ln Z_{it} + second - order\ terms + \sum_t \beta^t D_t + u_{it}, \end{aligned} \tag{6}$$

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 (6) are divided by their sample mean (the point of approximation).

The risk management and financial intermediation are intermediate activities. Thus, the variables measuring risk management (R) and financial intermediation (F) are likely to be endogenous[1]. 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 for the actual values in equation (6). Equation (6) is then estimated by restricted/residual maximum likelihood (REML) as implemented in the *Xtmixed* procedure of *Stata*. The proper test statistics of the different estimated parameters of the model are obtained from bootstrapped standard errors with 500 replications.

Shadow prices for risk management (μ_{it}) and financial intermediation (λ_{it}) outputs are computed from (6) using the following equations:

$$\mu_{it} = -\frac{\partial \ln CR}{\partial \ln R_{it}} \frac{CR_{it}}{R_{it}} \text{ and } \lambda_{it} = -\frac{\partial \ln CR}{\partial \ln F_{it}} \frac{CR_{it}}{F_{it}}. \tag{7}$$

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

[1] The general Hausman test shows that risk management and financial intermediation variables are endogenous.

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:

$$Efficiency(1)_i = \exp\left(\alpha_{\min} - \alpha_i\right) \tag{8a}$$

$$Efficiency(2)_i = 1 - \exp\left(\alpha_i - \alpha_{\max}\right) \tag{8b}$$

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).

4. Data and Variables

4.1. 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, negative risk management or financial intermediation variable 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.

4.2. Variables

4.2.1. 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

[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.

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 from 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

[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.

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 a term structure that is generated if observed interest rates decrease by the same specific amount (Δr). The effective duration ED is then obtained as: $ED = \dfrac{PV_{down} - PV_{up}}{2PV_o\, \Delta r}$.

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

[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.

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, while future payment will be based on the observed prices at the date of payment. 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 1 for details on the computation of liabilities' effective duration.

4.2.2. Output Quantities and Output Prices

Consistent with most of the prior insurance efficiency literature, output is defined as net 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*,

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[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.

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.

4.2.3. 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 present value of the sum of losses and loss adjustment expenses reserves, unearned premium reserves, and borrowed money.

4.2.4. Other Variables

Yearly dummy variables (*Year96-Year03*) are used to take into account of time. A set of

[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*.

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.

4.3. Summary Statistics

[Table I]

Summary statistics for all variables are presented in Table I 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 I 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.

5. Empirical Results

[Table II]

Table II 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 III]

Table III, Panel A, presents our main results for Equation (6) 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 III 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.

The coefficient for *Asset-liability risk* is positive and significant at the one percent level in all three models. A positive coefficient means that insurers with higher equity durations or lower risk management have higher insolvency risk and higher insurance costs, primarily due to higher costs of debt

[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.

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.

The results in Table III are obtained using 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.

[Table IV]

In Table IV, 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 III 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 not statistically significant which means that insurers more involved in long tail lines or more involved in short tail lines do not have significantly different costs' level.

[Table V]

In Table V, 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.

[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 management and financial intermediation activities. This observation is, of course, consistent with the empirical results presented in Table III, 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 III, Table IV, and Table V 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. This is consistent with the argument that larger insurers are more sophisticated and better

[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 7 because increasing risk management decreases asset-liability risk.

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.

Insurance-pooling efficiency results are presented in Panel C of Table III, Table IV, and Table V. We look at the efficiency measures (equations (8a) and (8b)) 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.

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.

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TABLE I
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 II
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 III
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

	Model 1.1		**Model 2.1**		**Model 3.1**	
Panel A: Results for the Cost Function Estimation						
	Estimate	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**
Intercept	13.2682	<.0001	13.1209	<.0001	13.3000	<.0001
Financial intermediation	-0.6273	<.0001	-0.1504	0.0610	-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	0.754	-0.1642	0.3980	0.1411	0.5790
Risk labour	0.1725	0.005	0.1600	0.0030	0.2012	0.1150
Business labour	0.0756	0.556	0.1511	0.2000	0.1469	0.3410
Debt Price	0.2540	0.025	0.2299	0.0290	-0.0053	0.9620
Equity Price	0.4242	<.0001	0.4451	<.0001	0.3770	<.0001
Year96	-0.1025	<.0001	-0.1088	<.0001	-0.0564	0.0030
Year97	-0.0279	0.052	-0.0076	0.5760	0.0103	0.4660
Year98	-0.0579	0.014	0.0194	0.5140	-0.0350	0.1280
Year99	0.0443	0.077	0.0777	0.0010	0.0108	0.5850
Year00	0.0032	0.918	0.0045	0.8970	-0.0968	0.0010
Year01	0.0951	0.216	0.1491	0.0730	-0.2696	<.0001
Year02	0.2998	0.012	0.3678	0.0020	-0.4049	<.0001
Year03	0.5593	<.0001	0.6166	<.0001	-0.1751	0.1490
-2 Log Likelihood	485.2		510.2		352.8	
Panel B: Shadow Prices for Intermediate Outputs						
	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						
	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 (7). 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 equations (8a,b). 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.

TABLE IV

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

Panel A: Results for the Cost Function Estimation

	Model 1.2		**Model 2.2**		**Model 3.2**	
	Estimate	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**
Intercept	12.4699	<.0001	12.3665	<.0001	12.7964	<.0001
Financial intermediation	-0.4817	<.0001	-0.1741	0.034	-2.8367	<.0001
Asset-liability risk	0.6107	<.0001	0.3632	<.0001	0.3007	<.0001
Total output	0.9081	<.0001	0.8946	<.0001	0.8779	<.0001
Share of personal	-0.0881	<.0001	-0.0827	0.002	-0.0848	0.0090
Share of long-tail	0.0481	0.4990	0.0322	0.539	0.0689	0.2510
Agent labour	0.0033	0.9880	-0.0392	0.876	-0.0917	0.7170
Risk labour	0.0617	0.2300	0.0775	0.213	0.0652	0.4760
Business labour	0.1655	0.1610	0.1494	0.196	0.4159	<.0001
Debt Price	0.2768	0.0320	0.1965	0.090	0.1406	0.0500
Equity Price	0.6159	<.0001	0.5836	<.0001	0.6741	<.0001
Year96	-0.0746	<.0001	-0.0832	<.0001	-0.0107	0.5550
Year97	-0.0061	0.6550	0.0108	0.246	0.0512	<.0001
Year98	-0.0099	0.6660	0.0418	0.094	0.0519	0.0060
Year99	0.1164	0.0010	0.1249	<.0001	0.0390	0.1050
Year00	0.0667	0.0020	0.0172	0.522	-0.0585	0.0180
Year01	0.2126	0.0010	0.2010	0.043	-0.5110	<.0001
Year02	0.5854	<.0001	0.5053	0.001	-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

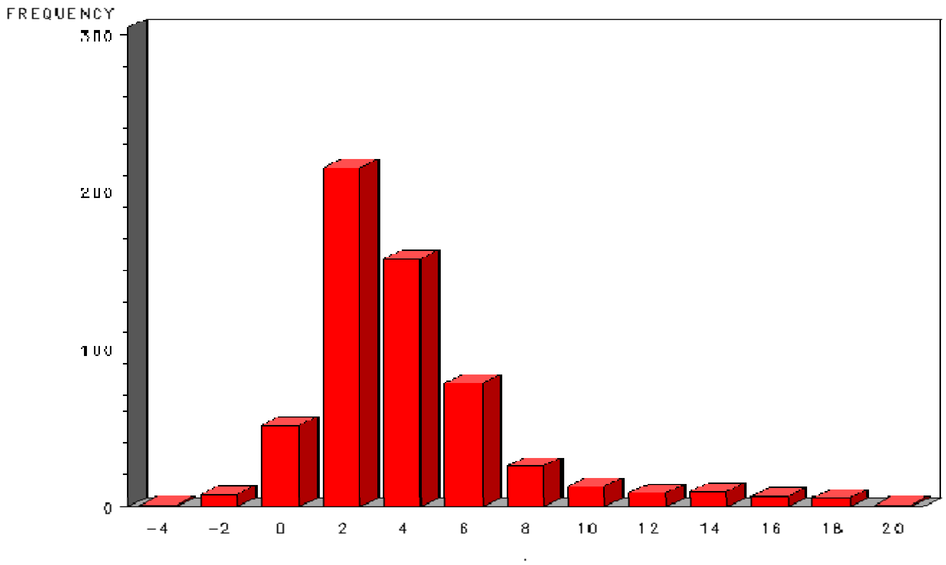
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Efficiency (1)	0.48	0.20	0.49	0.20	0.52	0.19
Efficiency (2)	0.47	0.21	0.44	0.20	0.41	0.20
Number of observations	5612		5578		5546	
Number of Insurers	1021		1017		1020	

TABLE V

Models Specified With Aggregated Output And Estimated With Sample 3

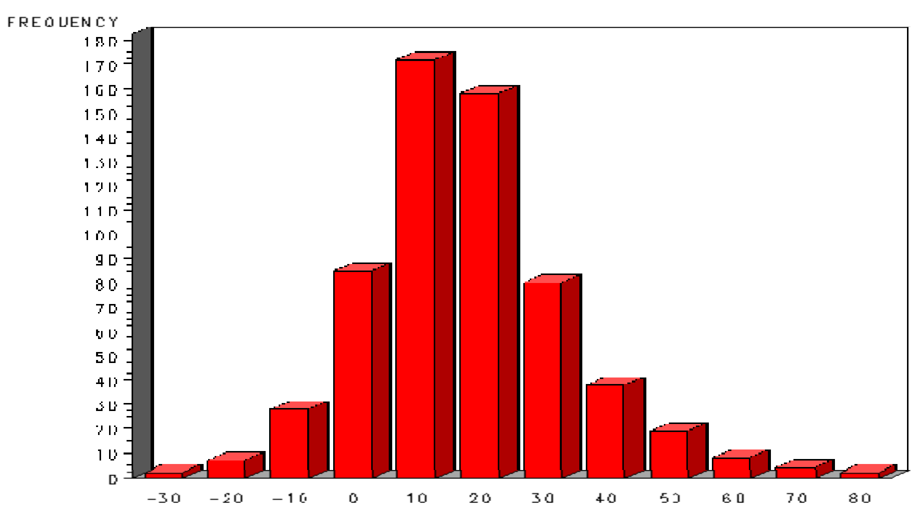
Model 1.3: *Invested assets* is the measure of financial intermediation output
Model 2.3: *Turnover* is the measure of financial intermediation output
Model 3.3: *Investment return* is the measure of financial intermediation output

	Model 1.3		**Model 2.3**		**Model 3.3**	
Panel A: Results for the Cost Function Estimation						
	Estimate	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**
Intercept	11.5843	<.0001	11.5370	<.0001	12.4139	<.0001
Financial intermediation	-0.3891	<.0001	-0.3658	<.0001	-2.9717	<.0001
Asset-liability risk	0.4269	0.0120	0.4924	<.0001	0.3535	<.0001
Total output	0.8234	<.0001	0.8010	<.0001	0.8031	<.0001
Agent labour	-0.1023	0.5320	-0.1344	0.5680	0.3883	0.145
Risk labour	0.0618	0.1940	0.1165	0.1090	0.1297	0.018
Business labour	0.1611	0.1050	0.1354	0.2270	0.2881	0.002
Debt Price	0.5501	<.0001	0.6265	<.0001	-0.0201	0.832
Equity Price	0.2892	<.0001	0.3905	<.0001	0.5706	<.0001
Year96	-0.0381	<.0001	-0.0673	<.0001	0.0171	0.072
Year97	0.0052	0.6700	0.0212	0.1680	0.0695	<.0001
Year98	-0.0104	0.5160	0.1241	<.0001	0.0708	<.0001
Year99	-0.0346	0.0890	0.0176	0.4260	-0.0246	0.225
Year00	0.0546	0.0040	0.0066	0.6880	-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	



<u>Shadow prices for risk management (10^{-2})</u>

Figure 1. The shadow prices for risk management. These prices are obtained from equation (7) applied to Model 1.1. The mean of the shadow prices for risk management is 0.0701.



<u>Shadow prices for financial intermediation (10^{-2})</u>

Figure 2. The shadow prices for financial intermediation. These prices are obtained from equation (7) applied to Model 1.1. The mean of the shadow prices for financial intermediation is 0.1768.

Appendix 1

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.

The Costs and Benefits of Reinsurance

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and Abdelhakim Nouira

Abstract

Purchasing reinsurance reduces insurers' insolvency risk by stabilizing loss experience, increasing capacity, limiting liability on specific risks, and/or protecting against catastrophes. Consequently, reinsurance purchase should reduce capital costs. However, transferring risk to reinsurers is expensive. The cost of reinsurance for an insurer can be much larger than the actuarial price of the risk transferred. In this article, we analyze empirically the costs and the benefits of reinsurance for a sample of U.S. property-liability insurers. The results show that reinsurance purchase increases significantly the insurers' costs but reduces significantly the volatility of the loss ratio. With purchasing reinsurance, insurers accept to pay higher costs of insurance production to reduce their underwriting risk.

Keywords: reinsurance, insolvency risk, risk management, financial intermediation, cost functions, panel data.

1. Introduction

Insurers issue policies and collect premiums against the promise of paying claims when accidents occur. For many types of insurance, the gap between the time of the accident and the time of the settlement could reach several years. If an insurer is defaulting during that period, policyholders could lose part of their claims. Therefore, the ultimate interest of any policyholder is the continued financial viability of the insurance company. Policyholders cannot diversify their risk by using many insurers and they do not perfectly monitor the managers of the insurance companies because it is costly and requires a specialized expertise. Furthermore, the potential of large catastrophic losses and the cyclical nature of the insurance business exacerbate the incentives conflict between the different stakeholders (Cummins, Harrington and Klein, 1991; Harrington and Niehaus, 2000; Weiss, 2007). Managing the underwriting residual risks through reinsurance purchase could limit large losses, alleviate the insurance cycle, and reduce agency costs. Hence, reinsurance reduces insolvency risk and strengthens the financial viability of insurance firms.

Most of reinsurance demand studies consider that insurers purchase reinsurance for the same reasons that motivate firms in other industries to purchase insurance or to actively manage their risks: limiting the expected costs of financial distress, stabilizing sources of funding, decreasing expected taxes by exploiting the convex structure of the tax code, and gaining comparative advantages in real services production (Mayers and Smith, 1990; Jean-Baptiste and Santomero, 2000; Cole and McCullough, 2006; Powell and Sommer, 2007; Adams, Hardwick and Zoo, 2008). Maximization of expected utility is another motivation for reinsurance demand (Aase, 2004; and Kaluszka and Okolewski, 2008).

Corporate finance theory suggests that firms purchase insurance to help solve underinvestment problems. The underinvestment problem occurs when stockholders have incentives to forgo an investment with positive net present value because all the benefits from the investment will accrue to debt holders. Mayers and Smith (1987) and Garven and MacMinn (1993) show that firms could guarantee incentive compatibility by including a covenant in the debt contract requiring insurance coverage.

The incentives conflict between stockholders and policyholders is specific to stock insurers. With the mutual ownership structure there is no such incentives conflict because policyholders are themselves the owners. However, mutual insurers purchase reinsurance in the same manner as stock insurers. The mutual ownership structure reduces the access of insurers to the capital market. Therefore, mutuals have traditionally relied on retained earnings as the primary, if not sole, source of capital. Retaining sufficient capital could prevent the need for frequent variations in premiums and dampen the effects of extraordinary periodic underwriting losses but could also create a free cash-flow problem. Wells, Cox and Gaver (1995) find that mutual insurers have a greater level of free cash flow than stock insurers. Thus, mutual insurers purchase reinsurance as an alternative source of capital and to reduce the free cash flow problem. Transferring risk to reinsurers is expensive. In an examination of the catastrophe reinsurance market, Froot (2001) finds that insurers pay several times the actuarial price of the risk transferred. The high price of reinsurance relative to expected losses could be explained by the combinations of many factors affecting the reinsurance market equilibrium. The shortage of capital in reinsurance and the resulting capacity shortfall drives-up the price of reinsurance, especially following large losses. The agency problems that reinsurers face, due to shareholder-manager incentives conflict and the lack of transparency, increase the costs of reinsurance capital and consequently increase reinsurance prices. Furthermore, it seems that reinsurers’ market power has intensified over time with the increase in the capital and market shares of large reinsurers (Cummins and Weiss, 2000b).

In this article, we estimate the effect of reinsurance purchase on the costs and the underwriting risks of U.S. property-liability insurers (554 insurers between 1995 and 2003). First, to estimate insurers’ cost function we consider ceded premiums to professional reinsurers as an output quality variable. Hence, for a given level of output, an insurer purchasing more reinsurance is considered as producing a higher quality of insurance services. The cost function is specified with four outputs (long and short-tail personal, long and short-tail commercial), one output quality variable (reinsurance as measured by ceded premiums), two intermediate output variables (risk management and financial intermediation as defined by Cummins et al. (2007)), six input prices (administrative labour, agent labour, risk labour, material, debt and equity) and yearly dummy variables. Reinsurance, risk management and financial intermediation are treated as endogeneous variables. The results show that reinsurance positively and significantly affects the costs of the insurers in our sample.

Secondly, to estimate the effect of reinsurance purchase on insurers’ underwriting risks we consider the growth rate of ceded premiums to non affiliates as a potential determinant of the growth rate of the volatility of the loss ratio. We control for the growth in underwriting risks exposure by including the growth rate of premiums written in each type of business and the growth rate of business concentration and geographic concentration. The results show that purchasing more reinsurance significantly decreases the volatility of loss ratio.

The remainder of the paper is organized as follows. In Section 2, we define the costs and benefits of reinsurance. Section 3 proposes the econometric model and estimation method, while Section 4 presents the data and variables. Section 5 presents and analyses the main results, and Section 6 concludes.

2. Defining the Costs and Benefits of Reinsurance

Reinsurance purchase is essentially a capital structure decision. Insurers seek to keep an optimal level of underwriting risk relative to their capitalization level. In the case of large losses, equity holders are only liable to pay losses until the assets of the company have been depleted. If there are remaining losses to be paid, equity holders have the option to declare bankruptcy and default in the remaining losses. Phillips, Cummins, and Allen (1998) find that policyholders consider the value of the insolvency option when deciding how much they are willing to pay for the insurance contract. To achieve their solvency target, insurers could increase their capitalization by raising new capital or reduce the risk by transferring a part of it to reinsurers. Thus, reinsurance plays the role of a substitute for capital (Hoerger, Sloan, and Hassan, 1990; and Garven and Lamm Tennant, 2003).

With reinsurance contracts, an insurer transfers premiums collected from customers to a reinsurer. In turn, the reinsurer accepts to bear a part of the risk assumed by the insurer. With proportional reinsurance, premiums and claims are shared between the insurer and the reinsurer in the proportion stipulated in the contractual agreement. In addition, the reinsurer pays a "ceding commission" to the insurer to compensate it for the costs of underwriting the ceded business. However, the commission is also determined by the nature and composition of the insured business and by the underwriting results. In non-proportional reinsurance, the reinsurer assumes only the losses that exceed a certain amount, called the retention or priority. In calculating the price of the risk transferred, the reinsurer takes into account the loss experience during the previous years and the expected future losses according to the type of risks involved.

An insurer will accept to pay loading fees over the actuarial price of the risk transferred. The loading fees should correspond to the cost of the marginal capital needed to support the risk. Since the cost and the quantity of the capital needed to support the risk could be different for the insurer and the reinsurer, the transaction could take place without arbitrage. The reinsurance contract is generally negotiated and signed before the beginning of its effectiveness. At that time, the agreement is accepted by both sides and considered as a fair contract. Moreover, loading fees could include the price of insurer's benefits from reinsurer product development skills and risk management expertise. The reinsurer plays an important role in assessing and underwriting risks, and in assisting insurer's efforts to handle claims efficiently (Swiss Re, 2004).

An insurer is able to diversify underwriting risk when losses of individual policyholders are statistically independent. In insurance markets where risks are statistically independent, such as automobile collision insurance, the average expected losses from a large pool of risks are highly predictable and the loss per claim is moderate. Hence, an insurer will provide coverage for large number of policyholders without having to hold large amounts of costly equity capital relative to the quantity of insurance being underwritten (Doherty and Dionne, 1993).

The problem is that statistical independence is violated when a mega-catastrophe occurs. A single event can cause losses to many policyholders simultaneously. However, the risk of a catastrophe in the U.S. for instance is independent from the risk of a catastrophe in other countries. This provides an economic motivation for a global reinsurance market. The U.S. insurance industry diversifies losses across the world to provide coverage and pay losses in areas such as Florida and California, which have high exposure to catastrophic risks and large concentrations of property values. Thus, with global diversification, the amount of capital needed by international reinsurers to support catastrophic risks is lower than the amount of capital needed by local insurers.

Insurance markets are subject to cycles, experiencing alternating phases of hard and soft markets (Cummins and Outreville, 1987; Cummins, Harrington, and Klein, 1991; Harrington and Niehaus, 2000; Weiss, 2007). In a hard market, the supply of coverage is restricted and prices rise, whereas in a soft market, coverage supply is plentiful and prices decline. Hard markets are usually triggered by capital depletions resulting from large event losses that cause insurers to reevaluate their pricing practices and reassess their exposure management. Following a large loss, it is difficult for insurers to raise capital at a relatively low cost. Thus, insurers have the choice between reducing coverage supply, increasing insolvency risk, and purchasing more reinsurance. Reinsurance allows insurers to maintain client relationships without increasing insolvency risk. However, underwriting cycles characterize both insurers and reinsurers because both of them share the large unexpected losses (Weiss and Chung, 2004; Meier and Outreville, 2006). In soft markets, insurers take advantage of low reinsurance prices and high coverage supply by reinsurers to increase their underwriting capacity. In hard markets, when insurers have the largest need for reinsurance, reinsurers' capacity is also reduced and reinsurance prices rise. Actually, this could aggravate insurers' crisis in hard market (Berger, Cummins, and Tennyson, 1992).

In spite of its susceptibility to cycles and crises, the reinsurance market is a global market, and capital markets respond quickly to new capital needs of reinsurers. Following catastrophic losses in 2004-2005, the reinsurance industry raised about $30 billion in new capital in a multitude ways: new equity capital for startup companies ($9.5 billion), seasoned equity issues ($12.5 billion), sidecars ($5 billion), and CAT bonds ($5 billion) (Cummins, 2007). Because of this superior capacity to raise quickly new capital, the reinsurance market responded efficiently to large unexpected losses and reinsurance prices began to soften in late 2006 and early 2007 (Benfield, 2007b). Hence, reinsurance alleviates the underwriting cycle and increases the speed of primary insurers to get out of hard market periods.

Even if reinsurance prices exceed the actuarial price of the risk transferred, the reinsurance purchased could remain profitable if the benefits are higher than the costs. Reinsurance reduces insurers' insolvency risk by stabilizing loss experience, increasing capacity, limiting liability on specific risks, and/or protecting against catastrophes. In addition, the purchase of reinsurance reduces incentive conflicts between different stakeholders and consequently reduces agency costs.

3. Econometric Models and Estimation Methods

3.1. Costs analysis

Most of the existing studies account for the risk pooling and the financial intermediation functions in estimating the cost function of insurers (Cummins and Weiss, 2000a). Cummins et al. (2006) account also for asset-liability management activities. They consider financial intermediation and asset-liability management as intermediate activities performed by the insurer. In this paper, we consider the amount of reinsurance purchased as an output attribute variable associated with the level of output produced by an insurer.[1]

We assume that insurance services are produced using a vector of inputs and two intermediate outputs: asset-liability risk management and financial intermediation. For a given level of insurance services, the amount of inputs used by an insurer would be affected by the level of ceded insurance (reinsurance). Presumably, reinsurance is costly and an insurer purchasing more reinsurance will have higher costs for a given level of insurance services. In this framework, reinsurance plays the role of an output attribute or quality variable defining more accurately the output of an insurer. Therefore, we suppose that an insurer is producing insurance services according to the following production function:

$$Y\left(Q, \mathrm{Re}; R, F, X^{I}, X^{R}, X^{F}, T\right) = 0, \tag{1}$$

where Q is the quantity of insurance services produced; *Re* is the quantity of reinsurance purchased; R and F are the intermediate outputs (asset-liability risk management and financial intermediation activities); X^I, X^R and X^F are respectively the quantities of inputs used to produce insurance services, asset-liability risk management, and financial intermediation; and T represents time (for simplicity, we omit the time and firm subscripts).

Under the assumption that insurance firms are cost minimizers and that Q, *Re*, R and F are pre-determined, the restricted cost function associated with the technology described by (1) is:

$$CR = CR\left(Q, \mathrm{Re}, R, F, P^{I}, P^{R}, P^{F}, T\right), \tag{2}$$

where CR are total costs, and P^I , P^R, and P^F are, respectively, the prices of inputs X^I, X^R and X^F. The restricted cost function defined by (2) gives the minimum cost of producing the level of insurance services (Q), given the level of reinsurance (*Re*), asset-liability risk management (*R*) and financial intermediation (*F*) undertaken by the insurer, the different input prices (P^I, P^R, and P^F), and time (T) which is included to take into account technical change.

Since the exact functional form of the restricted cost function defined by (2) is unknown, we use

[1] See Dionne, Gagné and Vanasse, 1998 for a discussion on the utilization of output attributes in the context of transportation firms.

the well known translog approximation which is given by:

$$\begin{aligned}\ln CR_{it} &= \alpha_i + \sum_v \beta_v^Q \ln Q_{vit} + \beta^{\mathrm{Re}} \ln \mathrm{Re}_{it} + \beta_i^R \ln R_{it} + \beta_i^F \ln F_{it} \\ &+ \sum_s \beta_s^I \ln P_{sit}^I + \sum_j \beta_j^R \ln P_{jit}^R + \sum_k \beta_k^F \ln P_{kit}^F \\ &+ second\text{–}order\ terms + \sum_t \beta^t D_t + u_{it},\end{aligned} \tag{3}$$

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 intercept (α_i) and the coefficients associated with the asset-liability risk management and financial intermediation variables (β_i^R and β_i^F) are firm-specific. 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 (3) are divided by their sample means (the point of approximation).

The reinsurance (*Re*), asset-liability risk management (*R*) and financial intermediation (*F*) variables are likely to be endogenous. Endogeneity is taken into account by first instrumenting these three variables. The set of instruments used includes the log of the insurance output and input prices, time dummy variables and other dummy variables measuring the 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 and therefore are properly considered exogenous. Also, ownership structure, group membership, distribution system and head office state are most of the time 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 reinsurance, risk management and financial intermediation would also affect these variables. The predicted values of each endogenous variable are obtained from OLS regressions on the set of instruments and are substituted for the actual values in equation (3). Equation (3) is then estimated by restricted/residual maximum likelihood (REML) as implemented in the *Xtmixed* procedure of *Stata*. The proper test statistics of the different estimated parameters of the model are obtained from bootstrapped standard errors with 500 replications.

3.2. Benefits analysis

Even though insurers can reduce underwriting risk by diversification, significant residual risk remains, and insurers' claim payments are highly stochastic. Reinsurance is used to reduce insolvency risk by limiting large losses and alleviating the underwriting cycle. Here, we measure the benefits of reinsurance through its effect on the volatility of the loss ratio (the ratio of present value of incurred losses-to-earned premiums). Thus, to assess the consequence of insurers' decision to purchase more or less reinsurance on underwriting risk we estimate the following equation:

$$\Delta\sigma(lr)_{it} = \alpha + \beta_{Re}\Delta Re_{it} + \beta_X \Delta X_{it} + \beta_Z Z_{it} + \beta_t D_t + e_{it} \quad (4)$$

where $\Delta\sigma(lr)_{it}$ is the growth rate of the volatility of loss ratio during the current year, $\Delta \mathrm{Re}_{it}$ is the growth rate of the reinsurance purchased during the current year, ΔX_{it} is a vector of variables measuring the growth rate of insurers' exposure to underwriting risks, Z_{it} is a vector of insurers' specific control variables, and D_t are time dummy variables.

To measure the growth rate in insurers' exposure to underwriting risks, we use the growth rate of premiums written in each type of business, the growth rate of business concentration, the growth rate of geographic concentration, and the growth rate of insurer size. Concentration is measured using Herfindahl indices based on net premiums written. As control variables, we use insurers' specific characteristics: ownership structure, group membership, and distribution system.[2]

4. Data and Variables

4.1. Data

The primary data for our analysis are taken from the regulatory annual statements filed by U.S. property-liability insurers with the National Association of Insurance Commissioners (NAIC). We include

[2] The Hausman test shows that the growth rate of reinsurance and the growth rate of size are endogenous. Thus, we first instrument these two variables using the same set of instruments as in the first stage of cost function estimation.

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. Our 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. Also, insurers reporting non-strictly positive input prices, asset-liability risk, or reinsurance are dropped as well.

Our final samples include 2,966 observations (554 firms). Even though the restriction of strictly positive outputs in all four lines reduces the sample size, most of the firms eliminated are small specialized firms. In fact, our sample accounts for about 84 percent of total industry premium volume in 2003.

4.2. Costs Analysis

Most previous studies estimating insurer cost functions consider only the net business assumed, excluding reinsurance quantity from the outputs and reinsurance costs from the total costs. In this paper, since we include reinsurance as an output attribute, we adjust the definition of total costs and the definition of quantities of outputs to reflect those of the total business written and not only outputs and costs associated with the net business assumed.

4.2.1. Total costs

The total costs of the net business assumed are generally 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. To measure total costs related to the total business written we should add the costs of underwriting the ceded premiums to reinsurers. Because direct insurers issue insurance policies and assume all the attached administrative costs, they receive a compensation in the form of commissions from reinsurers when they cede the premiums collected. Thus, the total costs (*Costs*) of business underwritten is the sum of total expenses, commissions received from the reinsurers, and the cost of capital.

The cost of capital is the sum of the cost of equity capital and the cost of debt capital.[3] 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.

4.2.2. Output quantities and output prices

The conventional measures of the quantities of outputs for insurers are incurred losses in the four principal property-liability insurance business lines: *Long-tail personal, Short-tail personal, Long-tail commercial* and *Short-tail commercial*. The output quantity for a given year is usually defined as the present value of incurred losses arising only from the exposure related to the business written during that year. Losses paid during that year but arising from exposures related to the business written during previous years are not included in that year's output quantity. 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.[4]

To be consistent with our approach of accounting for reinsurance, we measure the output associated with the total business written by insurer and not only the output of the net business assumed. Thus, incurred losses associated with the premiums ceded to non affiliated insurers are included in the total output produced by direct insurers.

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

[3] 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*. Equity price and debt price are defined below.

[4] The chain ladder method is a widely accepted actuarial technique for measuring loss payout patterns. See Taylor (2000).

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*.

4.2.3. Reinsurance

The quantity of reinsurance purchased is an attribute of the output produced by direct insurers. Everything else being equal, insurers purchasing more reinsurance are assumed to have lower insolvency risk. Reinsurance reduces the insolvency risk of direct insurers by stabilizing their loss experience, limiting their liabilities, and protecting against catastrophes. The most common measure of the quantity of reinsurance purchased is *Premiums ceded to non- affiliates*. However, since larger insurers produce more outputs, they can purchase a larger quantity of reinsurance compared to small insurers without ceding a higher proportion of the premiums written. Reinsurance demand studies show that larger insurers cede a lower proportion of premiums written compared to smaller insurers (Mayers and Smith, 1990; and Cole and McCullough, 2006). In our analysis, we also use the share of written premiums that is ceded to non-affiliates insurers (*Share ceded to non-affiliates*) as an alternative measure of reinsurance.

4.2.4. Intermediate Outputs

The first intermediate function we consider is financial intermediation. 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 is paid. 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 intermediate output has been used in several insurance efficiency studies (Cummins and Weiss, 2000a) and is equivalent to measures used in banks' efficiency studies under the intermediation approach (Berger and Humphrey, 1997).

The second intermediate function is risk management. 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.

Reducing the insurer's financial risk could create value through, among other things, reducing the market discount in insurance premiums for insolvency risk. As a result, managing the impact of interest rate movements on both assets and liabilities is crucial for insurers (Staking and Babbel, 1995; Santomero and Babbel, 1997). We use the dollar duration of the surplus (*Asset-liability Risk*) as a proxy for the quantity of output associated with risk management activities.[5] The dollar duration of the surplus is defined as: $SD_S = A\, D_A - PV(L)\, D_L$, 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, and $PV(L)$ 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. We do not assume that nil duration of surplus is optimal for insurers. The dollar duration of the surplus is a measure of the quantity of risk that is left after the insurer conducts risk management activities. Rather, we assume that more insurers' risk management activities imply a smaller dollar surplus duration, which contributes to increasing the insurer's value added for the policyholders.[6]

4.2.5. Variable 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 analyses, are materials and business services, debt capital, and equity capital. Administrative labour and materials/business services are shared by insurance, risk management, and financial intermediation activities and, therefore,

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

[6] See Cummins et al. (2006) for details on the computation of the dollar duration of the surplus.

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 needed for financial management and also to 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 insurer 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 insurer 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 insurer is located for the North American Industry Classification System (*NAICS*) code 52392- Portfolio management. The price of materials/business services (*Business Labour*) 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. 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 the occurrence of the accident and the payment of the claim. We compute *Debt Price* for each insurer 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 insurer varying by its credit quality and its liability's effective duration.[7]

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 insurers on

[7] 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).

financial markets.[8] 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 for the listed insurers.

4.2.6. Control Variables

Yearly dummy variables (*Year96-Year03*) are used to take into account of time. Also, a set of other dummy variables is used to account for insurer characteristics. The *Stock ownership* dummy is equal to 1 for stock insurers and is equal to 0 otherwise. The *Group* dummy is equal to 1 if the insurer is an insurance group and is equal to 0 otherwise. The *Distribution* dummy is equal to 1 if the insurer uses independent agents and is equal to 0 otherwise; and the *State(s)* dummy equals 1 if the head office of the insurer is in state *s*. The omitted state is New York.

4.3. Benefits Analysis

To assess the benefits of reinsurance purchase we estimate equation (4).The dependent variable in equation (4) is the *Growth rate of the volatility of the loss ratio*. The loss ratio is defined as the ratio of present value of incurred losses to premiums earned during the same year. It is measured as: $\Delta\sigma(lr)_{it} = \left(\sigma(lr)_{it} - \sigma(lr)_{i,t-1}\right) / \sigma(lr)_{i,t-1}$ where $\sigma(lr)_{it}$ is the volatility of the loss ratio including current year t and $\sigma(lr)_{i,t-1}$ is the volatility of the loss ratio excluding current year *t*. In other words: $\sigma(lr)_{it}^2 = \frac{1}{n}\sum_{j=t-n}^{t}\left(lr_j - \overline{lr}\right)^2$ and $\sigma(lr)_{i,t-1}^2 = \frac{1}{n}\sum_{j=t-n}^{t-1}\left(lr_j - \overline{lr}\right)^2$ where *n* is the number of historical observations used to calculate the volatility of the loss ratio. We use the historical data reported by insurers in Schedule P – Part 1 of the NAIC database that go up to the nine previous years. Hence, $\Delta\sigma(lr)_{it}$ is the relative change in the volatility of the loss ratio due only to the underwriting result of the current year.

Our main independent variable to explain the change in the volatility of loss ratio is the *Growth rate in the amount of reinsurance purchased* measured as $\Delta \mathrm{Re}_{it} = \left(\mathrm{Re}_{it} - \mathrm{Re}_{i,t-1}\right) / \mathrm{Re}_{i,t-1}$ where Re_{it} is

[8] We split listed insurers into three groups based on their A.M. Best's rating. For each 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.

defined as the premiums ceded to non affiliates. As with the cost function estimation, as a robustness check, we also use the share of premiums ceded to non affiliates as an alternative measure of reinsurance.

To control for the change in insurers' exposure to underwriting risk, we use the growth rate of total premiums written in each type of business (short and long-tail, personal and commercial). In addition, we control for the change in the level of diversification of underwriting activities. For that purpose, we use the *Growth rate in line concentration* and the *Growth rate in geographic concentration*. Line concentration is computed as the Herfindahl index of the percentage of premiums in each line of business written by the insurer, and geographic concentration is computed as the Herfindahl index of the percentage of premiums written in each state by the insurer. A higher Herfindahl index implies that the insurer is concentrated in fewer lines of business or in fewer states. Since large insurers are likely to be more diversified, we use also the *Growth rate in size*. We measure insurers' size as the natural logarithm of total assets.

We control for insurer specific characteristics by including the *Stock ownership* dummy, *Group* dummy, and *Distribution* dummy as defined previously. Finally, we include yearly dummy variables (*Year96*-*Year03*) to take into account the effect of time.

4.4. Summary Statistics

Summary statistics for all variables used in cost function and reinsurance benefits estimation are presented in Table I. Insurers ceded on average about $124 million/year of premiums to non affiliated reinsurers, representing about 21 percent of total premiums written and assumed from non affiliates during the period 1995-2003. The insurers in the sample produced more personal insurance than commercial insurance, and they produced more long-tail insurance than short-tail insurance. The average amount invested in financial assets is $1,926 million, the average return required by policyholders is 6 percent, and the average required return by equity holders is 17 percent.

[Table I]

Table I also indicates that the average volatility of the loss ratio is 9 percent. The insurance firms are more likely to be organized as insurance groups and more likely to use independent agents to sell their policies. The number of stock insurers in the sample is almost equal to the number of mutuals. During the1995-2003 period, insurers increased on average the volume of premiums written in each type of business and the average volatility of the loss ratio increased, at the same time, they increased on average their reinsurance purchases, their business diversification, and their geographical diversification.

5. Empirical results

5.1. Costs Analysis

Table II presents the estimation results for the first stage regressions of the endogenous variables.[9] The adjusted R^2 for *Asset-liability risk* (0.48), *Invested assets* (0.50) and *Premiums ceded to non affiliates* (0.38) are relatively 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 *Asset-liability risk*, *Invested assets,* and *Premiums ceded to non-affiliates* than unaffiliated single insurers. This is consistent with insurance groups being larger and more sophisticated than unaffiliated single insurers. Insurers that use independent agents have lower *Asset-liability risk*, lower *Invested assets,* and less *Premiums ceded to non-affiliates* than direct writer insurers. Thus, insurers that use independent agents are more active in asset-liability management but less active in the reinsurance market than insurers using direct marketing or exclusive agents.

Table II also shows that stock insurers purchase significantly more reinsurance than mutual insurers. In the prior literature, empirical results about the effect of organizational form on reinsurance demand are mixed. Mayers and Smith (1990) find that mutual insurers utilize more reinsurance than stock insurers. On the other hand, Garven and Lamm-Tenant (2003) find no significant difference, whereas Cole and McCullough (2006) find that stock insurers purchase more reinsurance than mutuals. These differences in the results may be due to the measure of reinsurance purchase used or the time period examined. Our empirical results show that stock insurers purchase more reinsurance from non affiliated insurers than do mutual insurers. This finding is expected given the importance of stockholders-

[9] The Hausman general test shows that reinsurance, asset-liability risk and financial intermediation variables are endogenous in the cost function specification described by equation (3).

policyholders incentives conflicts among stock insurers and the higher involvement of stock insurers in complex lines of business.[10]

[Table II]

Table III presents the results of the estimation of the cost function as specified in equation (3) with random intercept and random coefficients associated with the risk management and financial intermediation variables. Model 1 is specified with *Invested assets* and *Asset-liability risk* but without a reinsurance variable, Model 2 includes a reinsurance variable defined as the quantity of *Premiums ceded to non-affiliates,* and Model 3 is specified with a reinsurance variable defined as *Share ceded to non-affiliates*. The inclusion of the reinsurance purchase as a quality variable enhances the cost function specification and allows it to account for the level of underwriting risk being covered by professional reinsurers.

[Table III]

The results for Model 1 show that the coefficient for *Invested assets* is negative and significant at the 1 percent level. A negative coefficient means that the financial intermediation activities decrease the insurance activity costs. The coefficient for *Asset-liability risk* is positive and also significant at the 1 percent level. Thus, insurers with higher surplus durations or lower risk management have higher insolvency risk and higher insurance costs, primarily due to higher costs of debt and equity capital. The results for financial intermediation and risk management are in line with those found by Cummins et al. (2006).

The results of Model 2 show that the coefficient associated with *Premiums ceded to non-affiliates* is positive and significant at the 1 percent level. A positive coefficient means that insurers ceding more premiums to non-affiliated insurers have higher insurance costs. This result confirms that reinsurance is costly, as it increases the cost of producing insurance services. Results for Model 2 show that the coefficient associated with *Asset-liability risk* is positive and statistically significant at the 1 percent level,

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[10] 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.

and the coefficient for *Invested assets* is negative and statistically significant at the 1 percent level.

The results obtained for Model 3 show that the coefficient associated with the *Share ceded to non-affiliates* is positive and significant at the 1 percent level. Thus, even after controlling for the quantity of premiums written and assumed, ceding premiums to non affiliated insurers increases the total costs incurred by direct insurers. The results for *Invested assets* and *Asset-liability risk* remain significant with the same signs as in Model 1 and Model 2.

5.2. Benefits Analysis

Table IV presents the estimation results for the first stage regressions of the endogenous variables in the volatility of the loss ratio specification described by equation (4). Results from Hausman tests show that endogeneity of the growth rate of insurers' size and the growth rate of reinsurance is not rejected.[11]

[Table IV]

Table V presents the results of the estimation of reinsurance benefits as specified in equation (4). Model 1 is specified with a reinsurance variable defined as the *Growth rate of premiums ceded to non-affiliates,* and Model 2 is specified with a reinsurance variable defined as the *Growth rate of share of premiums ceded to non-affiliates*.

[Table V]

The results for Model 1 show that the coefficient associated with *Growth rate of premiums ceded to non affiliates* is negative and statistically significant at the 1 percent level. Thus, ceding more premiums to non affiliated insurers decreases significantly the volatility of the loss ratio. This result confirms that reinsurance purchasing stabilizes loss experience. The results obtained with Model 1 show also that writing more premiums or increasing the diversification of underwriting activities do not affect significantly the volatility of the loss ratio. However, group insurers and mutual insurers have significantly higher growth rates of loss ratio volatility.

The results obtained for Model 2 show that the coefficient associated with the *Growth rate of share of premiums ceded to non affiliates* is negative and statistically significant at the 5 percent level.

[11] Details regarding the Hausman test results are available from the authors on request.

Hence, ceding a larger share of written premiums to non affiliated insurers reduces significantly the volatility of the loss ratio. Results for the other variables are qualitatively the same as those obtained with Model 1 except for the coefficient associated with the growth rate of size which becomes statistically significant. Increasing the size of insurers reduces significantly the growth rate of the volatility of the loss ratio.

6. Conclusion

Even though insurers can reduce underwriting risk significantly by diversification and risk management, significant residual risk remains and insurers' claim payments are highly stochastic. One of the most important tools for managing insurance claim risk is reinsurance. Reinsurance reduces insurers' insolvency risk by stabilizing loss experience, increasing capacity, limiting liability on specific risks, and/or protecting against catastrophes. In addition, reinsurance reduces the incentive conflict between the different stakeholders and consequently it reduces agency costs. However, transferring risk to reinsurers is expensive. Reinsurance prices can be several times the actuarial price of the risk transferred (Froot, 2001).

This article estimates the effects of reinsurance on insurers' costs and insurers' underwriting risk by analyzing a sample of U.S. property-liability insurers over the 1995-2003 period. To estimate the effect of reinsurance on insurers' costs, we consider reinsurance as an output attribute of the insurance services produced, and we estimate a parametric cost function. To estimate the effect of reinsurance on insurers' underwriting risk, we consider the growth rate of reinsurance purchase as a determinant of the growth rate of the volatility of the loss ratio, controlling for the growth of insurers' exposure to underwriting risk.

The empirical results clearly indicate that reinsurance increases significantly the costs of producing insurance services and reduces significantly the volatility of the loss ratio. These results are robust to the use of alternative reinsurance measures: the quantity of premiums ceded to non affiliates and the share of total premiums that are ceded to non affiliates. Thus, insurers purchasing reinsurance accept to pay higher costs for the production of insurance services to reduce their underwriting risk.

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TABLE I
Summary Statistics: 1995–2003

Variable	Mean	Standard Deviation
Premiums ceded to non affiliates	124.15	448.54
Total premiums ceded	624.42	2485.29
Share ceded to non affiliates	0.21	0.18
Premiums ceded to total premiums	0.32	0.20
Invested assets	1926.00	6758.46
Asset-liability risk	18116.37	73846.93
Long-tail personal outputs	221.30	1090.78
Short-tail personal outputs	99.62	501.45
Long-tail commercial outputs	225.94	731.54
Short-tail commercial outputs	60.40	191.40
Price of long-tail personal	0.41	0.66
Price of short-tail personal	0.53	0.96
Price of long-tail commercial	1.30	7.66
Price of Short-tail commercial	0.89	2.59
Administrative labour	945.33	170.26
Agent labour	800.99	150.46
Risk labour	2050.42	1091.83
Material/Business labour	609.43	194.60
Debt Price	0.06	0.02
Equity Price	0.17	0.06
Equity	984.52	3930.24
Debt	1310.10	4131.37
Total Costs	499.25	1637.21
Volatility of loss ratio	0.0926	0.0844
Size	19.40	2.11
Long-tail personal premiums	323.38	1541.18
Short-tail personal premiums	158.18	751.04
Long-tail commercial premiums	351.08	1158.61
Short-tail commercial premiums	117.93	377.89
Line concentration	0.31	0.15
Geographic concentration	0.49	0.38
Group dummy	0.68	0.47
Stock ownership dummy	0.51	0.50
Distribution dummy	0.67	0.47
Number of observations	2966	
Number of firms	554	

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

TABLE II
Results from First Stage Regressions for Cost Function Estimation

	Asset-liability risk		Invested assets		Ceded premiums to non affiliates	
Variable	**Estimate**	**t Value**	**Estimate**	**t Value**	**Estimate**	**t Value**
Intercept	-3.4016	-17.23	-2.7299	-15.71	-2.7429	-15.90
Price of long-tail personal	0.0506	2.78	0.0322	2.01	-0.0185	-1.17
Price of short-tail personal	0.1052	4.94	0.1079	5.76	0.0748	4.02
Price of long-tail commercial	0.0281	1.74	0.0143	1.01	0.0188	1.34
Price of Short-tail commercial	0.0883	3.93	0.0713	3.60	0.0535	2.72
Price of administrative labour	0.6180	0.74	0.4953	0.68	0.4791	0.66
Price of agent labour	0.5672	1.33	0.9392	2.49	-0.6901	-1.85
Price of risk labour	-0.3141	-1.22	-0.0942	-0.41	0.3772	1.67
Price of material/business labour	0.7130	1.40	0.9458	2.11	1.4515	3.26
Debt Price	1.5549	3.95	2.1048	6.07	1.0641	3.09
Equity Price	-0.6351	-3.09	-0.5657	-3.12	0.1125	0.63
Distribution dummy	-0.9103	-12.40	-0.8152	-12.61	-0.3184	-4.96
Stock ownership dummy	-0.0379	-0.52	0.0987	1.54	0.3479	5.47
Group dummy	2.6431	35.83	2.3554	36.26	1.9487	30.22
Number of observations	2966		2966		2966	
Number of Insurers	554		554		554	
Adjusted R-sq	0.4868		0.5054		0.3820	

Note: Results for time dummy variables and state dummy variables are available upon request. Results for alternative measures of reinsurance are not presented but are also available.

TABLE III
Cost Function Estimates (Equation 3)

Model 1: Specified without reinsurance
Model 2: Specified with reinsurance defined as *Premiums ceded to non affiliates*
Model 3: Specified with reinsurance defined as *Share of premiums ceded to non-affiliates*

	Model 1		**Model 2**		**Model 3**	
	Estimate	**t-ratio**	**Estimate**	**t-ratio**	**Estimate**	**t-ratio**
Intercept	13.3993	212.00	13.5267	182.61	13.7071	116.20
Financial intermediation	-0.5793	-4.95	-0.7538	-4.81	-0.5207	-2.60
Asset-liability risk	0.7790	7.19	0.8673	6.72	0.8549	4.16
Reinsurance			0.1696	2.75	0.3482	2.64
Long-tail personal	0.2338	15.04	0.2157	13.61	0.1920	9.95
Short-tail personal	0.0837	5.52	0.0905	5.92	0.1024	5.76
Long-tail commercial	0.2586	23.32	0.2600	22.75	0.2626	18.56
Short-tail commercial	0.1207	8.94	0.1309	9.47	0.1315	7.40
Agent labour	0.4643	2.99	0.8499	4.96	1.3033	5.13
Risk labour	0.1466	2.99	0.1208	2.30	0.1052	1.56
Business labour	0.0641	0.70	-0.0565	-0.57	-0.0207	-0.16
Debt Price	0.0945	1.24	0.1499	1.92	0.0937	1.11
Equity Price	0.3870	10.54	0.3285	8.22	0.3970	8.43
Year96	-0.1055	-8.62	-0.0947	-7.56	-0.0967	-7.70
Year97	-0.0331	-2.45	-0.0214	-1.55	-0.0320	-2.36
Year98	-0.0951	-4.73	-0.0688	-3.21	-0.0870	-4.22
Year99	0.0018	0.08	-0.0016	-0.07	-0.0033	-0.15
Year00	-0.0431	-1.83	-0.0398	-1.69	-0.0449	-1.91
Year01	-0.0618	-1.24	-0.0355	-0.71	-0.0419	-0.84
Year02	0.0418	0.56	0.0286	0.39	0.0435	0.59
Year03	0.2495	2.64	0.1983	2.11	0.2411	2.57
Number of observations	2966		2966		2966	
Number of Insurers	554		554		554	
-2 Log Likelihood	-189		-183.6		-183.8	

Results for second-order terms are available from the authors upon request.

TABLE IV
Results from First Stage Regressions for Volatility of Loss Ratio Estimation

Variable	Growth rate of size (log of total assets)		Growth rate of premiums ceded	
	Estimate	**t Value**	**Estimate**	**t Value**
Intercept	0.01406	2.45	6.24959	1.65
Price of long-tail personal	0.00057	2.16	0.29511	1.70
Price of short-tail personal	-0.00010	-0.56	-0.05795	-0.48
Price of long-tail commercial	0.00002	0.89	0.00097	0.07
Price of Short-tail commercial	0.00013	1.95	0.00283	0.06
Price of administrative labour	-0.00001	-2.43	0.00056	0.20
Price of agent labour	-0.00001	-2.42	-0.00376	-2.13
Price of risk labour	0.00000	3.49	0.00018	0.57
Price of material/business labour	0.00000	0.94	0.00205	0.94
Debt Price	0.06513	1.11	-54.01708	-1.39
Equity Price	-0.02328	-3.84	-4.25408	-1.06
Distribution dummy	-0.00065	-1.66	-0.41769	-1.61
Stock ownership dummy	0.00113	2.85	0.47825	1.83
Group dummy	-0.00137	-3.40	0.09660	0.36
Number of observations	2966		2966	
Number of Insurers	554		554	
Adjusted R-sq	0.0432		0.0157	

Note: Results for time dummy variables and state dummy variables are available upon request. Results for alternative measures of reinsurance are not presented but are also available.

Table V
Volatility of Loss Ratio Estimates (Equation4)

Model 1: Specified with reinsurance defined as *Premiums ceded to non affiliates*
Model 2: Specified with reinsurance defined as *Share of premiums ceded to non-affiliates*

	Model 1		**Model 2**	
	Estimate	**t-ratio**	**Estimate**	**t-ratio**
Intercept	0.027180	2.10	0.033900	2.59
Growth rate of reinsurance	-0.013020	-2.62	-0.030140	-1.96
Growth rate of size	-1.989150	-1.23	-3.145200	-2.04
Growth rate of long-tail personal premiums	0.000006	0.35	0.000006	0.34
Growth rate of short-tail personal premiums	-0.000074	-0.83	-0.000066	-0.73
Growth rate of long-tail commercial premiums	0.001500	1.59	0.001470	1.56
Growth rate of short-tail commercial premiums	-0.000050	-0.60	-0.000051	-0.62
Growth rate of business concentration	-0.009420	-0.46	-0.011200	-0.55
Growth rate of geographic concentration	-0.011140	-1.01	-0.011510	-1.04
Group dummy	0.017260	2.80	0.014470	2.34
Stock ownership dummy	-0.016380	-2.73	-0.015820	-2.55
Distribution dummy	-0.000082	-0.01	0.001200	0.20
Year96	0.063030	5.91	0.060610	5.64
Year97	-0.011880	-1.11	-0.012460	-1.16
Year98	0.008500	0.77	0.005680	0.51
Year99	0.016990	1.26	0.005790	0.48
Year00	0.018480	1.47	0.015950	1.28
Year01	0.025860	2.34	0.024090	2.19
Year02	0.009520	0.86	0.008820	0.79
Year03	0.027500	2.44	0.028080	2.48
Number of observations	2966		2966	
Number of Insurers	554		554	
Adjusted R-sq	0.0309		0.0299	

Determinants of Insurers' Performance in Risk pooling, Risk Management, and Financial Intermediation Activities

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Abstract

Corporate finance theory predicts that firms' characteristics such as leverage, organizational forms, and distribution systems will affect agency costs and hence their efficiency. Cummins et al (2006) have proposed a cost function specification that measures separately insurer efficiency in handling risk pooling, risk management, and financial intermediation functions. In this study, we investigate the insurer characteristics that determine these efficiencies. Our empirical results show that mutuals outperform stock insurers in handling the three functions. Independent agents and high capitalization reduce the cost efficiency of risk pooling without significantly increasing the efficiency with which risk management and financial intermediation activities are handled. However, certain characteristics, such as being a group of affiliated insurers, a higher volume of business in commercial lines, a larger assumed reinsurance, or a higher proportion of assets invested in bonds, do significantly increase insurers' efficiency in risk management and financial intermediation.

Keywords: Risk pooling, risk management, financial intermediation, property-liability insurance, efficiency, agency costs.

1. Introduction

The efficiency of financial institutions has been studied by many researchers (see the surveys of Berger and Humphrey (1997) for the banking industry and Cummins and Weiss (2000) for the insurance industry). Insurance studies focus on many aspects that may influence the efficiency of this industry, aspects such as its distribution systems (Regan and Tennyson, 2000), its organizational forms (Mayers and

Smith, 2000) and insurers' economies of scope (Berger et al, 2000). In the banking industry, interest is more oriented to the effect of regulations; mergers and acquisition; market structure and organization; and, more recently, the effect of capital structure on bank performance (Berger and Bonaccorsi di Patti, 2006).

Cummins et al (2006) have extended this literature significantly, by explicitly considering two major activities as intermediate outputs when estimating the efficiency of insurance firms. They show that risk management and financial intermediation activities improve efficiency for property-liability insurers. They also estimate the shadow prices of these intermediate outputs. On average, shadow prices are positive, indicating that many insurers can still improve the efficiency of their risk pooling activities by increasing the level of their risk management and financial intermediation activities. Finally, their results clearly indicate that adding these two intermediate outputs as inputs in the restricted-cost function will improve its specification as compared to the usual cost function analyses.

The first objective of this study is to analyze the determinants of these estimated shadow-price distributions. The empirical results of Cummins et al (2006) also indicate that many insurers are far from achieving optimal levels of risk management and financial intermediation activities. Some insurers could reduce their risk pooling costs by increasing these activities, whereas others could lower their costs by reducing the level of these activities. There are many plausible determinants to explain the difference in risk management and financial intermediation efficiencies: membership in a group of insurers versus being a single insurer; being a stock or a mutual insurer; being an independent-agency insurer or a direct-writing insurer; having a different capital structure or business mix. These determinants are discussed in more detail in the literature review below.

We must emphasize that our contribution is the first in the literature to study the determinants of risk -management and financial intermediation as activities that increase, on average, the efficiency of insurers in their risk pooling activities or as providers of insurance. Some previous articles (Santomero and Babbel, 1997; Cummins, Phillips and Smith, 2001; and Froot, 2007) have analyzed how insurers engage in a variety of risk management activities to control their asset risks, interest-rate risks, and capital allocation. These studies isolate the determinants of risk management activities that directly increase the firm's value but do not explain how insurers create value by improving the economic efficiency of providing insurance. Nor do they consider the financial intermediation function when analyzing the effect of risk management on firm value. In fact, the estimated benefits attributed to the risk management function may contain some which come from the financial intermediation function. These distinctions are important if the benefits of risk management and financial intermediation are to be properly allocated. Under competition, the benefits of greater economic efficiency have a higher probability of being distributed, at least partially, to the policyholders.

This paper makes another important contribution by showing how a better specification of the cost function will improve the analysis of the relative efficiency of insurance firms. This is important because none of the previous studies on the efficiency of financial institutions (Berger and Humphrey 1997; Cummins and Weiss, 2000) has explicitly considered intermediate outputs (such as risk management and financial intermediation) in their econometric specification. This prevents them from distinguishing between the residual efficiency of producing insurance and the efficiency derived from intermediate outputs. As we shall see, this can be interpreted as a cost function specification error which may yield biased estimates of the efficiency of risk pooling activities.

In this paper, we explore separately the effect of insurers' characteristics on their efficiency in handling risk pooling, risk management, and financial intermediation activities. Our empirical results indicate that mutuals are more cost efficient than stocks in handling the three activities. Independent agents and higher capitalization reduce the cost efficiency of risk pooling without significantly enhancing insurers' efficiency in handling risk management and financial intermediation activities. Results also show that certain characteristics, such as being a group of affiliated insurers, a larger volume of business in commercial lines, a larger reinsurance assumed or a higher proportion of assets invested in bonds, will significantly increase insurers' efficiency in risk management and financial intermediation.

The remainder of the paper is organized as follows. Section 2 reviews the literature on the determinants of insurer efficiency and introduces the main hypotheses tested in this study. The discussion revolves around the three principal determinants discussed in this literature: organizational forms, distribution systems, and capital structure. Section 3 describes how we measure the insurer's relative efficiency in handling risk pooling, risk management, and financial intermediation activities. Section 4 presents the sample used and describes the variables. Section 5 discusses the results and Section 6 concludes.

2. Background and hypothesis

The insurance industry creates value through three principal functions or activities: risk pooling, financial intermediation, and risk management. Corporate finance theory predicts that only the efficient firms which minimize agency costs will remain in business in the long run. Insurers are subject to two main sources of agency costs: owner/policyholder and owner/manager incentive conflicts. Characteristics such as ownership composition, distribution system, group affiliation, capital structure, and business mix will have their effect on agency costs. The insurance industry is characterised by the co-existence of many different ownership structures and multiple distribution systems. Furthermore, the leverage of insurers is volatile and has shown a slight downward trend since the mid-1980s, mainly because of the growing sensitivity of customers and regulators to the risk of insolvency among insurers and the introduction of risk based capital regulation. Hence, insurers seeking to minimize agency costs and improve the efficiency of their three principal activities have many characteristics to choose among and combine.

2.1. Organizational form: stock versus mutual

Corporate finance theory (Jensen and Meckling, 1976) stipulates that only organizational forms minimizing agency costs will survive in the long run. However, a variety of organizational forms co-exist in the insurance industry. Organisational forms within the insurance industry include: common stock insurance companies with a standard corporate form, where manager, owner, and customer functions are potentially completely separate; mutuals and reciprocals which are run like cooperatives, where policyholders own the firm; and Lloyds associations which offer insurance contracts from syndicates of individual underwriters. In this research, the focus is on the two most important organizational forms in the US property-liability insurance industry: stock insurers and mutual insurers.

Mayers and Smith (1981, 1988) argue that stocks and mutuals have comparative advantages in dealing with different types of agency costs. The mutual form has the advantage of eliminating the owner/policyholder conflict, by merging the owner and policyholder functions, whereas, in the common stock ownership form, the owner/policyholder conflict is likely to be severe, since stockholders have an incentive to expropriate value from policyholders by activities such as risk-shifting. Hence, mutual insurers are predicted to be more efficient in business lines with lengthy claim settlement lags (maturity hypothesis) such as those common to liability insurance (i.e. worker compensation).

The stock ownership form has the advantage of providing more effective mechanisms for controlling owner/manager conflicts over such things as compensation programs that include stock options or direct ownership of shares, while mutual insurers do not seem to offer their managers any form of such compensation. Moreover, mutual manager compensation is more related to firm size which could tempt them to expand the company by issuing unprofitable policies, engaging in unprofitable acquisitions (free-cash-flow problem) (Jensen, 1986) or generating unnecessary costs through the consumption of perquisites (expense preference hypothesis). Mayers and Smith (1992) and Marx, Mayers, and Smith (2001) show that compensation programs for stock managers are more sensitive to firm performance than compensation programs for mutual managers.

Because control mechanisms differ across organizational forms, the level of managerial discretion approved by owners should also differ. According to the managerial discretion hypothesis (Mayers and Smith, 1988) stock insurers are more efficient in lines of insurance requiring higher managerial discretion in pricing and underwriting, such as commercial lines. Lamm-Tennant and Starks (1993) find that stock insurers are more often involved in riskier business than mutual insurers, where risk is measured by the volatility of the loss ratio.

According to agency theory, the mutual form reduces owner/policyholder conflict, while the stock form offers better control over owner/manager incentive conflicts. Hence, it is unclear which organisation form is the more efficient. Cummins, Weiss, and Zi (1999) use cross-frontier analysis to estimate the relative efficiency of alternative organizational forms in the property-liability insurance industry. They find that mutual and stock insurers operate with distinct technologies but none of them systematically outperforms the others (efficient structure hypothesis).

In this study, we split overall insurer efficiency into the efficiencies of an insurer's main functions: risk pooling, risk management, and financial intermediation. Because the mutual organizational form eliminates owner/policyholder incentive conflicts, we predict that mutual insurers will be more efficient in risk pooling (after controlling for the insurer's business mix), and because the stock organizational form gives better control over owner/manager incentive conflict, we assume that stock insurers will be more efficient in risk management and financial intermediation (after controlling for the insurer's risk characteristics). In other words, mutual insurers, with low-discretion managers, are more involved in standard business where the underwriting risk is shared efficiently among mutual members. However, in such circumstances, mutual managers have less discretion or incentive to focus on managing residual risks and financial intermediation. Correspondingly, stock insurers, with better mechanisms to control high-discretion managers, are more involved in riskier business where the residual underwriting risk is assumed by stockholders. Stockholders then use their authority to encourage managers to focus on managing residual risks and financial intermediation. In short: Mutual insurers are more efficient in risk pooling, while stock insurers are more efficient in risk management and financial intermediation.

2.2. Distribution system

The insurance industry uses a variety of distribution systems that can be grouped into two main categories, based upon the degree of insurer-agent dependence: direct writing and independent agency. The direct-writing category includes the use of employee sales agents and the use of exclusive agents. The independent agency category includes the use of independent agents representing more than one insurer and the use of insurance brokers who represent customers and negotiate with multiple insurers. These distribution systems have co-existed in insurance markets for many decades, even though independent agency insurers are known to have higher costs (Joskow, 1973; Cummins and VanDerhei, 1979). However, independent agents offer a wider range of services, e.g. providing policyholders additional assistance with their claim settlements (Regan and Tennyson, 1996) or reducing their search costs (Posey and Tennyson, 1998). Though independent agents charge more, they still survive because their higher fees are associated with higher product quality. Berger, Cummins and Weiss (1997) use frontier efficiency analysis to examine variations in both cost and profit efficiency across different insurance distribution systems. After controlling for the firm's business mix, they find that, though independent agency insurers are less cost efficient than direct writers, there are no significant differences in profit efficiency across the two distribution systems. Thus, independent agency insurers seem to generate higher costs to produce higher quality services which bring in higher revenues. Cummins and Doherty (2006) argue that independent agents are essentially market-makers who match policyholders' insurance needs with insurers who can meet these needs; they also provide empirical evidence that parts agents' compensations are passed on to policyholders in the premium.

Kim, Mayers and Smith (1996) focus on potential owner/policyholder incentive conflict as the prime determinant guiding the choice of a distribution system. They argue that independent agents should be more effective in monitoring and preventing expropriation by insurers, given these agents' ownership of policyholders list and their relationship with several insurers. Independent agents can credibly threaten to shift their business to another insurer. Independent agents should therefore be more valuable when owner/policyholder conflicts are important, such as with the stock organizational form or when the product mix is complex. Kim et al (1996) find a significant positive relationship between direct writing and the mutual form of ownership. Regan (1997) also finds that direct writers are associated with lower risk and lower product complexity.

In this study, we investigate what effect the choice of distribution system has on the efficiency of the various services offered by insurers. Because independent agents are more effective in getting insurers to pay legitimate claims promptly and fairly, we expect independent agency insurers to handle the cost of risk pooling less efficiently than direct writers. However, because independent agents reduce information asymmetries between policyholders and insurers, we expect independent agency insurers to be more efficient in risk- management and financial intermediation activities. Independent agents can indeed find a better match to meet the risk-adverse policyholder's need for less risky and more diversified insurance policies, for instance. Therefore, our second hypothesis to be tested is as follows: Direct writer insurers are more efficient in risk pooling, while independent agency insurers are more efficient in risk management and financial intermediation

2.3 Capital structure

Corporate theory suggests that capital structure affects agency costs and thereby influences firm performance (Jensen and Meckling, 1976). A higher leverage ratio reduces the agency costs arising from owner/manager conflicts by mitigating the free-cash-flow problem and encouraging managers to act more in the interest of owners (Jensen, 1986; Williams, 1987). However, higher leverage increases the agency costs related to owner/debt-holder conflicts, by reducing incentives (moral hazard), increasing the costs of financial distress, and exacerbating risk-shifting problems (Freixas and Rochet, 1997).

Insurers issue insurance policies and set aside capital in view of honouring their commitments in the event losses are higher than expected or investment returns are lower than expected. Thus, the level of capital needed will depend on the riskiness of the insurer. Cummins and Sommer (1996) provide evidence for a positive relationship between the insurer's capitalization and overall portfolio risk. Insurers writing more commercial line insurance need to hold more capital than firms specialized in personal lines, since commercial lines have a higher loss-ratio volatility than do personal lines. When insurers are large and diversified (either geographically or by line of business), they need less capital, since diversification reduces insurer's overall risk and large insurers are generally more diversified.

Because of the time lag between premium payments and claim settlement, policyholders are sensitive to the financial quality of insurers. If an insurer is under-capitalized, policyholders would expect stockholders to react opportunistically after issuing policies such as risk shifting. As insurers accumulate more capital, for the same policies, their probability of insolvency decreases, thus reducing the expected policyholder/owner incentive conflicts. Sommer (1996) shows that when policyholders consider insurance to be a risky debt, they accept to pay higher premiums to insurers with lower insolvency risks, despite the existence of guaranty funds. Moreover, Cummins and Danzon (1997) give evidence that the demand for insurance is inversely related to the insurer's insolvency risk and is imperfectly price elastic because of the effects of information asymmetries and private information on insurance markets. Under-capitalized insurers are thus penalized by both lower insurance prices and by the loss of customers who perceive their default risk as too high.

Insurers accumulate capital in profitable years to guard against a possible future underwriting crisis. Their reluctance to distribute equity capital accumulations as dividends is driven by informational asymmetries that make it difficult to raise external capital after loss or investment shock (Winter, 1994; Cummins and Danzon, 1997). And, because of their limited ability to raise new external capital, mutual insurers keep significantly higher capital-to-asset ratios than do stock insurers, as a cushion for future investment and loss shocks (Harrington and Niehaus, 2002; Viswanathan and Cummins, 2003).

Since the 1980s, the property-liability insurance industry has been characterized by a sharp decrease in leverage ratios. Cummins and Nini (2002) document that the ratio of premiums-to-surplus (equity capital) dropped from 2 in 1985 to less than 1 by 1999, and that the ratio of surplus-to-assets increased from 25 percent in 1985 to 37 percent in 1999. Cummins and Nini (2002) report that capital gains contributed 57 percent to the increase of equity capital over the 1995-1998 period. This could be explained mainly by the bull market in corporate equities. Data from our sample of insurers indicate that the premiums-to-surplus ratio decreased by 25 percent over the1995-2000 period, but it increased by 46 percent over the 2001-2003 period. Thus, we see that this increase in the insurance industry's capitalization was not sustained and was highly affected by financial-market cycles. Cummins and Nini (2002) use a non-parametric technique (DEA) to measure the efficiency of each firm. They find that most insurers make significant over-use of capital equity, an inefficiency for which they incur significant revenue penalties. Berger and Bonaccorsi di Patti (2006) use a stochastic frontier technique coupled with a free-distribution approach to measure efficiency in the U.S. banking industry. They find that higher leverage is significantly associated with higher profit efficiency.

The effect of leverage could be non-monotonic. Lower leverage reduces the agency costs of owner/policyholder conflicts by reducing the insolvency risk. However, if leverage falls very low, owner-manager agency costs will increase because of free-cash-flow problems and could result in higher total agency costs. The optimal leverage level is a trade-off between the marginal benefits of the lower insolvency risk and the marginal costs of the new capital.

In this study, we investigate the effect leverage levels have on the efficiency of insurers' risk pooling, risk management, and financial intermediation functions. From the above results, we expect that insurers who over-use capital to produce the same quantity of insurance policies should be less efficient in risk pooling activities. However, the net effect of higher capitalization on risk management efficiency is ambiguous. A lower insolvency risk will reduce the return required by policyholders, whereas higher capitalization will increase the return required by owners. The role of risk management is to optimize the use of capital in combination with other risk- management tools, such as asset-liability management, reinsurance, and derivatives. For example, reinsurance could be considered a substitute for capital since it allows the transfer of claims to reinsurers, thereby reducing the leverage ratio. With an over-capitalized insurance industry, what we expect to find (after controlling for firm-risk characteristics) is that lower leverage will have a negative effect on risk- management efficiency. Our third hypothesis is therefore: Higher capitalization has a negative effect on risk pooling efficiency, while its effect on risk management and financial- intermediation efficiencies is ambiguous.

3. Estimation of efficiency

Insurance firms produce their own internal risk management and financial intermediation services. These services are used as intermediate inputs to produce insurance services. Because risk management and financial intermediation services are not traded on external markets, their prices are not observable.

However, implicit or shadow prices can be estimated. Shadow prices correspond to the total costs saved in the production of insurance services for each unit increase in the use of intermediate inputs.

In Cummins et al (2006), shadow prices of risk management and financial intermediation were estimated using the following cost function:

$$\begin{aligned} \ln C_{it} = {} & \alpha_i + \sum_v \beta_v^Q \ln Q_{vit} + \beta_i^R \ln R_{it} + \beta_i^F \ln F_{it} \\ & + \sum_s \beta_s^A \ln P_{sit}^A + \sum_j \beta_j^R \ln P_{jit}^R + \sum_k \beta_k^F \ln P_{kit}^F \\ & + \beta^Z \ln Z_{it} + second-order\,terms + \sum_t \beta^t D_t + u_{it}, \end{aligned} \tag{1}$$

where C are the total costs of producing insurance services; Q are the different output measures for insurance services; R is the level of risk management activities produced internally by the insurance firm; F is the corresponding level of activities for financial intermediation; P are the input prices associated with the different inputs used for the production of insurance services (A), risk management (R), and financial intermediation (F) activities; Z are different control variables; D are time dummy variables; u are random disturbances; and i and t denote, respectively, insurance firms and time. The output of insurance services is defined as the current value of incurred losses in the four principal insurance business lines: long-tail personal, short-tail personal, long-tail commercial and short-tail commercial. The inputs used by insurers are administrative labour services, agent labour services, risk management labour services, debt capital, and equity capital. The level of activities for financial intermediation is measured by the total assets invested and the level of risk management activities is measured by the dollar duration of the surplus. These two variables are treated as endogenous in the econometric model. The cost function was estimated with an unbalanced panel of 613 U.S. property-liability insurers for the period 1995 through 2003 (3,320 observations). All the details regarding the econometric model, the econometric method and data can be found in Cummins et al (2006).

Note that in the above cost function, the intercept and the coefficients associated with the risk management and financial intermediation variables are firm-specific. These coefficients are treated as random for the estimation of the cost function. Once the cost function is estimated, it is possible to assign to each of the insurance firms in the sample a specific intercept and specific coefficients for both intermediate inputs. In turn, shadow prices for risk management (μ_{it}) and financial intermediation (λ_{it}) are computed by:

$$\mu_{it} = -\frac{\partial \ln C_{it}}{\partial \ln R_{it}}\frac{C_{it}}{R_{it}} \text{ and } \lambda_{it} = -\frac{\partial \ln C_{it}}{\partial \ln F_{it}}\frac{C_{it}}{F_{it}} \tag{2}$$

Since both shadow prices are a function of firm and time specific variables (*i*, *t*), it is possible to compute them for each of the 3,320 observations in the sample. However, given that**,** in the cost function**,** the coefficients associated with the risk management and financial intermediation variables are only firm-specific, the mean shadow price is used for each firm in the sample (613 firms). The distribution of the shadow prices are presented in Figures 1 and 2.

[Figures 1 and 2 about here]

The efficiencies of risk management and financial intermediation activities are computed with their respective shadow prices. An insurer is fully efficient in a given activity when the shadow price is nil, meaning that costs can no longer vary with an increase of this activity. To compute the relative efficiency of risk management and financial- intermediation activities, we first calculate the monetary value of the shadow prices (MSP), or the monetary value of insurer *i* inefficiency, as:

$$MSP_i^{\theta} = \left[\sum_{t=1}^{T_i} -\frac{\partial C}{\partial \theta_{it}} \times \theta_{it}\right] T_i^{-1} \tag{3}$$

where $\theta_{it} = R_{it}$ for risk management, $\theta_{it} = F_{it}$ for financial intermediation and T_i is the number of observations of insurer *i*. Then, we compute the *Relative shadow price* (*RSP*) as:

$$RSP_i^{\theta} = \frac{MSP_{\max}^{\theta} - MSP_i^{\theta}}{MSP_{\max}^{\theta} - MSP_{\min}^{\theta}}. \tag{4}$$

RSP always lies between 0 and 1. As insurers become more efficient in a given intermediate activity, their corresponding shadow price decreases and their relative shadow price (*RSP*) increases. The insurer with the lowest shadow price in the sample (most efficient insurer) has a relative shadow price equal to 1, while the insurer with the highest shadow price (less efficient insurer) has a relative shadow price equal to 0.

Using the firm-specific intercept (α_i), the relative risk pooling efficiency of each firm in the sample can also be computed. This is the efficiency that cannot be attributable to any specific input or intermediate outputs. Residual risk pooling efficiency is computed as:

$$RPE_i = \exp(\alpha_{\min} - \alpha_i). \qquad (5)$$

This measure of residual efficiency is analogous to the measure proposed by Berger (1993).[1] It defines relative efficiency as the ratio of the minimum costs needed (costs of the fully efficient firm) to the actual costs expended.

4. Variables, data, and summary statistics

4.1 Variables

Dependent variables. The estimation of the cost function as specified by equation (1) allows us to measure separately the efficiency of the three main functions provided by insurers: risk pooling, financial intermediation, and risk management. The relative shadow prices of risk management and financial intermediation as defined by equation (4) are used as the dependent variables in our econometric model. Residual risk pooling efficiency as computed by equation (5) is also used as a dependent variable.

For the purpose of comparison with the results in the literature, we also compute alternative measures of risk pooling efficiency using different cost function specifications. First, we compute the risk pooling efficiency, using a cost function specification without the risk management function and consider the financial intermediation activity as a regular output (*RPE-1)* (Berger, Cummins and Weiss, 1997). Second, we compute the risk pooling efficiency, using a cost function specification without the risk

[1] As in Berger (1993), the results for risk pooling efficiency are obtained from truncated measures. We set the top and bottom 5% of α_i to the 5th and 95th percentiles, respectively, of their distribution. The same transformations were also applied to the shadow prices for risk management and financial intermediation. Additional results with other truncation points are available from the authors.

management function, but consider the financial intermediation function as an endogenous intermediate output (*RPE-2*). Comparison with the more general model developed in Cummins et al (2006) will highlight the importance of considering both risk management and financial intermediation as endogenous variables in estimating the insurance cost function.

Independent variables. The effects of insurers' characteristics on their efficiencies are investigated. For organizational form, we define the *Stock* dummy variable as equal to 1 if the insurer is organized as a common stock firm; the *Other* dummy variable is equal to 1 if the insurer is organized as reciprocal or Lloyd. For the distribution system, we define the *Independent agents* dummy variable as equal to 1 if the insurer's products are distributed through independent agents or brokers and as equal to 0 if the insurer is a direct writer. To measure insurer capitalisation, we use the *Surplus-to-premiums* ratio, the capitalization ratio most commonly used in the insurance literature, where the surplus is defined as the total admitted assets minus the present value of liabilities.

In addition to the key variables employed to test specific hypotheses, we control for others factors that might influence insurers' efficiencies. Insurers' affiliation is taken into account by specifying a *Group* dummy variable equal to 1 if the insurer is a group of affiliated insurers and equal to 0 if insurer is a single affiliate, and we also control for insurer size by using the variable *Size* defined as the log of total admitted assets.

To account for business characteristics, we include as independent variables: *Share of* commercial, defined as the percentage of output produced in commercial business lines***;*** *Share of long-tail****,*** defined as the percentage of output produced in long-tail lines***;*** and *Share of premium in regulated states****,*** measured as the proportion of premiums written in rate regulated states. We control for risk pooling characteristics by including: *Reinsurance ceded****,*** computed as the proportion of premiums ceded to unaffiliated reinsurers***;*** *Reinsurance assumed****,*** computed as the proportion of premiums assumed from unaffiliated insurers***;*** *Volatility of economic loss ratio****,*** defined as the volatility of the ratio of the current value of incurred losses to premium earned; *Line concentration****,*** computed as the Herfindahl index of the percentage of premiums in each line of business written by the insurer***;*** and *Geographic concentration****,*** computed as the Herfindahl index of the percentage of premiums written by the insurer in each state. A higher Herfindahl index implies that the insurer is concentrated in fewer lines of business or in fewer states.

In order to control for the characteristics of the insurer's portfolio of assets, we include: *Taxable investment income*, measured as the proportion of investment income subject to taxation; *Share of bonds*, defined as the percentage of invested assets allocated for bonds and mortgage loans; *Share of stocks* defined as the percentage of invested assets allocated for stocks and real estates. The reference variable, *Share of cash*, is the percentage of assets allocated for cash and short-term investments.

Finally, we allow for a specific intercept when the shadow prices are negative, by including dummy variables equal to 1 if the estimated shadow prices are negative.

4.2 Data

The potential sample of insurers consists of all property-liability insurance firms reporting data to the National Association of Insurance Commissioners (NAIC) for the period 1995 through 2003. From this potential sample, we eliminate reporting firms showing negative surplus, assets, losses or expenses. 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. The cost function as specified by equation (1) was estimated by Cummins et al (2006) using only insurers with strictly positive input prices; a strictly positive output quantity in each of the four lines of insurance business: long-tail personal, short-tail personal, long-tail commercial and short-tail commercial; and strictly positive intermediate output quantities. The resulting sample is an unbalanced panel containing 3,320 observations (613 insurers) for the 9-year period. This sample accounts for about 90 percent of total industry premium volume in 2003.

4.3 Summary statistics

Summary statistics for all variables used are reported in Table I.

[Table I]

The summary statistics show that, compared to the most efficient firms, insurers are**,** on average, 48 percent as efficient in handling the risk pooling function, 88 percent as efficient in handling the risk management function, and 87 percent as efficient in handling the financial intermediation function. According to Table I, 58 percent of firms (354 insurers) in the sample are organized as common stock insurance companies, 35 percent (218 insurers) are organized as mutual insurance companies, and 7 percent (41 insurers) have another organizational form such as reciprocal or Lloyd. Table I also indicates that 73 percent of the firms (446 insurers) in the sample use independent agents or brokers to distribute their products, while 27 percent of firms (167 insurers) are direct writers. The specific summary statistics for stock and mutual insurers are reported in Table II.

[Table II]

In Table II, we see that mutual insurers, compared to stock insurers, have significantly higher risk pooling efficiency *(RPE* and *RPE-2*), and significantly higher relative shadow prices for risk management and financial intermediation. Table II also shows that stock insurers and mutual insurers have comparative advantages in dealing with different types of agency costs. Mutual insurers are more involved in long-tail business where owner/policyholder incentive conflicts are severe (*maturity hypothesis*), while stock insurers are more involved in commercial lines where owner/manager incentive conflicts are severe (*managerial discretion hypothesis*). Mutual insurers are smaller than stock insurers and they are less likely to be organized as a group (*free cash-flow problem*). Moreover, stock insurers are more capitalized and allocate more capital for cash and short-term investment, while mutual insurers invest more in stocks and real estate. Table III presents a breakdown of the summary statistics by type of distribution system: independent-agency insurers versus direct-writer insurers.

[Table III]

We see that direct-writer insurers display relatively higher risk pooling efficiency (in the case of *RPE* and *RPE*-1)**,** whereas independent-agency insurers have significantly higher shadow price***s*** for risk management and financial intermediation. These results are in line with our hypothesis about distribution systems. Table III also indicates that independent agency insurers are more involved in commercial and long-tail business. Thus, independent agents are more associated to business portfolios with a high potential for expropriation by the insurer. The intermediation of an independent third party in the distribution of this business reduces information asymmetries between policyholders and insurers.

[Figure 3]

Figure 3 illustrates the trend in the surplus-to-premiums ratio. It shows that the surplus-to-premiums ratio which increased over the 1995-2000 period has decreased sharply since 2001. The surplus-to-premiums ratio increased from 1.27 in 1995 to 1.7 in 2000 and then decreased to 1.16 in 2003. The average of surplus-to-premiums ratio for our sample of insurers over the period 1995-2003 is 1.5. This average capitalization could be considered as relatively high compared to the historical level of the surplus-to-premiums ratio (Cummins and Nini, 2002).

5. Empirical results

The three regression equations (risk management and financial intermediation, relative shadow prices, risk pooling efficiency) are jointly estimated using the seemingly unrelated regression equations (SURE) method. The t-statistics are computed using heteroskedastic robust standard-errors. As discussed above, we regress efficiency estimates on a series of firm characteristics to examine some of the determinants of efficiencies and to test the validity of our hypotheses regarding the organizational form, the distribution system, and the capital structure. Table IV shows the estimation results for different efficiency measures on firm characteristics.

[Table IV]

We begin by comparing the three risk pooling efficiency equations. The first column (RPE-1) corresponds to the usual estimation in the literature. This measure of efficiency comes from estimating the insurance cost function where risk management is not considered as an intermediate input and where the financial intermediation function is modeled as exogenous. We first observe that the adjusted R-square is significantly improved with the RPE-2 model, where risk pooling efficiency is estimated using a cost function which includes financial intermediation as an endogenous intermediate input (but no risk management variable).

Regarding the explanatory variables, three differences between the first two regressions (RPE-1 and RPE-2) are important for our purpose. Larger insurers and those with larger Surplus-to-premium ratios are less efficient in providing insurance, while groups show themselves to be more efficient. Adding risk management in the third regression (RPE) does not alter these conclusions but shows that stock insurers do become less efficient. It also reveals that those who are involved in selling reinsurance (*Reinsurance assumed*) are no more efficient in providing insurance. These results clearly indicate that if the risk management function is not taken explicitly into account in estimating the insurance cost function, this will significantly affect conclusions concerning risk pooling efficiency. They also indicate that intermediate outputs must be modeled as endogenous intermediate inputs.

The results regarding risk management and financial intermediation functions are even more significant, with higher adjusted R-squares (around 0.58). This was the result expected from our analysis of the descriptive statistics, since the relative shadow prices for both risk management and financial intermediation display greater variability between firms. The higher variability of the two variables makes it easier to identify their determinants at the firm level.

The first hypothesis tested stipulates that mutual insurers are more efficient in risk pooling and stock insurers are more efficient in risk management and financial intermediation activities. The effects of organizational forms are captured in two dummy variables. The first variable, *Stock*, compares the efficiency of stock insurers to the efficiency of mutual insurers and the second variable, *Other*, compares the efficiency of reciprocal, Lloyd and other organizational forms to the efficiency of mutual insurers. Using the traditional approach in measuring risk pooling efficiency (RPE-1), the organizational form does not matter. Neither of the coefficients for *Stock* and *Other* is statistically different from zero. This finding falls in line with results reported by previous studies (Cummins, Weiss, and Zi, 1999). However, using our approach in measuring risk pooling efficiency (RPE), where we account for risk management and financial intermediation as intermediate inputs, results show that stock insurers are less efficient than mutual insurers. This result is significant only at the ten percent level, however. Thus, separating efficiency in risk pooling activities from efficiency in risk management and financial intermediation shows that the mutual form has a comparative advantage over the stock form in handling risk pooling activities. As discussed above, this advantage is due mainly to the fact that the mutual form eliminates owner/policyholder conflicts.[2] The stock form has a different advantage over the mutual form. The owners of stock insurers have better mechanisms for controlling managers. They are allowed more discretion in writing business and more incentives in managing risks. However, the coefficients for *Stock* in risk management and financial intermediation with regard to shadow price regressions are negative and statistically significant. Nevertheless, the share of business written in commercial lines (*Share of commercial)* is associated with a significant increase in risk management and financial intermediation efficiency (but not risk pooling efficiency). This positive relationship is more acceptable to stock insurers than mutual insurers**,** since they write significantly more business in commercial lines.

Second, we test the hypothesis that direct-writing insurers are more cost efficient in risk pooling**,** while independent agency insurers are more efficient in risk management and financial intermediation activities. Table IV shows that coefficients for *Independent agents* in the different risk pooling efficiency regressions are negative and statistically significant at the 5 percent level. Thus, independent agents generate more costs than direct writers by providing customers additional assistance during their claim process and this reduces the information asymmetry between insurer and policyholders. This is crucial, since independent-agency insurers write significantly more business in long-tail and commercial lines than do direct-writing insurers. However, the coefficients for *Independent agents* in risk management and financial intermediation relative shadow price regressions are not statistically significant. This may be due partially to the fact that additional services provided by independent agents are passed on to policyholders through higher premiums (Cummins and Doherty, 2006)

[2] Another difference, not emphasized in this research, is the nature of insurance contracting (Doherty and Dionne, 1993).

Our third hypothesis is concerned with the way capitalization levels affect insurers' efficiency in handling risk pooling, risk management and financial intermediation. Contrary to the non-significant effect of capitalization levels (as measured by *Surplus-to-premiums*) obtained by the traditional approach used to measure insurers' efficiency (RPE-1), our approach, which considers risk management and financial intermediation as intermediate outputs, shows that higher capitalization has a significantly negative impact on risk pooling efficiency (RPE). This result falls in line with our prediction, since over consuming capital to produce the same output should rationally decrease the efficiency of the risk pooling function. However, the effects of surplus-to-premiums on the relative shadow prices of risk management and financial intermediation are more ambiguous. High capitalization reduces insurer/policyholder conflicts by lowering the risk of insolvency but exacerbate owner/managers conflicts by increasing free-cash-flow problems. Table IV shows that the coefficients for *Surplus-to-premiums* in the risk management and financial intermediation regressions are positive but not statistically significant. Hence, the benefits of stronger capitalization on risk management and financial intermediation are offset by the higher costs of equity capital.

Results concerning the effects of other firm characteristics on insurers' efficiency show that some characteristics, such as *Reinsurance assumed*, *Volatility of economic loss ratio*, *Geographic concentration*, *Line concentration,* and *Share of bonds* in invested assets, do significantly increase risk pooling efficiency (RPE-1), as measured by the traditional approach. However, using our measures of efficiencies, we find that *Volatility of economic loss ratio* and *line concentration* increase the risk pooling efficiency (RPE) without having any significant impact on risk management and financial intermediation efficiencies. *Share of commercial*, *Reinsurance assumed,* and *Share of bonds* in invested assets are all associated with a significant increase in risk management and financial intermediation efficiencies but have no significant effect on risk pooling efficiency (*RPE*). This illustrates how our measure of efficiencies splits the effect of firm characteristics between the three principal activities of insurers.

6. Conclusion

Corporate finance theory predicts that only firms minimizing agency costs will survive in the long run. However, the U.S. property-liability insurance industry is characterized by the co-existence of different organizational forms (i.e. mutual, stock, reciprocal, Lloyd) and the co-existence of different distribution systems (i.e. direct writing, independent agents, brokers). Moreover, regulators and customers have become more aware and more sensitive to insurers' insolvency risk.

In this article, we propose an important extension to the literature on measuring the efficiency of insurance firms. We pay explicit attention to three major activities instead of just the traditional risk pooling activity. Indeed, we add risk management and financial intermediation activities as intermediate intputs when estimating insurer cost function. We use the estimated shadow prices of these two activities to analyze the relative efficiency of insurers in terms of their organizational forms, distributions systems, and capital structure. We also consider their endogeneity in our estimation of the insurance cost function used to analyze the efficiency of risk pooling.

Our main results indicate, as predicted, that mutual insurers, direct-writing insurers, and more leveraged insurers are more cost efficient in risk pooling. The results for mutuals and more highly leveraged firms are obtained only when an endogenous modelling of intermediate inputs is considered. This new methodology also highlights the difference between group and large insurers: the latter are less efficient than the former in providing insurance. However, results show that neither distribution systems nor capitalization has any significant impact on the relative shadow prices of risk management and financial intermediation. Nevertheless, certain characteristics**,** such as being a group of affiliated insurers, a higher volume of business in commercial lines, a larger assumed reinsurance, or a higher proportion of assets invested in bonds, do significantly increase insurers' efficiency in risk management and financial intermediation.

It seems that commercial customers are more sensitive to insurers' insolvency risk. Hence, the stock form (which affords managers more discretion), independent agents (who reduce information asymmetry), and higher capitalization all give insurers a comparative advantage in commercial lines, but also decrease their efficiency in risk pooling. Insurers can choose among a variety of tools, such as asset-liability management, derivatives, and reinsurance, in managing their risks and reducing the probability of insolvency. Reinsurance should be used more efficiently as a substitute for the costly equity capital that decreases insurers' efficiency in risk pooling activities without enhancing significantly their risk management and financial intermediation efficiencies.

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Table I

Summary Statistics (613 insurers)

	Mean	Std Dev
Shadow price of risk management	0.0701	0.2378
Shadow price of financial intermediation	0.1768	0.2361
RSP of risk management	0.8841	0.2501
RSP of financial intermediation	0.8731	0.2582
Risk pooling efficiency (RPE)	0.4810	0.2191
RPE-1	0.7409	0.1201
RPE-2	0.5146	0.2103
Surplus-to-premiums	1.5010	1.7621
Stock	0.5775	0.4944
Other	0.0669	0.2500
Independent agents	0.7276	0.4456
Group	0.6264	0.4841
Size (log Assets)	18.9502	2.1086
Share of commercial	0.4693	0.3282
Share of long-tail	0.7174	0.1764
Premium in regulated states	0.6554	0.3604
Reinsurance ceded	0.2321	0.1856
Reinsurance assumed	0.1350	0.2877
Volatility of economic loss ratio	0.1678	0.1841
Geographic concentration	0.5052	0.3733
Line concentration	0.3392	0.1587
Taxable investment income	0.8402	0.1735
Share of bonds	0.6783	0.1760
Share of stocks	0.1895	0.1478
Share of cash	0.1320	0.1286
Dummy=1 if risk management SP<0	0.0489	0.2159
Dummy=1 if financial intermediation SP<0	0.1126	0.3163

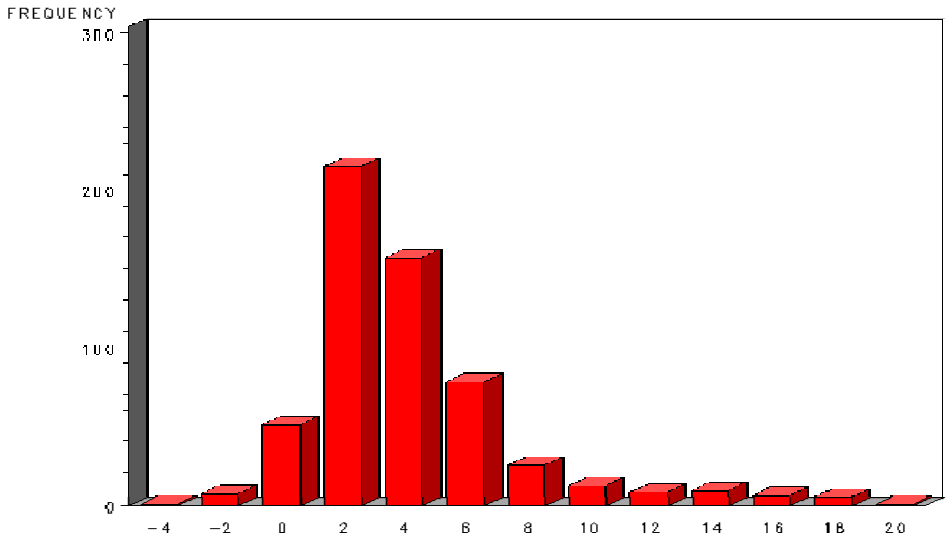

Figure 1. Shadow prices for risk management (10^{-2})

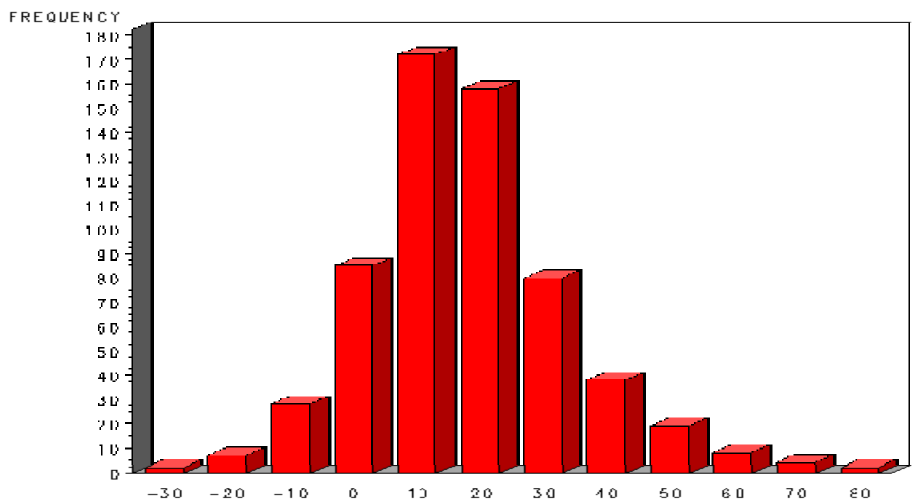

Figure 2. Shadow prices for financial intermediation (10^{-2})

Table II

Breakdown of Summary Statistics by Organization Form

	Mutual		Stock		t test	
	Mean	Std Dev	Mean	Std Dev	t Value	Pr > |t|
Shadow price of risk management	0.0687	0.2682	0.0698	0.2265	-0.05	0.9576
Shadow price of financial intermediation	0.2244	0.2669	0.1485	0.2192	3.70	0.0002
RSP of risk management	0.9303	0.1757	0.8655	0.2728	3.13	0.0018
RSP of financial intermediation	0.9214	0.1879	0.8548	0.2765	3.14	0.0018
Risk pooling efficiency (RPE)	0.5288	0.2033	0.4568	0.2229	3.88	0.0001
RPE-1	0.7463	0.1026	0.7344	0.1275	1.16	0.2454
RPE-2	0.5449	0.2023	0.5007	0.2113	2.47	0.0138
Surplus-to-premiums	1.0809	0.7244	1.6856	2.1503	-4.01	<.0001
Independent agents	0.7477	0.4353	0.7514	0.4328	-0.10	0.9210
Group	0.5413	0.4994	0.6836	0.4657	-3.45	0.0006
Size (log Assets)	18.504	1.8561	19.165	2.1799	-3.72	0.0002
Share of commercial	0.3483	0.265	0.5294	0.3407	-6.70	<.0001
Share of long-tail	0.7398	0.1302	0.7060	0.1900	2.32	0.0208
Premium in regulated states	0.5863	0.4136	0.6900	0.3216	-3.35	0.0009
Reinsurance ceded	0.2025	0.1616	0.2530	0.1925	-3.23	0.0013
Reinsurance assumed	0.0305	0.0681	0.1896	0.3448	-6.73	<.0001
Volatility of economic loss ratio	0.1556	0.1812	0.1734	0.1903	-1.11	0.2690
Geographic concentration	0.6216	0.3434	0.4354	0.3752	5.95	<.0001
Line concentration	0.3043	0.1275	0.3537	0.1666	-3.75	0.0002
Taxable investment income	0.8437	0.1647	0.8325	0.1788	0.75	0.4528
Share of bonds	0.6760	0.1689	0.6715	0.1873	0.29	0.7699
Share of stocks	0.1899	0.1369	0.1595	0.1434	2.51	0.0125
Share of cash	0.0909	0.0978	0.1364	0.1322	-4.40	<.0001
Dummy=1 if risk management SP<0	0.0092	0.0956	0.0763	0.2658	-3.59	0.0004
Dummy=1 if financial intermediation SP<0	0.0367	0.1885	0.1582	0.3654	-4.55	<.0001
Number of insurers	218		354			

Table III

Breakdown of Summary Statistics by Type of Distribution System

	Direct Writer		Independent Agents		t test	
	Mean	**Std Dev**	**Mean**	**Std Dev**	**t Value**	**Pr > |t|**
Shadow price of risk management	0.0661	0.1529	0.0716	0.2627	-0.26	0.7977
Shadow price of financial intermediation	0.1692	0.2143	0.1797	0.2440	-0.49	0.6236
RSP of risk management	0.8429	0.2822	0.8995	0.2355	-2.51	0.0124
RSP of financial intermediation	0.8322	0.2903	0.8885	0.2437	-2.41	0.0162
Risk pooling efficiency (RPE)	0.5058	0.2562	0.4718	0.2030	1.71	0.0870
RPE-1	0.7592	0.1340	0.7341	0.1139	2.31	0.0211
RPE- 2	0.5354	0.2433	0.5068	0.1962	1.50	0.1342
Surplus-to-premiums	1.5870	1.9544	1.4688	1.6857	0.74	0.4601
Stock	0.5269	0.5008	0.5964	0.4912	-1.55	0.1215
Other	0.1437	0.3519	0.0381	0.1917	4.74	<.0001
Group	0.6766	0.4692	0.6076	0.4888	1.57	0.1161
Size (log Assets)	19.316	2.2398	18.813	2.0431	2.64	0.0084
Share of commercial	0.4217	0.3462	0.4871	0.3198	-2.21	0.0278
Share of long-tail	0.6748	0.1916	0.7333	0.1678	-3.69	0.0002
Premium in regulated states	0.6832	0.3455	0.6450	0.3657	1.17	0.2438
Reinsurance ceded	0.1999	0.1846	0.2442	0.1847	-2.64	0.0084
Reinsurance assumed	0.1804	0.3613	0.1180	0.2530	2.40	0.0166
Volatility of economic loss ratio	0.1493	0.1664	0.1748	0.1900	-1.53	0.1268
Geographic concentration	0.5028	0.4078	0.5060	0.3601	-0.10	0.9242
Line concentration	0.3637	0.1562	0.3301	0.1588	2.35	0.0193
Taxable investment income	0.8093	0.1969	0.8518	0.1626	-2.72	0.0068
Share of bonds	0.6899	0.1716	0.6740	0.1776	0.99	0.3209
Share of stocks	0.1747	0.1344	0.1950	0.1523	-1.52	0.1298
Share of cash	0.1353	0.1463	0.1308	0.1215	0.38	0.7011
Dummy=1 if risk management SP<0	0.0299	0.1709	0.0561	0.2303	-1.33	0.1827
Dummy=1 if financial intermediation SP<0	0.1138	0.3185	0.1121	0.3159	0.06	0.9538
Number of Insurers	167		446			

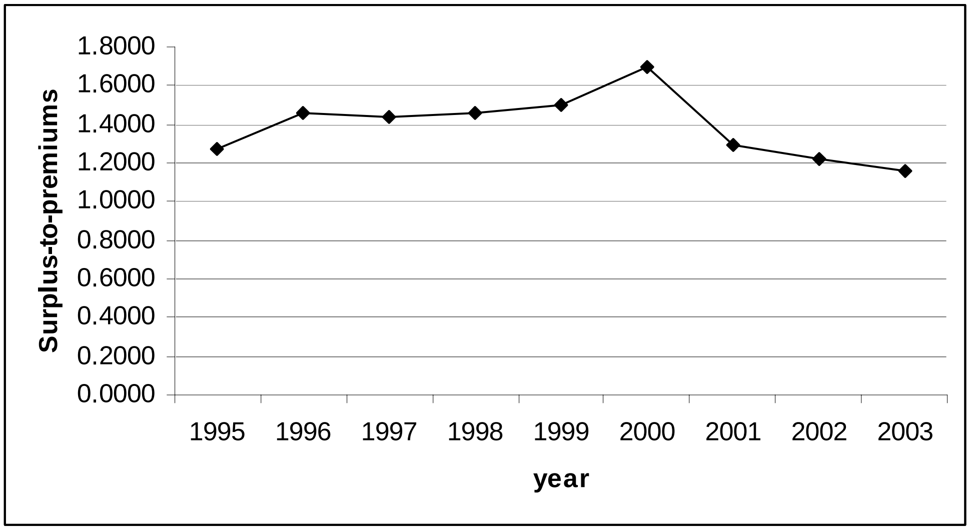

Figure 3. Surplus-to-premiums trend: 1995-2003

Table IV

Estimations of Different Efficiency Measures on Firm Characteristics (613 insurers)

	RPE-1		RPE-2		RPE		Risk Management		Financial Intermediation	
	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat	Estimate	t-stat.	Estimate	t-stat.
Intercept	0.6131 ***	6.78	1.9114 ***	16.52	1.6642 ***	11.95	2.5878 ***	20.26	2.6005 ***	19.79
Surplus-to-premium	0.0044	1.48	-0.0155 ***	-4.11	-0.0092 **	-2.02	0.0027	0.65	0.0014	0.32
Stock	-0.0088	-0.75	0.0047	0.32	-0.0333 *	-1.85	-0.0425 **	-2.57	-0.0453 ***	-2.67
Other	0.0155	0.72	0.0033	0.12	-0.0339	-1.03	-0.0739 **	-2.44	-0.0898 ***	-2.88
Independent agents	-0.0275 **	-2.43	-0.0762 ***	-5.26	-0.0748 ***	-4.29	0.0127	0.80	0.0122	0.74
Group	-0.0123	-1.01	0.1403 ***	9.04	0.1489 ***	7.97	0.0928 ***	5.41	0.0968 ***	5.49
Size (log Assets)	0.0007	0.20	-0.0828 ***	-17.74	-0.0679 ***	-12.09	-0.1013 ***	-19.66	-0.1041 ***	-19.65
Share of commercial	0.0053	0.30	0.0086	0.38	-0.0134	-0.49	0.1049 ***	4.18	0.1034 ***	4.01
Share of long-tail	0.0430	1.51	0.0656 *	1.80	0.0541	1.24	0.0280	0.70	0.0418	1.01
Premium in regulated states	-0.0096	-0.68	-0.0247	-1.37	-0.0307	-1.41	-0.0042	-0.21	-0.0067	-0.32
Reinsurance ceded	0.0364	1.24	0.0347	0.93	0.0528	1.17	-0.0461	-1.12	-0.0200	-0.47
Reinsurance assumed	0.0374 *	1.93	0.0547 **	2.21	-0.0018	-0.06	0.0720 ***	2.63	0.1081 ***	3.84
Volatility of economic loss ratio	0.0781 ***	2.85	0.1345 ***	3.84	0.1152 ***	2.73	-0.0369	-0.95	-0.0319	-0.80
Geographic concentration	0.0367 **	2.13	0.0080	0.37	-0.0074	-0.28	0.0279	1.15	0.0309	1.24
Line concentration	-0.0630 *	-1.81	-0.1657 ***	-3.72	-0.1005 *	-1.88	0.0857	1.75	0.0881	1.75
Taxable investment income	-0.0131	-0.44	0.0447	1.18	0.0566	1.25	-0.0432	-1.04	-0.0559	-1.31
Share of bonds	0.1371 ***	3.20	0.1293 **	2.36	0.0566	0.86	0.1618 ***	2.68	0.1935 ***	3.11
Share of stocks	0.0331	0.63	0.0755	1.12	0.0400	0.49	-0.0307	-0.41	-0.0227	-0.30
Dummy=1 if shadow price < 0							0.0573 ***	3.82	0.0135	1.27
Adjusted R-square	0.0765		0.5066		0.3421		0.5755		0.5786	

Note: ***, ** and * indicate statistical significance at the 1%, 5% and 10% confidence level respectively.

Conclusion Générale

L'activité de gestion des risques est actuellement présente dans plusieurs secteurs économiques. La littérature existante montre que la gestion des risques est pertinente en présence des imperfections du marché, telles que une structure convexe des taxes, coûts des difficultés financière, coûts d'opportunités d'investissement, ou présence d'asymétrie d'information. Toutefois, aucune étude n'a montré que l'activité de gestion des risques permet d'améliorer l'efficacité globale des entreprises. Dans cette thèse nous utilisons les données de l'industrie d'assurance responsabilité pour montrer comment la gestion des risques peut créer de la valeur ajoutée.

La gestion des risques est une activité primordiale pour les compagnies d'assurance puisque les assurés et les régulateurs sont hautement sensibles au risque d'insolvabilité. L'un des outils les plus importants à la disposition des assureurs pour gérer les risques financiers est l'appariement entre l'actif et le passif. De même, l'un des outils les plus importants pour gérer le risque de souscription est la réassurance.

Dans le premier chapitre nous avons analysé le rôle de la gestion des risques et de l'intermédiation financière dans la création de la valeur économique des institutions financières en considérant l'industrie de l'assurance responsabilité américaine. Nous avons trouvé que les deux activités augmentent significativement l'efficacité de l'industrie étudiée. La moyenne des prix implicites pour ces deux activités est positive indiquant que les compagnies d'assurance peuvent réduire davantage leurs coûts en intensifiant leurs activités de gestion des risques et d'intermédiation financière.

Dans le deuxième chapitre nous avons analysé les coûts et les bénéfices de la réassurance pour l'industrie de l'assurance responsabilité américaine. L'achat de la réassurance réduit le risque d'insolvabilité des assureurs en stabilisant les pertes réalisées, en augmentant la capacité d'offre d'assurance, en limitant l'exposition à certains risques, et/ou en limitant les pertes en cas de catastrophes. Toutefois, transférer les risques aux réassureurs est coûteux. Nos résultats empiriques montrent que l'achat de la réassurance augmente significativement les coûts des assureurs mais réduit significativement la volatilité de leur ratio de perte. En achetant de la réassurance, les assureurs acceptent de supporter un coût de production plus élevé afin de réduire leur risque de souscription.

Dans le troisième chapitre nous avons analysé les déterminants de la performance des assureurs dans ses différentes activités. Nous avons étudié les caractéristiques des assureurs qui déterminent différemment l'efficacité de l'offre d'assurance, de gestion des risques et d'intermédiation financière. Nos résultats empiriques montrent que les mutuelles dominent les assureurs à capital action dans les trois activités. Les assureurs utilisant des agents indépendants et à forte capitalisation ont des coûts plus élevés d'offre d'assurance.