**Enterprise Risk Management and Economies of Scale and Scope:**
**Evidence from the German Insurance Industry**


## Abstract

Enterprise risk management (ERM) is the approach of managing all risks faced by an enterprise in an integrated, holistic fashion. This research investigates whether the utilization of the ERM approach helps firms achieve economies of scale and scope. We use detailed survey data of German property-liability insurance companies that allows us to construct continuous measures of ERM quality. We find that ERM quality positively moderates the scale-cost efficiency (scale-revenue efficiency) and scope-cost efficiency (scope-revenue efficiency) relationships, indicating that ERM facilitates economies of scale and scope. Our results suggest that ERM's impact on economies of scale and scope is one answer to the question *how* ERM can create value.



*JEL Classifications:* C33; G22; G32; L25.

*Key words:* Enterprise risk management, economies of scale, economies of scope, efficiency analysis

## 1. Introduction

Enterprise risk management (ERM) is the approach of managing all risks faced by a firm in an integrated, holistic way. The ERM process is designed to identify potential events that may affect the firm, manage risk to be within the firm's risk appetite, and to provide reasonable assurance regarding the achievement of the firm's objectives (COSO, 2004). Traditionally, firms managed risks from their individual business units separately within each unit. ERM improves on this traditional "silo" based approach by coordinating and controlling and therefore offsetting risks across the enterprise.

A number of studies provide survey evidence documenting how firms implement the ERM approach to achieve such synergies between risk management activities (e.g., Altuntas, Berry-Stölzle, and Hoyt, 2011). Other studies focus on firms' decision to adopt the ERM approach and find that firms implement ERM for direct economic benefits (e.g., Pagach and Warr, 2011; Altuntas, Berry-Stölzle, and Hoyt, 2014). The third major strand of the ERM literature provides evidence that ERM is associated with an increase in firm performance and value (e.g., Grace at al., 2015; Hoyt and Liebenberg, 2011; Ai, Chen, and Zhou, 2104). This strand of the literature uses a number of arguments to explain why ERM can create value, namely that ERM creates synergies between different risk management activities, increases capital efficiency, reduces the underinvestment problem in financially constrained firms, and reduces the cost of external financing. However, there is hardly any empirical evidence supporting these claims.[1]

The goal of the present paper is to shed some light on the fundamental question of *how* ERM can create value, using empirical data. We specifically focus on the argument that ERM creates synergies between different risk management activities and increases capital efficiency.

[1] Detailed reviews of the ERM literature are provided in Kraus and Lehner (2012) and Gatzert and Martin (2015).

We test the hypotheses that ERM creates value by enabling firms to realize economies of scale and scope. The hypotheses are tested using a sample consisting of German property-liability (P-L) insurers for the sample period 1999-2009. We measure firm performance utilizing frontier efficiency scores estimated through data envelopment analysis (DEA). The DEA scores are then regressed on a set of variables designed to measure the characteristics of the firms in our sample. Included in our regressors are two measures of ERM quality obtained through a telephone survey of German P-L insurers conducted by the authors. This enables us to test whether higher quality ERM programs create more value than lower quality programs. We also distinguish between the concepts of *related* and *unrelated* diversification and test whether related diversification is more likely to create value by enabling firms to realize economies of scope.

We are argue that synergies created by ERM should be more pronounced in larger firms and in diversified firms. In larger firms, the fixed costs of running an ERM program can be spread over a larger volume of output. Larger firms are involved in a larger number of risky projects. Due to the law of large numbers the aggregate risk of a firm's portfolio of risky projects decreases as the size of such a risk pool increases, assuming the risk pool is well-managed. Such a reduction in risk reduces the need for costly risk management activities, reduces the amount of costly equity capital necessary to keep the probability of default within the firm's risk appetite, and reduces the firm's cost of debt financing (Stulz, 1996; Nocco and Stulz, 2006).

A well-executed ERM program can facilitate the risk-reducing effect of risk pooling. To clarify, the baseline effect is simply driven by the firm's scale of operation; larger firms benefit from diversification across projects with independent cash flows, leading to a decline in the average costs of risk per unit of output as the volume of output increases. However, ERM can help a firm achieve and manage this risk-reducing effect. Therefore, we argue that ERM helps to achieve economies of scale.

In a diversified firm with multiple divisions, a silo based risk management approach may lead to redundancies, for example, when two business units invest in the same risk management activity. ERM can help achieve cost scope economies by exploiting sharable risk management inputs in the production process. Therefore, we argue that ERM helps to achieve economies of scope by establishing production complementarities for risk management activities.

Of course, there are risky projects with offsetting cash flows in diversified firms resulting in natural hedges regardless of whether a firm has an ERM program or not. We address this concern explicitly by distinguishing between *related* and *unrelated diversification*. Two products are considered to be related if their production processes are similar (Hill, Hitt, and Hoskisson, 1992).[2] The main advantages of related diversification are economies of scope; a firm can share resources in the production of related products resulting in lower cost of joint production compared to the sum of the costs for producing each product separately (Teece, 1980). If ERM helps realize economies of scope, ERM adoption should economically benefit firms with a related diversification strategy. The benefits of unrelated diversification, on the other hand, are based on unrelated business units with different cash flow patterns combined with the headquarters ability to allocate resources more efficiently than outside investors could (Stein, 1997). ERM is likely to be less beneficial for firms with unrelated diversification strategies. Therefore, we do not expect ERM adoption to moderate a firm's unrelated diversification-production cost relationship.

We are only aware of two papers with a similar focus as the present paper, i.e., the identification of mechanisms through which ERM creates value. Berry-Stölzle and Xu (2016) examine the relationship between ERM adoption and a firm's cost of capital as a possible channel for value creation. They provide evidence that ERM adoption significantly reduces the

[2] There is a substantial body of literature on the advantages and disadvantages of related versus unrelated diversification strategies (e.g., Markides and Williamson, 1994; Keil et al., 2008; and Berry-Stölzle et al., 2012).

cost of capital for publicly-traded U.S. insurers. Ai, Bajtelsmit, and Wang (2014) investigate U.S. property-liability (P-L) insurers and find significant value creation related to product line diversification for insurers with relatively high quality ERM programs.

This research contributes to the literature by providing an additional answer to the fundamental question of *how* ERM can create value by studying its effects on economies of scale and scope. This research also contributes to the literature on technological progress and the optimal scale and scope of firms. ERM can be viewed as a new technology that became available during the past fifteen years, and ERM may have increased the optimal scale of firms as well as their optimal degree of diversification.

Section 2 develops the hypotheses. This is followed by a description of the data and methodology in section 3. The results are presented in section 4, and section 5 concludes.

## 2. Conceptual Background and Hypothesis Development

### *2.1. The ERM Literature*

The ERM literature can be divided into three strands: *ERM implementation*, *determinants of ERM adoption,* and *value implications of ERM adoption*. The first strand examines how firms actually implement the ERM approach (see, e.g., Colquitt, Hoyt, and Lee, 1999; Kleffner, Lee, and McGannon, 2003; Beasley, Clune, and Hermanson, 2005; Daud, Haron, and Ibrahim, 2011; Altuntas, Berry-Stölzle, and Hoyt, 2011). Information about risk management practices is gathered by using surveys or by scanning public sources. While the majority of these studies show that the level of implementation is strongly influenced by the existence of a chief risk officer (CRO), Altuntas, Berry-Stölzle, and Hoyt (2011) additionally investigate which risk sources are included in the ERM approach.

The second strand of ERM literature focuses on the relationship between firm-specific characteristics and the decision to adopt the ERM approach. Liebenberg and Hoyt (2003) and

Golshan and Rasid (2012) find that financial leverage is significantly positively related to ERM, supporting the notion that a more efficient risk management approach in highly leveraged firms mitigates potential losses arising from a greater risk of financial distress.[3] Pagach and Warr (2011) document that a firm's likelihood to adopt ERM is determined by firm size, volatility, institutional ownership, and the CEO's risk taking incentives. Their results support the notion that firms engage in ERM for direct economic benefit and not just to comply with regulation. Altuntas, Berry-Stölzle, and Hoyt (2014) argue that top management's decision to adopt ERM is influenced by managerial concerns about keeping their jobs. The career concerns argument predicts that a manager with high initial reputation should only adopt ERM after a period of poor performance. Their empirical results are consistent with this prediction.[4]

The third strand of literature investigates the value of a holistic ERM framework. Gordon, Loeb, and Tseng (2009) measure firm performance by the one-year excess stock market return and provide evidence for a strong positive impact of ERM on firm performance. Hoyt and Liebenberg (2011) find that ERM adoption leads to an increase in firm value measured by Tobin's Q for U.S. insurers. Eckles, Hoyt, and Miller (2014) find that firms with ERM programs experience a reduction in stock return volatility, which becomes stronger over time, and that risk-adjusted operating profits increase after ERM adoption. Grace et al. (2015) document that ERM-adopting firms experience higher levels of cost and revenue efficiency. Unlike previous studies which mainly focus on US firms, Ai, Chen, and Zhao (2014) analyze listed Chinese nonfinancial firms and provide evidence that ERM significantly increases firm value.[5]

In our study, we take the positive valuation effect of ERM as given and focus on the

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[3] Liebenberg and Hoyt (2003) interpret their result as evidence that firms start ERM programs to reduce information asymmetries regarding the firm's risk profile.

[4] Altuntas, Berry-Stölzle, and Hoyt (2014) also find that ERM adoption is accompanied by significant improvements in a firm's risk management quality.

[5] Diffferent from other studies, Ai et al. (2012) present a conceptual framework for operationalizing strategic ERM in a general firm. They develop a risk-constrained optimization approach to capital allocation decisions under ERM.

fundamental question of *how* ERM creates value. We specifically investigate whether economies of scale and scope are mechanisms for value creation through ERM. As mentioned, there are only two studies that investigate how ERM creates value, neither of which investigates scale or scope economies (Berry-Stölzle and Xu, 2016; Ai, Bajtelsmit, and Wang, 2014).

### *2.2. Hypotheses: The Impact of ERM on Economies of Scale and Scope*

Economies of scale arise if the average costs per unit of output decline as the volume of output increases. More formally, economies of scale are present if $C(\lambda y) < \lambda C(y)$, where $C(y)$ represents the cost function, $y$ is output quantity, and $\lambda$ is a scalar > 1 (Panzar and Willig, 1977). This definition corresponds to the decreasing part of the familiar U-shaped cost function from economic theory. The source of scale economies that receives the most attention in the literature is the spreading of a firm's fixed costs over a larger volume of output. Fixed costs are present whenever there is a need for relatively fixed factors of production including office space, a risk management system, managerial expertise with respect to risk management, as well as equity capital to deal with unexpected fluctuations in earnings. Scale economies can also arise if mangers can become more specialized and therefore more efficient in completing assigned tasks as the firm grows. This argument can be directly applied to risk managers and their task of managing the risk exposures of the firm. In addition, larger firms can have lower costs of capital if earnings volatility is inversely related to firm size (Hann, Ogneva, and Ozbas, 2013).

This last source of scale economies is the mechanism through which ERM can help larger firms to achieve additional benefits. A firm can be viewed as a portfolio of investment projects. Due to the law of large numbers, the aggregate risk of a portfolio of risky projects decreases as the number of projects in the portfolio increases, assuming the projects' cash flows are not perfectly correlated. ERM can facilitate this risk-reducing effect of risk pooling by basically ensuring that assumptions in the law of large numbers are met, namely the probability distributions characterizing individual risks should be independent of each other, have low correlations, or create natural hedges. Thus, ERM can increase the efficiency of diversification.

A structured approach to identify all risks faced by a firm may screen for risks outside the standard risk "silos" or business units and identify previously overlooked threats to the firm. Improved risk identification allows firms to choose the most effective tool to coordinate the identified risks instead of passively retaining them. In addition, ERM emphasizes the identification and management of interdependencies among different types of risks. Such an approach allows firms to coordinate risk management activities across all business units of a firm and to exploit natural hedges. Thus, ERM allows firms to avoid unforeseen accumulation of risks from different sources (e.g., fire risk, operational risk, commodity price risk, etc.).

Large unforeseen operating losses limit a firm's ability to invest in positive net present value projects and force a firm to raise external funds to address its financing constraints. Due to information asymmetries between managers and outside investors, however, external sources of funds are more expensive than internal sources (Froot, Scharfstein, and Stein, 1993); investors assume that only firms with less advantages investment opportunities issue new capital and demand a substantial discount on the price of new shares. Therefore, firms that need to raise external funds face an increase in their cost of capital. Since ERM focuses on reducing the probability of large losses and capital shocks, ERM reduces the probability that a firm has to raise expensive external financing and, hence, reduces the firm's expected costs.

It is also important for firms to have strong financial strength ratings. Standard & Poor's (S&P) as well as other rating agencies explicitly evaluate companies' ERM programs as part of the rating process.[6] In 2006, A.M. Best, the major rating agency specializing in the insurance industry, also added ERM to its rating process. Therefore, a well-functioning ERM program can

[6] S&P added ERM as major rating criterion for insurers in 2005 and for nonfinancial companies in 2008.

positively impact a firm's financial rating. The direct link between ERM programs and financial ratings creates an additional channel through which ERM adoption can reduce the cost of capital. This effect is expected to be greater for larger companies, because many small companies are not rated by rating agencies. Regarding these conceptual arguments, we can state the following testable hypothesis:

**Hypothesis 1 (H1):** ERM facilitates economies of scale.

Economies of scope refer to cost reductions achieved by producing a variety of outputs within a single firm rather than producing these outputs in separate firms. Let $C_J(y_1, y_2)$ represent the cost function for a firm jointly producing quantity $y_1$ of output 1and quantity $y_2$ of output 2. Let $C_{S_1}(y_1)$ represent the cost function for a specialized firm producing quantity $y_1$ of output 1, and let $C_{S_2}(y_2)$ be the cost function for a specialized firm producing quantity $y_2$ of output 2. Then economies of scope are present if: $C_J(y_1, y_2) < C_{S_1}(y_1) + C_{S_2}(y_2)$, i.e., if outputs can be produced at lower costs by a joint producer rather than by specialized, separate producers (Panzar and Willig, 1981). This differs from economies of scale, which for the two-output case would imply that $C_J(\lambda y_1, \lambda y_2) < \lambda\ C_J(y_1, y_2)$, for $\lambda > 1$.

Economies of scope can exist even if firms are operating at minimum average costs, i.e., if scale economies have been exhausted. Cost economies of scope arise due to *shareable inputs,* i.e., "inputs . . . procured for the production of one output, which [are] also available to aid in the production of other outputs" (Panzar and Willig, 1981). Economies of scale, on the other hand, mainly result from spreading a firm's fixed costs over a larger volume of output and from diversification, as explained above.

Proponents of the *conglomeration hypothesis* argue that producing a variety of products enables a firm to realize cost scope economies by exploiting shareable inputs, i.e., achieving *production complementarities*. By producing multiple lines of insurance a firm may be able to reduce costs by sharing inputs such as information systems, investment departments, and policyholder service centers (e.g., Teece, 1980). For example, the divisions of a joint producer may use a joint customer database at a lower cost than building and maintaining two databases. Cost scope economies also can arise from sharing managerial expertise and physical inputs such as offices, computers, or software. Cost scope economies also can arise from cross-line diversification which reduces earnings volatility and the cost of capital. Cost scope economies also can occur if the internal capital markets of diversified firms are less prone to informational asymmetries and other imperfections than external capital markets (Gertner et al., 1994).

In addition, diversification across multiple products can reduce a firm's cost of capital because the resulting reduction in earnings volatility reduces systematic risk through the avoidance of counter-cyclical deadweight costs (Hann, Ogneva, and Ozbas, 2013). Again, ERM can facilitate this risk-reducing effect of risk pooling in a portfolio of risky projects. ERM's impact on the aggregate risk of the risk pool should be relatively small if the pool already includes offsetting risks and benefits from natural hedges. However, ERM may have a substantial impact without such natural hedges in the pool. Therefore, we argue that ERM helps firms achieve cost economies of scope and creates value especially for firms with a related diversification strategy, less so for firms with unrelated diversification.

An ERM program is an example of a shared resource that can lead to scope economies. The main advantage of ERM over the traditional silo based risk management approach is that ERM manages all risks faced by the enterprise in a holistic way and, hence, facilitates the sharing and coordination of risk management activities across all business units of the firm.

Insurers also may be able to realize revenue scope economies, which arise if the firm can earn more revenues by producing several outputs than would be earned if the outputs were produced in separate, specializing firms. More formally, let $R_J(y_1, y_2)$ represent the revenue function for a firm jointly producing quantity $y_1$ of output 1and quantity $y_2$ of output 2. Let $R_{S_1}(y_1)$ represent the revenue function for a specialized firm producing quantity $y_1$ of output 1, and let $R_{S_2}(y_2)$ represent the revenue function for a specialized firm producing quantity $y_2$ of output 2. Then revenue scope economies are present if: $R_J(y_1, y_2) > R_{S_1}(y_1) + R_{S_2}(y_2)$.

Whereas cost scope economies arise due to production complementarities, revenue scope economies arise due to *consumption complementarities* (Berger et al., 2000).The conglomeration hypothesis holds that diversified firms will have higher revenues than focused firms because consumers are willing to pay more for the convenience of purchasing multiple products from the same source, i.e., "one-stop shopping." Consumption complementarities may arise from reductions in buyer transaction, transportation, and search costs associated with consuming financial services jointly from the same provider, rather than consuming the services separately from different providers. The hypothesis holds that buyers are willing to reward joint provision up to the amount of savings they obtain from joint consumption. Sharing a brand name also may raise revenues, if consumers are convinced that branded products are of higher quality.

To the extent that ERM succeeds in reducing the probability of financial distress more efficiently in diversified firms than in specialized firms, such firms will be able to realize revenue scope economies if buyers are willing to pay higher prices for insurance from safer firms, because insurer customers are especially sensitive to credit risk (Nocco and Stulz, 2006).

Proponents of the *conglomeration hypothesis* need to contend with an alternative hypothesis – the *strategic focus hypothesis* posits that firms can maximize value by focusing on core businesses and core competencies. A fundamental argument is that conglomeration exacerbates managerial incentive conflicts and agency costs by increasing the span of control, motivating central managers to add divisions to protect their human capital, and providing more opportunities for the misalignment of incentives between central and divisional managers (Berger et al., 2000). Conglomeration also can lead to inefficient investment decisions by providing additional free cash flow or unused debt capacity (e.g., Jensen, 1986). Internal capital markets also may be less efficient than external capital markets, leading to value-destroying cross-subsidization among divisions (Scharfstein and Stein, 2000). In addition, the various lines of insurance tend to serve somewhat different economic needs, and it is not always clear that significant synergies are available. Thus, it is possible that focusing on specific lines of insurance may dominate a diversification strategy because the synergies from offering several types of insurance do not overcome the agency and managerial costs created by conglomeration.

On the revenue side, proponents of strategic focus argue that most buyers of insurance are not willing to pay more for one-stop shopping but rather prefer to buy the highest quality product at the lowest price for each type of insurance. Revenue scope diseconomies may arise if specialists have better knowledge and expertise and can better tailor products for individual customers, and thereby charge more than joint producers. Recent technological trends may have tended to favor strategic focus as providing a competitive advantage in the insurance industry, e.g., advances in technology such as the Internet may have significantly attenuated revenue economies of scope by reducing consumer search costs (Cummins et al., 2010). Insurance buyers can also utilize the services of independent agents and brokers, who can create "virtual supermarkets" by shopping the market for the best price and policy for each coverage purchased.

Also relevant to this discussion is the *diversification discount* literature, which shows that conglomerate firms tend to have lower market values than their subsidiaries would have if traded separately (e.g., Berger and Ofek, 1995). Other studies document an increase in firm value associated with the decision to refocus (Comment and Jarrell, 1995). Nevertheless, other research suggests that a diversification discount does not necessarily negate scope economies for insurers. For example, Berger and Ofek (1995) find that the diversification discount is smaller when the segments of the diversified firm are in the same two-digit SIC code. Our study focuses on diversification within an even narrower industry definition, i.e., a four-digit SIC code. Other studies have found that the existence and extent of the discount may be industry-specific (e.g., Santalo and Becerra, 2008). Research has also shown that banks affiliated with a multibank bank holding company do more lending and hold less capital than unaffiliated banks, suggesting that these organizations benefit from the intra-firm allocation of resources (Klein and Saidenberg, 2010). Hence, we believe there is reason to predict a possible beneficial effect from diversification within the German property-liability (P-L) insurance industry and that this effect is related to the existence and quality of insurers' ERM programs. With respect to these conceptual arguments, we hypothesize:

**Hypothesis 2A (H2A):** ERM facilitates economies of scope.

Two business lines or products are considered to be related if their production processes are similar (Hill, Hitt, and Hoskisson, 1992).[7] The economic benefits of related diversification have been argued to stem from cost economies of scope, i.e., which are predicted to be stronger for related production processes than for unrelated processes. Economic benefits also can be realized from unrelated diversification to the extent that it leads to efficient internal governance mechanisms (Williamson, 1985). The main argument is that the headquarters of an unrelated firm can more directly control inefficient expenditures and discipline divisional managers who fail to maximize profits than could outside investors if these divisions were stand-alone firms (Hill, Hitt, and Hoskisson, 1992). Nevertheless, because of the expected stronger effects of unrelated diversification on cost scope economies, we formulate the following hypothesis:

[7] A broad literature exists on the advantages and disadvantages of related versus unrelated diversification strategies (e.g., Markides and Williamson, 1994; Miller, 2004; Keil et al., 2008).

**Hypothesis 2B (H2B):** ERM's positive impact on scope economies are less pronounced for firms with an unrelated diversification strategy than for firms with a related diversification strategy.

## 3. Estimation Approach, Data, and Variable Development

This section gives a brief overview of efficiency estimation methods and provides our estimation strategy. It also describes our data base and discusses the measurement of outputs, inputs, and prices used in estimating efficiency. The section concludes by presenting our ERM indicators and control variables.

### *3.1. Estimating Efficiency Using Data Envelopment Analysis (DEA)*

To measure economies of scale and scope, we use data envelopment analysis (DEA) (e.g., Cooper, Seiford, and Tone, 2000).[8] DEA is used to estimate efficient production, cost, revenue, and profit frontiers, providing measures of technical, cost, revenue, and profit efficiency for each firm in the sample. This technique enables decomposing overall efficiency and estimating scale and scope economies, where efficiency is measured for each firm in an industry relative to "best practice" efficient frontiers consisting of dominant firms in the industry.[9]

We adopt the DEA approach because it has attractive statistical properties. First, as shown in Banker (1993), DEA is equivalent to a maximum likelihood estimation. Second, DEA estimators are consistent and converge faster than estimators from other frontier methods (Grosskopf, 1996). Third, DEA estimators are also unbiased if we assume that there is no underlying model or reference technology. If one believes in an underlying model, then the problem of bias in DEA estimates arises, but this bias deceases with sample size (Kittelsen, 1999). Fourth, Banker and Natarajan (2008) show that DEA is a non-parametric stochastic frontier estimation methodology that performs better than parametric procedures in the

[8] The alternative to DEA is stochastic frontier analysis (SFA), which requires the specification of a functional form for the cost and revenue frontiers and distributional assumptions about the regression error terms. Cummins and Zi (1998) and Elling and Luhnen (2010) find that parametric analysis and DEA generally produce consistent results.
[9] The efficiency scores vary between 0 and 1, with efficiencies equal to 1 for fully efficient firms and efficiencies between 0 and 1 for inefficient firms.

estimation of individual decision making unit productivity. Finally, Banker and Natarajan (2008) also show that the two-stage approach utilized here (DEA followed by regressions) is statistically consistent in a composed error framework, i.e., that DEA (like SFA) incorporates random errors.

In our study, we estimate six types of frontiers: production frontiers with constant returns to scale (CRS) (*technical efficiency*), production frontiers with variable returns to scale (VRS) (*pure technical efficiency*), cost frontiers, revenue frontiers, profit frontiers, and the distance between the VRS frontier and the CRS frontier (*scale efficiency*). All six types of efficiency are estimated for each individual firm in each year of the sample period.

For a given firm, *cost efficiency* is defined as the ratio of the costs of a fully efficient firm with the same output quantities and input prices to the given firm's actual costs. Firms are cost efficient when they are operating on the efficient cost frontier, that means that they have adopted the best practice technology (are technically efficient) and have chosen the optimal mix of inputs (are allocatively efficient (AE)) (Cummins and Weiss, 2013).[10] *Revenue efficiency* is the ratio of the revenues of a firm to the revenues of a fully efficient firm, i.e., firms operating on the efficient revenue frontier, with the same input vector and output prices. Except for profit efficiency, efficiency scores vary between 0 and 1, with efficiencies equal to 1 for fully efficient firms and efficiencies between 0 and 1 for inefficient firms.

Finally, *profit efficiency* represents the net effects of cost and revenue efficiency, and appears to be a relevant metric due to the fact that profit maximization is the ultimate goal of the firm. However, estimating cost and revenue efficiency remains relevant to identify the sources of inefficiency and test separately for cost and revenue economies of scale and scope. The DEA profit efficiency model we utilize is from Cooper, Seiford, and Tone (2000). It actually gives a measure of profit *inefficiency*, defined as maximum potential profits minus actual profits, divided

[10] Cost efficiency based on the CRS technology is the product of pure technical, scale, and allocative efficiency.

by the sum of total costs and revenues (Cooper, Seiford, and Tone, 2000; Cummins and Weiss, 2013).[11] Therefore, profit inefficiency is not constrained to be less than or equal to one.

***3.2 Estimation Strategy***

The analysis is based on the two-step methodology proposed in Banker and Natarajan (2008) and Cummins et al. (2010). In the first step, as discussed above, we estimate firms' technical, pure technical, cost, revenue, scale, and profit efficiency using DEA. In the second step, we then regress firms' efficiency scores on firm characteristics to test for economies of scale and scope and the moderating effect of ERM. More precisely, we use the following regression specification to analyze economies of scale and ERM, where the unit of observation is the firm-year:

$$Efficiency = \alpha + \beta_1 Size + \beta_2 ERM + \beta_3 Size \times ERM + \beta_4' Controls + \varepsilon \qquad (1)$$

where $Size$ is a measure of firm size, $ERM$ is a measure of the quality of the firm's ERM progam, and $Controls$ is a vector of control variables. We estimate the model separately for each type of efficiency score as the dependent variable. We expect to find that the coefficient of the interaction term between firm *Size* and an *ERM* indicator is positive and significant, indicating that ERM helps firms achieve economies of scale.

Next, we sort the firms by size and split the sample into subsamples. We then separately examine the relationship between economies of scope and ERM for the different size groups. The baseline regression specification is as follows:

$$Efficiency = \alpha + \beta_1 Diversification + \beta_2 ERM + \beta_3 Diversification \times ERM + \beta_4' Controls + \varepsilon \qquad (2)$$

The model is estimated for various measures of product diversification that capture the scope of a firm's operations, including the measure of unrelated diversification from Berry-Stölzle et al.

[11] Actual or optimal profits are not used as the denominator because actual profits can be negative and optimal profits can be zero. See Cummins and Weiss (2013). The use of the sum of costs and revenues as the denominator is somewhat arbitrary but has become the standard approach in the DEA profit efficiency literature.

(2012). We expect the coefficients of the interaction terms between standard measures of product diversification and the ERM indicator to be positive and significant, indicating that ERM helps firms achieve economies of scope. We also expect that the coefficient of the interaction term between a measure of unrelated diversification and ERM to be insignificant because such firms should benefit from natural hedges regardless of whether a firm has an ERM program.

To clarify, we do not have a prior on the coefficient of the diversification measures. There are costs associated with diversification and those costs may outweigh the benefits of scope economies. There is a substantial body of literature that diversification does not necessarily enhance firm performance (e.g., Acharya, Hassan, and Saunders, 2006). Our argument focuses on the moderating effect ERM has on the diversification-efficiency relationship. For diversified firms as well as for firm operating at a larger scale, we expect to find that ERM has a positive effect on measures of cost, revenue, and profit efficiency, and we interpret such a finding as evidence that ERM helps firms achieve economies of scale and scope.

### *3.3. Determinants of Insurer Efficiency*

To examine whether ERM facilitates economies of scale and scope, we use two measures of ERM quality. Both measures are based on our suvey data on German P-L insurers, discussed in more detail below. The first measure captures the average quality of the basic components of an ERM system. More precisely, the *Average Risk Management Quality Index* for firm *k* in year *t* is defined as:

$$ERMindex_{k,t} = \frac{1}{7}\sum_{j=1}^{7} Comp_{k,j,t} \qquad (3)$$

where $Comp_{k,j,t}$, $j = 1,...,7$ denotes the quality of the following seven ERM components: (1) identifying the firm's risk appetite, (2) risk aggregation, (3) risk capital allocation, (4) using risk-adjusted performance measures, (5) linking management incentives to risk, (6) risk management culture, and (7) audit. The quality of each ERM component is measured on a scale from zero to one based on individual survey items (the details are provided in the Appendix). Thus, the *ERMindex* defined in equation (3) takes on values between zero and one, with higher values indicating a higher average quality.

The second measure of ERM quality captures the main idea of ERM, namely, the degree to which a firm actually has a holistic approach towards risk management. Since, a risk management program is only as strong as its weakest component, having a high *average* quality across fragmented risk management activities may not be the best approach. Thus, we calculate an entropy measure of a firm's degree of diversification across the different ERM components (see Palepu, 1985). The measure takes on higher values for firms that have a balanced risk management approach; the measure takes on lower values for firms that just focus on improving some ERM components while ignoring the weakest one.[12] Specifically, we calculate the *Holistic Risk Management Index* of firm *k* in year *t* as:

$$ERMentropy_{k,t} = \sum_{j=1}^{7}\left(\frac{Comp_{k,j,t}}{\sum_j Comp_{k,j,t}}\ln\left(\frac{\sum_j Comp_{k,j,t}}{Comp_{k,j,t}}\right)\right) \tag{4}$$

where $Comp_{k,j,t}$ denotes ERM component $j = 1,\ldots,7$.

To provide evidence on the effects of ERM on economies of scale and scope while controlling for other firm characteristics that may influence efficiency, we conduct multiple regression analysis with efficiency scores as dependent variables. To test our economies of scale hypothesis (H1), we include interaction terms between the two ERM indicators and *Size*, where

[12] We use the entropy measure and not a Herfindahl index based measure of diversification for conceptual reasons. At the heart of ERM is the idea that a risk management program is only as strong as its weakest part. Therefore, ERM focuses on a balanced, enterprise-wide approach to risk management. The entropy measure is better in capturing this basic concept than a Herfindahl index measure of diversification as the following example highlights: Firm A and B both have three ERM components. The quality of the three components for Firm A is 0.2, 0.38 and 0.42, respectively. The quality of Firm B's ERM components is 0.215, 0.33 and 0.435, respectively. Firm B's weakest component has a higher quality than Firm A's weakest component (0.215 > 0.2). The entropy measure we use in this study assigns Firm B a higher value than Firm A. However, a Herfindahl index (HHI) based measure of diversification (1-HHI) would assign Firm A a higher value than Firm B.

*Size* is defined as the natural logarithm of total assets. A positive coefficient on the interaction term variables would imply that ERM helps firms to achieve economies of scale.

To test our economies of scope hypotheses (H2A and H2B), we include interaction terms between the two ERM indicators and four standard measures of product diversification used in the literature on insurer diversification (see, e.g., Liebenberg and Sommer, 2008; Berry-Stölzle et al., 2012). Our first measure is a total diversification measure (*Total*) is defined as 1 minus the Herfindahl index of premiums written by line. Because the Herfindahl index reflects concentration rather than diversification, firms with higher values of *Total* are more diversified. Our second measure is a dummy variable which is 1 if the insurer operates in more than 3 business lines (*Multiline*), 0 otherwise. To control for industry-diversification, we include a third measure which is a dummy variable equal to 1 if the insurer also operates in the life insurance business (*Life*), 0 otherwise.

Our fourth measure of diversification is an unrelated diversification score (*Unrelated*), which is 1 minus the weighted average relatedness of the insurer's underwriting portfolio. The measure is derived in two steps. First, we follow Bryce and Winter's (2009) general relatedness index approach and compute relatedness scores for each pair of business lines. Then, we use these scores to compute unrelated diversification measures for the underwriting portfolios of the insurers in our sample.[13] A detailed description of this approach can be found in Berry-Stölzle et al. (2012). A positive coefficient on the interaction term variables would imply that ERM helps firms to achieve economies of scope. Summary statistics on the relatedness of the principal insurance lines of business in Germany are presented in Appendix Table A.1.

Other control variables in the regressions include important firm characteristics such as

[13] Firms with an unrelated diversification score closer 1 exhibit relatively high levels of unrelated diversification; whereas firms with an unrelated diversification score closer 0 only diversify in related business lines or do hardly diversify at all. Undiversified firms, by definition, have an unrelated diversification score of 0.

distribution system, organizational form, leverage, reinsurance, and the riskiness of the investment portfolio.[14] Line of business controls and year dummy variables are also included in the regressions but are not shown in the regression tables to conserve space. The line of business control variables measure the fraction of premiums written in each line of business and, hence, capture differences between business lines including differences in the loss distributions and volatilities of the business lines.[15]

### *3.4. Data Sources and the Sample*

The empirical analysis is based on company-level data for P-L insurance companies regulated by Germany's Federal Financial Supervisory Authority (*BaFin*).[16] We have two data sources: a detailed survey of how companies implement risk management and the KIVI GmbH financial statement database.[17] The KIVI database includes financial statements of all German P-L insurance companies with premiums written in excess of 40 million Euros. Thus, we used 40 million Euros in premiums written as the threshold and included all P-L insurers exceeding this threshold in 2009 in the survey. There are 113 such insurers in Germany, and 95 of them participated in the survey. Hence, the survey response rate is 84% and the participating insurers have a combined market share of over 90% of the German P-L insurance market.

The survey was based on an extensive questionnaire designed and administered by the authors of this paper. The survey included 86 questions on 21 aspects of ERM and was conducted as a series of standardized telephone interviews in the first half of 2009. The

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[14] In addition to stock and mutual insurers, there is a third organizational form in the German market: public insurance companies. Public insurance companies are non-profit organizations under public law; they are owned by state or local authorities. Historically, the function of public insurers was to serve a certain region by providing reliable insurance coverage, and until today, most public insurers restrict their business to "their" region (for more details, see Berry-Stölzle, Lai, and Wende, 2010).

[15] The lines-of-business included in the calculation are: personal accident, personal liability, total auto, legal expenses, fire, homeowners' personal property, residential and commercial building damage, and transportation. The omitted category is the aggregate of credit insurance and other miscellaneous business.

[16] BaFin is the abbreviation for the authority's German name, Bundesanstalt für Finanzdienstleistungsaufsicht, http://www.bafin.de/.

[17] KIVI GmbH is the Cologne Institute of Insurance Information and Economic Services, an economic research firm in Cologne, Germany affiliated with the University of Cologne (http://www.kivi-online.de/).

questionnaire specifically asks whether a company has an ERM program and when the company adopted it. In addition, the questionnaire includes detailed questions about specific ERM activities and a company's risk management process in general. For each risk management activity, the questionnaire also identifies the point in time when the activity was implemented.

We merge the survey data with financial statement data from the KIVI database for the years 1999 to 2009. Due to mergers, acquisitions, and legal restructurings, not all firms included in the survey have a consistent financial statement record for the entire 1999 to 2009 period. To ensure that a firm's performance measures can be compared over time we start with the set of survey respondents in 2009 and work backwards through the years. We drop firm-year observations prior to any mergers, acquisitions, or legal restructurings. In addition, we exclude firms that report negative direct premiums written, premiums earned, total assets, policyholders surplus, or investment positions and eliminate observations if the return on equity (ROE) has a value above one or below minus one (Berger and Ofek, 1995).[18] The resulting unbalanced panel data set consists of 926 firm-year observations.

### 3.5. Outputs, Inputs, and Prices

#### 3.5.1. Output quantities and prices

We follow most of the recent insurance efficiency literature in adopting a modified value-added approach to measure property-liability insurers' outputs (Cummins et al., 2010; Cummins and Weiss, 2013). Property-liability insurers provide three principal services: (1) real services related to insured losses, (2) risk-pooling and risk-bearing, and (3) intermediation. We use the present value of losses incurred net of reinsurance in short-tail business lines and the present value of losses incurred net of reinsurance in long-tail business lines to proxy for the amount of

[18] We also exclude outliers by eliminating companies with no equity capital, reducing the sample by only two observations. To minimize the impact of outliers, we winsorize outputs, inputs, and prices (except for the input price "operating expense ratio," which is the labor cost index for insurance business divided by the deflator, and "average technical provisions," which is the two to three-year German treasury bill rate) at the 1st and 99th percentiles.

risk-pooling and real insurance services provided by an insurance company.[19] Using two separate output variables for short-tail and long-tail lines controls for differences in insurers' business mix.[20] We select the average of beginning and end-of-year total invested assets as a third output variable to proxy for the amount of financial intermediation. All three outputs are deflated to the base year 2008 using the German Consumer Price Index (CPI) from Statistisches Bundesamt.[21]

The price of each insurance output is the difference between real premiums earned and the real present value of losses incurred net of reinsurance for the output divided by the real present value of losses incurred net of reinsurance. The price for the financial intermediation output is the realized investment income return for the year.[22]

*3.5.2. Input quantities and prices*

We classify insurance inputs into three different groups: labor and business services, equity capital, and debt capital. We use an insurance company's operating expenses including commissions and salaries to proxy for the amount of labor and business services employed in the production process. The input price is the Statistisches Bundesamt (SB) index for insurance business services (the BI index), which measures average expenses for insurance business

[19] The German accounting standard does not require insurers to report losses incurred net of reinsurance by line of business. German insurers only report gross losses incurred by business line. We, hence, approximate losses incurred net of reinsurance using the following steps: First, we add gross losses incurred from liability insurance and auto liability to get gross losses incurred in long-tail lines. Second, we add gross losses incurred from all other lines to get gross losses incurred from short-tail lines. Third, we multiply gross losses incurred in short-tail and long-tail lines with the ratio of total losses incurred net of reinsurance to total gross losses incurred. Fourth, we compute the present value of the approximated losses incurred net of reinsurance. Loss payouts for each line are calculated with data from the German insurance authority (*BaFin*) using the chain-ladder method. Losses are discounted using German Treasury yield curves from the Deutsche Bundesbank. This four step approximation is accurate if the fraction of reinsured losses is the same for long-tail lines, short-tail lines and the total insurance portfolio. We examine this assumption with aggregate industry-level data and find that the fraction of reinsured losses for long-tail and short-tail lines is close to the fraction of total reinsured losses for all sample years.

[20] In our study, we follow the business lines classification suggested by the Gesamtverband der Deutschen Versicherungswirtschaft (GDV), the German Insurers Association in GDV (2005). Long-tail lines include liability insurance and auto liability. In our dataset, we cannot distinguish personal lines from commercial lines since the German accounting standards do not require that insurance companies make this distinction.

[21] Statistisches Bundesamt or Destatis is the Federal Statistical Office of Germany, charged with collecting and analyzing statistical information on the economy, society, and the environment (https://www.destatis.de/).

[22] The rate of return on the realized investment income is calculated by dividing the realized investment income for the year with the average of beginning and end-of-year total invested assets.

services including wages for commissions and salaries. Following Cummins et al. (2010), we define the quantity of labor and business services as total labor and business services expenditures divided by the BI index. We use the book value of surplus to proxy for the amount of equity capital employed by the insurer. Following Cummins, Weiss, and Zi (1999), we use the insurer's expected return on equity as the price measure for the equity capital input.[23] Finally, we use the technical provisions net of reinsurance to proxy for the quantity of debt capital,[24] and the two to three-year German Treasury Bill rates as the price for debt capital. Monetary input values are deflated by the 2008 German CPI wherever appropriate.

**4. Results**

The non-efficiency variables used in the study are defined in Table 1, and summary statistics on these variables are presented in Table 2. The table shows means and standard deviations for the full sample and also for diversified firms and specialists categorized according to each of our four diversification measures. The table also reports the results of t-tests of significance for differences between means of the variables for diversified firms and specialists.

As an example of interpreting the table, consider the classification of firms using the *Multiline* variable. A firm is categorized as diversified based on the *Multiline* variable if the number of business lines for which it has positive direct premiums written is greater than 3, and otherwise classified as a specialist. Using the *Multilne* definition, 450 firms are classified as diverrsified and 163 are classified as specialists. Diversified firms have significantly higher average outputs in both short-tail and long-tail lines than specialists. E.g., firms classified as diversified according to the *Multiline* definition have average long-tail output of $198.9 million,

[23] We calculate the expected return on equity as the predicted value of the ratio of net income before taxes to book value surplus. The prediction is based on a pooled cross-sectional time-series regression of the return on equity variable on the following independent variables capturing insurer characteristics: The percentage of stocks in the investment portfolio, the percentage of bonds in the investment portfolio, the insurance output quantities, the premiums-to-surplus ratio, the intermediate-term government bond yield, and year dummies.
[24] Technical provisions net of reinsurance is the terminology used in Germany for insurance reserve liabilities.

whereas average long-tail output for specialized firms is only $22.0 million.

Diversified firms also have higher short-tail and long-tail output as well as higher average total investments than specialists according to all four definitions used to classify firms as diversified vs. specialized. Diversified firms are also consistently larger than specialists under all four classifications in terms of operating expenses, equity capital, and technical provisions. Diversified firms are also more likely to be mutuals than specialists under all four definions of diversified. Specialist firms buy significantly more reinsurance as a percentage of premiums than diversified firms, as expected if smaller firms need more reinsurance because their policyholder pools are less diversified.

Summary statistics on the estimated frontier efficiencies are shown in Table 3. As in Table 2, results are shown for the full sample and for diversified firms and specialists categorized according to our four diversification measures. According to all four definitions of diversification, diversified firms have significantly higher average pure technical efficiencies than specialists, as expected if larger firms are more successful in optimizing the use of technology than smaller firms due to their size advantage. Specialists are more cost efficient than diversified firms when diversification is defined using the *Multiline* and *Life* definitions but not when the other two definitions are used. However, specialists are significantly more revenue efficient and significantly less profit inefficient than diversified firms under all four categorizations of diversification. This provides some preliminary evidence that strategic focus may be a superior strategy to conglomeration for insurers, consistent with the Cummins et al. (2010) findings for U.S. P-L insurers.

Specialist firms have significantly higher scale efficiency than diversified firms according to all four definitions of diversification, as expected if larger firms are more likely to encounter scale diseconomies. This inference is confirmed by the returns to scale results, which show that specialists are significantly more likely to be in the increasing returns to scale (IRS) region of the cost curve and significantly less likely to realize decreasing returns to scale (DRS). A higher proportion of specialist firms also operate with constant returns to scale (CRS), and these differences are statistically significant for the *Multiline* and *Life* definitions of diversification.

To test our hypothesis H1, we conduct multiple regression analysis with efficiency scores as dependent variables and provide evidence on the relationship between ERM and efficiency. We are especially interested in the interaction term between ERM and firm size. Table 4 presents our economies of scale results. In the cost and revenue regressions for VRS efficiency the *ERM-index* variable is negative and significant indicating that ERM adopted firms are inefficient in terms of cost and revenue efficiency. This might be due to the fact that ERM is a cost-intensive investment which reduces efficiency. We also conduct regressions where we purge the effects of scale economies from the cost and revenue efficiency scores by dividing CRS cost and revenue efficiency by scale efficiency. The purged regressions are labelled *CEScope* and *REScope* in Table 4. However, for *CEScope* and *REScope* we do not observe any significant effects.

The net effects of diversification on insurer performance are shown in the profit inefficiency regression in Table 4 (labelled as *PI*). For profit inefficiency, we observe a positive and significant effect implying that firms that adapt ERM are profit inefficient. This also holds for scale efficiency. The relationship between ERM-index and scale efficiency is negative and significant. However, the interaction term between *ERM-index* and *Size* becomes positive and significant for VRS cost and revenue efficiency revealing that larger firms that have adopted ERM are cost and revenue efficient. This positive and significant result can also be detected for profit and scale efficiency. In Table 5 we interchange *ERM-index* with *ERM-entropy* and find that our results are stable irrespective of the chosen ERM measure. In summary, we interpret these findings as evidence that ERM facilitates economies of scale.

Tables 6 to 8 (10 to 12) report the efficiency regressions with respect to our hypothesis H2A. We describe the results with a focus on the interaction terms. A positive and significant coefficient on the interaction terms would imply that diversified insurers that have adopted ERM are more efficient than specialists that have adopted ERM, with opposite prediction for profit inefficiency regression. Table 6 presents the insurer efficiency regressions with *ERM-index* and *Total* as independent variables. The coefficient of *Total* in the cost efficiency regressions is negative and significant for CRS and VRS efficiency. In the revenue efficiency regressions *Total* is negative and significant for CRS efficiency but insignificant for VRS efficiency. Hence, when scale efficiency is corrected by estimating the frontier under CRS, the diversified insurers are less significant in terms of cost and revenue efficiency than specialists. In the purged regressions (*CEScope* and *REScope*) the sign of the diversification variable is negative and significant for cost and revenue efficiency and are consistent with CRS cost and revenue efficiency results. However; the coefficient of the interaction term between *ERM-index* and *Total* becomes positive and significant for revenue efficiency (CRS revenue efficiency and *REScope*). For CRS and VRS cost efficiency the sign becomes insignificant, only for *CEScope* the sign remains negative and significant. We observe the same patterns irrespective of which diversification variable - *Multiline* and *Life* (see Tables 7 and 8) - we use.

The significant and negative coefficient on the interaction term in the profit inefficiency regression reveals that diversified insurers with ERM engagement are more profit efficient than specialists, hence diversified insurers that adapt ERM have a net efficiency advantage over specialists that adapt ERM. Table 7 illustrates this effect more clearly. While the coefficient on the diversification variable *Multiline* is positive and significant, implying that diversified insurers are profit inefficient relative to specialists, the ERM interaction term becomes negative and significant revealing that ERM has a positive effect on profit efficiency for diversified insurers.

Combining these results, we interpret these findings as evidence that ERM facilitates economies of scope.

We next discuss the results with respect to our hypothesis H2B. Our results are shown in Table 9. While the coefficient of the unrelated diversification variable *Unrelated* is significantly positively related to technical and pure technical efficiency, the interaction terms become negative and significant. This also holds for the cost efficiency regressions. In all regressions (CRS, *CEScope* and VRS) the coefficients of *Unrelated* are positive and significant, however, the interaction terms turn their signs and the previously positive relationships become negative and remain significant at 1% level. For revenue efficiency the coefficients of the interaction terms are also negative and significant. The net effects are shown in the profit inefficiency regressions. The coefficient of the interaction term is positive and significant confirming our hypothesis that ERM's positive impact on scope economies are less pronounced for firms with an unrelated diversification strategy than for firms with a related diversification strategy. Even if we interchange *ERM-index* with *ERM-entropy* (see Table 13), our results remain qualitatively the same.

**5. Conclusion**

ERM is the approach of managing all risks faced by an enterprise in an integrated, holistic fashion. The goal of this research is to shed some light on the fundamental question *how* ERM can create value. Furthermore, this research contributes to the literature on technological progress and the optimal scale and scope of firms. ERM can be viewed as a new technology that became available during the past fifteen years, and ERM may have increased the optimal scale of firms as well as their optimal degree of diversification. Hence, we focus on the relationship between ERM adoption and economies of scale and scope. Detailed survey data of German property-liability insurance companies allows us to construct continuous measures of ERM quality. Our results reveal that ERM positively moderates the relationship between the operating scale of a firm and measures of its cost, revenue and profit efficiency, and find the same moderating effect of ERM for firm's scope of operation. Overall, we provide evidence that ERM can help firms achieve economies of scale and scope and that this mechanism is one answer to the question *how* ERM creates value.

**Appendix: ERM Components from Survey**

The average ERM quality index as well as the ERM entropy measure are based on the following seven components of an ERM system:

*1. Identification of firm's risk appetite = (targetrating + riskstrategy) / 2*

*targetrating* = indicator variable equal to 1 if company determines how much risk they are willing to assume (e.g., in the form of an acceptable ruin probability or a target rating), 0 otherwise.
*riskstrategy* = indicator variable equal to 1 if the company has a risk strategy (in the context of the overall corporate strategy), which defines how risks should be handled, 0 otherwise.

*2. Risk aggregation = (investrisk + liquidrisk + underwrisk + concentrisk + catastrisk + operatrisk + stratrisk + reputrisk + corrmodel + opulas) / 10*

*investrisk* = indicator variable equal to 1 if the company's aggregate risk model includes investment risk, 0 otherwise.
*liquidrisk* = indicator variable equal to 1 if the company's aggregate risk model includes liquidity risk, 0 otherwise.
*underwrisk* = indicator variable equal to 1 if the company's aggregate risk model includes underwriting risks in different business lines, 0 otherwise.
*concentrisk* = indicator variable equal to 1 if the company's aggregate risk model includes concentration risk, 0 otherwise.
*catastrisk* = indicator variable equal to 1 if the company's aggregate risk model includes catastrophe claim risk, 0 otherwise.
*operatrisk* = indicator variable equal to 1 if the company's aggregate risk model includes operational risk, 0 otherwise.
*stratrisk* = indicator variable equal to 1 if the company's aggregate risk model includes strategic risk, 0 otherwise.
*reputrisk* = indicator variable equal to 1 if the company's aggregate risk model includes reputation risk, 0 otherwise.
*corrmodel* = indicator variable equal to 1 if company models correlations between individual risks in the risk aggregation process, 0 otherwise.
*copulas* = indicator variable equal to 1 if company uses copulas (non-linear correlations) to model dependencies in the risk aggregation process, 0 otherwise.

*3. Risk capital allocation = (units + risktypes + regions + products + investrisk + liquidrisk + underwrisk + concentrisk + catastrisk + operatrisk + stratrisk + reputrisk + diversification) / 13*

*units* = indicator variable equal to 1 if company allocates risk capital to more than one business unit/department, 0 otherwise.
*risktypes* = indicator variable equal to 1 if company allocates risk capital to more than one type of risk, 0 otherwise.
*regions* = indicator variable equal to 1 if company allocates risk capital to more than one region, 0 otherwise.
*products* = indicator variable equal to 1 if company allocates risk capital to more than one product, 0 otherwise.

*investrisk* = indicator variable equal to 1 if company considers investment risk in the capital allocation process, 0 otherwise.
*liquidrisk* = indicator variable equal to 1 if company considers liquidity risk in the capital allocation process, 0 otherwise.
*underwrisk* = indicator variable equal to 1 if company considers underwriting risks in different business lines in the capital allocation process, 0 otherwise.
*concentrisk* = indicator variable equal to 1 if company considers concentration risk in the capital allocation process, 0 otherwise.
*catastrisk* = indicator variable equal to 1 if company considers catastrophe claim risk in the capital allocation process, 0 otherwise.
*operatrisk* = indicator variable equal to 1 if company considers operational risk in the capital allocation process, 0 otherwise.
*stratrisk* = indicator variable equal to 1 if company considers strategic risk in the capital allocation process, 0 otherwise.
*reputrisk* = indicator variable equal to 1 if company considers reputation risk in the capital allocation process, 0 otherwise.
*diversification* = indicator variable equal to 1 if company's capital allocation procedure takes portfolio or diversification effects into account, 0 otherwise.

*4. Performance measurement = (measure + divisions + perfimpact) / 3*

*measure* = indicator variable equal to 1 if company measures business success with one or several (performance-)measure(s), 0 otherwise.
*divisions* = indicator variable equal to 1 if company uses performance measurement for divisions/departments within the company, 0 otherwise.
*perfimpact* measures to what degree assumed risks influence measured performance in the company. The original survey response is on a seven-point Likert scale (from 1 = no influence to 7 = very strong influence); the *perfimpact* variable is standardized to be 1 for the scale value 7.

*5. Incentive contracts = (compensation + compimpact) / 2*

*compensation* = indicator variable equal to 1 if manager compensation depends on performance measures, 0 otherwise.
*compimpact* measures to what degree assumed risks have an impact on manager compensation. The original survey response is on a seven-point Likert scale (from 1 = no impact to 7 = very strong impact); the *compimpact* variable is standardized to be 1 for the scale value 7.

*6. Risk management culture = (employees + training + intranet + system + suggestion + decision + strategy) / 7*

*employees* measures to what degree "employees are familiar with the risk management concept." The original survey response is on a seven-point Likert scale (from 1 = no impact to 7 = very strong impact); the *employees* variable is standardized to be 1 for the scale value 7.
*training* measures to what degree "in-house training addresses risk management." The original survey response is on a seven-point Likert scale (from 1 = no impact to 7 = very strong impact); the *training* variable is standardized to be 1 for the scale value 7.
*intranet* measures to what degree an intranet platform is used to support risk management. The original survey response is on a seven-point Likert scale (from 1 = no impact to 7 = very strong impact); the *intranet* variable is standardized to be 1 for the scale value 7.
*system* measures to what degree "there is an employee suggestion system on risk management." The original survey response is on a seven-point Likert scale (from 1 = no impact to 7 = very strong impact); the *system* variable is standardized to be 1 for the scale value 7.

*suggestion* measures to what degree "employees' suggestions related to risk management are considered." The original survey response is on a seven-point Likert scale (from 1 = no impact to 7 = very strong impact); the *suggestion* variable is standardized to be 1 for the scale value 7.
*decision* measures to what degree "employees consider risks in their decisions." The original survey response is on a seven-point Likert scale (from 1 = no impact to 7 = very strong impact); the *decision* variable is standardized to be 1 for the scale value 7.
*strategy* = indicator variable equal to 1 if company has a strategy for risk management culture, 0 otherwise.

*7. Audit = (independent + right + legal + corporate + quality + data + efficiency) / 7*

*independent* = indicator variable equal to 1 if company's risk management process is evaluated by an independent department (e.g. internal audit), 0 otherwise.
*right* = indicator variable equal to 1 if company's internal audit function has the unrestricted right to conduct evaluations, 0 otherwise.
*legal* = indicator variable equal to 1 if company evaluates the compliance with legal and regulatory requirements, 0 otherwise.
*corporate* = indicator variable equal to 1 if company evaluates the compliance with corporate guidelines and policies, 0 otherwise.
*quality* = indicator variable equal to 1 if company evaluates the quality of the risk management process, 0 otherwise.
*data* = indicator variable equal to 1 if company evaluates the relevance and quality of the data used in the risk management process, 0 otherwise.
*efficiency* = indicator variable equal to 1 if company evaluates the efficiency of the risk management process, 0 otherwise.

**Appendix: Table A 1. Relatedness Scores**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) Personal accident | 1.000 | | | | | | | | | |
| (2) Personal liability | 0.876 | 1.000 | | | | | | | | |
| (3) Total auto | 0.813 | 0.849 | 1.000 | | | | | | | |
| (4) Fire | 0.388 | 0.585 | 0.523 | 1.000 | | | | | | |
| (5) Homeowners' personal property | 0.737 | 0.819 | 0.655 | 0.658 | 1.000 | | | | | |
| (6) Residential and commercial building damage | 0.627 | 0.749 | 0.771 | 0.807 | 0.895 | 1.000 | | | | |
| (7) Transportation | 0.379 | 0.558 | 0.553 | 0.361 | 0.312 | 0.315 | 1.000 | | | |
| (8) Legal expenses | 0.279 | 0.387 | 0.387 | 0.213 | 0.425 | 0.305 | 0.160 | 1.000 | | |
| (9) Credit | 0.123 | 0.166 | 0.161 | 0.069 | 0.093 | 0.145 | 0.075 | 0.123 | 1.000 | |
| (10) Rest | 0.587 | 0.737 | 0.725 | 0.428 | 0.497 | 0.613 | 0.513 | 0.220 | 0.165 | 1.000 |

*Notes:* The relatedness of business line with itself is 1 by definition. The relatedness of line *i* with line *j* is the same as the relatedness of line *j* with line *i*.

## References


Acharya, V.V., I. Hasan, and A. Saunders, 2006, "Should Banks Be Diversified? Evidence from Individual Bank Loan Portfolios," *Journal of Business* 79: 1355-1412/

Ai, J., V.L. Bajelsmit, and T. Wang, 2014, Enterprise Risk Management and Diversification Effects for Property and Casualty Insurance Companies, working paper, University of Hawaii at Manoa, Honolulu, HI.

Ai, J., P.L. Brockett, W.W. Cooper, and L.L. Golden, 2012, Enterprise Risk Management through Strategic Allocation of Capital, *Journal of Risk and Insurance* 79(1): 29-56.

Ai, J., H. Chen, and Y. Zhao, 2014, Does ERM Improve Firm Value? Evidence from Listed Chinese Nonfinancial SOEs, Working Paper, University of Hawaii at Manoa, Honolulu, HI.

Altuntas, M., T. R. Berry-Stölzle, and R. E. Hoyt, 2011, Implementation of Enterprise Risk Management: Evidence from the German Property-Liability Insurance Industry, *The Geneva Papers on Risk and Insurance – Issues and Practice* 36: 414-439.

Altuntas, M., T. R. Berry-Stölzle, and R. E. Hoyt, 2014, Dynamic Determinants of Enterprise Risk Management Adoption: Evidence from the Property-Liability Insurance Industry, Working paper, University of Georgia, Athens, GA.

Banker, R.D., 1993, Maximum Likelihood, Consistency, and Data Envelopment Analysis: A Statistical Foundation, *Management Science* 39: 1265-1273.

Banker, R. D. and R. Natarajan, 2008, Evaluating Contextual Variables Affecting Productivity Using Data Envelopment Analysis, *Operations Research* 56: 48-58.

Beasley, M. S., R. Clune, and D. R. Hermanson, 2005, Enterprise Risk Management: An Empirical Analysis of Factors Associated with the Extent of Implementation, *Journal of Accounting and Public Policy* 24: 521-531.

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

Berger, P.G. and E. Ofek, 1995, Diversifications' Effect on Firm Value, *Journal of Financial Economics* 37: 39-65.

Berry-Stölzle, T.R., G.C. Lai, and S. Wende, 2010, The Effect of Regulation on Comparative Ad-Vantages of Different Organizational Forms: Evidence From the German Property-Liability Insurance Industry, Working Paper, University of Georgia, Athens, GA.

Berry-Stölzle, T.R., A.P. Liebenberg, J.S. Ruhland, and D.W. Sommer, 2012, Determinants of Corporate Diversification: Evidence from the Property-Liability Insurance Industry, *Journal of Risk and Insurance* 79(2): 381-413.

Berry-Stölzle, T.R. and J. Xu, 2016, Enterprise Risk Management and the Cost of Capital, *Journal of Risk and Insurance*, Forthcoming.

Bryce, D. J. and S. G. Winter, 2009, A General Interindustry Relatedness Index, *Management Science* 55(9): 1570-1585.

Colquitt, L. L., R. E. Hoyt, and R. B. Lee, 1999, Integrated Risk Management and the Role of the Risk Manager, *Risk Management and Insurance Review* 2: 43-61.

Comment, R. and G.A. Jarrell, 1995, Corporate Focus and Stock Returns, *Journal of Financial Economics* 37: 67-87.

Cooper, W.W., Seiford, L.M., Tone, K., 2000, *Data Envelopment Analysis: A Comprehensive Test with Models, Applications, References, and DEA-Solver Software* (Boston: Kluwer Academic).

COSO (Committee of Sponsoring Organizations of the Treadway Commission), 2004, *COSO Enterprise Risk Management – Integrated Framework* (Durham, NC: American Institute of Certified Public Accountants).

Cummins, J. D., M. A. Weiss, X. Xie, and H. Zi, 2010, Economies of Scope in Financial Services: A DEA Efficiency Analysis of the US Insurance Industry, *Journal of Banking and Finance* 34(7): 1525-1539.

Cummins, J.D. and M.A.Weiss, 2013, Analyzing Firm Performance in the Insurance Industry Using Frontier Efficiency and Productivity Methods, in G. Dionne, ed., *Handbook of Insurance*, 2nd ed. (New York: Springer).

Cummins, J.D., M.A. Weiss, and H. Zi, 1999, Organizational Form and Efficiency: The Coexistence of Stock and Mutual Property-Liability Insurers, *Management Science* 45: 1254-1269.

Cummins, J.D. and H. Zi, 1998, Comparison of Frontier Efficiency Methods: An Application to the Life Insurance Industry, *Journal of Productivity Analysis* 10: 131-152.

Daud, W. N. W., H. Haron, and D.N. Ibrahim, 2011, The Role of Quality Board of Directors in Enterprise Risk Management (ERM) Practices: Evidence from Binary Logistic Regression, *International Journal of Business and Management* 6(12): 205-211.

Eckles, D. L., R. E. Hoyt, and S. M. Miller, 2014, The Impact of Enterprise Risk Management on the Marginal Cost of Reducing Risk: Evidence from the Insurance Industry, *Journal of Banking and Finance* (43): 247-261.

Eling, M. and M. Luhnen, 2010, Efficiency in the International Insurance Industry: A Cross-country Comparison, *Journal of Banking and Finance* 34: 1497-1509.

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

Gatzert, N. and M. Martin, 2015, Determinants and Value of Enterprise Risk Management: Empirical Evidence from the Literature, *Risk Management and Insurance Review* 18: 29-53.

GDV (The German Insurers), 2005, "Discussion Paper on A Standard Modeling Approach Within the Solvency II Framework (Pillar I) – Model Description," (version 1.0), Berlin.

Gertner, R.H., D.S. Scharfstein, and J.C. Stine, 1994, Internal Versus External Capital Markets, *Quarterly Journal of Economics* 109: 1211-1230.

Golshan, N. M. and S.A. Rasid, 2012, Determinants of Enterprise Risk Management Adoption: An Empirical Analysis of Malaysian Public Listed Firms, *International Journal of Social and Human Sciences* 6: 119-126.

Gordon, L., M. Loeb, and C. Tseng, 2009, Enterprise Risk Management and Firm Performance: A Contingency Perspective, *Journal of Accounting and Public Policy* 28(4): 301-327.

Grace, M. F., J. T. Leverty, R. D. Phillips, and P. Shimpi, 2015, The Value of Investing in Enterprise Risk Management, *Journal of Risk and Insurance* 82: 289-316.

Grosskopf, S., 1996, Statistical Inference and Nonparametric Efficiency: A Selective Survey, *Journal of Productivity Analysis* 7: 161-176.

Hann, R. N., M. Ogneva, and O. Ozbas, 2013, Corporate Diversification and the Cost of Capital, *Journal of Finance* 68: 1961-1999.

Hill, C.W.L., M. A. Hitt, and R.E. Hoskisson, 1992, Cooperative versus Competitive Structures in Related and Unrelated Diversified Firms, *Organization Science* 3(4): 501-521.

Hoyt, R. E. and A. P. Liebenberg, 2011, The Value of Enterprise Risk Management, *Journal of Risk and Insurance* 78: 795-822.

Ingham, J. and S. Thompson, 1995, Deregulation, Firm Capabilities, and Diversifying Entry Decisions: The Case of Financial Services, *Review of Economics and Statistics* 77 (1): 177-183.

Jensen, M.C., 1986, Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers, *American Economic Review* 76: 323-329.

Keil, T., M. Maula, H. Schildt, and S.A. Zahra, 2008, The Effect of Governance Modes and Relatedness of External Business Development Activities on Innovative Performance, *Strategic Management Journal* 29: 895-907.

Kittelsen, S., 1999, Monte Carlo Simulations of DEA Efficiency Measures and Hypothesis Tests, Memorandum 09/99, Department of Economics, University of Oslo, Oslo, Norway.

Kleffner, A. E., R. B. Lee, and B. McGannon, 2003, The Effect of Corporate Governance on the Use of Enterprise Risk Management: Evidence from Canada, *Risk Management and Insurance Review* 6: 53-73.

Klein, P.G. and M.R. Saidenberg, 2010, Organizational Structure and the Diversification iscount: Evidence from Commercial Banking, *Journal of Industrial Economics* 58: 127-155.

Kraus, V. and O.M. Lehner, 2012, The Nexus of Enterprise Risk Management and Value Creation: A Systematic Literature Review, *ACRN Journal of Finance and Risk Perspectives* 1 (1): 91-163.

Liebenberg, A. P. and R. E. Hoyt, 2003, Determinants of Enterprise Risk Management: Evidence from the Appointment of Chief Risk Officers, *Risk Management and Insurance Review* 6: 37-52.

Liebenberg, A. P. and D. W. Sommer, 2008, Effects of Corporate Diversification: Evidence From the Property-Liability Insurance Industry, *Journal of Risk and Insurance* 75(4): 893-919.

Markides, C. C., and P. J. Williamson, 1994, Related Diversification, Core Competencies and Corporate Performance, *Strategic Management Journal* 15: 149-165.

Miller, D. J., 2004, Firms' Technological Resources and the Performance Effects of Diversification: A Longitudinal Study, *Strategic Management Journal* 25: 1097-1119.

Nocco, B.W. and R.M. Stulz, 2006, Enterprise Risk Management: Theory and Practice, *Journal of Applied Corporate Finance* 18 (4): 8-20.

Pagach, D., and R. Warr, 2011, The Characteristics of Firms that Hire Chief Risk Officers, *Journal of Risk and Insurance* 78: 185-211.

Palepu, K. 1985, Diversification Strategy, Profit Performance, and the Entropy Measure, *Strategic Management Journal* 6: 239-255.

Panzar, J.C. and R.D. Willig, 1977, Economies of Scale in Multi-output Production, *Quarterly Journal of Economics* 91: 481-493.

Panzar, J.C. and R.D. Willig, 1981, Economies of Scope, *American Economic Review* 71: 268-272.

Santolo, J. and M. Becerra, 2008, Competition from Specialized Firms and the Diversification Performance Linkage, *Journal of Finance* 53 (2): 851-883.

Scharfstein, D.S. and J.C. Stein, 2000, The Dark Side of Internal Capital Markets: Divisional Rent Seeking and Inefficient Investment, *Journal of Finance* 55: 2537-2567.

Stein, J. C., 1997, Internal Capital Markets and the Competition for Corporate Resources, *Journal of Finance* 52(1): 111-133.

Stulz, R.M., 1996, Rethinking Risk Management, *Journal of Applied Corporate Finance* 9: 8-24.

Teece, D. J., 1980, Economies of Scope and the Scope of the Enterprise, *Journal of Economic Behavior and Organization* 1: 223-247.

Williamson, O. E., 1985, *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting* (New York: Free Press).

**Table 1. Variable Definitions**

| Variables | Definitions |
|---|---|
| *Output* | |
| Long-tail business | Losses incurred in Mill.€ for long-tail business*present value factor for long-tail business*net of reinsurance approximation for long-tail business. |
| Short-tail business | Losses incurred in Mill.€ for short-tail business*present value factor for short-tail business*net of reinsurance approximation for short-tail business. |
| Average of total investments | Average of beginning and end-of-year total investment in Mill.€. |
| *Output prices* | |
| Long-tail business | Difference of real premiums earned and real present value of losses incurred net of reinsurance for the long tail business divided by the real present value of losses incurred net of reinsurance for the long tail business. |
| Short-tail business | Difference of real premiums earned and real present value of losses incurred net of reinsurance for the short tail business divided by the real present value of losses incurred net of reinsurance for the short tail business. |
| Average of total investments | Realized investment income for the year divided by the average of beginning and end-of-year total invested assets. |
| *Input* | |
| Operating expenses* | Total operating expenses net of reinsurance in Mill.€ divided by labor cost index for insurance business. |
| Average equity capital | Average of beginning and end-of-year equity capital in Mill.€. |
| Average technical provisions | Average of beginning and end-of-year technical provisions in Mill.€ (net of reinsurance). |
| *Input prices* | |
| Operating expenses ratio | Labor cost index for insurance business services divided by the deflator. |
| Average equity capital | We first performed an outlier screen and dropped companies with return on equity >+1 and <-1. We than calculated the expected return on equity as the predicted value of the ratio of net income before taxes to book value surplus with OLS estimation. The prediction is based on a pooled cross-sectional time-series regression of the return on equity variable on the following independent variables capturing insurer characteristics: The percentage of stocks in the investment portfolio, the percentage of bonds in the investment portfolio, the insurance output quantities, the premiums-to-surplus ratio, the intermediate-term government bond yield, and year dummies. |
| Average technical provisions | Two to three-year German treasury bill rates. |
| *ERM variables* | |
| ERM-index | Average risk management quality index which captures the following components, see Appendix. |
| ERM-entropy | Measures an insurer's degree of diversification across the different ERM components, see Appendix. |
| *Diversification variables* | |
| Total | Total diversification, which is 1 minus the Herfindahl concentration index of direct premiums written across business lines. |
| Multiline | Dummy variable, equal to 1 if the number of lines in which insurer has positive direct premiums written > 3, 0 otherwise. |
| Life | Dummy variable, equal to 1 if the parent company of the property-casualty insurer owns also a life insurer, 0 otherwise. |
| Unrelated | Unrelated diversification, which is 1 minus weighted average relatedness of insurer's underwriting portfolio. |
| *Other variables* | |
| Single channel | Dummy variable, equal to 1 if the insurer uses only one single distribution channel, 0 otherwise. |
| Mutual | Dummy variable, equal to 1 if insurer is a mutual, 0 otherwise. |
| Public | Dummy variable, equal to 1 if insurer is organized as an insurer under public law, 0 otherwise. |
| Size | Natural logarithm of total assets. |
| Capital to asset | Ratio of the equity capital to total assets. |
| Reinsurance | Difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. |
| Risky investment | Stock and real estate divided by total assets. |

* Operating expenses are divided by the labor cost index for insurance business services.

## Table 2. Summary Statistics and Univariate Differences for Diversified and Specialized Insurers

| *Variables* | *Full Sample* | | *Diversified* | | | | *Specialist* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | | | | Mean | | | |
| | | | dTotal | Multiline | Life | dUnrelated | dTotal | Multiline | Life | dUnrelated |
| | *N=613* | | *N=543* | *N=450* | *N=556* | *N=541* | *N=70* | *N=163* | *N=57* | *N=72* |
| *Output* | | | | | | | | | | |
| Long-tail business | 151.87 | 194.96 | 171.41 | 198.91 | 165.34 | 172.04 | 0.29 *** | 22.01 *** | 20.42 *** | 0.29 *** |
| Short-tail business | 213.13 | 219.29 | 223.90 | 249.07 | 225.78 | 224.06 | 129.61 *** | 113.90 *** | 89.78 *** | 131.05 *** |
| Average of total investments | 1350.71 | 1596.36 | 1458.45 | 1664.59 | 1452.15 | 1460.45 | 514.97 *** | 484.18 *** | 361.31 *** | 526.18 *** |
| *Output prices* | | | | | | | | | | |
| Long-tail business | 0.31 | 0.32 | 0.35 | 0.41 | 0.34 | 0.35 | 0.01 *** | 0.04 *** | 0.06 *** | 0.01 *** |
| Short-tail business | 0.59 | 0.37 | 0.59 | 0.59 | 0.60 | 0.59 | 0.53 | 0.58 | 0.45 *** | 0.56 |
| Average of total investments | 0.05 | 0.03 | 0.05 | 0.05 | 0.05 | 0.05 | 0.04 *** | 0.05 | 0.04 *** | 0.04 *** |
| *Input* | | | | | | | | | | |
| Operating expenses* | 124.10 | 150.50 | 132.31 | 151.44 | 133.27 | 132.71 | 60.35 *** | 48.61 *** | 34.58 *** | 59.36 *** |
| Average equity capital | 314.16 | 404.22 | 341.22 | 382.99 | 338.41 | 342.11 | 104.25 *** | 124.13 *** | 77.61 *** | 104.16 *** |
| Average technical provisions | 1021.13 | 1310.68 | 1101.93 | 1259.71 | 1095.86 | 1102.37 | 394.33 *** | 362.47 *** | 292.11 *** | 410.69 *** |
| *Input prices* | | | | | | | | | | |
| Operating expenses ratio | 1.05 | 0.04 | 1.05 | 1.05 | 1.05 | 1.05 | 1.04 ** | 1.04 ** | 1.04 ** | 1.04 ** |
| Average equity capital | 0.18 | 0.06 | 0.18 | 0.19 | 0.19 | 0.18 | 0.18 | 0.18 * | 0.18 | 0.19 |
| Average technical provisions | 0.03 | 0.01 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 * | 0.03 ** | 0.03 | 0.03 * |
| *ERM variables* | | | | | | | | | | |
| ERM-index | 0.33 | 0.23 | 0.34 | 0.34 | 0.35 | 0.34 | 0.33 | 0.33 | 0.22 *** | 0.32 |
| ERM-entropy | 0.98 | 0.67 | 0.97 | 0.98 | 1.01 | 0.97 | 1.04 | 0.98 | 0.65 *** | 1.03 |
| *Diversification variables* | | | | | | | | | | |
| Total | 0.55 | 0.30 | - | - | - | - | - | - | - | - |
| Multiline | 0.73 | 0.44 | - | - | - | - | - | - | - | - |
| Life | 0.91 | 0.29 | - | - | - | - | - | - | - | - |
| Unrelated | 0.27 | 0.14 | - | - | - | - | - | - | - | - |
| *Other variables* | | | | | | | | | | |
| Single channel | 0.38 | 0.49 | 0.40 | 0.31 | 0.33 | 0.40 | 0.19 *** | 0.57 *** | 0.82 *** | 0.25 ** |
| Mutual | 0.30 | 0.46 | 0.32 | 0.33 | 0.31 | 0.32 | 0.14 *** | 0.21 *** | 0.19 * | 0.14 *** |
| Public | 0.20 | 0.40 | 0.21 | 0.22 | 0.22 | 0.21 | 0.13 | 0.13 ** | 0.00 *** | 0.13 |
| Size | 6.85 | 1.02 | 6.94 | 7.10 | 6.94 | 6.94 | 6.18 *** | 6.17 *** | 5.99 *** | 6.20 *** |
| Capital to asset | 0.20 | 0.10 | 0.21 | 0.20 | 0.21 | 0.21 | 0.16 *** | 0.21 | 0.19 | 0.16 *** |
| Reinsurance | 0.05 | 0.11 | 0.05 | 0.04 | 0.05 | 0.05 | 0.11 *** | 0.08 *** | 0.14 *** | 0.11 *** |
| Risky investment | 0.31 | 0.15 | 0.31 | 0.32 | 0.32 | 0.31 | 0.33 | 0.29 ** | 0.26 *** | 0.32 |

*Notes:* This table presents descriptive statistics and univariate differences between diversified and specialist insurers. We have in total four diversification measures. *dTotal* presents a dummy variable of our total diversification measure (*Total*); it is denoted as 1 if total diversification > 0, 0 otherwise. *Multiline* is 1 if the number of lines in which insurer has positive direct premiums written > 3, 0 otherwise. *Life* is 1 if the parent company of the property-casualty insurer owns also a life insurer, 0 otherwise. *dUnrelated* presents a dummy variable of our unrelated diversification measure (*Unrelated*); it is denoted as 1 if unrelated diversification > 0, 0 otherwise. Statistical significance of differences between diversified and specialist insurers are based on a t-test for means.. *N* denotes firm-year observations. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009. For variable definitions see Table 1.

*Operating expenses are divided by the labor cost index for insurance business services.

## Table 3. Summary Statistics of Pooled Frontier Efficiency

| *Variables* | *Full Sample* | | *Diversified* | | | | *Specialist* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | | | | Mean | | | |
| | | | dTotal | Multiline | Life | dUnrelated | dTotal | Multiline | Life | dUnrelated |
| | *N=613* | | *N=543* | *N=450* | *N=556* | *N=541* | *N=70* | *N=163* | *N=57* | *N=72* |
| TE | 0.8677 | 0.1110 | 0.8698 | 0.8638 | 0.8671 | 0.8697 | 0.8516 | 0.8784 | 0.8739 | 0.8528 |
| PTE | 0.9279 | 0.0881 | 0.9338 | 0.9323 | 0.9322 | 0.9334 | 0.8821*** | 0.9157** | 0.8860*** | 0.8864*** |
| CE | 0.5306 | 0.1659 | 0.5292 | 0.5113 | 0.5193 | 0.5277 | 0.5416 | 0.5840*** | 0.6409*** | 0.5524 |
| CEScope | 0.5687 | 0.1695 | 0.5698 | 0.5545 | 0.5603 | 0.5680 | 0.5602 | 0.6078*** | 0.6500*** | 0.5738 |
| VCE | 0.6640 | 0.2148 | 0.6728 | 0.6660 | 0.6620 | 0.6708 | 0.5961*** | 0.6586 | 0.6832 | 0.6128** |
| RE | 0.5784 | 0.1927 | 0.5666 | 0.5320 | 0.5637 | 0.5661 | 0.6698*** | 0.7065*** | 0.7219*** | 0.6704*** |
| REScope | 0.6177 | 0.1909 | 0.6083 | 0.5752 | 0.6059 | 0.6075 | 0.6905*** | 0.7348*** | 0.7325*** | 0.6940*** |
| VRE | 0.7943 | 0.1884 | 0.7982 | 0.7883 | 0.7983 | 0.7978 | 0.7638 | 0.8107 | 0.7545* | 0.7675 |
| PI | 0.4192 | 0.3777 | 0.4359 | 0.4638 | 0.4325 | 0.4338 | 0.2894*** | 0.2960*** | 0.2893*** | 0.3091*** |
| SE | 0.9358 | 0.0846 | 0.9320 | 0.9272 | 0.9307 | 0.9323 | 0.9657*** | 0.9597*** | 0.9858*** | 0.9627*** |
| | | | | | | | | | | |
| CRS | 0.2055 | 0.4044 | 0.2026 | 0.1689 | 0.1906 | 0.2033 | 0.2286 | 0.3067*** | 0.3509*** | 0.2222 |
| IRS | 0.0962 | 0.2952 | 0.0773 | 0.0800 | 0.0809 | 0.0776 | 0.2429*** | 0.1411** | 0.2456*** | 0.2361*** |
| DRS | 0.6982 | 0.4594 | 0.7201 | 0.7511 | 0.7284 | 0.7190 | 0.5286*** | 0.5521*** | 0.4035*** | 0.5417*** |

*Notes:* This table presents descriptive statistics of pooled frontier efficiencies and univariate differences between diversified and specialist insurers. We have in total four diversification measures. *dTotal* presents a dummy variable of our total diversification measure (*Total*); it is denoted as 1 if total diversification > 0, 0 otherwise. *Multiline* is 1 if the number of lines in which insurer has positive direct premiums written > 3, 0 otherwise. *Life* is 1 if the parent company of the property-casualty insurer owns also a life insurer, 0 otherwise. *dUnrelated* presents a dummy variable of our unrelated diversification measure (*Unrelated*); it is denoted as 1 if unrelated diversification > 0, 0 otherwise. Statistical significance of differences between diversified and specialist insurers are based on a t-test for means. The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone.(2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". CRS − Constant returns to scale; VRS − Variable returns to scale; IRS − increasing returns to scale; DRS − decreasing returns to scale. *N* denotes firm-year observations. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

## Table 4. Frontier Efficiency Regressions: ERM-index and Economies of Scale

| *Variables* | *TE* *(1)* | *PTE* *(2)* | *CE* *(3)* | *CEScope* *(4)* | *VCE* *(5)* | *RE* *(6)* | *REScope* *(7)* | *VRE* *(8)* | *PI* *(9)* | *SE* *(10)* |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-index | -0.102 | 0.015 | -0.208** | -0.130 | -0.452*** | -0.107 | -0.047 | -0.264** | 0.867** | -0.131*** |
| | (0.074) | (0.067) | (0.092) | (0.094) | (0.107) | (0.124) | (0.128) | (0.129) | (0.341) | (0.043) |
| ERM-index*Size | 0.006 | -0.007 | 0.022 | 0.014 | 0.071*** | 0.013 | 0.006 | 0.041** | -0.087* | 0.015** |
| | (0.011) | (0.010) | (0.014) | (0.014) | (0.016) | (0.019) | (0.019) | (0.019) | (0.051) | (0.007) |
| Total | -0.172*** | -0.151*** | -0.334*** | -0.328*** | -0.338*** | -0.300*** | -0.287*** | -0.260*** | 0.139 | -0.026* |
| | (0.024) | (0.022) | (0.029) | (0.030) | (0.034) | (0.040) | (0.041) | (0.041) | (0.109) | (0.014) |
| Single channel | -0.021*** | -0.017** | 0.040*** | 0.043*** | 0.052*** | 0.003 | 0.005 | 0.001 | 0.113*** | -0.004 |
| | (0.008) | (0.007) | (0.010) | (0.010) | (0.012) | (0.013) | (0.014) | (0.014) | (0.037) | (0.005) |
| Mutual | 0.032*** | 0.023*** | 0.084*** | 0.080*** | 0.061*** | -0.016 | -0.021 | -0.018 | 0.010 | 0.010** |
| | (0.008) | (0.008) | (0.010) | (0.011) | (0.012) | (0.014) | (0.015) | (0.015) | (0.039) | (0.005) |
| Public | -0.023 | -0.016 | 0.105*** | 0.113*** | 0.091*** | -0.091*** | -0.092*** | -0.040* | -0.023 | -0.007 |
| | (0.014) | (0.013) | (0.017) | (0.018) | (0.020) | (0.023) | (0.024) | (0.024) | (0.064) | (0.008) |
| Size | -0.003 | 0.029*** | 0.024*** | 0.046*** | 0.077*** | -0.029*** | -0.010 | 0.071*** | 0.038 | -0.033*** |
| | (0.005) | (0.005) | (0.006) | (0.006) | (0.007) | (0.009) | (0.009) | (0.009) | (0.024) | (0.003) |
| Capital to asset | -0.036 | -0.017 | -0.352*** | -0.352*** | -0.386*** | -0.258*** | -0.254*** | 0.107* | 0.140 | -0.021 |
| | (0.034) | (0.031) | (0.043) | (0.044) | (0.050) | (0.058) | (0.060) | (0.060) | (0.159) | (0.020) |
| Reinsurance | -0.037 | -0.064** | -0.060 | -0.085* | -0.154*** | -0.273*** | -0.297*** | -0.321*** | 0.397** | 0.025 |
| | (0.034) | (0.031) | (0.042) | (0.043) | (0.050) | (0.057) | (0.059) | (0.060) | (0.158) | (0.020) |
| Risky investment | 0.079*** | 0.059*** | -0.089*** | -0.102*** | -0.125*** | -0.068* | -0.085** | -0.096** | -0.027 | 0.024* |
| | (0.023) | (0.021) | (0.029) | (0.030) | (0.034) | (0.039) | (0.040) | (0.041) | (0.108) | (0.014) |
| Constant | 0.951*** | 0.803*** | 0.605*** | 0.510*** | 0.442*** | 1.118*** | 1.045*** | 0.577*** | 0.001 | 1.153*** |
| | (0.038) | (0.035) | (0.047) | (0.048) | (0.055) | (0.064) | (0.066) | (0.067) | (0.176) | (0.022) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.301 | 0.273 | 0.512 | 0.530 | 0.602 | 0.414 | 0.380 | 0.440 | 0.329 | 0.419 |
| N | 926 | 926 | 926 | 926 | 926 | 926 | 926 | 926 | 926 | 926 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone.(2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-index* is the average risk management quality index which captures the following components: (1) identifying the firm's risk appetite, (2) risk aggregation, (3) risk capital allocation, (4) using risk-adjusted performance measures, (5) linking management incentives to risk, (6) risk management culture, and (7) audit. *Total* means total diversification, which is 1 minus the Herfindahl concentration index of direct premiums written across business lines. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

## Table 5. Frontier Efficiency Regressions: ERM-entropy and Economies of Scale

| *Variables* | *TE (1)* | *PTE (2)* | *CE (3)* | *CEScope (4)* | *VCE (5)* | *RE (6)* | *REScope (7)* | *VRE (8)* | *PI (9)* | *SE (10)* |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-entropy | -0.073*** | -0.014 | -0.068** | -0.030 | -0.135*** | -0.056 | -0.023 | -0.123*** | 0.329*** | -0.065*** |
| | (0.027) | (0.025) | (0.034) | (0.034) | (0.040) | (0.046) | (0.047) | (0.048) | (0.125) | (0.016) |
| ERM-entropy*Size | 0.005 | -0.001 | 0.007 | 0.003 | 0.022*** | 0.005 | 0.001 | 0.018** | -0.032 | 0.008*** |
| | (0.004) | (0.004) | (0.005) | (0.005) | (0.006) | (0.007) | (0.007) | (0.007) | (0.019) | (0.002) |
| Total | -0.169*** | -0.149*** | -0.333*** | -0.329*** | -0.336*** | -0.296*** | -0.285*** | -0.256*** | 0.132 | -0.024* |
| | (0.023) | (0.022) | (0.029) | (0.030) | (0.035) | (0.040) | (0.041) | (0.041) | (0.109) | (0.014) |
| Single channel | -0.022*** | -0.017** | 0.039*** | 0.043*** | 0.050*** | 0.001 | 0.004 | -0.001 | 0.117*** | -0.005 |
| | (0.008) | (0.007) | (0.010) | (0.010) | (0.012) | (0.013) | (0.014) | (0.014) | (0.037) | (0.005) |
| Mutual | 0.035*** | 0.024*** | 0.087*** | 0.082*** | 0.064*** | -0.014 | -0.021 | -0.016 | -0.006 | 0.012** |
| | (0.008) | (0.008) | (0.010) | (0.011) | (0.012) | (0.014) | (0.015) | (0.015) | (0.039) | (0.005) |
| Public | -0.024* | -0.018 | 0.109*** | 0.117*** | 0.093*** | -0.095*** | -0.096*** | -0.043* | -0.036 | -0.006 |
| | (0.013) | (0.012) | (0.017) | (0.017) | (0.020) | (0.023) | (0.023) | (0.024) | (0.062) | (0.008) |
| Size | -0.007 | 0.028*** | 0.023*** | 0.047*** | 0.078*** | -0.029*** | -0.008 | 0.066*** | 0.043* | -0.036*** |
| | (0.006) | (0.005) | (0.007) | (0.007) | (0.008) | (0.009) | (0.010) | (0.010) | (0.026) | (0.003) |
| Capital to asset | -0.031 | -0.013 | -0.351*** | -0.351*** | -0.395*** | -0.258*** | -0.255*** | 0.103* | 0.129 | -0.020 |
| | (0.034) | (0.031) | (0.043) | (0.044) | (0.050) | (0.058) | (0.060) | (0.060) | (0.158) | (0.020) |
| Reinsurance | -0.050 | -0.074** | -0.057 | -0.079* | -0.141*** | -0.285*** | -0.307*** | -0.323*** | 0.403** | 0.022 |
| | (0.034) | (0.031) | (0.042) | (0.043) | (0.050) | (0.057) | (0.059) | (0.060) | (0.157) | (0.020) |
| Risky investment | 0.084*** | 0.062*** | -0.083*** | -0.098*** | -0.120*** | -0.064* | -0.083** | -0.093** | -0.056 | 0.027** |
| | (0.023) | (0.021) | (0.029) | (0.030) | (0.034) | (0.039) | (0.040) | (0.041) | (0.107) | (0.014) |
| Constant | 0.975*** | 0.811*** | 0.602*** | 0.498*** | 0.434*** | 1.123*** | 1.039*** | 0.611*** | -0.013 | 1.172*** |
| | (0.040) | (0.037) | (0.051) | (0.052) | (0.059) | (0.068) | (0.071) | (0.071) | (0.188) | (0.024) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.315 | 0.279 | 0.512 | 0.529 | 0.599 | 0.417 | 0.381 | 0.441 | 0.332 | 0.427 |
| N | 926 | 926 | 926 | 926 | 926 | 926 | 926 | 926 | 926 | 926 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone.(2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-entropy* measures an insurer's degree of diversification across the different ERM components. The measure takes on higher values for firms that have a balanced risk management approach; the measure takes on lower values for firms that just focus on improving some ERM components while ignoring the weakest one. *Total* means total diversification, which is 1 minus the Herfindahl concentration index of direct premiums written across business lines. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

## Table 6. Frontier Efficiency Regressions: ERM-index and Economies of Scope, Total Diversification Measure

| *Variables* | *TE* *(1)* | *PTE* *(2)* | *CE* *(3)* | *CEScope* *(4)* | *VCE* *(5)* | *RE* *(6)* | *REScope* *(7)* | *VRE* *(8)* | *PI* *(9)* | *SE* *(10)* |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-index | -0.044 | 0.043 | -0.044 | 0.009 | -0.002 | -0.068 | -0.020 | 0.083 | 0.401*** | -0.093*** |
| | (0.039) | (0.033) | (0.049) | (0.049) | (0.058) | (0.065) | (0.067) | (0.063) | (0.131) | (0.026) |
| ERM-index*Total | -0.021 | -0.086* | -0.077 | -0.114* | -0.071 | 0.198** | 0.170* | -0.047 | -0.391** | 0.071** |
| | (0.053) | (0.045) | (0.067) | (0.067) | (0.080) | (0.089) | (0.091) | (0.086) | (0.179) | (0.035) |
| Total | -0.056 | 0.033 | -0.279*** | -0.230*** | -0.225*** | -0.179*** | -0.123* | -0.045 | -0.010 | -0.090*** |
| | (0.041) | (0.035) | (0.051) | (0.051) | (0.061) | (0.068) | (0.070) | (0.066) | (0.137) | (0.027) |
| Single channel | -0.016* | -0.000 | 0.023* | 0.035*** | 0.065*** | 0.050*** | 0.061*** | 0.073*** | 0.008 | -0.016** |
| | (0.010) | (0.008) | (0.012) | (0.012) | (0.015) | (0.016) | (0.017) | (0.016) | (0.033) | (0.006) |
| Mutual | 0.033*** | 0.008 | 0.088*** | 0.071*** | 0.026 | -0.033* | -0.050** | -0.044** | 0.014 | 0.025*** |
| | (0.011) | (0.010) | (0.014) | (0.014) | (0.017) | (0.019) | (0.020) | (0.018) | (0.039) | (0.008) |
| Public | 0.004 | 0.007 | 0.118*** | 0.122*** | 0.094*** | -0.103*** | -0.109*** | -0.045* | 0.160*** | -0.002 |
| | (0.015) | (0.013) | (0.019) | (0.019) | (0.023) | (0.026) | (0.026) | (0.025) | (0.051) | (0.010) |
| Size | -0.010** | 0.031*** | 0.033*** | 0.063*** | 0.143*** | -0.034*** | -0.010 | 0.108*** | 0.024 | -0.042*** |
| | (0.005) | (0.004) | (0.006) | (0.006) | (0.007) | (0.008) | (0.008) | (0.008) | (0.016) | (0.003) |
| Capital to asset | 0.010 | 0.052 | -0.269*** | -0.257*** | -0.333*** | -0.168** | -0.141* | 0.244*** | -0.231 | -0.042 |
| | (0.045) | (0.038) | (0.056) | (0.056) | (0.067) | (0.074) | (0.076) | (0.072) | (0.150) | (0.029) |
| Reinsurance | -0.002 | -0.034 | 0.015 | -0.010 | -0.067 | -0.267*** | -0.298*** | -0.263*** | 0.401*** | 0.031 |
| | (0.035) | (0.030) | (0.044) | (0.044) | (0.052) | (0.059) | (0.060) | (0.056) | (0.118) | (0.023) |
| Risky investment | -0.020 | -0.058** | -0.065* | -0.087** | -0.131*** | -0.291*** | -0.327*** | -0.283*** | 0.468*** | 0.038** |
| | (0.030) | (0.025) | (0.037) | (0.037) | (0.044) | (0.050) | (0.051) | (0.048) | (0.100) | (0.019) |
| Constant | 0.988*** | 0.759*** | 0.534*** | 0.377*** | -0.013 | 1.158*** | 1.044*** | 0.225*** | 0.021 | 1.232*** |
| | (0.042) | (0.036) | (0.053) | (0.053) | (0.063) | (0.071) | (0.073) | (0.068) | (0.142) | (0.028) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.373 | 0.281 | 0.563 | 0.576 | 0.625 | 0.420 | 0.378 | 0.436 | 0.388 | 0.536 |
| N | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone (2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-index* is the average risk management quality index which captures the following components: (1) identifying the firm's risk appetite, (2) risk aggregation, (3) risk capital allocation, (4) using risk-adjusted performance measures, (5) linking management incentives to risk, (6) risk management culture, and (7) audit. *Total* means total diversification, which is 1 minus the Herfindahl concentration index of direct premiums written across business lines. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

**Table 7. Frontier Efficiency Regressions: ERM-index and Economies of Scope, Multiline as Diversification Measure**

| *Variables* | *TE* (1) | *PTE* (2) | *CE* (3) | *CEScope* (4) | *VCE* (5) | *RE* (6) | *REScope* (7) | *VRE* (8) | *PI* (9) | *SE* (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-index | -0.097*** | 0.000 | -0.104** | -0.046 | -0.076 | -0.106* | -0.051 | 0.019 | 0.467*** | -0.104*** |
| | (0.037) | (0.032) | (0.048) | (0.048) | (0.056) | (0.061) | (0.063) | (0.059) | (0.125) | (0.025) |
| ERM-index*Multiline | 0.038 | -0.025 | 0.012 | -0.023 | 0.027 | 0.161*** | 0.131** | 0.010 | -0.343*** | 0.070*** |
| | (0.037) | (0.032) | (0.048) | (0.048) | (0.057) | (0.062) | (0.064) | (0.060) | (0.126) | (0.025) |
| Multiline | -0.075*** | -0.043** | -0.082*** | -0.065** | -0.106*** | -0.192*** | -0.173*** | -0.130*** | 0.241*** | -0.035** |
| | (0.022) | (0.019) | (0.029) | (0.029) | (0.034) | (0.037) | (0.038) | (0.035) | (0.074) | (0.015) |
| Single channel | -0.023** | -0.006 | 0.018 | 0.030** | 0.057*** | 0.036** | 0.048*** | 0.060*** | 0.023 | -0.017** |
| | (0.010) | (0.008) | (0.013) | (0.013) | (0.015) | (0.016) | (0.017) | (0.016) | (0.033) | (0.007) |
| Mutual | 0.039*** | 0.015 | 0.089*** | 0.073*** | 0.031* | -0.020 | -0.036* | -0.029 | -0.001 | 0.023*** |
| | (0.012) | (0.010) | (0.015) | (0.015) | (0.018) | (0.019) | (0.020) | (0.019) | (0.040) | (0.008) |
| Public | 0.011 | 0.016 | 0.109*** | 0.115*** | 0.093*** | -0.084*** | -0.089*** | -0.026 | 0.123** | -0.004 |
| | (0.015) | (0.013) | (0.020) | (0.020) | (0.023) | (0.025) | (0.026) | (0.025) | (0.052) | (0.010) |
| Size | -0.009* | 0.034*** | 0.028*** | 0.059*** | 0.141*** | -0.028*** | -0.003 | 0.114*** | 0.011 | -0.043*** |
| | (0.005) | (0.004) | (0.006) | (0.006) | (0.007) | (0.008) | (0.008) | (0.008) | (0.016) | (0.003) |
| Capital to asset | -0.013 | 0.021 | -0.251*** | -0.243*** | -0.338*** | -0.234*** | -0.211*** | 0.180** | -0.118 | -0.035 |
| | (0.045) | (0.038) | (0.058) | (0.058) | (0.069) | (0.075) | (0.077) | (0.072) | (0.152) | (0.030) |
| Reinsurance | 0.008 | -0.024 | 0.013 | -0.011 | -0.062 | -0.239*** | -0.270*** | -0.238*** | 0.359*** | 0.030 |
| | (0.035) | (0.030) | (0.045) | (0.045) | (0.053) | (0.058) | (0.060) | (0.056) | (0.118) | (0.023) |
| Risky investment | -0.020 | -0.049* | -0.099*** | -0.116*** | -0.153*** | -0.277*** | -0.307*** | -0.267*** | 0.421*** | 0.030 |
| | (0.029) | (0.025) | (0.038) | (0.038) | (0.044) | (0.048) | (0.050) | (0.047) | (0.099) | (0.019) |
| Constant | 0.986*** | 0.756*** | 0.540*** | 0.382*** | -0.012 | 1.113*** | 0.999*** | 0.200*** | 0.061 | 1.234*** |
| | (0.042) | (0.036) | (0.054) | (0.054) | (0.064) | (0.069) | (0.071) | (0.067) | (0.141) | (0.028) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.383 | 0.291 | 0.536 | 0.555 | 0.619 | 0.439 | 0.396 | 0.452 | 0.394 | 0.533 |
| N | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone (2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-index* is the average risk management quality index which captures the following components: (1) identifying the firm's risk appetite, (2) risk aggregation, (3) risk capital allocation, (4) using risk-adjusted performance measures, (5) linking management incentives to risk, (6) risk management culture, and (7) audit. *Multiline* is 1 if the number of lines in which insurer has positive direct premiums written > 3, 0 otherwise. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

## Table 8. Frontier Efficiency Regressions: ERM-index and Economies of Scope, Life as Diversification Measure

| *Variables* | *TE* *(1)* | *PTE* *(2)* | *CE* *(3)* | *CEScope* *(4)* | *VCE* *(5)* | *RE* *(6)* | *REScope* *(7)* | *VRE* *(8)* | *PI* *(9)* | *SE* *(10)* |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-index | -0.305*** | -0.140** | -0.253** | -0.148 | -0.147 | -0.231* | -0.133 | -0.095 | 0.878*** | -0.173*** |
| | (0.076) | (0.065) | (0.099) | (0.099) | (0.117) | (0.129) | (0.132) | (0.124) | (0.258) | (0.051) |
| ERM-index*Life | 0.246*** | 0.122* | 0.207** | 0.131 | 0.141 | 0.285** | 0.211* | 0.142 | -0.688*** | 0.129*** |
| | (0.073) | (0.062) | (0.095) | (0.095) | (0.112) | (0.124) | (0.127) | (0.119) | (0.248) | (0.049) |
| Life | -0.028 | 0.011 | -0.101*** | -0.083*** | -0.083** | -0.073* | -0.044 | 0.006 | 0.128 | -0.042*** |
| | (0.023) | (0.020) | (0.030) | (0.030) | (0.036) | (0.039) | (0.040) | (0.038) | (0.079) | (0.015) |
| Single channel | -0.012 | 0.005 | 0.017 | 0.028** | 0.059*** | 0.049*** | 0.062*** | 0.079*** | 0.006 | -0.018*** |
| | (0.010) | (0.009) | (0.013) | (0.013) | (0.015) | (0.017) | (0.017) | (0.016) | (0.034) | (0.007) |
| Mutual | 0.026** | 0.000 | 0.087*** | 0.070*** | 0.026 | -0.033* | -0.051** | -0.054*** | 0.012 | 0.026*** |
| | (0.012) | (0.010) | (0.015) | (0.015) | (0.018) | (0.020) | (0.020) | (0.019) | (0.040) | (0.008) |
| Public | -0.004 | 0.000 | 0.106*** | 0.112*** | 0.085*** | -0.107*** | -0.112*** | -0.056** | 0.148*** | -0.003 |
| | (0.015) | (0.013) | (0.020) | (0.020) | (0.023) | (0.026) | (0.026) | (0.025) | (0.052) | (0.010) |
| Size | -0.013*** | 0.030*** | 0.023*** | 0.053*** | 0.135*** | -0.036*** | -0.011 | 0.105*** | 0.017 | -0.043*** |
| | (0.005) | (0.004) | (0.006) | (0.006) | (0.007) | (0.008) | (0.008) | (0.007) | (0.016) | (0.003) |
| Capital to asset | 0.036 | 0.068* | -0.218*** | -0.213*** | -0.294*** | -0.153** | -0.132* | 0.272*** | -0.201 | -0.034 |
| | (0.044) | (0.037) | (0.057) | (0.057) | (0.067) | (0.074) | (0.076) | (0.071) | (0.148) | (0.029) |
| Reinsurance | -0.005 | -0.034 | -0.013 | -0.036 | -0.090* | -0.271*** | -0.298*** | -0.265*** | 0.383*** | 0.027 |
| | (0.035) | (0.030) | (0.045) | (0.045) | (0.053) | (0.059) | (0.060) | (0.056) | (0.118) | (0.023) |
| Risky investment | -0.042 | -0.073*** | -0.109*** | -0.127*** | -0.166*** | -0.299*** | -0.330*** | -0.306*** | 0.441*** | 0.033* |
| | (0.029) | (0.025) | (0.038) | (0.038) | (0.044) | (0.049) | (0.050) | (0.047) | (0.098) | (0.019) |
| Constant | 1.027*** | 0.780*** | 0.643*** | 0.477*** | 0.076 | 1.174*** | 1.042*** | 0.242*** | 0.004 | 1.251*** |
| | (0.044) | (0.037) | (0.057) | (0.057) | (0.067) | (0.074) | (0.076) | (0.071) | (0.149) | (0.029) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.384 | 0.291 | 0.537 | 0.554 | 0.614 | 0.417 | 0.376 | 0.438 | 0.390 | 0.533 |
| N | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone (2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-index* is the average risk management quality index which captures the following components: (1) identifying the firm's risk appetite, (2) risk aggregation, (3) risk capital allocation, (4) using risk-adjusted performance measures, (5) linking management incentives to risk, (6) risk management culture, and (7) audit. *Life* is 1 if the parent company of the property-casualty insurer owns also a life insurer, 0 otherwise. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

**Table 9. Frontier Efficiency Regressions: ERM-index and Economies of Scope, Unrelated Diversification Measure**

| *Variables* | *TE* (1) | *PTE* (2) | *CE* (3) | *CEScope* (4) | *VCE* (5) | *RE* (6) | *REScope* (7) | *VRE* (8) | *PI* (9) | *SE* (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-index | 0.099** | 0.130*** | 0.129** | 0.158*** | 0.186*** | 0.147** | 0.169** | 0.160** | -0.136 | -0.029 |
| | (0.040) | (0.034) | (0.052) | (0.052) | (0.061) | (0.068) | (0.070) | (0.065) | (0.137) | (0.027) |
| ERM-index*Unrelated | -0.559*** | -0.490*** | -0.755*** | -0.745*** | -0.799*** | -0.366* | -0.328* | -0.356* | 1.196*** | -0.086 |
| | (0.113) | (0.096) | (0.146) | (0.146) | (0.172) | (0.192) | (0.197) | (0.184) | (0.385) | (0.076) |
| Unrelated | 0.200*** | 0.178*** | 0.317*** | 0.317*** | 0.298*** | 0.020 | 0.009 | 0.043 | -0.298 | 0.028 |
| | (0.055) | (0.046) | (0.071) | (0.071) | (0.083) | (0.093) | (0.095) | (0.089) | (0.186) | (0.037) |
| Single channel | -0.016* | -0.001 | 0.026** | 0.037*** | 0.067*** | 0.052*** | 0.062*** | 0.074*** | 0.009 | -0.015** |
| | (0.010) | (0.008) | (0.012) | (0.012) | (0.015) | (0.016) | (0.017) | (0.016) | (0.033) | (0.006) |
| Mutual | 0.031*** | 0.006 | 0.077*** | 0.060*** | 0.017 | -0.032* | -0.049** | -0.046** | 0.004 | 0.024*** |
| | (0.011) | (0.010) | (0.014) | (0.014) | (0.017) | (0.019) | (0.020) | (0.018) | (0.038) | (0.008) |
| Public | 0.003 | 0.010 | 0.100*** | 0.106*** | 0.080*** | -0.108*** | -0.111*** | -0.047* | 0.139*** | -0.006 |
| | (0.015) | (0.013) | (0.019) | (0.019) | (0.023) | (0.025) | (0.026) | (0.024) | (0.050) | (0.010) |
| Size | -0.011** | 0.032*** | 0.025*** | 0.055*** | 0.137*** | -0.034*** | -0.009 | 0.107*** | 0.012 | -0.043*** |
| | (0.005) | (0.004) | (0.006) | (0.006) | (0.007) | (0.008) | (0.008) | (0.007) | (0.016) | (0.003) |
| Capital to asset | 0.029 | 0.059 | -0.195*** | -0.190*** | -0.271*** | -0.149** | -0.131* | 0.262*** | -0.197 | -0.030 |
| | (0.043) | (0.037) | (0.056) | (0.056) | (0.066) | (0.073) | (0.075) | (0.070) | (0.147) | (0.029) |
| Reinsurance | 0.025 | -0.010 | 0.034 | 0.009 | -0.040 | -0.241*** | -0.273*** | -0.243*** | 0.307** | 0.034 |
| | (0.035) | (0.030) | (0.045) | (0.045) | (0.053) | (0.059) | (0.061) | (0.057) | (0.119) | (0.024) |
| Risky investment | -0.025 | -0.058** | -0.110*** | -0.129*** | -0.165*** | -0.285*** | -0.316*** | -0.287*** | 0.400*** | 0.034* |
| | (0.029) | (0.024) | (0.037) | (0.037) | (0.043) | (0.048) | (0.050) | (0.047) | (0.097) | (0.019) |
| Constant | 0.904*** | 0.701*** | 0.419*** | 0.271*** | -0.123* | 1.097*** | 0.995*** | 0.218*** | 0.265* | 1.202*** |
| | (0.046) | (0.039) | (0.060) | (0.060) | (0.070) | (0.079) | (0.080) | (0.075) | (0.157) | (0.031) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.395 | 0.308 | 0.549 | 0.567 | 0.624 | 0.420 | 0.381 | 0.441 | 0.393 | 0.527 |
| N | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone (2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-index* is the average risk management quality index which captures the following components: (1) identifying the firm's risk appetite, (2) risk aggregation, (3) risk capital allocation, (4) using risk-adjusted performance measures, (5) linking management incentives to risk, (6) risk management culture, and (7) audit. *Unrelated* means unrelated diversification, which is 1 minus weighted average relatedness of insurer's underwriting portfolio. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

**Table 10. Frontier Efficiency Regressions: ERM-entropy and Economies of Scope, Total Diversification Measure**

| *Variables* | *TE* *(1)* | *PTE* *(2)* | *CE* *(3)* | *CEScope* *(4)* | *VCE* *(5)* | *RE* *(6)* | *REScope* *(7)* | *VRE* *(8)* | *PI* *(9)* | *SE* *(10)* |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-entropy | -0.036*** | -0.000 | -0.024 | -0.002 | -0.006 | -0.042* | -0.021 | 0.012 | 0.179*** | -0.037*** |
| | (0.013) | (0.012) | (0.017) | (0.017) | (0.020) | (0.023) | (0.023) | (0.022) | (0.045) | (0.009) |
| ERM-entropy*Total | 0.006 | -0.020 | -0.014 | -0.027 | -0.020 | 0.063** | 0.049 | -0.019 | -0.152** | 0.028** |
| | (0.019) | (0.016) | (0.024) | (0.024) | (0.028) | (0.032) | (0.033) | (0.031) | (0.063) | (0.012) |
| Total | -0.077* | 0.020 | -0.297*** | -0.245*** | -0.233*** | -0.180*** | -0.117* | -0.045 | 0.034 | -0.098*** |
| | (0.041) | (0.035) | (0.051) | (0.052) | (0.062) | (0.069) | (0.071) | (0.067) | (0.138) | (0.027) |
| Single channel | -0.017* | -0.000 | 0.024* | 0.036*** | 0.066*** | 0.047*** | 0.058*** | 0.073*** | 0.012 | -0.017*** |
| | (0.010) | (0.008) | (0.012) | (0.012) | (0.015) | (0.016) | (0.017) | (0.016) | (0.033) | (0.006) |
| Mutual | 0.034*** | 0.006 | 0.090*** | 0.071*** | 0.026 | -0.034* | -0.053*** | -0.048*** | 0.007 | 0.027*** |
| | (0.011) | (0.010) | (0.014) | (0.014) | (0.017) | (0.019) | (0.020) | (0.018) | (0.038) | (0.007) |
| Public | 0.004 | 0.004 | 0.122*** | 0.124*** | 0.095*** | -0.109*** | -0.117*** | -0.053** | 0.153*** | 0.001 |
| | (0.015) | (0.013) | (0.019) | (0.019) | (0.022) | (0.025) | (0.026) | (0.024) | (0.050) | (0.010) |
| Size | -0.009* | 0.032*** | 0.033*** | 0.062*** | 0.143*** | -0.031*** | -0.008 | 0.110*** | 0.020 | -0.041*** |
| | (0.005) | (0.004) | (0.006) | (0.006) | (0.007) | (0.008) | (0.008) | (0.008) | (0.016) | (0.003) |
| Capital to asset | 0.012 | 0.051 | -0.259*** | -0.249*** | -0.329*** | -0.184** | -0.159** | 0.234*** | -0.228 | -0.040 |
| | (0.044) | (0.038) | (0.055) | (0.056) | (0.066) | (0.074) | (0.076) | (0.071) | (0.148) | (0.029) |
| Reinsurance | -0.015 | -0.042 | 0.009 | -0.011 | -0.070 | -0.283*** | -0.310*** | -0.273*** | 0.435*** | 0.025 |
| | (0.035) | (0.030) | (0.044) | (0.044) | (0.053) | (0.059) | (0.061) | (0.057) | (0.118) | (0.023) |
| Risky investment | -0.015 | -0.057** | -0.060 | -0.086** | -0.128*** | -0.288*** | -0.326*** | -0.284*** | 0.447*** | 0.043** |
| | (0.029) | (0.025) | (0.037) | (0.037) | (0.044) | (0.050) | (0.051) | (0.048) | (0.099) | (0.019) |
| Constant | 0.984*** | 0.757*** | 0.535*** | 0.382*** | -0.016 | 1.144*** | 1.031*** | 0.214*** | 0.038 | 1.229*** |
| | (0.043) | (0.037) | (0.054) | (0.054) | (0.065) | (0.072) | (0.074) | (0.070) | (0.144) | (0.028) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.382 | 0.281 | 0.563 | 0.574 | 0.625 | 0.419 | 0.374 | 0.434 | 0.395 | 0.540 |
| N | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone (2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-entropy* measures an insurer's degree of diversification across the different ERM components. The measure takes on higher values for firms that have a balanced risk management approach; the measure takes on lower values for firms that just focus on improving some ERM components while ignoring the weakest one. *Total* means total diversification, which is 1 minus the Herfindahl concentration index of direct premiums written across business lines. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

## Table 11. Frontier Efficiency Regressions: ERM-entropy and Economies of Scope, Multiline as Diversification Measure

| *Variables* | *TE* (1) | *PTE* (2) | *CE* (3) | *CEScope* (4) | *VCE* (5) | *RE* (6) | *REScope* (7) | *VRE* (8) | *PI* (9) | *SE* (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-entropy | -0.048*** | -0.011 | -0.036** | -0.014 | -0.027 | -0.048** | -0.026 | -0.003 | 0.187*** | -0.039*** |
| | (0.013) | (0.011) | (0.017) | (0.017) | (0.019) | (0.021) | (0.022) | (0.020) | (0.043) | (0.008) |
| ERM-entropy*Multiline | 0.018 | -0.005 | 0.009 | -0.001 | 0.014 | 0.047** | 0.035 | -0.004 | -0.114** | 0.025*** |
| | (0.013) | (0.011) | (0.017) | (0.017) | (0.020) | (0.022) | (0.023) | (0.021) | (0.044) | (0.009) |
| Multiline | -0.081*** | -0.049*** | -0.083*** | -0.068** | -0.107*** | -0.188*** | -0.168*** | -0.128*** | 0.235*** | -0.034** |
| | (0.022) | (0.019) | (0.028) | (0.029) | (0.033) | (0.036) | (0.037) | (0.035) | (0.074) | (0.014) |
| Single channel | -0.023** | -0.006 | 0.019 | 0.031** | 0.058*** | 0.034** | 0.046*** | 0.059*** | 0.024 | -0.017** |
| | (0.010) | (0.008) | (0.013) | (0.013) | (0.015) | (0.016) | (0.017) | (0.016) | (0.033) | (0.007) |
| Mutual | 0.039*** | 0.015 | 0.091*** | 0.074*** | 0.032* | -0.020 | -0.037* | -0.030 | -0.006 | 0.025*** |
| | (0.012) | (0.010) | (0.015) | (0.015) | (0.018) | (0.019) | (0.020) | (0.019) | (0.039) | (0.008) |
| Public | 0.013 | 0.015 | 0.115*** | 0.119*** | 0.097*** | -0.087*** | -0.093*** | -0.030 | 0.116** | -0.002 |
| | (0.015) | (0.013) | (0.020) | (0.020) | (0.023) | (0.025) | (0.026) | (0.024) | (0.051) | (0.010) |
| Size | -0.007 | 0.035*** | 0.027*** | 0.057*** | 0.141*** | -0.025*** | -0.000 | 0.116*** | 0.006 | -0.043*** |
| | (0.005) | (0.004) | (0.006) | (0.006) | (0.007) | (0.008) | (0.008) | (0.008) | (0.016) | (0.003) |
| Capital to asset | -0.011 | 0.021 | -0.238*** | -0.232*** | -0.331*** | -0.247*** | -0.227*** | 0.170** | -0.122 | -0.032 |
| | (0.044) | (0.038) | (0.058) | (0.058) | (0.068) | (0.074) | (0.076) | (0.071) | (0.150) | (0.030) |
| Reinsurance | -0.005 | -0.031 | 0.010 | -0.010 | -0.064 | -0.252*** | -0.280*** | -0.246*** | 0.396*** | 0.024 |
| | (0.035) | (0.030) | (0.046) | (0.046) | (0.054) | (0.058) | (0.060) | (0.056) | (0.118) | (0.023) |
| Risky investment | -0.014 | -0.047* | -0.095** | -0.115*** | -0.152*** | -0.273*** | -0.304*** | -0.263*** | 0.401*** | 0.033* |
| | (0.029) | (0.025) | (0.038) | (0.038) | (0.045) | (0.049) | (0.050) | (0.047) | (0.099) | (0.019) |
| Constant | 0.978*** | 0.751*** | 0.541*** | 0.388*** | -0.009 | 1.094*** | 0.982*** | 0.183*** | 0.098 | 1.230*** |
| | (0.042) | (0.036) | (0.055) | (0.055) | (0.065) | (0.070) | (0.073) | (0.068) | (0.143) | (0.028) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.393 | 0.294 | 0.535 | 0.554 | 0.618 | 0.438 | 0.393 | 0.452 | 0.399 | 0.537 |
| N | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone (2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-entropy* measures an insurer's degree of diversification across the different ERM components. The measure takes on higher values for firms that have a balanced risk management approach; the measure takes on lower values for firms that just focus on improving some ERM components while ignoring the weakest one. *Multiline* is 1 if the number of lines in which insurer has positive direct premiums written > 3, 0 otherwise. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

**Table 12. Frontier Efficiency Regressions: ERM-entropy and Economies of Scope, Life as Diversification Measure**

| *Variables* | *TE* (1) | *PTE* (2) | *CE* (3) | *CEScope* (4) | *VCE* (5) | *RE* (6) | *REScope* (7) | *VRE* (8) | *PI* (9) | *SE* (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-entropy | -0.305*** | -0.140** | -0.253** | -0.148 | -0.147 | -0.231* | -0.133 | -0.095 | 0.878*** | -0.173*** |
| | (0.076) | (0.065) | (0.099) | (0.099) | (0.117) | (0.129) | (0.132) | (0.124) | (0.258) | (0.051) |
| ERM-entropy*Life | 0.246*** | 0.122* | 0.207** | 0.131 | 0.141 | 0.285** | 0.211* | 0.142 | -0.688*** | 0.129*** |
| | (0.073) | (0.062) | (0.095) | (0.095) | (0.112) | (0.124) | (0.127) | (0.119) | (0.248) | (0.049) |
| Life | -0.028 | 0.011 | -0.101*** | -0.083*** | -0.083** | -0.073* | -0.044 | 0.006 | 0.128 | -0.042*** |
| | (0.023) | (0.020) | (0.030) | (0.030) | (0.036) | (0.039) | (0.040) | (0.038) | (0.079) | (0.015) |
| Single channel | -0.012 | 0.005 | 0.017 | 0.028** | 0.059*** | 0.049*** | 0.062*** | 0.079*** | 0.006 | -0.018*** |
| | (0.010) | (0.009) | (0.013) | (0.013) | (0.015) | (0.017) | (0.017) | (0.016) | (0.034) | (0.007) |
| Mutual | 0.026** | 0.000 | 0.087*** | 0.070*** | 0.026 | -0.033* | -0.051** | -0.054*** | 0.012 | 0.026*** |
| | (0.012) | (0.010) | (0.015) | (0.015) | (0.018) | (0.020) | (0.020) | (0.019) | (0.040) | (0.008) |
| Public | -0.004 | 0.000 | 0.106*** | 0.112*** | 0.085*** | -0.107*** | -0.112*** | -0.056** | 0.148*** | -0.003 |
| | (0.015) | (0.013) | (0.020) | (0.020) | (0.023) | (0.026) | (0.026) | (0.025) | (0.052) | (0.010) |
| Size | -0.013*** | 0.030*** | 0.023*** | 0.053*** | 0.135*** | -0.036*** | -0.011 | 0.105*** | 0.017 | -0.043*** |
| | (0.005) | (0.004) | (0.006) | (0.006) | (0.007) | (0.008) | (0.008) | (0.007) | (0.016) | (0.003) |
| Capital to asset | 0.036 | 0.068* | -0.218*** | -0.213*** | -0.294*** | -0.153** | -0.132* | 0.272*** | -0.201 | -0.034 |
| | (0.044) | (0.037) | (0.057) | (0.057) | (0.067) | (0.074) | (0.076) | (0.071) | (0.148) | (0.029) |
| Reinsurance | -0.005 | -0.034 | -0.013 | -0.036 | -0.090* | -0.271*** | -0.298*** | -0.265*** | 0.383*** | 0.027 |
| | (0.035) | (0.030) | (0.045) | (0.045) | (0.053) | (0.059) | (0.060) | (0.056) | (0.118) | (0.023) |
| Risky investment | -0.042 | -0.073*** | -0.109*** | -0.127*** | -0.166*** | -0.299*** | -0.330*** | -0.306*** | 0.441*** | 0.033* |
| | (0.029) | (0.025) | (0.038) | (0.038) | (0.044) | (0.049) | (0.050) | (0.047) | (0.098) | (0.019) |
| Constant | 1.027*** | 0.780*** | 0.643*** | 0.477*** | 0.076 | 1.174*** | 1.042*** | 0.242*** | 0.004 | 1.251*** |
| | (0.044) | (0.037) | (0.057) | (0.057) | (0.067) | (0.074) | (0.076) | (0.071) | (0.149) | (0.029) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.384 | 0.291 | 0.537 | 0.554 | 0.614 | 0.417 | 0.376 | 0.438 | 0.390 | 0.533 |
| N | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone (2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-entropy* measures an insurer's degree of diversification across the different ERM components. The measure takes on higher values for firms that have a balanced risk management approach; the measure takes on lower values for firms that just focus on improving some ERM components while ignoring the weakest one. *Life* is 1 if the parent company of the property-casualty insurer owns also a life insurer, 0 otherwise. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.

**Table 13. Frontier Efficiency Regressions: ERM-entropy and Economies of Scope, Unrelated Diversification Measure**

| *Variables* | *TE* (1) | *PTE* (2) | *CE* (3) | *CEScope* (4) | *VCE* (5) | *RE* (6) | *REScope* (7) | *VRE* (8) | *PI* (9) | *SE* (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| ERM-entropy | 0.017 | 0.028** | 0.039** | 0.051*** | 0.067*** | 0.041* | 0.049** | 0.047** | -0.025 | -0.010 |
| | (0.014) | (0.012) | (0.018) | (0.018) | (0.021) | (0.023) | (0.024) | (0.022) | (0.047) | (0.009) |
| ERM-entropy*Unrelated | -0.173*** | -0.140*** | -0.231*** | -0.223*** | -0.281*** | -0.167** | -0.150** | -0.154** | 0.448*** | -0.039 |
| | (0.038) | (0.033) | (0.050) | (0.050) | (0.058) | (0.065) | (0.067) | (0.062) | (0.129) | (0.026) |
| Unrelated | 0.181*** | 0.150*** | 0.287*** | 0.282*** | 0.309*** | 0.072 | 0.057 | 0.085 | -0.342* | 0.037 |
| | (0.054) | (0.047) | (0.071) | (0.071) | (0.083) | (0.093) | (0.095) | (0.089) | (0.185) | (0.037) |
| Single channel | -0.015 | -0.001 | 0.028** | 0.038*** | 0.069*** | 0.052*** | 0.062*** | 0.074*** | 0.005 | -0.015** |
| | (0.010) | (0.008) | (0.012) | (0.012) | (0.015) | (0.016) | (0.017) | (0.016) | (0.032) | (0.006) |
| Mutual | 0.030*** | 0.005 | 0.078*** | 0.061*** | 0.016 | -0.038** | -0.054*** | -0.051*** | 0.005 | 0.025*** |
| | (0.011) | (0.010) | (0.014) | (0.014) | (0.017) | (0.019) | (0.019) | (0.018) | (0.038) | (0.007) |
| Public | -0.001 | 0.004 | 0.099*** | 0.105*** | 0.077*** | -0.119*** | -0.123*** | -0.058** | 0.147*** | -0.005 |
| | (0.014) | (0.012) | (0.019) | (0.019) | (0.022) | (0.025) | (0.025) | (0.024) | (0.049) | (0.010) |
| Size | -0.010** | 0.032*** | 0.024*** | 0.054*** | 0.137*** | -0.031*** | -0.007 | 0.109*** | 0.008 | -0.042*** |
| | (0.005) | (0.004) | (0.006) | (0.006) | (0.007) | (0.008) | (0.008) | (0.007) | (0.015) | (0.003) |
| Capital to asset | 0.034 | 0.059 | -0.184*** | -0.181*** | -0.262*** | -0.155** | -0.140* | 0.255*** | -0.217 | -0.024 |
| | (0.043) | (0.037) | (0.056) | (0.056) | (0.065) | (0.073) | (0.075) | (0.070) | (0.145) | (0.029) |
| Reinsurance | 0.012 | -0.020 | 0.031 | 0.009 | -0.036 | -0.247*** | -0.277*** | -0.247*** | 0.327*** | 0.032 |
| | (0.035) | (0.030) | (0.046) | (0.046) | (0.054) | (0.060) | (0.061) | (0.057) | (0.119) | (0.024) |
| Risky investment | -0.019 | -0.057** | -0.106*** | -0.128*** | -0.163*** | -0.284*** | -0.318*** | -0.288*** | 0.380*** | 0.039** |
| | (0.028) | (0.024) | (0.037) | (0.037) | (0.043) | (0.048) | (0.050) | (0.047) | (0.097) | (0.019) |
| Constant | 0.899*** | 0.706*** | 0.427*** | 0.286*** | -0.131* | 1.061*** | 0.965*** | 0.191** | 0.326** | 1.192*** |
| | (0.046) | (0.040) | (0.060) | (0.060) | (0.071) | (0.079) | (0.081) | (0.076) | (0.157) | (0.031) |
| Line of business controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.399 | 0.302 | 0.545 | 0.563 | 0.626 | 0.422 | 0.380 | 0.441 | 0.402 | 0.531 |
| N | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 | 613 |

*Notes:* The dependent variables are various types of frontier efficiency. TE − technical efficiency; PTE − pure technical efficiency; CE − cost efficiency based on CRS technology; CEScope − CE purged of scale efficiency; VCE − cost efficiency based on VRS technology; RE − revenue efficiency based on CRS technology; REScope − RE purged of scale efficiency; VRE − revenue efficiency based on VRS technology; PI − profit inefficiency, based on Cooper, Seiford, and Tone (2000), equation 8.1. CRS indicates "Constant returns to scale"; SE – input-oriented scale efficiency; VRS indicates "Variable returns to scale". *N* denotes firm-year observations. *ERM-entropy* measures an insurer's degree of diversification across the different ERM components. The measure takes on higher values for firms that have a balanced risk management approach; the measure takes on lower values for firms that just focus on improving some ERM components while ignoring the weakest one. *Unrelated* means unrelated diversification, which is 1 minus weighted average relatedness of insurer's underwriting portfolio. *Single channel* is 1 if the insurer uses only one single distribution channel, 0 otherwise. *Mutual* is 1 if insurer is a mutual, 0 otherwise. *Public* is 1 if insurer is organized as an insurer under public law, 0 otherwise. *Size* is the natural logarithm of total assets. *Capital to asset* is equal to the ratio of the equity capital to total assets. *Reinsurance* is captured by the difference between total direct premiums written and net premiums written (i.e., after reinsurance ceded), divided by net premiums written. *Risky investment* is stock and real estate divided by total assets. *Line of business controls* are calculated by dividing premiums written in each line of business by total premiums written. *Year dummies* (Year FE) are included in each regression. Standard errors are in parenthesis below each coefficient estimate. *, **, and *** denote statistical significance at the 10, 5, and 1 percent levels, respectively. Data are for the years 1999 through 2009.