Institute of Insurance Economics

University of St.Gallen

FRONTIER EFFICIENCY METHODOLOGIES TO MEASURE PERFORMANCE IN THE INSURANCE INDUSTRY: OVERVIEW AND NEW EMPIRICAL EVIDENCE

MARTIN ELING

MICHAEL LUHNEN

WORKING PAPERS ON RISK MANAGEMENT AND INSURANCE NO. 56

EDITED BY HATO SCHMEISER

CHAIR FOR RISK MANAGEMENT AND INSURANCE

JULY 2008

FRONTIER EFFICIENCY METHODOLOGIES TO MEASURE PERFORMANCE IN THE INSURANCE INDUSTRY: OVERVIEW AND NEW EMPIRICAL EVIDENCE

Martin Eling, Michael Luhnen*

JEL Classification: D23, G22, L11

ABSTRACT

The purpose of this paper is to provide an overview and new empirical evidence on frontier efficiency measurement in the insurance industry, a topic of great interest in the academic literature during the last several years. In the first step, we review 87 studies and put them into a joint evaluation of efficiency measurement in the field of insurance. In the second step, a broad efficiency comparison of 3,555 insurers from 34 countries is conducted. Different methodologies, countries, organizational forms, and company sizes are compared, considering life and non-life insurers. We find a steady technical and cost efficiency growth in international insurance markets from 2002 to 2006, with large differences across countries. Denmark and Japan have the highest average efficiency, whereas the Philippines is the least efficient. Furthermore, the analysis shows that mutuals are more efficient than stock companies. Only minor variations are found when comparing different frontier efficiency methodologies (data envelopment analysis, stochastic frontier analysis). The results give valuable insights into the international competitiveness of insurers in various countries.

1. INTRODUCTION

In recent years, efficiency measurement has captured a great deal of attention. The insurance sector in particular has seen rapid growth in the number of studies applying frontier efficiency methods. Berger/Humphrey (1997) and Cummins/Weiss (2000) surveyed eight and 21 studies, respectively. Now, less than ten years after the Cummins/Weiss survey, we find 87 studies on efficiency measurement in the insurance industry. Recent work in the field has refined methodologies, addressed new topics (e.g., market structure and risk management), and extended geographic coverage from a previously US-focused view to a broad set of countries around the world, including emerging markets such as China and Taiwan.

The first aim of this paper is to survey these 87 studies. We provide a comprehensive categorization of this rapidly growing body of literature and point out new develop-

* Both authors are with the University of St. Gallen, Institute of Insurance Economics, Kirchlistrasse 2, 9010 St. Gallen, Switzerland. We are grateful to Rajiv Banker, Mareike Bodderas, Steve Diacon, Martin Grace, Ines Holzmüller, Karligash Kenjegalieva, Paul Klumpes, Thomas Parnitzke, Richard Phillips, Hato Schmeiser, Denis Toplek, Lucinda Trigo-Gamarra, Thomas Url, Xiaoying Xie, and the participants of the Journal of Banking & Finance Conference on Performance Measurement in the Financial Services Sector (Imperial College, London) for valuable suggestions and comments.

ments. Frontier efficiency methodologies have been used in the analysis of many important economic issues, such as comparing the efficiency of insurers located in different countries (see, e.g., Diacon/Starkey/O'Brien, 2002), having different organizational forms (see, e.g., Cummins/Weiss/Zi, 1999), and of varying sizes (see, e.g., Fecher/Perelman/Pestieau, 1991). Other research questions have involved the efficiency effects of mergers and acquisitions (see, e.g., Cummins/Tennyson/Weiss, 1999) and the comparison of different frontier efficiency methodologies (see, e.g., Cummins/Zi, 1998). In our overview, we will review these fields of application, summarize the methodologies, and survey recent developments. Whenever possible, we highlight emerging best practices in the field.

Existing cross-country comparisons of efficiency in the insurance industry provide valuable insights into the competitiveness of insurers in different countries. However, the geographic coverage of these studies is limited to certain countries or regions. Weiss (1991b) compares the US, Germany, France, Switzerland, and Japan. Donni/Fecher (1996) analyze 15 OECD countries. Both authors were restricted to using aggregated economic information instead of individual company data. Diacon/Starkey/O'Brien (2002) and Fenn et al. (2008) use individual company data, but concentrate on European countries (15 and 14, respectively). Rai (1996) takes a look at nine European countries, Japan, and the US, but considers a relatively small dataset of 106 companies. What is missing is a broad comparison of efficiency at the international level that incorporates a large number of countries and companies.

The second aim of this paper is thus to contribute to the growing body of literature on frontier efficiency at the international level by answering key research questions based on a large number of countries and companies. We therefore consider a broad international dataset—the AM Best Non US database. Our cross-country analysis uses data on 3,555 insurance companies from 34 countries, which gives our study one of the largest samples ever analyzed for the insurance industry. We consider five main aspects: (1) methodologies, (2) countries, (3) organizational forms, (4) lines of business, and (5) company size. These five aspects allow us to address many of the economic questions set out in the first part of the paper. Another important contribution of this paper is that we determine and compare efficiency for 12 countries that have not been considered in the literature to date: Barbados, Bermuda, Brazil, Hong Kong, Indonesia, Lithuania, Mexico, Norway, Poland, Russia, Singapore, and South Africa. Our empirical analysis thus provides a broad evaluation of efficiency in the international insurance industry, including many emerging markets from all over the world.

Our four main empirical findings are as follows. (1) There is steady technical and cost efficiency growth in international insurance markets during the sample period (2002–2006), with large efficiency differences between the 34 countries. The highest efficiency scores are found for Denmark and Japan, the lowest for the Philippines. (2) Our analysis does not show evidence in support of the expense preference hypothesis or for the managerial discretion hypotheses, i.e., in our sample, mutuals are consistently more efficient than stock companies. (3) In line with most other empirical studies, we find that larger companies are more efficient than smaller companies; we also uncover evidence for economies of scale. (4) There is very little difference in the results of the two frontier efficiency methodologies—data envelopment analysis and stochastic frontier analysis.

The remainder of the paper is organized as follows. Section 2 contains the overview of 87 studies on efficiency measurement in the insurance industry. The empirical examination is performed in Section 3. The results of the study are summarized in Section 4.

2. Overview of Efficiency Measurement in the Insurance Industry

The following overview of 87 papers (60 published articles, 27 working papers) builds upon and significantly extends two earlier surveys of efficiency measurement literature in the financial services industry: One by Berger/Humphrey (1997), which focuses on banks. The second one by Cummins/Weiss (2000) focuses on the insurance industry and covers 21 studies that have been published until the year 1999. Three studies (Weiss, 1986, Weiss, 1991b, Bernstein, 1999) that are considered in Cummins/Weiss (2000) have been excluded from this overview since they are not efficient frontier based, but focus on productivity (these studies are included in an extended overview that we present in Appendix 1).

Table 1 is arranged according to ten different application areas (first column). Some of these application areas have been selected following Berger/Humphrey's (1997) overview for the banking sector. However, we extended and refined their systematization to account for the specifics of the insurance sector. Although many studies make contributions to more than one topic, we tried to focus on the primary field of application. More detailed information, such as input and output factors, types of efficiencies analyzed, sample periods, lines of business covered, and main findings, is presented in Appendix 1.

Table 1: Studies on Efficiency in the Insurance Industry

Application	Country	Method	Author (Date)
Distribution systems	US	DFA	Berger/Cummins/Weiss (1997)
	US	DEA	Brockett et al. (1998)
	US	DEA	Carr/Cummins/Regan (1999)
	UK	SFA	Klumpes (2004)
	Germany	DEA	Trigo Gamarra/Growitsch (2008)
	UK	SFA	Ward (2002)
Financial and risk management, capital utilization	US	DEA	Brockett et al. (2004)
	US	SFA	Cummins et al. (2006)
	US	DEA	Cummins/Nini (2002)
General level of efficiency and evolution over time	Portugal	DEA	Barros/Barroso/Borges (2005)
	Nigeria	DEA	Barros/Obijiaku (2007)
	Netherlands	SFA	Bikker/van Leuvensteijn (2008)
	US	DEA	Cummins (1999)
	Tunisia	DEA, SFA	Chaffai/Ouertani (2002)
	Italy	DEA	Cummins/Turchetti/Weiss (1996)
	US	SFA	Cummins/Weiss (1993)
	France	DEA, SFA	Fecher et al. (1993)
	US	DFA	Gardner/Grace (1993)
	Taiwan	DFA	Hao (2007)
	Taiwan	DFA, SFA	Hao/Chou (2005)
	UK	SFA	Hardwick (1997)
	China	SFA	Huang (2007)
	Germany	DEA	Kessner/Polborn (1999)
	China	DEA	Leverty/Lin/Zhou (2004)
	Malaysia	DEA	Mansor/Radam (2000)
	Greece	DEA	Noulas et al. (2001)
	China	DEA	Qiu/Chen (2006)
	India	DEA	Tone/Sahoo (2005)
	14 European countries	SFA	Vencappa/Fenn/Diacon (2008)
	US	SFA	Weiss (1991a)
	Australia	DEA	Worthington/Hurley (2002)
	China	DEA	Yao/Han/Feng (2007)
Intercountry comparisons	France, Belgium	DEA, SFA	Delhausse et al. (1995)
	6 European countries	DEA	Diacon (2001)
	15 European countries	DEA	Diacon/Starkey/O'Brien (2002)
	15 OECD countries	DEA	Donni/Fecher (1997)
	Germany, UK	DEA	Kessner (2001a)
	Austria, Germany	DEA	Mahlberg (1999)
	11 OECD countries	DFA, SFA	Rai (1996)
Market structure	US	SFA	Choi/Weiss (2005)
	US	SFA	Choi/Weiss (2008)
	14 European countries	SFA	Fenn et al. (2008)
Mergers	US	DEA	Cummins/Tennyson/Weiss (1999)
	US	DEA	Cummins/Xie (2008)
	7 European countries	DEA	Davutyan/Klumpes (2008)
	US	DFA	Kim/Grace (1995)
	7 European countries	DEA	Klumpes (2007)
Methodology issues, comparing different techniques or assumptions	US	DEA, DFA, FDH, SFA	Cummins/Zi (1998)
	Spain	SFA	Fuentes/Grifell-Tatjé/Perelman (2001)
	Japan	DEA	Fukuyama/Weber (2001)
	Taiwan	DEA	Hwang/Kao (2008)
	US	DEA	Leverty/Grace (2008)
	Canada	DEA	Wu et al. (2007)
	Canada	DEA	Yang (2006)
Organizational form, corporate governance issues	US	DEA	Brockett et al. (2005)
	Spain	DEA	Cummins/Rubio-Misas/Zi (2004)
	US	DEA	Cummins/Weiss/Zi (1999)
	Germany	DEA	Diboky/Ubl (2007)
	Belgium	FDH	Donni/Hamende (1993)
	US	DEA	Erhemjamts/Leverty (2007)
	Japan	DEA	Fukuyama (1997)
	US	SFA	Greene/Segal (2004)

Notations: DEA: data envelopment analysis; DFA: distribution-free approach; FDH: free disposal hull; SFA: stochastic frontier approach; TFA: thick frontier approach

Table 1: Studies on Efficiency in the Insurance Industry (continued)

Application	Country	Method	Author (Date)
Organizational form, corporate governance issues (cont.)	UK	DEA	Hardwick/Adams/Zou (2004)
	Japan	DEA	Jeng/Lai (2005)
	US	DEA	Jeng/Lai/McNamara (2007)
	US	DEA	Xie (2008)
Regulation change	Ukraine	DEA	Badunenko/Grechanyuk/Talavera (2006)
	Korea, Philippines, Taiwan, Thailand	DEA	Boonyasai/Grace/Skipper (2002)
	Spain	DEA	Cummins/Rubio-Misas (2006)
	Austria	SFA	Ennsfellner/Lewis/Anderson (2004)
	Germany, UK	DEA, DFA	Hussels/Ward (2006)
	Germany	DEA	Mahlberg (2000)
	Germany	DEA	Mahlberg/Url (2000)
	Austria	DEA	Mahlberg/Url (2003)
	Germany, UK	DEA	Rees et al. (1999)
	US	DFA	Ryan/Schellhorn (2000)
	US	SFA	Yuan/Phillips (2008)
Scale and scope economies	US	TFA, SFA	Berger et al. (2000)
	US	DEA	Cummins/Weiss/Zi (2007)
	France	SFA	Fecher/Perelman/Pestieau (1991)
	Spain	SFA	Fuentes/Grifell-Tatjé/Perelman (2005)
	Japan	SFA	Hirao/Inoue (2004)
	Ireland	DFA	Hwang/Gao (2005)
	Germany	DEA	Kessner (2001b)
	US	DFA	Meador/Ryan/Schellhorn (2000)
	Finland	SFA	Toivanen (1997)
	US	SFA, TFA	Yuengert (1993)

Notations: DEA: data envelopment analysis; DFA: distribution-free approach; FDH: free disposal hull; SFA: stochastic frontier approach; TFA: thick frontier approach

2.1. FRONTIER EFFICIENCY METHODOLOGIES

The concept of efficiency measurement means that the performance of a company is measured relative to a "best practice" frontier, which is determined by the most efficient companies in the industry. There are two main approaches in efficient frontier analysis: the econometric approach and the mathematical programming approach. We shortly introduce these two approaches (including references to detailed overviews), discuss their application to the insurance field, and highlight recent innovations.

Econometric approaches

The econometric approaches specify a production, cost, revenue, or profit function with a specific shape and make assumptions about the distributions of the inefficiency and error terms. There are three principal types of econometric frontier approaches. Although they all specify an efficient frontier form—usually translog, but also alternative forms such as generalized translog, Fourier flexible, or composite cost— they differ in their distributional assumptions of the inefficiency and random components (see Cummins/Weiss, 2000). The *stochastic frontier approach* (SFA) assumes a composed error model where inefficiencies follow an asymmetric distribution (e.g., half-normal, exponential, or gamma) and the random error term follows a symmetric distribution, usually normal. The *distribution-free approach* (DFA) makes fewer specific assumptions, but requires several years of data. Efficiency of each company is assumed to be stable over time, and the random noise averages out to zero. Finally, the *thick frontier approach* (TFA) does not make any distributional assumptions for the random error and inefficiency terms, but assumes that inefficiencies differ between the highest and lowest quartile firms (see, e.g., Kumbhakar/Lovell, 2000).

Mathematical programming approaches

Compared with the econometric approaches, the mathematical programming approaches put significantly less structure on the specification of the efficient frontier and do not decompose the inefficiency and error terms. The most widespread mathematical programming approach is *data envelopment analysis* (DEA), which uses linear programming to measure the relationship of produced goods and services (outputs) to assigned resources (inputs). DEA determines the efficiency score as an optimization result. DEA models can be specified under the assumption of constant (CRS) or variable returns to scale (VRS) and can be used to decompose cost efficiency into its single components—technical, pure technical, allocative, and scale efficiency. The *free-disposal hull* (FDH) approach is a special configuration of DEA. Under this approach, the points on the lines connecting the DEA vertices are excluded from the frontier and the convexity assumption on the efficient frontier is relaxed (see Cooper/Seiford/Tone, 2007). The concept of *total factor productivity* is often used in combination with efficiency studies. Total factor productivity growth is measured as the change in total outputs net of the change in total input usage. The *Malmquist index of total factor productivity* decomposes total factor productivity growth into two elements: First, technical efficiency changes to determine in how far the distance of an individual firm to the efficient frontier has changed. Second, technical change to determine the movements of the efficient frontier itself due to technical change over time (see Grosskopf, 1993; Cummins/Weiss, 2000).

Both the econometric and mathematical programming have their advantages and disadvantages (see Berger/Humphrey, 1997) and there is no consensus as to which method is superior (see, e.g., Cummins/Zi, 1998; Hussels/Ward, 2006). But the DEA approach has been most frequently used. Out of the 87 studies surveyed, 50 use DEA, 20 SFA, seven DFA, and one FDH. Nine studies follow the advice given by Cummins/Zi (1998) and consider multiple approaches, ideally from both the econometric and mathematical programming sides. Most of these find highly correlated results when ranking firms by their relative efficiency according to different approaches (see, e.g., Hussels/Ward, 2006). However, both approaches illuminate efficiency from different perspectives and thus deliver different insights. This is why we consider both approaches in the empirical part of this paper. For DEA, the most widely used specifications have been under the assumption of VRS. For SFA, most studies chose the translog functional form. Total factor productivity has been calculated by 23 studies—in combination with DEA in 20 cases and with SFA in three cases. The choice of methods is often determined by the available data. For example, if the available data are known to be noisy, the econometric approach, featuring an error term to accommodate noise, may lead to more accurate results. In this case, the mathematical programming approach would not be appropriate, since it mistakes the noise as inefficiencies due to the fact that there is no error term (see Cummins/Weiss, 2000).

In recent years, there have been a number of proposals for the improvement of efficient measurement in the field of insurance. For the *econometric approach*, a major direction has been to apply more flexible specifications of the functional form. Examples are the composite cost function or the Fourier flexible distribution (see, e.g., Fenn et al. 2008). Also, Bayesian stochastic frontier models (see van den Broek et al., 1994), featuring advantages such as exact small-sample inference on efficiencies, have been applied to insurance (see, e.g., Ennsfellner/Lewis/Anderson, 2004). A further proposal has been made regarding the incorporation of firm-specific variables into the estimation process. Instead of using a two-stage approach, which first estimates inefficiency of sample firms and then examines the association of inefficiency with firm-specific variables through regressions, a one-stage approach is suggested. In this approach, the estimated frontier directly takes into account firm-specific variables by modeling mean inefficiency as a function of firm-specific variables (conditional mean approach, see, e.g., Greene/Segal, 2004; Huang/Liu, 1994). Fenn et al. (2008) address the drawback of the conditional mean approach, that the variance of the random and efficiency errors are assumed constant. Following a procedure by Kumbhakar/Lovell (2000), they explicitly model the variance of both types of errors and thus correct for heteroskedasticity. Another contribution has been made with regard to the Malmquist index of total factor productivity. Although this index is usually applied to nonparametric DEA for insurance companies, Fuentes/Grifell-Tatjé/Perelman (2001) develop a parametric distance function that enables them to calculate the Malmquist index also for the econometric approach.

One major drawback of the *mathematical programming approach* has been the lack of statistical properties. But Banker (1993) has shown that DEA estimators can also be interpreted as maximum likelihood estimators under certain conditions, providing a statistical base to DEA. However, the sampling distribution of the underlying DEA efficiency estimators stays unknown (see, e.g., Berger/Humphrey, 1997). Also, DEA efficiency estimates have been shown to be biased upward in finite examples (see, e.g., Simar/Wilson, 1998). In this context, the bootstrapping procedure proposed by Simar/Wilson (1998) has been applied to the insurance industry. It accounts for various kinds of efficiency (cost, technical, revenue) as well as CRS and VRS models. It provides an empirical approximation of the sampling distribution of efficiency estimates and corrects the upwards bias (see, e.g., Cummins/Weiss/Zi, 2007; Erhemjamts/Leverty, 2007; Diboky/Ubl, 2007). A further innovation is the introduction of crossfrontier efficiency analysis, which estimates efficiency of firms using one particular technology relative to the best practice frontier of firms with an alternative technology. Doing this, it is possible to determine whether the outputs of one specific technology could be produced more efficiently using the alternative technology (see Cummins/Weiss/Zi, 1999, 2003). Finally, Brocket et al. (2004, 2005) apply a range-adjusted measure version of DEA to the insurance industry. This DEA version, in contrast to other DEA models, offers the advantage of being able to produce efficiency rankings suitable for significance tests such as the Mann-Whitney statistic.

2.2. Input and Output Factors Used in Efficiency Measurement

Choice of input factors

There are three main insurance inputs: *labor*, *business service and materials*, and *capital*. Labor can be further divided into agent and home-office labor. The category of business service and materials is usually not further subdivided, but includes items like travel, communications, and advertising. At least three categories of capital can be distinguished: physical, debt, and equity capital (see Cummins/Tennyson/Weiss, 1999; Cummins/Weiss, 2000). Data on the number of employees or hours worked are not publicly available for the insurance industry in most cases. Therefore, in order to proxy labor and business service input, input quantities are derived by dividing the expenditures for these inputs with publicly available wage variables or price indices. For example, the US Department of Labor data on average weekly wages for SIC Class 6311 (home-office life insurance labor), can be used in the case of studying the US insurance industry (see, e.g., Berger/Cummins/Weiss, 1997; Cummins/Zi, 1998). Physical capital is often included in the business service and materials category, but debt and equity capital are important inputs for which adequate cost measures have to be found (see, e.g., Cummins/Weiss/Zi, 1999).

Fifty-eight of the 87 studies use at least labor and capital as inputs and most of them also add a third category (often business services; see Appendix 1). Out of those 58 studies, 18 differentiate between agent and nonagent labor. Also, the number of studies using both equity and debt capital is low: only 13 do so. Considering the 29 contributions that do not follow the standard input categories, 16 of them incorporate broader expenditure categories as inputs—e.g., total operating expenses—without decomposing them into quantities and prices (see, e.g., Rees et al., 1999; Mahlberg/Url, 2003). Nine studies do not cover capital explicitly, i.e., they consider labor only or labor and an additional composite category. Finally, four studies that focus on financial intermediation consider only capital-related inputs (see, e.g., Brocket et al., 1998).

Choice of output factors

There are three principal approaches to measuring outputs. The *intermediation approach* views the insurance company as a financial intermediary that manages a reservoir of assets, borrowing funds from policyholders, investing them on capital markets, and paying out claims, taxes, and costs (see Brocket et al., 1998). The *user-cost method* differentiates between inputs and outputs based on the net contribution to revenues. If a financial product yields a return that exceeds the opportunity cost of funds or if the financial costs of a liability are less than the opportunity costs, it is deemed a financial input. Otherwise, it is considered a financial output (see Hancock, 1985; Cummins/Weiss, 2000). The *value-added approach* counts outputs as important if they contribute a significant added value based on operating cost allocations (see Berger et al., 2000). Usually, several types of outputs are defined, representing the single lines of business under review.

The value-added approach has been established as best practice; 74 of the 87 studies apply this approach (see Appendix 1). However, there is a debate among those using the value-added approach as to whether claims/benefits or premiums/sum insured are the most appropriate proxy for value added. Out of the 74 articles, 40 follow Cummins/Weiss (2000) and specify output as either claims/present value of claims (property-liability) or benefits/net incurred benefits (life). Thirty-one studies specify output as premiums/sum insured. Two studies use both proxies—claims for non-life and premiums for life insurance. One study uses neither of the two main proxies: Yuengert (1993) takes reserves/additions to reserves as a proxy for value added. Although more studies use claims/benefits to proxy output than premiums/sum insured, there is no recognizable trend over time as to whether either of the two main proxies is gaining more of a following among researchers.[1] Since the value-added approach to output measurement dominants the literature, there have only been few innovations with regard to output measurement. Hwang/Kao (2008) introduce a new relational two-stage production process, in which the outputs of the first production stage, called "premium acquisition", are the inputs for the second production stage, called "profit generation". Regarding the other two approaches for output measurement, five studies employ the intermediation approach, e.g., taking ROI, liquid assets to liability, and solvency scores as outputs (see Brockett et al., 2004, 2005). As argued by Cummins/Weiss (2000), this approach is not optimal because insurers provide many services in addition to financial intermediation. None of the studies reviewed uses the user-cost approach, because this approach requires precise data on product revenues and opportu-

[1] We categorized the number of studies by usage of output proxy and year of publication: from 1991 to 1995 3 studies use claims/benefits and 5 use premiums/sum insured; 1996–2000: 12/7; 2001–2005: 12/12; 2006–2008: 13/7. In the empirical section of our paper, we follow Cummins/Weiss (2000) and use claims/benefits to proxy output; we assume that premiums/sum insured might be used in many studies because these measures are more readily available for most countries.

nity costs, which are not available in the insurance industry (see Klumpes, 2007). Five studies use both the value-added and intermediation approaches (see, e.g., Jeng/Lai, 2005; Leverty/Grace, 2008). Two studies apply physical outputs, e.g., Toivanen (1997) uses number of product units produced as insurance output.

2.3. Fields of Application in Efficiency Measurement and Results

Distribution systems

Brockett et al. (1998, 2004), studying the US, and Klumpes (2004), studying the United Kingdom, both find that independent agent distribution systems are more efficient than direct systems involving company representatives or employed agents. Berger/Cummins/Weiss (1997) find for the US that independent agent systems are less cost efficient, but equally profit efficient. On a more general level, Ward (2002) finds for the United Kingdom that insurers focusing on one distribution system are more efficient than those employing more than one mode of distribution. Trigo Gamarra/Growitsch (2008), in a study for German life insurance, finds that single line insurers are neither more cost nor more profit efficient than multichannel insurers.

Financial and risk management, capital utilization

Cummins et al. (2006) were the first to explicitly investigate the relationship between risk management, financial intermediation, and economic efficiency. In their application to the US property-liability industry, they analyze whether both activities contribute to efficiency through reducing costs of providing insurance. In order to show the contribution of risk management and financial intermediation to efficiency, they estimate shadow prices of these two activities. They find positive shadow prices of both activities and conclude that they significantly contribute to increasing efficiency. Brockett et al. (2004) find that solvency scores have limited impact on efficiency in the US property liability market. Cummins/Nini (2002) find for the same country and line of business, that large increases in capitalization between 1989 and 1999 represent an inefficiency in so far as equity capital is significantly over-utilized.

General level of efficiency and evolution over time

This category contains a large number of studies that represent a first application of efficiency frontier methods to countries. Examples are Nigeria (see Barros/Obijiaku, 2007), Tunisia (see Chaffai/Ouertani, 2002), Malaysia (see Mansor/Radam, 2000), or Australia (see Worthington/ Hurley, 2002). Given the broad range of countries and time horizons employed, findings regarding efficiency and productivity are mixed. However, nearly all studies note that there are significant levels of inefficiency with corresponding room for improvement. For example the Netherlands with 75% cost efficiency on average have significant improvement potential (see Bikker/van Leuvensteijn, 2008). The same is true for China with average technical efficiency of 77%

in non-life and 70% in life (see Yao/Han/Feng, 2007), as well as Greece with average cost efficiency of 65% (see Noulas et al., 2001).

Intercountry comparisons

The implementation of the single European Union (EU) insurance license in 1994 raised concerns about international competitiveness among insurers (see Diacon/Starkey/O'Brien, 2002). Consequently, there have been quite a few efficiency studies on this topic. For a sample of 450 companies from 15 European countries and for the period 1996–1999, Diacon/Starkey/O'Brien (2002) find striking international differences in average efficiency. According to their study, insurers doing long-term business in the United Kingdom, Spain, Sweden, and Denmark have the highest levels of technical efficiency. However, UK insurers seem to have particularly low levels of scale and allocative efficiency in the European comparison. Additionally, in a recent study involving 14 European countries for the period 1995–2001, Fenn et al. (2008) find increasing returns to scale for the majority of EU insurance companies. The results indicate that mergers and acquisitions, facilitated by the liberalized EU market, have led to efficiency gains. They also find that larger firms and firms with high market shares tentatively operate at higher levels of cost inefficiency. There are also cross-country efficiency studies looking at OECD country samples, e.g., Donni/Fecher (1997), comparing 15 OECD countries and Rai (1996), analyzing 11 OECD countries.

Market structure

Choi/Weiss (2005, 2008) analyze three hypotheses derived from the industrial organization literature: (1) The structure-conduct-performance hypothesis predicts that increased market concentration leads to higher prices and profits through increased possibilities for collusion among firms; (2) The relative market power (RMP) hypothesis focuses on economic rents and predicts that firms with relatively large market shares will exercise their market power and charge higher prices; (3) The efficient structure (ES) hypothesis claims that more efficient firms charge lower prices than their competitors, allowing them to capture larger market shares as well as economic rents, leading to increased market concentration. Choi/Weiss (2005) confirm the ES hypothesis and suggest that regulators should be more concerned with efficiency rather than market power arising from industry consolidation. Results of Choi/Weiss (2008) support the RMP hypothesis, implying that insurers in competitive and non-stringently regulated US states could profit from market power and charge higher unit prices. However, firms in those states have been found, on average, more cost efficient, and cost efficient insurers charge lower prices, earning smaller profits. A further contribution to the topic of market structure with a focus on the EU has been made by Fenn et al. (2008), finding that larger firms with high market shares tend to be less cost efficient.

Mergers

Mergers and acquisitions is a relatively new field for the application of efficiency methods. Kim/Grace (1995) simulate efficiency gains from hypothetical horizontal mergers in the US life insurance industry. The results indicate that most mergers would improve cost efficiencies, with the exception of mergers between large firms. Two other US studies (Cummins/Tennyson/Weiss (1999) for life insurance and Cummins/Xie (2008) for property-liability insurance) conclude that mergers are beneficial for the efficiency of acquiring and target firm. Financially vulnerable firms are more likely to be acquired. Klumpes (2007) tests the same hypothesis as Cummins/Tennyson/Weiss (1999) and Cummins/Xie (2008) for the European insurance market and finds that acquiring firms are more likely to be efficient than nonacquiring firms. However, he finds no strong evidence that target firms achieve greater efficiency gains than nontarget firms. Merger activity in the European insurance markets seems to be mainly driven by solvency objectives—i.e., financially weak insurers are bought by financially sound companies— and less by value maximization, as in the US.

Methodology issues, comparing different techniques or assumptions

A few studies primarily solve methodological issues or compare different techniques and assumptions over time. Cummins/Zi (1998) compare different frontier efficiency methods—DEA, DFA, FDH, SFA—and Fuentes/Grifell-Tatjé/Perelman (2001) introduce a parametric frontier approach for the application of the Malmquist index. Leverty/Grace (2008) compare the value-added and intermediation approaches to efficiency measurement and find that these approaches are not consistent (see Section 2.1 and 2.2 for more details on methodology and techniques).

Organizational form, corporate governance issues

A well-developed field of frontier efficiency analysis deals with the effect of organizational form on performance. The two principal hypotheses in this area are the expense preference hypothesis (see Mester, 1991) and the managerial discretion hypotheses (see Mayers/Smith, 1988). The expense preference hypothesis states that mutual insurers are less efficient than stock companies due to higher perquisite consumption of mutual managers. The managerial discretion hypothesis claims that the two organizational forms use different technologies and that mutual companies are more efficient in lines of business with relatively low managerial discretion (see Cummins/Weiss, 2000). The empirical evidence on these two hypotheses with regards to insurance companies has been mixed. Most studies find that stock companies are more efficient than mutuals, confirming the expense preference hypothesis (see, e.g., Cummins/Weiss/Zi, 1999 and Erhemjamts/Leverty, 2007 for the US market; Diboky/Ubl, 2007 for Germany). However, other studies have found mutuals more efficient than stocks. For example, Diacon/Starkey/O'Brien (2002), in a comparison of 15 European countries, find higher levels of technical efficiency for mutuals than for stocks. Also, Greene/Segal (2004) in an application to the US life insurance industry, suggest that mutual companies are as cost efficient as stock companies. Other studies investigate efficiency improvements after demutualization (see, e.g., Jeng/Lai/McNamara, 2007) and compare the efficiency of firms after initial public offerings versus that of private firms (see Xie, 2008). Looking at corporate governance issues, the relation between cost efficiency and the size of the corporate board of directors is analyzed (see Hardwick/Adams/Zou, 2004).

Regulation change

The aim of deregulation in the financial services sector is to improve market efficiency and enhance consumer choice through more competition. However, the evidence on efficiency gains due to deregulation has been mixed. Rees et al. (1999) find modest efficiency improvements from deregulation for the UK and German life insurance markets for the period from 1992–1994. Hussels/Ward (2006) do not find clear evidence for a link between deregulation and efficiency for the same countries and line of business during the period 1991–2002. Mahlberg (2000) even finds decreasing efficiency for Germany considering life and property-liability insurance for the period of 1992–1996, but an increase in productivity. For Spain, Cummins/Rubio-Misas (2006) find clear evidence for total factor productivity growth for the period of 1989–1998, with consolidation reducing the number of firms in the market. Boonyasai/Grace/Skipper (2002) find evidence for productivity increases in Korea and the Philippines due to deregulation. On the issue of changing regulation in the US, Ryan/Schellhorn (2000) find unchanged efficiency levels from the start of the 1990s to the middle of that decade, a period during which risk-based capital requirements (RBC) became effective. Yuan/Phillips (2008) find empirical evidence for cost scope diseconomies and revenue scope economies for the integrated banking and insurance sectors after changes due to the Gramm-Leach-Bliley Act of 1999.

Scale and scope economies

Scale economies have been extensively researched in the context of consolidation and the justification of mergers (see Cummins/Weiss, 2000). Although detailed results vary across studies, depending on countries, methods, and time horizons employed, many contributions have found, on average, evidence for increasing returns to scale (see, e.g., Hardwick, 1997, for UK, Hwang/Gao, 2005, for Ireland, Qiu/Chen, 2006, for China, and Fecher/Perelman/Pestieau, 1991 for France). However, the differentiation between size clusters must be considered to achieve more specific results. For example, Yuengert (1993) finds increasing returns to scale for US life insurance firms with up to US$15 billion in assets and constant returns to scale for bigger firms. In contrast, Cummins/Zi (1998), for the same market, find increasing returns to scale for firms having up to US$1 billion in assets, and decreasing returns to scale for all others except for a few firms with constant returns to scale. An increasing number of cross-industry mergers involve insurers from different lines of business. In this context, researchers have found evidence for the existence of economies of scope, meaning that multi-product/-branch firms are more efficient than specialized firms (see, e.g., Meador/Ryan/Schellhorn, 2000; Cummins/Weiss/Zi, 2007; Fuentes/Grifell-Tatjé/ Perelman, 2005). Again, looking at the study results in more detail gives additional insights: For example, Berger et al. (2000) show for the US that profit scope economies are more likely to be realized by larger firms.

3. NEW EMPIRICAL EVIDENCE

As mentioned above, the geographic coverage of efficiency studies in the insurance industry has to date been limited to certain countries or regions. The contribution of this section is to give new insights into efficiency at the international level by analyzing technical and cost efficiency of a large number of countries and insurance companies. We compare different (1) methodologies, (2) countries, (3) organizational forms, (4) lines of business, and (5) company sizes, which allows us to address many of the research questions surveyed in Section 2. In each case, the results are presented at different levels of aggregation, which enables us to identify the effect of methodologies, countries, organization, lines of business, and size on efficiency. We determine and compare efficiency for 12 countries that have, to our knowledge, not been considered in the literature to date: Barbados, Bermuda, Brazil, Hong Kong, Indonesia, Lithuania, Mexico, Norway, Poland, Russia, Singapore, and South Africa.

3.1. DATA AND METHODOLOGY

The main data source is the 2007 edition of the AM Best Non US database (Version 2007.3). It contains information on 4,372 life and non-life insurance companies from 98 countries.[2] The database has five years of data, covering the period 2002–2006. Companies were included in our analysis if they had positive values for all the inputs and outputs described in Table 2, however, they were not required to have data for all years; we thus consider unbalanced panel data. This reduces our sample to 3,966 companies from 90 countries. Furthermore, in order to appropriately compare the different countries we require each country to have at least a total of 30 firm years and to have data for each of the five years that we analyze. This reduces our sample to 3,555 companies from 34 countries. The remaining 411 companies from 56 countries were in-

[2] The database also contains information on 659 insurance groups with 2,381 firm years that we did not include in our analysis.

cluded in the analysis as "other" countries.[3] As discussed above, there is widespread agreement in literature with regard to the choice of inputs. We thus use *labor*, *business services and material*, *debt capital*, and *equity capital* as inputs. Due to data availability, it was necessary to simplify this scheme by combining labor and business services as only operating expenses (including commissions) are available in the AM Best data. This simplification is common in many other international comparisons (see Diacon/Starkey/O'Brien, 2002; Fenn et al., 2008) for much the same reason it is made here. Furthermore, Ennsfellner/Lewis/Anderson (2004) argue that the operating expenses should be treated as a single input in order to reduce the number of parameters that will need to be estimated. We thus use operating expenses to proxy both labor and business services and handle these as a single input in the following analysis.

Cummins/Weiss (2000) showed in their analysis of operating expenses in the US insurance market that these are mostly labor related, i.e., in both life and non-life insurance, the largest expenses are employee salaries and commissions. We therefore concentrate on labor to determine the price of the operating-expenses-related input factor. The *price of labor* is determined using the ILO October Inquiry, a worldwide survey of wages and hours of work published by the International Labour Organization (ILO; see http://laborsta.ilo.org/) and used in a variety of efficiency applications (see, e.g., Fenn et al., 2008). The *price of debt capital* is proxied using country-specific one-year treasury bill rates for each year of the sample period. The *price of equity capital* is determined using the 20-year-average of the yearly rates of total return of the country-specific MSCI stock market indices (all data were obtained from the Datastream database; see Cummins/Rubio-Misas (2006) for a comparable selection and a discussion on selection depending on the insurer's capital structure and portfolio risk). To ensure that all monetary values are directly comparable, we deflate each year's value by the *consumer price index* to the base year 2002 (see Weiss, 1991b; Cummins/Zi, 1998). Country-specific consumer price indices were obtained from the ILO.

3 These countries are: Antigua and Barbuda (1 company/3 firm years), Argentina (4/15), Bahamas (10/43), Bahrain (4/18), Bolivia (14/37), British Virgin Islands (3/8), Bulgaria (5/14), Cayman Islands (14/57), Chile (50/144), China (8/19), Croatia (4/12), Cyprus (5/17), the Czech Republic (7/28), the Dominican Republic (1/4), Ecuador (40/106), Egypt (6/27), El Salvador (7/16), Estonia (12/47), Greece (3/6), Guernsey (2/6), Hungary (2/3), Iceland (7/21), India (12/52), the Isle of Man (3/9), Israel (10/28), Jamaica (3/12), Jordan (2/6), Kazakhstan (1/5), Kenya (4/14), Kuwait (4/17), Latvia (8/29), Lebanon (1/5), Macau (4/19), Malta (2/8), Monaco (1/1), Montserrat (1/2), Nigeria (2/9), the Northern Mariana Islands (1/4), Oman (3/8), Pakistan (4/14), Panama (3/13), Peru (9/27), Qatar (3/14), Romania (3/6), Saudi Arabia (1/5), Slovakia (10/23), Slovenia (4/15), South Korea (9/45), Tanzania (5/16), Thailand (17/45), Trinidad and Tobago (6/27), Tunisia (2/10), the Ukraine (3/9), the United Arab Emirates (3/7), Uruguay (12/34), and Venezuela (46/192). For many South American countries, there are no data available for 2006, which is why we excluded these from the country-specific analysis even though the number of companies is relatively large. Canadian insurers were not included, because they are presented in a separate section of the AM Best database with different data fields. We also did tests to ensure data consistency, e.g., for Denmark and Hong Kong; we are grateful to Steve Diacon and Xiaoying Xie for highlighting the specifics of these countries.

As done in most studies on efficiency in the insurance industry, we use the value-added approach to determine the outputs. We thus distinguish between the three main services provided by insurance companies—risk-pooling/-bearing, financial services, and intermediation. According to Yuengert (1993), a good proxy for the amount of risk-pooling/-bearing and financial services is the value of real incurred losses, defined as current losses paid plus additions to reserves. As different types of services are provided by life and non-life insurance firms, we need separate output measures for each type of firm (see Choi/Weiss, 2005). We use the present value of *net incurred claims plus additions to reserves* as a proxy for the output for non-life insurance and the present value of *net incurred benefits plus additions to reserves* for life insurance. The output variable, which proxies the intermediation function, is the real value of *total investments*. To obtain present values we again deflate each year's value using the consumer price indices.

Panel A of Table 2 presents an overview of the inputs, outputs and prices used in this analysis. Panel B of Table 2 contains summary statistics on the variables employed. The cost variable, necessary for the calculation of cost efficiency, is calculated as operating expenses plus cost of equity capital, following Choi/Weiss (2005). For comparative purposes, all numbers were deflated to 2002 using the ILO consumer price indices and converted into US dollars using the exchange rates published in the AM Best database.

Table 2: Inputs and Outputs

Panel A: Overview	
Inputs	Proxy
Labor and business service	AM Best operating expenses/ILO October Inquiry wage per year
Debt capital	AM Best total liabilities
Equity capital	AM Best capital & surplus
Input prices	
Price of labor	ILO October Inquiry wage per year
Price of debt capital	Long-term government bond rates
Price of equity capital	20-year-average MSCI stock market return indices
Outputs	
Non-life claims + additions to reserves	AM Best net incurred claims + additions to reserves
Life benefits + additions to reserves	AM Best net incurred benefits + additions to reserves
Investments	AM Best total investments

Panel B: Summary statistics for variables used					
Variable	Unit	Mean	St. Dev.	Min.	Max.
Labor and business service	Quantity	3,663	16,576	0.02	409,472
Debt capital	Million $	3,419	18,024	0.00	393,159
Equity capital	Million $	375	1,950	0.00	82,010
Price of labor	$	29,287	22,426	227,18	113,300
Price of debt capital	%	5.55	6.44	0.00	57.96
Price of equity capital	%	13,51	16,42	0.01	104.17
Non-life claims + additions to reserves	Million $	317	2,251	0.00	111,614
Life benefits + additions to reserves	Million $	1,844	6,393	0.00	119,084
Investments	Million $	3,319	18,046	0.02	432,088
Operating expenses	Million $	116	565	0.00	24,117
Costs	Million $	176	1,127	0.01	75,488
Assets	Million $	3,794	19,407	0.03	439,691
ILO consumer price index	%	3.78	5.29	-3.07	44.96

In the next two sections, we analyze technical and cost efficiency considering two methodologies (data envelopment analysis, stochastic frontier analysis), 34 countries (see Table 3 for a list), two organizational forms (stocks, mutual), two branches (life, non-life), and three company sizes (large, medium, small). Company-specific information on domiciliary country, organization type, and lines of business is extracted from the AM Best database. Total assets is a widespread measure of insurer size (see, e.g., Cummins/Zi, 1998; Diacon/Starkey/O'Brien, 2002). For comparison of different company sizes, we thus subdivide all companies by their total assets into large (total assets larger than $286 million/$2,958 million in non-life/life), medium, and small (total assets smaller than $40 million/$313 million in non-life/life) insurers. Although the comparability of findings from different efficiency studies is limited, e.g., due to different sample compositions and time horizons, we try to integrate our empirical results into the existing literature whenever possible.

3.2. Data Envelopment Analysis

For data envelopment analysis, we calculate efficiency values assuming input orientation and variable returns to scale. Both technical efficiency and cost efficiency are addressed. The results of the data envelopment analysis (Table 3) are presented at different levels of aggregation so as to focus on different aspects of efficiency.[4] The first focus is on countries, see Panel A, the second on organization, see Panel B, the third on lines of business, see Panel C, and the fourth on size, see Panel D. For comparison purposes, the average values are presented in the last line of the table. The left part of Table 3 shows technical efficiency; cost efficiency is shown on the right. Altogether, our analysis covers 3,555 insurers with a total of 12,887 firm years. Note that the DEA results in Table 3 always show combined effects, e.g., the efficiency of a country given the line of business, the size, or the organizational form. To isolate effects, an additional analysis with results clustered into homogenous groups is available from the authors upon request. Additional results, e.g., efficiency of different countries controlled for size, are available from the authors upon request. These tests show that the ranking of countries is robust for different size groups.

[4] The DEA results in Table 3 are based on a one-world frontier and estimated separately for all years, while we present results for an unbalanced panel for the SFA analysis (Table 4). Our DEA implementation only allows a pooled estimation using balanced panel data and we did that to check the robustness of our results. We find comparable results considering the pooled sample and the results for separate years. However, for methodological consistency, our estimation on time trend is presented with the SFA results.

Technical efficiency

The last line of Table 3 shows that technical efficiency in life insurance is, on average, 0.86, and 0.72 in non-life insurance.[5] Large efficiency differences can be found between countries, both for life and non-life. The country with the highest efficiency is Denmark—average efficiency of 0.87 (non-life) and 0.95 (life)—followed by Japan and Finland. Diacon/Starkey/O'Brien (2002), as well as Fenn (2008), also find Denmark to be among the most efficient European insurance markets. Japanese insurance companies are usually found to be not very efficient (see Donnie/Fecher, 1997; Weiss, 1991b), but the empirical evidence on the Japanese market is relatively old. In this context, it is important to recognize that the Japanese insurance industry experienced severe industrial reorganization starting from the beginning of the 1990s. The high efficiency values found in our data might thus indicate efficiency improvements as a result of this reorganization process over the last 15 years (see Lai/Limpaphayom (2003) and Souma/Tsutsui (2005) for the development of the Japanese insurance market). The lowest efficiency values are found for the Philippines (average efficiency 0.52 in non-life). Developed countries in Asia and Europe achieve higher efficiency scores than do emerging market countries. The efficiency of the largest economies under evaluation fall in the middle of the field. Taking non-life as an example, Germany is in 18th place (average efficiency 0.71), France is in 19th place with a score of 0.69 on average, and the United Kingdom is in 22nd place with an efficiency of 0.66.[6]

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5 Note that we cannot conclude from this result that life insurers are more efficient than non-life insurers because we estimated separate efficient frontiers for these two branches.

6 Rai (1996) also finds relatively low efficiency scores for the United Kingdom. In contrast, Diacon (2001) concludes that the United Kingdom is the most technically efficient of six European countries for the year 1999.

Table 3: Results of the data envelopment analysis

	Technical efficiency				**Cost efficiency**			
	Non-Life		Life		Non-Life		Life	
Year	No. of firm years	Average	No. of firm years	Average	No. of firm years	Average	No. of firm years	Average
Panel A: Comparison of countries								
Australia	276	0.64	130	0.84	276	0.59	130	0.77
Austria	52	0.62	14	n/a	52	0.58	14	n/a
Barbados	40	0.74	1	n/a	40	0.67	1	n/a
Belgium	210	0.72	83	0.85	210	0.65	83	0.73
Bermuda	287	0.77	41	0.65	287	0.73	41	0.56
Brazil	111	0.68	88	0.78	111	0.51	88	0.63
Denmark	389	0.87	210	0.95	389	0.81	210	0.83
Finland	98	0.82	154	0.91	98	0.76	154	0.84
France	467	0.69	239	0.86	467	0.64	239	0.78
Germany	1098	0.71	1003	0.88	1098	0.65	1003	0.76
Hong Kong	67	0.74	8	n/a	67	0.67	8	n/a
Indonesia	42	0.65	3	n/a	42	0.53	3	n/a
Ireland	303	0.55	164	0.82	303	0.51	164	0.71
Italy	242	0.67	221	0.88	242	0.60	221	0.79
Japan	110	0.88	172	0.92	110	0.79	172	0.85
Lithuania	68	0.59	18	n/a	68	0.47	18	n/a
Luxembourg	51	0.75	40	0.95	51	0.70	40	0.83
Malaysia	113	0.76	28	n/a	113	0.70	28	n/a
Mexico	93	0.57	54	0.81	93	0.45	54	0.65
Netherlands	745	0.76	269	0.86	745	0.68	269	0.78
New Zealand	79	0.61	22	n/a	79	0.52	22	n/a
Norway	166	0.80	42	0.93	166	0.76	42	0.90
Other	669	0.66	310	0.76	622	0.59	287	0.58
Philippines	46	0.52	10	n/a	46	0.47	10	n/a
Poland	44	0.64	30	0.80	44	0.57	30	0.69
Portugal	58	0.75	39	0.91	58	0.67	39	0.80
Russia	64	0.53	5	n/a	64	0.47	5	n/a
Singapore	47	0.75	7	n/a	47	0.72	7	n/a
South Africa	72	0.61	57	0.82	72	0.52	57	0.70
Spain	672	0.78	284	0.91	672	0.69	284	0.76
Sweden	274	0.73	116	0.92	274	0.67	116	0.86
Switzerland	348	0.84	84	0.88	348	0.77	84	0.80
Taiwan	44	0.78	19	n/a	44	0.70	19	n/a
Turkey	32	0.58	7	n/a	32	0.50	7	n/a
UK	933	0.66	501	0.82	933	0.59	501	0.76
Panel B: Comparison of organizational types								
Mutual	1493	0.80	770	0.93	1493	0.73	770	0.82
Stocks	6859	0.70	3707	0.85	6859	0.63	3707	0.74
Panel C: Comparison of lines of business								
One line	1063	0.73	659	0.83	1063	0.66	659	0.73
More than one line	3472	0.69	1479	0.86	3472	0.63	1479	0.77
Panel D: Comparison of company size								
Large	2803	0.72	1492	0.91	2803	0.67	1492	0.88
Medium	2803	0.70	1492	0.88	2803	0.63	1492	0.76
Small	2804	0.73	1493	0.79	2804	0.64	1493	0.63
Total	8410	0.72	4477	0.86	8410	0.65	4477	0.76

The second focus of our analysis concerns different organizational forms and their effects on efficiency (see Panel B of Table 3).[7] We cannot confirm the expense preference hypothesis, as the average technical efficiency values of stock companies (0.70 in non-life and 0.85 in life) are lower than those of mutual insurers (0.80 in non-life and 0.93 in life). A detailed analysis (available upon request) shows that our finding is

7 A small group of other organizational types (i.e., public companies) is not analyzed in Table 3. For that reason the firm years in Panel B do not add up to our total sample size of 8,410 (non-life)/4,477 (life).

robust among different countries, lines of business, and company sizes. For example, in only four of the 34 countries (Bermuda, Portugal (only for non-life), Sweden, and France (only for life)) are stocks are more efficient than mutuals. Important also is the robustness among different lines of business, as the managerial discretion hypotheses claims that mutuals are more efficient than stock companies in lines of business with low managerial discretion and less efficient in lines with high managerial discretion. An analysis on a more disaggregate level for different lines of business does not confirm the managerial discretion hypotheses either. For example, we do not find that stocks are more efficient than mutuals in lines of business where managers need more discretion, such as commercial (see Cummins/Weiss, 2000).[8] According to an unequal variances t-test (see Ruxton, 2006), the difference between stocks and mutuals is significant at the 1% level for both life and non-life. The differences are also significant for different lines of business (e.g., commercial).

We compare companies that are active in only one line of business with companies that are active in more than one line of business (see Panel C of Table 3).[9] Technical efficiency is comparable in both groups, with a slight advantage for specialized firms (those active in only one line) in non-life insurance (0.73 vs. 0.69). In life insurance, however, multi-line firms are more efficient than specialized firms. These results give only a rough indication of the (non-) existence of economies of scope in international insurance markets. However, our finding is in line with Cummins/Weiss/Zi (2008), who conclude that diversifying in different lines of business is not always better than a strategic focus on one line. Further research on scope economies in different lines of business is needed, e.g., considering companies that change from single- to multi-line during the investigation period or considering mergers of single-line companies from different lines of business.

In Panel D of Table 3 the total sample is subdivided by total assets into three size categories—large, medium, and small insurers. In agreement with most research, we find that large life insurers have higher efficiency than small companies. Average efficiency for large companies is 0.91, whereas it is only 0.88 for medium-sized companies, and 0.79 for small companies. However, no large differences can be found regarding size for non-life insurers. The efficiency for small and large insurers is comparable, while that of medium-sized insurers is a bit lower. An additional analysis on

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8 This analysis is available upon request. The results are also robust for different model specifications, e.g., for the case that stocks and mutuals share one common technology (i.e., estimation of one frontier for stocks and mutuals) and for the case that stocks and mutuals use different technologies (i.e., estimation of two different frontiers). Our findings indicate that the industrial organization in many emerging markets might be more beneficial for mutuals compared to the US market where stocks are often found to be more efficient.

9 Some insurers only indicate whether they are operating in life or non-life and do not offer detailed information on the lines of business covered. We do not consider these particular companies in Panel C, which is why the number of firm years does not add up to our total sample size of 8,410 (non-life)/4,477 (life).

returns to scale (available upon request) shows that many small insurers exhibit increasing returns to scale, whereas most large insurers operate under decreasing returns to scale. This finding indicates that merger activity with small insurers might improve efficiency, but not with large companies.

Cost efficiency

Cost efficiency is on average lower than technical efficiency, with a value of 0.65 in non-life and 0.76 in life insurance. The cost efficiency results are very similar to the technical efficiency results. Denmark has the highest value, the Philippines the lowest (Panel A), mutuals are more cost efficient than stock companies (Panel B), companies operating in one line are not too different from multi-line firms (Panel C), and large companies are more efficient than small ones, especially in life insurance (Panel D).

3.3. STOCHASTIC FRONTIER ANALYSIS

We also employ an econometric frontier efficiency method (stochastic frontier analysis) in order to validate our findings from the mathematical programming method (data envelopment analysis). For the calculation of *technical efficiency*, we specify a translog stochastic input distance function. The distance function formulation was chosen so as to accommodate multiple outputs and multiple inputs (see, e.g., Coelli/Perelman, 1996; Coelli, 2005). The inefficiency term is assumed to follow a truncated normal distribution and permitted to vary systematically with time in our unbalanced panel setting (see Battese/Coelli, 1992). For the calculation of *cost efficiency*, an equivalent translog stochastic cost function specification was chosen. For the formal expression and more details on the SFA specification, the reader is referred to Appendix 2.

Table 4 is structured like Table 3 and shows the results of the stochastic frontier analysis. Again, average efficiency is presented for different countries (Panel A), organization types (Panel B), lines of business (Panel C), and company sizes (Panel D). Additionally, we analyze the change of efficiency over time (Panel E). The left part of Table 4 shows technical efficiency; cost efficiency is shown on the right. Like other studies employing both DEA and SFA (see, e.g., Hussels/Ward, 2006), the results from SFA are generally consistent with those from DEA. We will therefore only highlight the most important SFA findings and discuss the main differences to the DEA results.

Table 4: Results of the stochastic frontier analysis

	Technical efficiency				**Cost efficiency**			
	Non-Life		Life		Non-Life		Life	
Year	No. of firm years	Average	No. of firm years	Average	No. of firm years	Average	No. of firm years	Average
Panel A: Comparison of countries								
Australia	276	0.66	130	0.83	276	0.66	130	0.46
Austria	52	0.65	14	n/a	52	0.68	14	n/a
Barbados	40	0.79	1	n/a	40	0.79	1	n/a
Belgium	210	0.73	83	0.87	210	0.74	83	0.75
Bermuda	287	0.78	41	0.58	287	0.76	41	0.31
Brazil	111	0.72	88	0.80	111	0.73	88	0.55
Denmark	389	0.84	210	0.92	389	0.76	210	0.85
Finland	98	0.85	154	0.90	98	0.77	154	0.86
France	467	0.73	239	0.88	467	0.71	239	0.79
Germany	1098	0.74	1003	0.86	1098	0.75	1003	0.68
Hong Kong	67	0.77	8	n/a	67	0.73	8	n/a
Indonesia	42	0.70	3	n/a	42	0.68	3	n/a
Ireland	303	0.56	164	0.82	303	0.67	164	0.64
Italy	242	0.70	221	0.90	242	0.72	221	0.78
Japan	110	0.87	172	0.93	110	0.76	172	0.76
Lithuania	68	0.64	18	n/a	68	0.68	18	n/a
Luxembourg	51	0.76	40	0.92	51	0.73	40	0.85
Malaysia	113	0.81	28	n/a	113	0.79	28	n/a
Mexico	93	0.61	54	0.81	93	0.64	54	0.64
Netherlands	745	0.76	269	0.87	745	0.70	269	0.73
New Zealand	79	0.65	22	n/a	79	0.62	22	n/a
Norway	166	0.80	42	0.95	166	0.79	42	0.80
Other	669	0.68	310	0.78	622	0.65	287	0.31
Philippines	46	0.55	10	n/a	46	0.64	10	n/a
Poland	44	0.69	30	0.83	44	0.68	30	0.69
Portugal	58	0.81	39	0.95	58	0.80	39	0.94
Russia	64	0.57	5	n/a	64	0.64	5	n/a
Singapore	47	0.78	7	n/a	47	0.84	7	n/a
South Africa	72	0.64	57	0.82	72	0.61	57	0.31
Spain	672	0.79	284	0.88	672	0.72	284	0.81
Sweden	274	0.74	116	0.90	274	0.73	116	0.81
Switzerland	348	0.84	84	0.86	348	0.71	84	0.80
Taiwan	44	0.82	19	n/a	44	0.78	19	n/a
Turkey	32	0.63	7	n/a	32	0.56	7	n/a
UK	933	0.67	501	0.77	933	0.66	501	0.63
Panel B: Comparison of organizational types								
Mutual	1493	0.78	770	0.90	1493	0.77	770	0.85
Stocks	6859	0.72	3707	0.84	6859	0.70	3707	0.64
Panel C: Comparison of lines of business								
One line	1063	0.74	659	0.81	1063	0.71	659	0.65
More than one line	3472	0.72	1479	0.86	3472	0.71	1479	0.69
Panel D: Comparison of company size								
Large	2803	0.73	1492	0.89	2803	0.72	1492	0.78
Medium	2803	0.72	1492	0.88	2803	0.70	1492	0.72
Small	2804	0.74	1493	0.79	2804	0.71	1493	0.53
Panel E: Comparison of efficiency over time								
2002	2018	0.71	996	0.84	2018	0.70	996	0.64
2003	2002	0.72	1083	0.85	2002	0.72	1083	0.67
2004	1902	0.73	1057	0.86	1902	0.71	1057	0.68
2005	1561	0.75	815	0.87	1561	0.70	815	0.69
2006	927	0.75	526	0.87	927	0.73	526	0.71
Total	8410	0.73	4477	0.85	8410	0.71	4477	0.68

Technical efficiency

Considering the *country analysis* (Panel A), Japan and Denmark are among the most efficient, both in life and non-life insurance. Additionally, Finland and Switzerland rank high in non-life insurance, while Portugal and Norway do so in life insurance. The lowest efficiency values are found for the Philippines, Turkey, and Russia. Again, developed countries in Europe and Asia achieve higher efficiency scores than emerging markets. In regard to the different *organizational forms* (Panel B in Table 4), the SFA results do not support the expense preference hypothesis, as mutual insurers show higher efficiency than stock insurers. Analyzing our results at a more disaggregated level (e.g., for commercial lines), we cannot confirm the managerial discretion hypothesis either. Similar to the DEA result, these results are robust across different lines of business, company sizes, and countries; the unequal variances t-test again shows a significant difference between the efficiency values of stocks and mutuals. As for different *lines of business* (Panel C in Table 4), non-life insurers operating in more than one line of business are nearly as efficient as specialized insurers. In life insurance, however, insurers with more than one line of business seem to be more efficient. Panel D in Table 4 again illustrates size advantages of large insurers, especially for life, and a little less clearly for non-life. Looking at Panel E, there is steady technical *efficiency growth* for non-life (+5.5%) and life firms (+3.7%) from 2002 to 2006.

Cost efficiency

Cost efficiency in the sample has been increasing over time for both non-life (+3.8%) and life insurers (+10.0%). Denmark and Japan are still among the most cost efficient, but Singapore is now the most cost efficient in non-life and Portugal in life. Turkey and the Philippines are among the least cost efficient. Mutuals are more efficient than stocks (see Panel B) and large companies are more efficient than small ones, again especially for life (see Panel D). For different lines of business, we again find somewhat conflicting results (see Panel C): insurers operating in more than one line are more efficient than specialized companies in life insurance, but not more efficient than companies specializing in non-life insurance.

3.4. CONDITIONAL MEAN ANALYSIS

To identify some key drivers of efficiency, we implemented a one-stage approach that models the mean of the inefficiency term dependent on a vector of firm- and country-specific variables, the so called conditional mean approach (see Battese/Coelli, 1995, and Greene/Segal, 2004, for an application to the insurance industry) This approach builds upon stochastic frontier analysis, so the reader is again referred to Appendix 2 for the formal representation.[10] We use the following explanatory variables for our

[10] We also conducted a Tobit regression analysis (see Tobin, 1958), a methodological alternative building on data envelopment analysis (results available upon request). The Tobit analysis has been criticized in the literature, e.g., because it incorporates serial correlation problems due to its two-step nature. As a one-step approach, the conditional mean approach does not suffer from these problems. We thus decided to restrict our presentation to the conditional mean analysis. A methodologically improved alternative to using a Tobit regression would be the truncated regression presented by Simar/Wilson (2007). One assumption of the condi-

regression: (1) Organization: 1 if the insurer is a stock company; 0 otherwise. (2) A solvency variable: 1 if the company's ratio of equity capital to total assets is above the median in the respective branch; 0 if not. (3) Company size: Defined as the natural logarithm of total assets. (4) Squared company size: To capture nonlinearities between size and efficiency. (5) A developed country variable: 1 if company is from a developed country; 0 if not.[11] (6) A corruption variable determined using the Corruption Perceptions Index provided by Transparency International (available at http://www.transparency.org); it ranges from 0 to 10, with 10 indicating the lowest level of corruption and 0 the highest. (7) The Gross Domestic Product (GDP) for each country and each year obtained from the IMF Word Economic Outlook Database (Version April 2008). (8) Year variables are incorporated in order to capture time effects. We follow Greene/Segal (2004) and Battese/Coelli (1995) and use a single time indicator, which captures continuous efficiency change over time (2002 = 1; 2003 = 2; 2004 = 3; 2005 = 4; 2006 = 5).

Table 5 shows results of the conditional mean analysis by branch (life vs. non-life) and efficiency type. Since the conditional mean approach models the inefficiency term, a negative coefficient indicates a decrease in inefficiency, i.e., an increase in efficiency, and a positive coefficient indicates an increase in inefficiency, i.e., a decrease in efficiency. The likelihood-ratio test for all analyses rejected the null hypothesis that the inefficiency term is not significantly different from 0 at the 1% level.

tional mean approach is the homoskedasticity regarding the random error and inefficiency terms. Fenn et al. (2008) address this drawback by explicitly modeling the variance of both terms.

[11] We therefore subdivided our countries according to the advanced economy list of the International Monetary Fund (see IMF, 2008) into 22 developed and 12 not developed countries.

Table 5: Results of the conditional mean analysis

	Based on technical efficiency			**Based on cost efficiency**		
	Coefficient	St. Error	t-Statistic	Coefficient	St. Error	t-Statistic
Panel A: Non-life						
Intercept	-7.51	1.40	-5.36***	-11.55	1.92	-6.02***
Organization	1.16	0.11	10.77***	2.61	0.53	4.96***
Solvency	-5.26	0.38	-13.76***	-2.44	0.47	-5.18***
Size	0.77	0.26	2.92***	1.10	0.13	8.38***
Squared size	-0.04	0.01	-3.71***	-0.06	0.01	-7.61***
Developed	-1.42	0.12	-12.15***	-0.85	0.15	-5.50***
Corruption	-0.09	0.02	-4.59***	0.12	0.04	3.37***
GDP	0.00	0.00	-1.12	0.00	0.00	-0.07
Time	-0.33	0.04	-8.03***	-0.01	0.02	-0.61
Panel B: Life						
Intercept	2.75	0.45	6.12***	-2.49	0.58	-4.28***
Organization	1.10	0.07	16.03***	4.19	0.19	22.11***
Solvency	1.49	0.05	29.75***	1.99	0.11	17.43***
Size	-1.29	0.08	-16.96***	-0.32	0.10	-3.17***
Squared size	0.04	0.00	13.06***	-0.01	0.00	-1.39*
Developed	-1.74	0.07	-25.51***	-2.51	0.11	-22.82***
Corruption	0.33	0.01	24.72***	0.24	0.03	9.03***
GDP	0.00	0.00	5.88***	0.00	0.00	15.91***
Time	-0.07	0.02	-4.29***	-0.08	0.02	-3.61***

Note: * (**, ***) indicates significance level of 10% (5%, 1%).

The results of the conditional mean analysis confirm for both branches that mutual insurers have significantly higher cost and technical efficiencies than do stock insurers: coefficients are positive, indicating higher inefficiency of stock insurers. For the impact of the equity to total assets ratio on efficiency, we find for non-life insurers a negative coefficient for technical and cost efficiency, indicating that a high equity to assets ratio is in line with higher efficiency. However, for life firms, we obtain the opposite result: here, a high equity to assets ratio indicates lower efficiency, meaning, perhaps, that equity capital is not used efficiently. Size and squared size are also found to be important drivers for efficiency. The interaction between size and squared size is different for life and non-life: there is a negative size coefficient and a positive squared size coefficient for non-life; for life insurance, the size coefficient is positive and the coefficient for squared size negative.

The developed country variable confirms that insurers from developed countries are more efficient than those from emerging markets: the coefficient is negative and significant for both branches and efficiency types. The results for the corruption variable are mixed: For non-life technical efficiency, a high corruption score (i.e., a low level of corruption in a country) leads to a negative coefficient (i.e., higher efficiency). However, for non-life, cost efficiency, as well as life technical and cost efficiency, a lower level of corruption indicates lower efficiency (positive coefficients). This is an unexpected result; further research is needed to explain it. For GDP, we find a significant impact only in life insurance. Regarding efficiency change over time, the conditional mean analysis confirms a positive relationship between time and efficiency for all types of efficiency and lines of business (negative coefficients). However, the coefficient for non-life technical efficiency is not significant.

4. CONCLUSION

The main contribution of this paper was to provide a broad evaluation of efficiency measurement in the insurance industry with a special emphasis on an international comparison of efficiency. We first review recent studies on efficiency in the insurance industry and extend two earlier surveys, one by Berger/Humphrey (1997) and the other by Cummins/Weiss (2000). The 87 considered studies show that during the last several years, methodologies have been refined, new topics have been addressed, and geographic coverage has been extended beyond a US focused view to a broad set of countries. The large number of studies illustrates the increasing interest in the international competitiveness and efficiency of insurance companies.

In the second part of the paper, we extended existing cross-country comparisons of efficiency in the insurance industry by analyzing a broad international dataset that has not yet been the subject of an efficiency study (the AM Best Non US database). The cross-country analysis covers data on 3,555 insurance companies from 34 countries, which, to our knowledge, is the largest dataset ever analyzed in insurance-related efficiency literature. A total of 12,887 firm years were analyzed using both data envelopment analysis and stochastic frontier analysis, allowing us to glean a broad range of new insights into the efficiency of the international insurance industry:

- During the sample period from 2002 to 2006, there is a steady growth in efficiency in the international insurance markets, although there are large differences between countries. According to our cross-country comparison, Denmark and Japan have the most efficient insurance companies, whereas insurers in the Philippines have the lowest efficiency values.
- We are the first to determine technical and cost efficiency for the following 12 countries: Barbados (0.74 average non-life technical efficiency under DEA/0.79 average non-life technical efficiency under SFA), Bermuda (0.77/0.78), Brazil (0.68/0.72), Hong Kong (0.74/0.77), Indonesia (0.65/0.70), Lithuania (0.59/0.64), Mexico (0.57/0.61), Norway (0.80/0.80), Poland (0.64/0.69), Russia (0.53/0.57), Singapore (0.75/0.78), and South Africa (0.61/0.64).
- The results of data envelopment analysis and stochastic frontier analysis and the economic insights that can be derived from them turn out to be very similar, both for technical efficiency and cost efficiency. This result agrees with the few other studies that have considered multiple frontier efficiency methodologies in their empirical applications.

- In our international dataset, mutual insurers are consistently more efficient than stock insurers. Therefore, we cannot confirm either the expense preference hypothesis or the managerial discretion hypothesis. This result adds to the mixed evidence regarding the effect of organizational form on efficiency in insurance, where some studies, especially those covering the US market, have found stock companies more efficient than mutuals. However, other international comparisons have found mutuals to be more efficient than stocks. Further research is needed to solve this ambiguity over the relationship between organizational form and efficiency in international insurance markets.
- We find that diversifying in different lines of business is not always better than a strategic focus on one line. We recommend studying scope economies on an international level in order to find out when it would be best to employ a single product strategy as opposed to providing multiple products.
- In line with most of the literature, large insurers are more efficient than small insurers. However, for many small insurers we find increasing returns to scale, whereas most large insurers are operating under decreasing returns to scale.
- The conditional mean analysis reveals that insurers from developed countries are on average more efficient than insurers working in emerging markets. A positive relationship between capitalization and efficiency can be identified for non-life insurers; a negative one for life insurers.

Our results provide valuable insights into the competitiveness of insurers from different countries. At the country level, the results can be used to compare different insurance markets with each other. This is especially interesting for regulators and politicians, as well as for the boards of national insurance associations. Apart from knowing how efficient their market is compared to others, they can direct their activities toward areas where efficiency needs to be improved, e.g., for small insurers. On a regional level (e.g., within the European Union), it might be of interest to monitor whether the efficiency levels of insurance markets converge as a result of deregulation and facilitated market entry for foreign companies.

At the individual-company level, the results can be used to compare performance with other firms in the industry, nationally and internationally. This can, for example, help managers in making decisions regarding international growth. A relatively efficient insurer from a country with an efficient insurance market might consider international growth opportunities (through new entry or acquisitions) in markets where it has a relative efficiency advantage. In this case, the transfer of knowledge and best practice, as well as economies of scale advantages, might be used in order to achieve more efficient operations in the new, less efficient, country. However, our results give only a rough indication as whether such will actually be the case, and thus more research on the efficiency effects of cross-border mergers and acquisitions is needed. Another implication from our research of relevance to managers, as well as regulators, concerns the choice of organizational form. Although insurance markets have seen a great deal of demutualization in recent years, we suggest that this step should be carefully considered, since mutuals appear to be the more efficient insurers in many markets and countries.

A number of important issues regarding efficiency in international insurance markets still need to be addressed. Among these are an international analysis of efficiency of different distribution systems in order to verify whether the tendency toward increased independent agent distribution can also be supported by efficiency considerations. Furthermore, there is no cross-country efficiency study that covers sublines of business (such as auto, homeowners, or liability insurance), which are expected to show largely different efficiency scores due to different competitive dynamics. Lastly, adding US data to this international analysis would be a valuable step in order to investigate whether the largest insurance market in the world is also among the most efficient.

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APPENDIX 1: OVERVIEW OF 90 STUDIES ON EFFICIENCY MEASUREMENT IN THE INSURANCE INDUSTRY

Authors	Countries	No. insurers	Sample period	Lines of business	Me-thod	Input type	Output type	Output approach	Main types of effi-ciencies analyzed	Application category	Selected findings
Badunenko/ Grechanyuk/ Talavera (2006)	Ukraine	163	2003-2005	Life, non-life	DEA	Fixed assets, current assets, liabili-ties, equity	Premiums	Value added	Technical, scale	Regulation change	Increased capitalization requirements have positively influenced Ukrainian insurance market and helped improve both technical and scale efficiency
Barros/Barroso/Borges (2005)	Portugal	27	1995-2001	Life, non-life	DEA	Wages, capital, total investment income, premiums issued	Claims paid, profits	Value added	Technical, pure technical, scale	General level of efficiency and evolution over time	Improvement of technical efficiency over time, but deterioration in terms of technological change
Barros/Obijiaku (2007)	Nigeria	10	2001-2005	Life, non-life	DEA	Capital, operative costs, number of employees, total investments	Profits, net premiums, settled claims, outstanding claims, investment income	Value added	Technical, pure technical, scale	General level of efficiency and evolution over time	Most companies are VRS efficient
Berger et al. (2000)	US	684	1988-1992	Life, property-liability	TFA, SFA	Labor, business services, reserves, financial equity capital	Invested assets, present value of real losses incurred (P/L), incurred benefits (Life)	Value added	Cost, revenue, profit	Scale and scope economies	Conglomeration hypothesis holds for some types while strategic focus hypothe-sis dominates for others
Berger/Cummins/Weiss (1997)	US	472	1981-1990	Property-liability	DFA	Labor, business services, debt capital, equity capital	Total real invested assets, present value of losses incurred	Value added	Cost, profit	Distribution systems	Independent agents less cost efficient but equally profit efficient as direct writers
Bernstein (1999)	Canada	12	1979-1989	Life	Index	Labor, buildings capital, machinery capital, materials	Number of policies	Physical	n/a	General level of efficiency and evolution over time	Average annual productivity growth of 1% for period 1979-1989
Bikker/van Leuvensteijn (2008)	Netherlands	84-105	1995-2003	Life	SFA	Acquisition cost, other cost (man-agement cost, salaries, depreciation on capital equipment, etc.)	Premium income, number of outstanding policies, sum total of insured capital, sum total of insured annuities, unit-linked fund policies	Physical	Cost	General level of efficiency and evolution over time	Cost inefficiency of 28% on average
Boonya-sai/Grace/Skipper (2002)	Korea, Philippines, Taiwan, Thailand	49-110	1978-1997	Life	DEA	Labor, capital, materials	Premium income, net investment income	Value added	Technical, pure technical, scale	Regulation change	Increasing productivity in Korea and Philippines due to deregulation and liberalization; little effect of liberalization on productivity in Taiwan and Thailand
Brockett et al. (1998)	US	1524	1989	Property-liability	DEA	Surplus previous year, change in capital and surplus, underwriting and investment expense, policyholder-supplied debt capital	ROI, liquid assets to liability, solvency scores	Financial interme-diary	n/a	Distribution systems	Stock companies more efficient than mutuals; agency more efficient marketing system than direct
Brockett et al. (2004)	US	1524	1989	Property-liability	DEA	Surplus previous year, change in capital and surplus, underwriting and investment expense, policyholder-supplied debt capital	ROI, liquid assets to liability, solvency scores	Financial interme-diary	n/a	Financial and risk management, capital utilization	Solvency scores as output only with limited impact on efficiency scores
Brockett et al. (2005)	US	1524	1989	Property-liability	DEA	Surplus previous year, change in capital and surplus, underwriting and investment expense, policyholder-supplied debt capital	ROI, liquid assets to liability, solvency scores	Financial interme-diary	n/a	Organizational form, corporate governance issues	Stock firms with higher inefficiency in the input dimension while mutuals with higher shortfalls in all areas of output; direct systems with more inefficiencies than agency
Carr/Cummins/Regan (1999)	US	66	n/a	Life	DEA	Labor (admin., agents), business services, financial capital	Incurred benefits, additions to reserves	Value added	Cost, revenue	Distribution systems	Exclusive dealing insurers less efficient than nonexclusive dealing or direct writers; nonexclusive dealing insurers should focus on fewer product lines; firms adopting one of Porter's 3 generic strategies are more efficient than rivals
Chaffai/Ouertani (2002)	Tunisia	13	1990-2000	Life, non-life	DEA, SFA	Labor, physical capital, financial capital	Total premiums earned	Value added	Technical	General level of efficiency and evolution over time	Significant potential for increase of efficiency
Choi/Weiss (2005)	US	n/a	1992-1998	Property-liability	SFA	Labor (agent, nonagent), materials, equity capital	Present value of losses incurred, total invested assets	Value added	Cost, revenue	Market structure	Cost-efficient firms charge lower prices and earn higher profits; prices and profits higher in revenue-efficient firms
Choi/Weiss (2008)	US	n/a	1992-1998	Property-liability (auto)	SFA	Labor (agent, nonagent), materials, equity capital (assumed same as in Choi/Weiss, 2005, according to reference in paper; however, inputs not explicitly described in paper)	Present value of losses incurred, total invested assets (assumed same as in Choi/Weiss, 2005, according to reference in paper; however, outputs not explicitly described in paper)	Value added	Cost, revenue	Market structure	Insurers in competitive and non-stringently regulated states may benefit from market power by charging higher unit prices; insurers in these states are on average more cost efficient and cost efficient insurers charge lower prices and earn smaller profits; insurers in some rate regulated states are less revenue and cost-scale efficient than in competitive states.
Cummins (1999)	US	750	1988-1995	Life	DEA	Labor (admin., agents), business services, financial capital	Incurred benefits, additions to reserves	Value added	Pure technical, scale, allocative, cost, revenue	General level of efficiency and evolution over time	Efficiency scores in insurance relatively low compared to other financial servic-es industries; also widely dispersed; small insurers operate with IRS; big insurers with DRS; brokerage system most efficient

APPENDIX 1: OVERVIEW OF 90 STUDIES ON EFFICIENCY MEASUREMENT IN THE INSURANCE INDUSTRY (CONTINUED)

Authors	Countries	No. insurers	Sample period	Lines of business	Me-thod	Input type	Output type	Output approach	Main types of effi-ciencies analyzed	Application category	Selected findings
Cummins et al. (2006)	US	1636	1995-2003	Property-liability	SFA	Labor (admin., agents, risk management), material and business service, debt capital, equity capital	Present value of losses incurred, invested assets, dollar duration of surplus	Value added	Cost	Financial and risk management, capital utilization	Risk management and financial intermediation increase efficiency
Cummins/Nini (2002)	US	770-970	1993-1998	Property-liability	DEA	Labor (office, sales), materials and business service, financial equity capital	Present value of losses incurred, total invested assets	Value added	Technical, allocative, cost, revenue	Financial and risk management, capital utilization	On weighted industry average, firms could reduce labor by 62%, materials by 36%, and capital by 46%; capital is used suboptimally
Cummins/Rubio-Misas (2006)	Spain	331-508	1989-1998	Life, non-life	DEA	Labor, business services, debt capital, equity capital	Non-life losses incurred, life losses incurred, reinsurance reserves, nonreinsurance reserves, invested assets	Value added	Cost, pure technical, allocative, scale	Regulation change	Consolidation leads to growth in TFP and increases number of firms operating with decreasing returns to scale
Cummins/Rubio-Misas/Zi (2004)	Spain	347	1989-1997	Life, non-life	DEA	Labor, business services, debt capital, equity capital	Life and non-life insurance losses incurred	Value added	Technical, allocative, cost, revenue	Organizational form, corporate governance issues	In cost and revenue efficiency, stocks of all sizes dominate mutuals in the production of stock output vectors, and smaller mutuals dominate stocks in the production of mutual output vectors; larger mutuals are neither dominated by nor dominant over stocks
Cum-mins/Tennyson/Weiss (1999)	US	750	1988-1995	Life	DEA	Home-office labor, agent labor, business services (including physical capital), financial capital	Incurred benefits, additions to reserves	Value added	Cost, technical, allocative, pure technical, scale, revenue	Mergers	M&A beneficial for efficiency; target life insurers achieve greater efficiency gains than firms that have not been involved in M&As
Cum-mins/Turchetti/Weiss (1996)	Italy	94	1985-1993	Life, non-life	DEA	Labor (acquisition, admin.), fixed capital expense, equity capital	Life insurance: sum of life insurance benefits, changes in reserves, invested assets Non-life insurance: Losses incurred, invested assets	Value added	Technical	General level of efficiency and evolution over time	Stable efficiency over time (70%–78% for the industry) with sharp decline (25% cumulative) in productivity due to technological regress
Cummins/Weiss (1993)	US	261	1980-1988	Property-liability	SFA	Labor, capital, intermediate materials	Discounted incurred losses, loss settlement, intermediary services	Value added	Cost, allocative, technical	General level of efficiency and evolution over time	Large insurers at 90% relative to their cost frontier; medium and small insurers at 80% and 88%, respectively; scale economies with small and medium-sized insurers
Cummins/Weiss/Zi (1999)	US	417	1981-1990	Property-liability	DEA	Labor, materials, debt capital, equity capital	Present value of real losses incurred, total invested assets	Value added	Technical, cost	Organizational form, corporate governance issues	Stock cost frontier dominates mutual cost frontier
Cummins/Weiss/Zi (2007)	US	817	1993-1997	Life (incl. health), property-liability	DEA	Labor (office, agent), materials and business service, financial equity capital	Life/health: Real value of incurred benefits, additions to reserves; P/L: Present value of real losses incurred, real invested assets	Value added	Technical, cost, revenue	Scale and scope economies	Weak evidence for existence of economies of scope; although diversified firms dominate specialists in the production of diversified firm output vectors in terms of revenue efficiency for both life-health and property-liability insurance, specialist firms dominate diversified firms for the production of specialist output vectors in revenue efficiency and also dominate diversified firms in cost efficiency for property-liability output vectors
Cummins/Xie (2008)	US	1550	1994-2003	Property-liability	DEA	Labor (admin., agent), materials and business services, financial equity capital	Present value of losses incurred, real invested assets	Value added	Cost, technical, allocative, pure technical, scale, revenue	Mergers	M&As in property-liability insurance are value enhancing; acquiring firms achieved more revenue efficiency gains than nonacquiring firms, and target firms experienced greater cost and allocative efficiency growth than nontargets
Cummins/Zi (1998)	US	445	1988-1992	Life	DEA, DFA, FDH, SFA	Labor, financial capital, materials	Benefit payments, additions to reserves	Value added	Cost, technical, allocative	Methodology issues, comparing different techniques or assumptions	Choice of estimation method can have a significant effect on the conclusions of an efficiency study; efficiency rankings are well preserved among the econometric methods; but the rankings are less consistent between the econometric and mathematical programming methods
Davutyan/Klumpes (2008)	7 European countries	472	1996-2002	Life, non-life	DEA	Labor, business services, equity capital	Present value of losses incurred, premiums, invested assets	Value added	Technical, pure technical, scale	Mergers	In life insurance, after mergers, business inputs replace labor for both targets and acquirers, but these effects do not apply to non-life targets; mergers do not significantly impact acquirer behavior
Delhausse et al. (1995)	Belgium, France	434	1984-1988	Non-life	DEA, SFA	Labor costs, other outlays (capital consumption, purchase of equipment and supplies, etc.)	Premiums	Value added	Technical, scale	Intercountry comparisons	French companies on average more efficient than Belgian ones; overall low efficiency levels; high correlation between results of both approaches
Diacon (2001)	6 European countries	431	1999	General insurance	DEA	Total operating expenses, total capital, total technical reserves, total borrowings from creditors	Net earned premiums, total investment income	Value added	Technical	Intercountry comparisons	Average efficiencies: UK (77%), France (67%), Germany (70%), Italy (56%), Netherlands (69%), Switzerland (66%)
Diacon/Starkey/O'Brien (2002)	15 European countries	454	1996-1999	Life incl. pension, and health	DEA	Total operating expenses, total capital, total technical reserves, total borrowings from creditors	Net earned premiums, total investment income	Value added	Pure technical, scale, mix	Intercountry comparisons	Striking international differences and decreasing levels of average technical efficiency over sample period
Diboky/Ubl (2007)	Germany	90	2002-2005	Life	DEA	Labor, business services, financial debt capital, equity capital	Gross premium, net income	Value added	Technical, cost and allocative efficiency	Organizational form, corporate governance issues	Stock ownership is superior to mutual and public structure

APPENDIX 1: OVERVIEW OF 90 STUDIES ON EFFICIENCY MEASUREMENT IN THE INSURANCE INDUSTRY (CONTINUED)

Authors	Countries	No. insurers	Sample period	Lines of business	Me-thod	Input type	Output type	Output approach	Main types of effi-ciencies analyzed	Application category	Selected findings
Donni/Fecher (1997)	15 OECD countries	n/a	1983-1991	Life, non-life	DEA	Labor	Net premiums	Value added	Technical	Intercountry comparisons	Average efficiency levels rather high and dispersed; growth in productivity observed in all countries and due to improvements in technical progress
Donni/Hamende (1993)	Belgium	300	1982-1988	Life, non-life	FDH	Labor cost, other cost	Premiums; alternatively, losses incurred	Value added	Technical	Organizational form, corporate governance issues	Superior efficiency of nonprofit insurance companies
Ennsfell-ner/Lewis/Anderson (2004)	Austria	97-105	1994-1999	Life/ health, non-life	SFA	Net operating expenses, equity capital, technical provisions	Health/life: Incurred benefits, changes in reserves, total invested assets Non-life: Losses incurred, total invested assets	Value added	Technical	Regulation change	Deregulation had positive effects on production efficiency
Erhemjamts/Leverty (2007)	US	1070	1995-2004	Life	DEA	Labor, business services, equity capital, policyholder-supplied debt capital	Incurred benefits, additions to reserves	Value added	Technical	Organizational form, corporate governance issues	Stock production technology dominates mutual technology; mutuals that are further away from mutual efficient frontier more likely to demutualization; access to capital important reason for demutualization
Fecher et al. (1993)	France	327	1984-1989	Life, non-life	DEA, SFA	Labor cost, other outlays	Gross premiums	Value added	Technical	General level of efficiency and evolution over time	High correlation between parametric and nonparametric results; wide dispersion in the rates of inefficiency across companies
Fech-er/Perelman/Pestieau (1991)	France	327	1984-1989	Life, non-life	SFA	Labor cost, other outlays	Gross premiums	Value added	Cost	Scale and scope economies	Increasing returns to scale
Fenn et al. (2008)	14 European countries	n/a	1995-2001	Life, non-life, composite	SFA	Capital, technical provisions, labor, debt capital	Net incurred claims (= gross claims paid – claims received from reinsurers + increase in loss reserves + bonuses and rebates)	Value added	Cost	Market structure	Most European insurers operating under IRS; size and domestic market share lead to higher levels of cost inefficiency
Fuentes/Grifell-Tatjé/Perelman (2001)	Spain	55-70	1987-1994	Health, life, non-life	SFA	Labor costs, composite input	Annual premiums	Value added	Technical	Methodology issues, comparing different techniques or assump-tions	Malmquist index of productivity growth can also be estimated on basis of parametric frontier approach
Fuentes/Grifell-Tatjé/Perelman (2005)	Spain	n/a	1987-1997	Health, life, property-liability	SFA	Labor costs, composite input	Annual premiums	Value added	Technical	Scale and scope economies	Overall low productivity growth over time (less than 2% per year), multi-branch companies perform better than specialized firms
Fukuyama (1997)	Japan	25	1988-1993	Life	DEA	Labor (office, sales), capital	Insurance reserves, loans	Financial interme-diary	Technical, pure technical, allocative, scale	Organizational form, corporate governance issues	Mutual and stock companies possess identical technologies; productive efficiency and productivity performances differ across 2 ownership types and different economic conditions
Fukuyama/Weber (2001)	Japan	17	1983-1994	Non-life	DEA	Labor (office, sales), capital	Reserves, loans, investments	Financial interme-diary	Technical	Methodology issues, comparing different techniques or assump-tions	Productivity and technological progress over time in Japan
Gardner/Grace (1993)	US	561	1985-1990	Life	DFA	Labor, physical capital, misc. items	Premiums, securities investments	Value added	Cost	General level of efficiency and evolution over time	Persistent inefficiency
Greene/Segal (2004)	US	136	1995-1998	Life	SFA	Labor, capital, materials	Premiums, investments	Value added	Cost	Organizational form, corporate governance issues	Inefficiency negatively associated with profitability; stock companies as efficient and profitable as mutual companies
Hao (2007)	Taiwan	26	1981-2003	Life	DFA	Labor, physical capital, claims	Premiums, investments	Value added	Cost	General level of efficiency and evolution over time	Firms with large market share tend to be cost efficient
Hao/Chou (2005)	Taiwan	26	1977-1999	Life	DFA, SFA	Labor, physical capital, claims	Premiums, investments	Value added	Cost	General level of efficiency and evolution over time	Firms with larger market share are more profitable; product diversification does not improve efficiency
Hardwick (1997)	UK	54	1989-1993	Life incl. pension, and health	SFA	Labor, capital	Premiums	Value added	Economic, scale, total inefficiency	General level of efficiency and evolution over time	High level of inefficiency; increasing returns to scale
Hardwick/Adams/Zou (2004)	UK	50	1994-2001	Life	DEA	Labor, capital	Incurred benefits, additions to reserves	Value added	Cost, technical, allocative	Organizational form, corporate governance issues	Cost efficiency positively related to size of corporate board of directors

APPENDIX 1: OVERVIEW OF 90 STUDIES ON EFFICIENCY MEASUREMENT IN THE INSURANCE INDUSTRY (CONTINUED)

Authors	Countries	No. insurers	Sample period	Lines of business	Me-thod	Input type	Output type	Output approach	Main types of effi-ciencies analyzed	Application category	Selected findings
Hirao/Inoue (2004)	Japan	33	1980-1995	Property-liability	SFA	Labor, agencies, materials	Real incurred losses (net claims paid and changes in loss re-serves)	Value added	Cost	Scale and scope economies	Statistically significant economies of scale and scope
Huang (2007)	China	n/a	1999-2004	Life, property-liability	SFA	Labor, capital, business services	Premiums earned, incurred benefits and additions to re-serves, total invested assets	Value added	Cost, profit	General level of efficiency and evolution over time	Non-state-owned companies and foreign companies are superior in terms of cost efficiency to the property insurance industry, state-owned companies, and domestic companies
Hussels/Ward (2006)	Germany and UK	47 (UK) 31 (GE)	1991-2002	Life	DEA, DFA	Labor, capital	Net written premiums, additions to reserves	Value added	Cost, technical, allocative, scale	Regulation change	Comparability of results from DEA and DFA; UK efficiency frontier less efficient than German frontier; no clear evidence for link between deregulation and efficiency levels
Hwang/Gao (2005)	Ireland	11	1991-2000	Life	DFA	Labor (admin., agent), financial capital	Insurance benefits, investable funds	Value added	Cost	Scale and scope economies	Increasing returns to scale; magnitude of cost economies varies with firm size
Hwang/Kao (2008)	Taiwan	24	2001-2002	Non-life	DEA	Operation expenses, insurance expenses	Intermediate products: direct written premiums, reinsurance premiums; Final outputs: underwriting profit, investment profit	New 2-stage production process	n/a	Methodology issues, comparing different techniques or assump-tions	New relational model is more reliable in measuring efficiencies than indepen-dent models
Jeng/Lai (2005)	Japan	19	1985-1994	Non-life	DEA	VA: Labor, business services, capital (debt + equity) FI: Surplus previous year/assets, change in surplus/assets, underwrit-ing + investment expenses/assets, policyholder debt capital/assets	VA: Number of policies, total invested assets FI: ROA, 3 principal components of financial conditions	Value add-ed/financial intermedia-tion	Technical, cost	Organizational form, corporate governance issues	Keiretsu firms more cost efficient than NSIFs; otherwise not possible to reject null hypothesis that all equally efficient; deteriorating efficiency for all company types; FI and VA approaches with different, but complementary, results
Jeng/Lai/McNamara (2007)	US	11	1980-1995	Life	DEA	VA: Labor, business services, capital (debt + equity) FI: Surplus previous year/assets, change in surplus/assets, underwrit-ing + investment expenses/assets, policyholder debt capital/assets	VA: Number of policies, total invested assets FI: ROA, 3 principal components of financial conditions	Value add-ed/financial intermedia-tion	Cost, technical, allocative	Organizational form, corporate governance issues	For both approaches, no efficiency improvement after demutualization; excep-tion: improvement for mutual control insurers under FI approach
Kessner (2001a)	Germany and UK	87 (UK) 78 (GE)	1994-1999	Life	DEA	New business cost, administration cost, cost for capital management, reinsurance contributions	Gross and net written premiums, interest on capital	Value added	Technical	Intercountry comparisons	British insurers more efficient than German insurers; increasing efficiency in both markets
Kessner (2001b)	Germany	75	1989-1994	Life	DEA	New business cost, administration cost, cost for capital management, reinsurance contributions	Sum insured (new and existing business), net returns on capital investments	Value added	Technical, scale	Scale and scope economies	Small companies with increasing returns to scale; big companies with decreas-ing returns to scale
Kessner/Polborn (1999)	Germany	110	1990-1993	Life	DEA	New business cost, administration cost	Sum insured of new and in-force business	Value added	Technical	General level of efficiency and evolution over time	High level of inefficiency
Kim/Grace (1995)	US	248	1988-1992	Life	DFA	Labor (agent, nonagent), capital, materials	Claims, changes in reserves, investment expenses	Value added	Cost	Mergers	Smaller firms with larger cost savings from mergers than large firms; no cost savings in mergers of mutuals; mergers of efficient with less efficient companies increase combined firm efficiency
Klumpes (2004)	UK	40	1994-1999	Life	SFA	Labor, materials, policy supplied debt capital, financial equity capital	Claims, real invested assets	Value added	Cost, profit	Distribution systems	IFA-based firms less cost and profit efficient than AR/CR firms
Klumpes (2007)	7 European countries	1183	1997-2001	Life, general insurance	DEA	Labor, business services, debt capital, equity capital	Premiums, investment income	Value added	Cost, technical, allocative, pure technical, scale, revenue	Mergers	Acquiring firms achieve greater efficiency gains than either target firms or firms not involved in mergers; no beneficial effect of mergers on target firms; M&A driven mostly by solvency objectives
Leverty/Grace (2008)	US	n/a	1989-2000	Property-liability	DEA	VA: Labor (admin, agent), materials and business services, financial equity capital, policyholder-supplied debt capital FI: Policyholder surplus, underwriting and investment expenses, policyhold-er-supplied debt capital	VA:Real losses incurred, real invested assets FI: ROI, liquid assets to liabilities, solvency score	Value added, financial intermedia-tion	Pure technical, scale, technical, allocative, cost, revenue	Methodology issues, comparing different techniques or assump-tions	Value-added and financial intermediation approach are not consistent; value-added approach closely related to traditional measures of firm performance; financial intermediation approach generally not

APPENDIX 1: OVERVIEW OF 90 STUDIES ON EFFICIENCY MEASUREMENT IN THE INSURANCE INDUSTRY (CONTINUED)

Authors	Countries	No. insurers	Sample period	Lines of business	Me-thod	Input type	Output type	Output approach	Main types of effi-ciencies analyzed	Application category	Selected findings
Leverty/Lin/Zhou (2004)	China	20-41	1995-2002	Life, property-casualty	DEA	Business expenses, financial equity capital, debt capital	Life: Net premiums written, real invested assets P&C: Losses incurred, real invested assets	Value added	Technical, scale, pure technical	General level of efficiency and evolution over time	Productivity growth; in P&C due to presence of technically efficient foreign firms
Mahlberg (1999)	Austria and Germany	n/a	1992-1996	Life, health, property-liability	DEA	Administration and distribution cost (1 input)	Claims, change in reserves, refund of premium	Value added	Technical	Intercountry comparisons	Inefficiencies in both markets; Austrian insurers more efficient than German insurers
Mahlberg (2000)	Germany	348	1992-1996	Life, health, property-liability	DEA	Administration and distribution cost (1 input)	Claims, change in reserves, refund of premium	Value added	Technical	Regulation change	Decreasing efficiency; increasing productivity
Mahlberg/Url (2000)	Germany	464-533	1992-1996	Life, health, property-liability	DEA	Administration and distribution cost (1 input)	Claims, net change in provisions, allocated investment returns, bonuses and returned premia	Value added	Technical	Regulation change	Still cost-saving potential; increasing divergence between fully efficient firms and efficiency laggards; low cost-savings potential from further mergers
Mahlberg/Url (2003)	Austria	59-70	1992-1999	Life, health, property-liability	DEA	Administration and distribution cost (1 input), cost of capital investments	Claims, net change in provisions, allocated investment returns, bonuses and returned premia	Value added	Technical	Regulation change	Still considerable inefficiency; increased productivity
Mansor/Radam (2000)	Malaysia	12	1987-1997	Life	DEA	Claims, commission, salaries, expenses, other cost	New policy issued, premium, policy in force	Value added	Technical	General level of efficiency and evolution over time	Productivity growth; but low compared to real growth of economy
Meador/Ryan/ Schellhorn (2000)	US	358	1990-1995	Life	DFA	Labor, physical capital, misc. items	Premiums, securities investments	Value added	Cost	Scale and scope economies	Multi-product firms more efficient than focused firms
Noulas et al. (2001)	Greece	16	1991-1996	Non-life	DEA	Salaries and expenses (1 input) and payment to insurers and expenses incurred in the production of services (1 input)	Premium income, revenue from investment activities	Value added	Technical	General level of efficiency and evolution over time	Industry highly inefficient, with notable differences between different companies
Qiu/Chen (2006)	China	14-32	2000-2003	Life	DEA	Labor, equity capital, other	Benefit payments, additions to reserve, yield of investment	Value added	Technical, pure technical, scale	General level of efficiency and evolution over time	Average technical efficiency declining over time; increasing returns to scale
Rai (1996)	11 OECD countries	106	1988-1992	Life incl.health, non-life	DFA, SFA	Labor, capital, benefits and claims	Premiums (life and non-life)	Value added	Cost	Intercountry comparisons	Firms in Finland and France with lowest inefficiency; firms in UK with highest; small firms more cost efficient than large firms; specialized firms more cost efficient than combined firms
Rees et al. (1999)	Germany and UK	n/a	1992-1994	Life	DEA	Distribution cost, administration cost	Total premium income and change in total premium income (UK), aggregate sum insured and change in aggregate sum insured (GE)	Value added	Technical	Regulation change	Looser regulation and increased competition increase efficiency
Ryan/Schellhorn (2000)	US	321	1990-1995	Life	DFA	Labor, financial capital, materials	Benefit payments, additions to reserves	Value added	Cost	Regulation change	Unchanged efficiency levels after RBC became effective
Toivanen (1997)	Finland	21	1989-1991	Non-life	SFA	Labor	Number of units produced	Physical	Cost	Scale and scope economies	Diseconomies of scale at firm and economies of scale at branch level; econo-mies of scope in production
Tone/Sahoo (2005)	India	n/a	1982-2001	Life	DEA	Labor, business services, debt capital, equity capital	Present value of real losses incurred, ratio of liquid assets to liabilities	Value added	Technical, allocative, cost, scale	General level of efficiency and evolution over time	Increasing allocative inefficiencies after 1994; increase in cost efficiency in 2000
Trigo Gamarra/ Growitsch (2008)	Germany	115	1997-2005	Life	DEA	Acquisition and administration expenses, equity capital	Incurred benefits, additions to reserves, bonuses and rebated	Value added	Cost, profit, scale	Distribution systems	Specialized single-channel insurers do not outperform multi-channel insurers in terms of cost or profit efficiency
Vencappa/Fenn/Diacon (2008)	14 European countries	n/a	1995-2001	Life, non-life	SFA	Labor and materials, financial capital, debt capital	Incurred claims	Value added	Technical	General level of efficiency and evolution over time	Temporal variations in rate of overall productivity growth for life and non-life, driven by patterns of technological progress and regress, together with consis-tent positive contributions from scale efficiency; in most years, modest growth in technical efficiency
Ward (2002)	UK	44	1990-1997	Life	SFA	Labor, capital	Claims, additions to reserves	Value added	Cost, revenue, profit	Distribution systems	Cost benefits for firms focusing on one mode of distribution
Weiss (1986)	US	2	1976-1980	Life	Index	Labor (supervisor, agent, other); materials; capital (home office, field)	Number of policies, constant dollar insurance in force, real premium	n/a	n/a	Methodology issues, comparing different techniques or assump-tions	Theoretically sound method for measuring productivity in life insurance industry has been introduced

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Authors	Countries	No. insurers	Sample period	Lines of business	Me-thod	Input type	Output type	Output approach	Main types of effi-ciencies analyzed	Application category	Selected findings
Weiss (1991a)	US	100	1980-1984	Property-liability	SFA	Labor (agent, supervisory, nonsuper-visory), material, capital	Incurred losses, reserves	Value added	Technical, allocative, scale	General level of efficiency and evolution over time	Estimated inefficiency costs of 12–33% of premiums
Weiss (1991b)	France, Germany, Japan, Switzerland, US	n/a	1975-1987	Property-liability	Index	Labor, capital	Incurred losses, reserves	Value added	n/a	Intercountry comparisons	Japan with weakest productivity growth; US and Germany with overall high productivity
Worthington/Hurley (2002)	Australia	46	1998	General insurance	DEA	Labor, information technology, physical capital, financial capital	Net premium revenues, invested assets	Value added	Pure technical, scale, allocative, cost	General level of efficiency and evolution over time	Low average level of efficiency; mostly due to allocative inefficiency
Wu et al. (2007)	Canada	71-78	1996-1998	Life incl. health	DEA	Prod: Labor expenses, general operating expenses, capital equity, claims incurred Inv: Net actuarial reserves, invest-ment expenses, total investments, total segregated funds	Prod: Net premiums written, net income Inv: Investment gains in bonds and mortgages, investment gains in equities and real estate	Value add-ed/financial intermedia-tion	Systematic, production, investment	Methodology issues, comparing different techniques or assump-tions	New model allows integration of production performance and investment performance; Canadian companies operated very efficiently
Xie (2008)	US	107	1993-2004	Property-liability	DEA	Labor, (admin, agent), business service and materials, financial equity capital	Present value of losses incurred, real invested assets	Value added	Cost, revenue	Organizational form, corporate governance issues	IPO firms perform no worse than private firms in terms of cost and revenue efficiency changes
Yang (2006)	Canada	72	1998	Life incl. health	DEA	Prod: Labor expenses, general operating expenses, capital equity, claims incurred Inv: Net actuarial reserves, invest-ment expenses, total investments, total segregated funds	Prod: Net premiums written, net income Inv: Investment gains in bonds and mortgages, investment gains in equities and real estate	Value add-ed/financial intermedia-tion	Systematic, technical (production), invest-ment	Methodology issues, comparing different techniques or assump-tions	New model allows integration of production performance and investment performance; Canadian companies operated fairly efficiently
Yao/Han/Feng (2007)	China	22	1999-2004	Life, non-life	DEA	Labor, capital, payment and benefits	Premiums, investment income	Value added	Technical	General level of efficiency and evolution over time	Average efficiency of 0.77 for non-life and 0.70 for life companies
Yuan/Phillips (2008)	US	613 insurers (260 diversified 1450 banks)	2003-2005	life, property-liability, (commercial banks, thrifts)	SFA	Labor (admin, agent), material and physical capital, financial equity capital, debt capital	P/L: Present value of real losses incurred Life: Incurred benefits plus additions to reserves	Value added	Cost, revenue, profit scope	Regulatory change	Significant number of cost scope diseconomies, revenue scope economies, weak profit scope economies exist in post-GLB integrated banking and insur-ance sectors
Yuengert (1993)	US	765	1989	Life incl. accident and health	SFA, TFA	Labor, physical capital	Reserves, additions to reserves	Value added	Cost, scale	Scale and scope economies	Economies of scale, but not for whole sample; x-inefficiency 35–50%; weak-ness of TFA; half-normal SFA specification not flexible enough

Notations: DEA: data envelopment analysis; DFA: distribution-free approach; FDH: free disposal hull; SFA: stochastic frontier approach; TFA: thick frontier approach. Three contributions to performance measurement in insurance by Weiss (1986, 1991b) and Bernstein (1999) are excluded from the overview, but included in this table, since they are not efficient-frontier based and focus only on productivity.

APPENDIX 2: STOCHASTIC FRONTIER ANALYSIS SPECIFICATION

For the calculation of *technical efficiency,* we specify a translog stochastic input distance function. The distance function formulation was chosen so as to accommodate multiple outputs and multiple inputs (see, e.g., Coelli/Perelman, 1996; Coelli, 2005). The translog functional form was selected due to its broad acceptance in stochastic frontier analysis in insurance (see, e.g., Cummins/Weiss, 2000 and our overview in Section 2). The technical efficiency SFA model is as follows:

$$\begin{aligned} -\ln(x_{Kit}) = {} & \alpha_0 + \sum_{m=1}^{M} \alpha_{mi} \ln(y_{mit}) + 0.5 \sum_{m=1}^{M} \sum_{n=1}^{N} \alpha_{mn} \ln(y_{mit}) \ln(y_{nit}) \\ & + \sum_{k=1}^{K-1} \beta_k \ln(x_{kit}^*) + 0.5 \sum_{k=1}^{K-1} \sum_{l=1}^{L-1} \beta_{kl} \ln(x_{kit}^*) \ln(x_{lit}^*) \\ & + \sum_{k=1}^{K-1} \sum_{m=1}^{M} \phi_{km} \ln(x_{kit}^*) \ln(y_{mit}) \\ & + \varphi_1 t + 0.5 \phi_{11} t^2 + \sum_{m=1}^{M} \gamma_{1m} t \ln(y_{mit}) + \sum_{k=1}^{K-1} \kappa_{1k} t \ln(x_{kit}^*) \\ & + v_{it} - u_{it}, \end{aligned} \tag{1}$$

where x_{kit} are the *k* inputs of insurer *i* at time *t* and y_{mit} are the *m* outputs of insurer *i* at time *t*. To ensure linear homogeneity of degree 1 in inputs, we randomly choose one input (such as x_{Ki} in our case) and divide all other inputs by this input. Thus $x_{ki}^* = x_{ki} / x_{Ki}$. This is also why all summations in Equation (1) involving x_{ki}^* are over M-1 and not M. To account for technological change over time, a time factor *t* is included as a regressor in the model. The random error is included in Equation (1) by v_{it}, which is assumed to be distributed normally. Inefficiencies are modeled by the term u_{it}, which is assumed to follow a truncated normal distribution and permitted to vary systematically with time in our unbalanced panel setting (see Battese/Coelli, 1992). In addition, using a one-stage approach, the mean m_{it} of u_{it} is assumed to vary depending on a vector of firm-specific variables ("conditional mean approach"; see Battese/Coelli, 1995, and Greene/Segal, 2004, for an application to the insurance industry):

$$m_{it} = \delta_0 + \delta_1 a_{it} + \delta_2 b_{it} + \delta_3 c_{it} + \delta_4 d_{it} + \delta_5 f_{it} + \delta_6 g_{it} + \delta_7 h_{it} + \delta_8 t, \tag{2}$$

where a_{it} is a dummy variable reflecting organizational form, with 1 for stock companies and 0 for mutuals. b_{it} is a solvency variable: 1 if the company's ratio of equity capital to total as-sets is above the median in the respective branch; 0 if not. c_{it} reflects size and is proxied by the natural logarithm of assets of each firm for each year. d_{it} is squared size. f_{it} is a developed country variable (1 if company is from a developed country, 0 if not). g_{it} is a corruption variable determined using the Corruption Perceptions Index provided by Transparency International (available at http://

www.transparency.org); it ranges from 0 to 10, with 10 indicating the lowest level of corruption and 0 the highest. h_{it} reflects the Gross Domestic Product (GDP) for each country and each year obtained from the IMF Word Economic Outlook Data-base (Version April 2008). A time factor t is included to account for efficiency change over time.

The technical efficiency score TE_{it} is calculated by the following formula:

$$TE_{it} = \exp(-u_{it}) \tag{3}$$

For the calculation of *cost efficiency*, we specify a translog stochastic cost function:

$$\begin{aligned} \ln\left(\frac{C_{it}}{p_{Kit}}\right) = {} & \alpha_0 + \sum_{m=1}^{M} \alpha_{mi} \ln(y_{mit}) + 0.5 \sum_{m=1}^{M} \sum_{n=1}^{N} \alpha_{mn} \ln(y_{mit}) \ln(y_{nit}) \\ & + \sum_{k=1}^{K-1} \beta_k \ln(p^*_{kit}) + 0.5 \sum_{k=1}^{K-1} \sum_{l=1}^{L-1} \beta_{kl} \ln(p^*_{kit}) \ln(p^*_{lit}) \\ & + \sum_{k=1}^{K-1} \sum_{m=1}^{M} \phi_{km} \ln(p^*_{kit}) \ln(y_{mit}) \\ & + \varphi_1 t + 0.5 \phi_{11} t^2 + \sum_{m=1}^{M} \gamma_{1m} t \ln(y_{mit}) + \sum_{k=1}^{K-1} \kappa_{1k} t \ln(p^*_{kit}) \\ & + v_{it} + u_{it}, \end{aligned} \tag{4}$$

where C_{it} are total cost of insurer *i* at time *t*. p_{kit} are the *k* input prices of insurer *i* at time *t* and y_{mit} are the *m* outputs of insurer *i* at time t. To ensure linear homogeneity of degree 1 in input prices, we randomly choose one input price (such as p_{Ki} in our case) and divide the dependent variable (C_{it}) and all other input prices by this input price. The rest of the model specification, including the distributional assumptions of the random error v_{it} and the inefficiency term u_{it}, are analogous to the technical efficiency SFA model.