Dissertation

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"Ownership and Efficiency in the German Life Insurance Market: A DEA Bootstrap Approach"

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Deutsche Zusammenfassung

Die Frage nach der Wahl der optimalen Eigentümerstruktur eines Unternehmens beschäftigt Wissenschaft und Praxis schon seit Jahrzehnten. Insbesondere die Trennung von „*ownership*“ und „*control*“ und die dadurch möglicherweise entstehenden Interessenskonflikte zwischen den Eigentümern eines Unternehmens, die i.d.R. nur generelle strategische Leitlinien ausgeben, und dem Management, das tagesaktuelle Entscheidungen (ohne Rücksprache mit den Eigentümern) trifft, standen und stehen im Mittelpunkt des Interesses. Der Versicherungsmarkt mit seinen darin tätigen Unternehmen stellt dabei ein besonders gutes Untersuchungsobjekt für verschiedene Theorien dar, da neben Versicherungsaktiengesellschaften (VAG) in den meisten Ländern auch noch genossenschaftlich organisierte Versicherungsvereine auf Gegenseitigkeit (VVaG) agieren. Insofern fokussieren internationale Studien zu Principal-Agent-Konflikten häufig auf dem Gegensatz zwischen „*stock ownership* und „*mutual ownership* in der Versicherungsindustrie. Der deutsche Versicherungsmarkt allerdings kann diesbezüglich als ein Spezifikum betrachtet werden, da hier eine dritte Form von Eigentümerstruktur existiert, nämlich die der öffentlich-rechtlichen Versicherungsunternehmen (ÖRV).

Diese Dreiteilung des Marktes ermöglicht eine erweiterte Analyse der traditionellen Hypothesen zu unterschiedlichen Eigentümerstrukturen und den damit verbundenen Principal-Agent-Problemen. In einem weiteren Schritt bearbeitet diese Studie nicht nur die Interessenskonflikte, welche sich aus der Eigentümerstruktur des Versicherungsunternehmens ergeben, sondern analysiert auch den Einfluss der Eigentümerstruktur der Holdinggesellschaft (falls vorhanden). Um diesbezügliche Aussagen zu machen, wurde die Gruppenzugehörigkeit aufgrund der Eigentümerstruktur der höchsten Gruppenebene zugeteilt.

Im Folgenden wurden auch Mischformen, d.h. beispielsweise eine Aktiengesellschaft, deren Mutter auch eine Aktiengesellschaft ist, mit Mischformen (Unternehmen ist eine VVaG, Mutter eine VAG) verglichen und erstmals untersucht, ob Mischformen Einfluss auf die Effizienz eines Lebensversicherungsunternehmens haben.

Williamson (1963) formulierte als erster die „*expense preference hypothesis*“, die besagt, dass AGs hinsichtlich ihrer Kostenstruktur effizienter sind als andere Formen von Eigentum, da Aktionäre (z.B. im Gegensatz zu Mitgliedern einer Genossenschaft) stärkere Kontrollrechte gegenüber dem Management besitzen. Fama & Jensen (1983) nennen den komparativen Vorteil als eine Erklärungsmöglichkeit dafür, dass in manchen Industriezweigen, wie eben der Versicherungsbranche, seit langer Zeit mehrere Formen von Eigentum gleichzeitig existieren und miteinander konkurrieren. Da jede dieser Eigentumsformen offenbar auf einer eigenen „*production frontier*“ agiere, gebe es keine generelle Dominanz einer Gruppe über die anderen, so dass auch keine Verdrängung stattfinde: die „*efficient structure hypothesis*“.

Die vorliegende Arbeit beschäftigt sich hauptsächlich mit diesen zwei Hypothesen im Zusammenhang mit der Effizienz unterschiedlicher Eigentumsformen in einem Markt. Diese Hypothesen wurden für die drei auf dem deutschen Lebensversicherungsmarkt tätigen Eigentümerstrukturen VAG, VVaG und ÖRV überprüft. Basierend auf einem Datensatz, der ca. 90% des Marktes für einen Zeitraum von 2002 bis 2005 abdeckt, konnte nachgewiesen werden, dass im deutschen Lebensversicherungsmarkt Marktsegmentierung vorliegt, dass also VAGs, VVaGs und ÖRVs sowohl unterschiedliche Produktionstechnologien verwenden als auch gruppenspezifische Kostenstrukturen aufweisen. Des Weiteren zeigte sich, dass die „*efficient structure hypothesis*“ zumindest für ÖRVs verworfen werden kann, da diese, trotz der Existenz von gruppenspezifischen Technologien, die für sie typischen Input-Output-Kombinationen weniger effizient als die beiden anderen Gruppen herstellen. VAGs dagegen sind bei der Produktion spezifischer Outputs den beiden anderen Gruppen überlegen; VVaGs dominieren zumindest die Gruppe der ÖRVs und sind bei den ihnen eigenen Input-Output-Kombinationen nicht weniger effizient als VAGs. Die „*expense preference hypothesis*“ fand schließlich in der vorliegenden Arbeit Bestätigung. Die Gruppe der VAGs „profitiert“ offenbar tatsächlich von den besseren Kontrollmöglichkeiten durch die Eigentümer und weist eine effizientere Kostenstruktur auf als genossenschaftlich organisierte oder öffentliche VUs.

Weiterhin wurden Unterschiede in der Effizienz innerhalb der einzelnen Eigentumsformen untersucht. Dabei zeigte sich, dass manche öffentlich zugängliche Firmenkennzahlen einen signifikanten Zusammenhang zum Effizienzgrad eines VU aufweisen. So haben VUs mit hoher technischer Effizienz ebenfalls einen hohen RoA, geringe Abschlusskosten und eine niedrige Stornoquote. Das selbe gilt auch für kosteneffiziente Firmen, die allerdings anstelle geringer Abschlusskosten eine niedrige Verwaltungskostenquote ausweisen. Vor allem die Ergebnisse bezüglich ÖRVs, die gegenüber VUs in

Privateigentum Effizienznachteile zu haben scheinen, stehen in der Tradition der Theorie zu öffentlichem Eigentum. Dass diese Unternehmensform am deutschen Versicherungsmarkt jedoch schon seit Jahrhunderten existiert und bislang von privatwirtschaftlichen VUs nicht verdrängt werden konnte, steht jedoch im Widerspruch zur Theorie effizienter Märkte. Allerdings gilt insbesondere für die Resultate hinsichtlich der Gruppe der ÖRVs zu beachten, dass die Aussagen der vorliegenden Arbeit insofern limitiert sind, als ein „*4-Input/2-Output*"-Modell Verwendung findet. Gerade aber ÖRVs nehmen für sich in Anspruch, auch andere Leistungen zu erbringen, die oftmals im Widerspruch zum gewinnmaximierenden Verhalten privater VUs stehen, aber trotzdem dem Gemeinwohl zugute kommen (z.B. die Schaffung von Arbeitsplätzen, gerade in wirtschaftlich weniger entwickelten Regionen oder die Förderung von Wissenschaft, Kunst und Sport). Diese Formen von Outputs sind qualitativer Natur, entsprechend finden sie in der vorliegenden quantitativ ausgerichteten Untersuchung keine Berücksichtigung.

Die im deutschen Versicherungsmarkt vorhandene Form der ÖRVs, die einerseits, anders als die meisten öffentlichen Unternehmen, in anderen Sektoren keine Monopolstellung inne haben, sondern mit privatwirtschaftlich orientierten, gewinnmaximierenden VUs konkurrieren müssen, andererseits aber durch den Einfluss des öffentlichen Eigentümers Aktivitäten setzen und Leistungen erbringen, die zwar wohlfahrtsstiftend sein mögen, aber wohl kaum die Effizienz erhöhen, wird durch die traditionelle „*efficient structure hypothesis*" nicht erfasst. Die Ergänzung einer Effizienzanalyse des deutschen Versicherungsmarktes um den „sozialen Output" von VUs, insbesondere von ÖRVs, bleibt somit künftigen Untersuchungen vorbehalten.

Abstract

This thesis provides new insights into the effect of ownership on efficiency by analyzing the German life insurance market over the period 2002-2005. Previous research on alternative organizational forms in the life insurance industry has focused on stock and mutual ownership only. Due to the uniqueness of the German insurance market, where privately owned companies face competition by public insurers, we add to the literature on the well-known debate on public vs. private ownership on investigating stock, mutual and public ownership structures. The thesis calculates the technical, cost and allocative efficiency scores in order to test the efficient structure hypothesis as well as the expense preference hypothesis. The underlying method is traditional DEA as well as the recently introduced SW-bootstrapping method to correct for the bias of DEA estimators. The results give strong support to the expense preference hypothesis. No evidence is found that public ownership is an efficient corporate structure for life insurers. Thus, stock ownership is superior to mutual and public structures, with smaller stock insurers being even more dominant in production technology. Half of the German stock insurers are owned by mutual or public holding companies. The present work identifies the superstructure of stock insurers in order to test for any impact of the organizational form of a holding company on the efficiency of its differently organized subsidiaries. The findings suggest that uniformly organized groups of companies dominate hybrid forms and that the difference in organizational forms between a holding company and its subsidiary may lead to frictions which will cause inefficiencies.

Ownership and Efficiency in the German Life Insurance Market: A DEA Bootstrap Approach

1 Introduction

The structure of corporate ownership in the insurance industry and its implications for managerial control have been subject to academic debate since the late 1970s (see Fama & Jensen (1983), Finsinger (1983) or Demsetz & Lehn (1985)). In particular, the dichotomy of organizational structure has attracted much attention. Beside stock companies which employ the standard corporate form, the so called mutual ownership, where consumers are at the same time the sole owners of the firm that produces the good to be consumed by the consumer owners, is quite unique in our well-established economic systems.

The German insurance market can be considered of great interest because of the existence of a third ownership structure. After basic forms of private cooperatives for fire insurance had emerged in the early 18th century, the German principalities nationalized those activities to create monopoly fire insurance. In the late 19th century, these public insurance companies extended their activities to other lines of insurance, such as property and life insurance, where they had to compete with private insurance companies already in existence at the time (like Anglo-American stock insurers or domestic mutual insurers).

Today public insurance companies still participate in the competitive life insurance market, with the sole owner and responsible body being a local authority (mostly a federal state in alliance with some municipal savings banks). As a result of their origin, public insurers still restrict their activities to the historical administrative region where they were founded (the boundaries of a principality perished long ago) to eliminate potential competition with other public insurers. In contrast to publicly owned companies in other branches, companies organized in this third form of ownership do not aim to make profits (to decrease the public budget deficit) but act on a non-profit basis for the benefit of its policyholders, similar to mutual insurers. Moreover, public insurance companies assign themselves (or are assigned by their owners) an important role in local employment opportunities and in the promotion of arts, sciences, sports and other social activities. Finally, a public owner is assumed to have more power to control managerial decisions and compensation than a general meeting of a mutual insurance company. On the other hand, critics of the system of public enterprises often argue that, in companies under public law, decisions may be made on political grounds instead of economic ones which could lead to inefficient managerial actions required (or at least approved) by a public owner.

We add to the existing literature on organizational structure in the life insurance industry in manifold ways: firstly, by studying the German market, while most prior studies on organizational forms in the life insurance industry have focused on the United States; secondly, by updating results of the few existing studies that dealt with the German market; thirdly, by combining the approaches of previous studies which either dealt with private vs. public ownership or (especially in the insurance industry) with stock vs. mutual structure by investigating differences between these three forms of ownership structure; then, we use recently introduced bootstrapping techniques to obtain statistical inference in our non-parametric approach, in trying to quantify agency costs which arise from the different forms of ownership and the resulting conflicts of interest of life insurance companies. We use the widespread method of Data Envelopment Analysis (first introduced by Charnes, Cooper & Rhodes (1978)) to measure the efficiency of almost all German life insurers from 2002 to 2005. Moreover, we use the bootstrapping method to correct for the bias of DEA efficiency estimators as proposed by Simar & Wilson (1998) and Simar & Wilson (2000).

Furthermore, we present an analysis of the holding structure hypothesis, which says that the corporate structure of a holding company has an influence on the efficiency of its respective subsidiaries. We test this hypothesis in three steps. First, we identify the companies according to the ownership of the highest level of the corporate structure, second, we make a deeper analysis of stock insurers (the only form of ownership that can have a holding structure with another ownership structure). Third, we compare pure ownership structure (e.g. stock firm with stock holding) to hybrid forms (e.g. stock firm with mutual holding).

A large number of German stock insurers is actually owned by a mutual holding company or a public entity. We assume that a stock insurer owned by a mutual holding company (mutual stock insurer, henceforth) and a stock insurer owned by a public holding company (public stock insurer, henceforth) tend to act like a mutual insurer and a public insurer, respectively. These hybrid forms of ownership lack the typical properties of a stock company. Mutual stock insurers are not able to use any of the control mechanisms of stock companies named before, since the sole owner is a mutual body. Public stock insurers may face the same uneconomic decisions by political representatives of their public owner as "pure" public companies do.

The thesis is structured as follows. Section 2 gives an overview of the existing literature. Section 3 formulates our hypotheses and outlines the methodology used in this thesis. Section 4 describes the data set used and summarizes the descriptive statistics of German life insurance companies. Section 5 presents the results of the data envelopment analysis at the firm level. Section 6 describes the estimation results at the holding level, section 7 provides a deeper insight into stock insurers with a differently organized holding structure, and finally, section 8 summarizes the results of the Logit regression analysis with efficiency as the dependent variable explained by insurance companies characteristics. Section 9 gives a summary of our findings.
In Appendix A, results of the Malmquist Index, which is an estimation of efficiency improvement over time for the observed time period, is presented, and in Appendix B, results of the bootstrapping are illustrated.

2 Related Literature

This section gives a brief overview of previous research on different forms of ownership. The theoretical fundamentals of the separation of ownership and control and its consequences are laid in Berle & Means (1932) and later in Coase (1960) who was the first to introduce the problem of separation of ownership and control and the resulting concept of agency costs. He argues that different forms of ownership face different conflicts of interest which in turn results in different levels of agency costs. Williamson (1963) was the first to formulate one of the main hypotheses in the corporate structure debate, the so called expense preference hypothesis, which states that stock firms are most efficient concerning their cost structure because they deal better with manager/owner conflicts. Fama & Jensen (1983) suggest that the coexistence of two different ownership structures in the industry over a long period of time could be explained by comparative advantage. Since both types operate on their respective production frontiers (and not on a common one), neither shows overall predominance to expel companies of the competing structure from the industry. Mayers & Smith (1994) strengthen the theoretical arguments of Fama & Jensen (1983) and find that different ownership structures are more concentrated in different lines of business. They conclude that each organization form has its own advantage and formulate the efficiency structure hypothesis.

The most recent theoretical papers dealing with the German insurance market are Breuer & Breuer (2002) and Breuer & Breuer (2004). Breuer & Breuer (2002) argue that federal authorities have taken regulatory actions to decrease potential agency conflicts significantly, so that no efficiency differences between mutual and stock insurers should be observable. Breuer & Breuer (2004) list various theoretical arguments for the predominance of public insurance companies (compared to stock and mutual insurers): public firms deal best with manager/owner conflicts because of their mechanism of managerial control; furthermore, public firms work on a non-profit basis and therefore eliminate owner/policyholder conflicts; moreover, public insurers have a competitive advantage because their respective owners assume (unlimited) liability. The authors conclude that *ceteris paribus* public ownership is the most efficient corporate form in the insurance industry.

Empirical studies on ownership differences and their effects on corporate efficiency in the insurance industry are numerous, and their respective results are not unambiguous. Some of the main findings are listed below.

Cummins, Weiss & Zi (1999) use Data Envelopment Analysis to analyze a data set of almost 90% of property liability insurers in the USA from 1981-1990. The authors introduce the concept of cross efficiency, i.e. measuring the efficiency of stock insurers against the production frontier of mutual insurance companies and vice versa. Their results show evidence for the fact that mutual and stock insurers operating on different production frontiers use different technologies (efficient structure hypothesis). Moreover, since their study indicates that stock insurers dominate mutual insurers even on the mutual cost frontier, their findings give strong support to the expense preference hypothesis. Lai & Limpaphayom (2003) analyze the Japanese market by examining 26 firms in the period from 1983-1994 by pooled regression analysis. The Japanese financial market is quite unique due to the existence of horizontal "Keiretsu" groups (i.e. interwoven financial groups). The authors analyze the ownership differences between stocks belonging to a Keiretsu and independent stock and mutual insurers and find that Keiretsu firms show higher profitability and higher loss ratios than their independent counterparts. Furthermore, Japanese mutual insurers have higher levels of free cash flow, higher investment incomes and lower financial leverage than stock insurers have. Finally, the authors find evidence for the efficient structure hypothesis formulated in Mayers & Smith (1994). Cummins, Rubio-Misas & Zi (2004) apply the same method of cross-frontier DEA as used in the study of U.S. property/liability insurers by Cummins et al. (1999) to analyze the Spanish insurance market from 1989-1997. Their results support the efficient structure hypothesis, but are generally not consistent with the expense preference hypothesis. Green & Segal (2004) use a stochastic frontier approach to test for efficiency of 136 firms in a data set consisting of 478 observations in the time period from 1995-1998. The authors are unable to find any difference in efficiency and profitability between mutual and stock owned firms. Nevertheless, their results suggest that cost efficiency in the life insurance industry is substantially relative to earnings and that inefficiency is negatively correlated with profitability measures like, for instance, return on equity.

The first important efficiency analysis of the ownership structure of insurance companies that deals with the German insurance market is published by Finsinger (1983). Using OLS regressions the author analyzes 100 life insurance companies subdivided by their ownership form in the year 1980 and finds that public insurers are able to give a competitive edge to policyholders with respect to surrender values as well as net returns from investing in term life insurance policies. Furthermore, this author is the first to look at the form of ownership of life insurance subsidiaries as well as at the corporate structure of the respective holding companies. A recent study of the German insurance industry were conducted Hussels & Ward (2006), Trigo

Gamarra (2007) and Trigo Gamarra (2008). The effects of liberalization on the Austrian insurance market were analyzed by Mahlberg & Url (2003).

3 Hypotheses and Methodology

3.1 Hypotheses

Based on previous theoretical and empirical studies, it is reasonable to assume that the three different forms of ownership existing in the German life insurance market have comparative advantages to deal with different agency conflicts, which results in different agency costs (see Fama & Jensen (1983) and Mayers & Smith (1994)).

As often argued, stock ownership deals better with owner/manager conflict than mutual ownership: managers in a stock firm are confronted with elaborate control mechanisms such as proxy fights, hostile takeovers, and stock options as part of managerial compensation. These mechanisms can reduce the incentives for managers to extract excessive values from the company and, as a result, from company owners and policyholders (see Coase (1960) and Williamson (1963)). Control mechanisms for mutual firms seem to be much weaker, such that managers are able to expropriate value from the company resulting in higher operating expenses, as has always been argued in literature (see e.g. O'Hara (1981)). Although German mutual insurers have a tripartite organizational structure similar to stock companies (management board, supervisory board and general meeting), the absence of large institutional investors with a substantial number of shares in the company's stock can lead to unsystematic activities of policyholder owners in controlling managerial decisions. Since every policyholder only owns a small part of the company (based on the portion of his/her personal insurance coverage compared to the company's overall amount of insurance), incentives to bear the expenses for managerial control are quite small. Grossman & Hart (1980) suggest that, in the absence of other control mechanisms such as takeover bids, this free rider problem cannot be solved. Furthermore, the general meeting of mutual policyholder owners often has no right to (re-)elect board members or replace retired ones. Instead, the articles often assign to the remaining board the power to co-opt a new member to the board (without approval of the general meeting). Thereby, the board is able to act independently from the company owners whom they represent and act in collusion with the management.

On the other end of the spectrum, there are public insurance companies. Since public enterprises are owned by a single entity only, one expects higher incentives to accept agency costs for controlling the management. On the other hand, managerial replacement in a public firm could be long delayed because of political influence. An unexpected change in management could be the result of mismanagement in the past and could be utilized by political opponents. Furthermore, whereas owners of stock insurers are usually directly affected by inefficient management (e.g. through lower cash dividends), the representatives of the owner of a public insurer normally do not suffer from financial penalties immediately.

The other important agency conflict is the policyholder/owner conflict as owners and policyholders of stock insurers have different interests. Profits generated by the company can either be distributed to shareholders (usually in the form of dividends) or can increase the benefit of with-profit policies (the common type of life insurance policies in Germany) resulting in a trade-off between shareholders' earnings and policyholders' benefits. Additionally, as argued in Fama & Jensen (1983), owners have a moral hazard opportunity, since they can change the company's attitude towards risk without conferring with policyholders.

The conflict described above does not apply to mutual insurers, because policyholders are at the same time the sole owners of the company. For public insurers, the role of policyholders and owners is separated (as is with stock companies), but a non-profit basis as the intention of the owner is prescribed by the statutes (similar to the mutual insurer). On the other hand, the public owner may act contrary to policyholders' concerns (and to the public benefit as well). Boycko, Shleifer & Vishny (1996) argue that politicians cause government-owned firms to employ excess labor inputs, and Krueger (1990) suggests that managers in the public sector are primarily employed on political grounds.

As stated above, previous literature on corporate structure and agency costs mainly focused on two main hypotheses (see, for example, Cummins et al. (2004)). Firstly, the efficient structure hypothesis predicts that stock and mutual firms operate on different frontiers and that each have a comparative advantage in agency and production costs on their respective own frontier. For the analysis of the German life insurance market it seems reasonable to conclude that stock, mutual and public firms operate on separate production frontiers, since all three types have been in existence for centuries, still share the market and have not been able to replace each other. Secondly, the expense preference hypothesis says that stock firms are more efficient in minimizing costs and maximizing revenues due to better reduction of agency conflicts. With respect to the German insurance market, it can be assumed that stock insurers' cost efficiency frontier dominates the cost frontiers of mutual and public ones.

Recent empirical work on the efficiency of German insurance companies dates back to the early 1980s. This thesis tries to fill the gap, update results for Germany and compare the efficiency of different forms of ownership with results from other countries. To test the hypotheses described above, a non-parametric efficient frontier approach as in Cummins et al. (1999) and Cummins et al. (2004) is used.

This hypothesis will be firstly examined based on the form of ownership of the insurance company itself. Subsequently we rerun our calculations for the ownership structure of the holding company. In this context we present the holding structure hypothesis, which states that the corporate structure of a holding company has an influence on the efficiency of its respective subsidiaries. We analyze this hypothesis in manifold ways. First, we show that the re-parted sample due to the form of ownership on the highest corporation level is significant in terms of an own technology, and showed similar results as at the firm level. Secondly, we assume that a stock insurer owned by a mutual holding company (mutual stock insurer) and a stock insurer owned by a public holding company (public stock insurer) tend to act like a mutual insurer and a public insurer, respectively. These hybrid forms of ownership lack the typical properties of a stock company. Mutual stock insurers are not able to use any of the control mechanisms of the stock companies mentioned befor since the sole owner is a mutual body. Public stock insurers may face the same uneconomic decisions by political representatives of their public owner as "pure" public companies do.

Moreover, the relation between the efficiency of an insurance company and other observable firm characteristics such as size, policy cancellation rate, complaints ratio and gross premium level is investigated. Since DEA defines efficiency in terms of social welfare and identifies efficient firms, we finally try to explain the consequences of inefficient insurance companies for their owners and policyholders. And finally, our last question is, do efficient firms offer advantages to policyholders or owners?

3.2 Data Envelopment Analysis

The methodology used in this thesis was originally developed by Farrell (1957) and (for the purpose of efficiency measurement of insurance companies) expanded by Cummins et al. (1999) and used also in Cummins et al. (2004). For analyzing production frontiers we employ the input-oriented distance function (see, for example, Thanassoulis (2001)). We consider a sample of N firms. Each firm is a DMU (Decision Making Unit) represented by an input vector $x_i = \left(x_1^{(i)}, \ldots, x_k^{(i)}\right) \in \mathbb{R}_+^k$, and an output vector $y_i = \left(y_1^{(i)}, \ldots, y_m^{(i)}\right) \in \mathbb{R}_+^m$. The set $V(y)$ denotes the subset of $\mathbb{R}_+^k$ of the input vectors x_i that can produce at least y_i, for $i = 1, \ldots, N$ (each i is a DMUs). We assume $V(y)$ is a closed and convex set.

Farrell's measure of input technical efficiency $T(x_i, y_i)$ is $D(x_i, y_i)^{-1}$ with

$$D(x_i, y_i) = \sup\{\theta : (y_i, \frac{x_i}{\theta}_i) \in V(y)\}.$$

The quantity $D(x_i, y_i)$ must be ≥ 1, and $T(x_i, y_i)$ is ≤ 1 but > 0 [1].

Relying on the previous studies on insurance companies' efficiency, we use a constant return to scale (CRS) DEA model. The CRS approach is quite comprehensive for our purpose because it represents the optimal outcome from an economic perspective. CRS identifies deviations from the optimal scale as inefficiency.[2]

The technical efficiency as defined above is a linear programming problem. Using the duality of max/min problems in linear programming and concretizing the quite abstract equation above we can derive the following equations

[1]Let all inputs of a DMU be contracted radially as far as feasible, without detriment to its output levels. The technical efficiency of the DMU is the maximum proportion of any one of its contracted input levels is of the observed level of that input(see Thanassoulis (2001))

[2]Moreover, the CRS model allows to perform so called cross-efficiency measures to check for predominance of one production technology over the others (see below).

over all DMUs:

$$
\begin{aligned}
&\min\nolimits_{\theta\lambda}\ \theta \\
\text{s.t.}\quad & -y_i + Y\lambda \geq 0 \\
& \theta x_i - X\lambda \geq 0 \\
& \lambda \ \geq 0
\end{aligned}
$$

where $\theta = T(x_i, y_i)$ is the technical efficiency of the ith-DMU (firm i) with (x_i, y_i) the associated input/output vector of that firm, λ is a $N+1$ vector of constants, being N the Number of DMUs (firms), X is the matrix of all inputs and Y the matrix of all outputs (see Coelli (1996)).

The minimum cost function or cost frontier is defined in a similar way using the distance function defined above. Let $w_i = (w_1^i, \ldots, w_k^i)$ denote the input price vector corresponding to the input vector x_i. Then the cost frontier is defined as:

$$C(w_i, y_i) = \min_{x_i}\{w_i' x_i : D(x_i, y_i) \geq 1\}$$

overall DMUs, which can be rewritten as

$$C(w_i, y_i) = \min_{x_i}\{w_i' x_i : (x_i, y_i) \in V(y)\}.$$

The optimal input vector $\tilde{x_i}$ minimizes the costs of producing output y_i when input prices w_i are given. Cost efficiency is defined as the ratio

$$\gamma = \frac{w_i' \tilde{x}_i}{w_i' x_i},$$

where x_i is the actual input vector used by the respective DMU.

Equivalent to technical efficiency, cost efficiency is estimated by solving a linear programming problem over all DMUs that is described as follows.

$$
\begin{aligned}
&\min\nolimits_{\lambda, x_i^*}\ w_i' x_i^* \\
\text{s.t.}\quad & -y_i + Y\lambda \geq 0 \\
& \theta x_i^* - X\lambda \geq 0 \\
& N1'\lambda = 1 \\
& \lambda \ \geq 0
\end{aligned}
$$

with w_i being the vector of input prices, x_i^* being the cost minimal vector of input quantities for the i-th DMU given the input prices w_i and the output levels y_i (see Coelli (1996)).

Allocative efficiency for a DMU is estimated by using the relationship

$$C(x_i, y_I) = T(x_i, y_i) * A(x_i, y_i),$$

where $C(x_i, y_i)$ is cost efficiency, $T(x_i, y_i)$ is technical efficiency and $A(x_i, y_i)$ is allocative efficiency. Allocative efficiency measures the efficiency of the allocation of inputs for given prices and outputs.

To test the efficient structure hypothesis, we first pool all DMUs to calculate the efficiency for stock, mutual and public insurers with respect to a joint production frontier (and joint cost frontier, respectively). However, pooling may not be an appropriate approach because each firm is compared against members of its own group in addition to members of other groups, and the inefficiency might result from within-groups effects instead of the desired between-groups effects (see Brockett, Chang, Rousseau, Semple & Yang (2004)). If each group operates on its own production frontier (i.e. using its unique production technology), pooled results will be biased. Therefore, we estimate distance functions for all three groups with respect to various reference sets. For example, the technical efficiency of stock insurers (s) with respect to a reference set consisting of stock firms only is denoted by $T_S(x_s, y_s)$.

To test for the existence of separate production frontiers, we calculate $T_S(x_{si}, y_{si})$, $T_M(x_{ml}, y_{ml})$ and $T_P(x_{pj}, y_{pj})$[3], respectively, and compare within-group efficiencies with pooled results. The same method is used to test for the existence of separate cost frontiers. Moreover, we compute cross-efficiency measures (as in Cummins et al. (1999) and Cummins et al. (2004)) as the distance of stock firms to the mutual frontier and the public frontier, distance of mutual firms to the stock frontier and the public frontier, and, finally, the distance of public firms to the stock frontier and the mutual frontier, i.e. each group of firms is measured against the frontiers of the two remaining groups.

For example, cross technical efficiency for one stock firm (i) with reference to the set of mutual firms is given by:

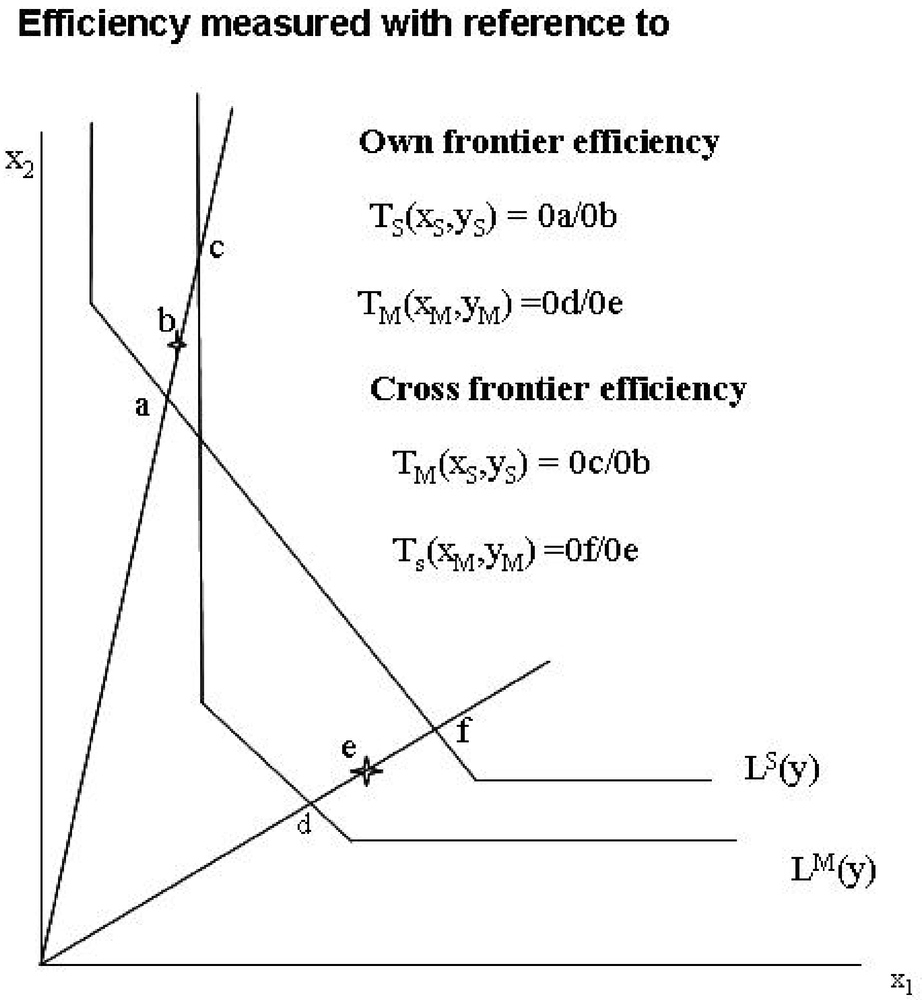
$$T_M(x_{i,s}, y_{i,s}) = [D_M(x_{i,s}, y_{i,s}) = \sup\{\theta : (y_{i,s}, \frac{x_{i,s}}{\theta_i}) \in V^M(y)\}]^{-1}.$$

[3]for $i = 1, \ldots, I$ (number of stock firms), $l = 1, \ldots, L$ number of mutual firms and $j = 1, \ldots, J$ number of public firms.

Although within-group efficiency is always ≤ 1 (i.e. a firm is not able to operate better than the most efficient firm(s) within its group), cross-efficiency can even be > 1. If a firm's cross-efficiency is > 1, the firm's input/output combination is unfeasible when using the production technology of the reference group.[4]

[4]Cross-efficiencies can be calculated under the assumption of CRS only. When using DEA with Variable Returns to Scale (VRS), the problem of comparability of the three different subsamples in our analysis would call for methods like mutual projection (see e.g. Steinmann, Dittrich, Karmann & Zweifel (2004)).

Figure 1: Illustration of a double-input (x_1, x_2) and single-output model (y)



In figure 1 we illustrate a simplified double-input/one-output framework for two different technologies. $L^S(y)$ is the efficient frontier for stock insurers and $L^M(y)$ is the one for mutual insurers. The point $b(x_S, y_S)$ is a DMU and represents a single stock insurer, whereas the point $e(x_M, y_M)$ is a mutual insurer (to make this illustration possible, constant output y is assumed). In this graph, it can be easily seen that technical efficiency is measured as the relation of the length of the vector determined by the point of the DMU to the length of the vector determined by the intersection point of the efficient frontier and the line through the DMU point and the origin. Technical X-efficiency then is measured on the other efficiency frontier.

Furthermore, based on the hypotheses explained above, we would expect stock (mutual, public) insurers to operate in a region where stock (mutual, public) production technology dominates. To test for this assumption, we measure the distance between the three frontiers of all DMUs in our sample. For example, the distance between the stock production frontier and the mutual production frontier for a mutual insurer is defined as:

$$DF_T = 1 - \frac{T_M(x_s, y_s)}{T_S(x_s, y_s)}.$$

A distance value < 0 would imply that stock technology dominates mutual technology for the respective input/output combination, a distance value > 0 would show mutual dominance. Distance values are calculated for all firms and for all inter-group combinations. The respective distance formulas are defined in table 4. Moreover, we define and compute distance values for cost frontiers and for allocative efficiency in an analogous way.

3.3 SW-Bootstrapping for DEA

As with other non-parametric methods, DEA has often been claimed as *non-statistical* and many researchers have complained about the lack of statistical properties so far. Moreover, since DEA scores are based on a finite sample of DMUs, efficiency results are rather considered estimates of the true (but unobservable) efficiency frontiers, which raises the question of the consistency of these estimators and the rates of convergence. Consistency for DEA estimators was shown by Banker (1993) and Korostelev, Simar & Tsybakov (1995), however, only under weak general conditions. When trying to measure the sensitivity of efficiency scores to the sampling variation, analytic results on the sampling distribution can be obtained for a single-input DEA only. For a multivariate DEA, however, the bootstrap is the only approach for estimating the sampling variation of efficiency estimators. The bootstrap method dates back to the late 1970s (Efron (1979)) and was first used with frontier models in Simar (1992). An application of bootstrapping to non-parametric efficiency estimators was later introduced by Simar & Wilson

(1998) and refined by Simar & Wilson (2000). In order to distinguish their approach from Loethgren (1998) and Loethgren & Tambour (1999), who presented an alternative methodology for bootstrapping DEA efficiency estimators, the literature refers to mehtod presented in Simar & Wilson (1998) as SW-bootstrap, whereas the latter is named LT-bootstrap.

For our analysis, we use the SW-bootstrap to correct for the bias of the DEA efficiency estimators.[5] In general, bootstrapping is a repetitive resampling of the data, applying the original estimator on each sample, so that the underlying distribution is maintained and sensitivities of the estimators are obtained. The generated value for technical efficiency for the firm i with input x_i and output y_i is, as defined before, $T(x_i, y_i)$, but, under the bootstrap methodology, this is just an estimator of the underlying real efficiency score and thus denoted as $\widehat{T(x_i, y_i)}$. Based on the empirical distributions of the $\widehat{T(x_i, y_i)}$, a pseudo sample for the input vector x_i is generated conditionally on y_i denoted as $V(y)^* = (x_i^*, y_i)$. Then the bootstrap inputs are given by:

$$\widehat{x_i^*} = \frac{\widehat{T(x_i, y_i)}}{T(x_i^*, y_i)} x_i.$$

For a detailed description of the consistency of the estimators and possible ways to smoothe the bootstrap estimators, see Simar & Wilson (1998) and Simar & Wilson (2000).

Most calculations of these sections were programmed by using Matlab. Additionally, a few estimations concerning the bootstrap estimations were run by the free statistical computing software *R* which was supplemented by the software library *FEAR 1.0* (see Wilson (2008)).

4 Sample, Outputs and Inputs

4.1 Data

The data set consists of about 90 German (the exact number varies for each year) life insurance companies over the period 2002-2005 totaling to 356 observations which represent more than 90% of the German life insurance

[5] See Simar & Wilson (2000) for a detailed description.

market. The data has been compiled from audited annual reports of the respective companies and was amended by the yearbooks of the Federal Financial Supervisory Authority (Bafin) and the German Insurance Association (GDV). Subdivided into groups by form of ownership, 73 mutual insurers, 263 stock insurers and 20 public insurers are analyzed. Summary statistics of our data set are shown in section 4.3.

4.2 Outputs, Inputs, and Prices

The selection of appropriate variables representing inputs and outputs is decisive as regards the validity of the results produced by DEA and is particularly difficult for insurance companies (as compared to manufacturing firms where attributing inputs to outputs is less challenging). Traditional literature on the efficiency of insurance firms has used the so called "production approach" to efficiency (see e.g. Cummins & Weiss (1993), Cummins et al. (1999) and Cummins et al. (2004)), which was introduced by Berger & Humphrey (1997), treating insurance companies like manufacturing companies. However, especially the use of "claims paid" or "losses incurred" as an output of the "production approach" has attracted criticism because an unexpected upward change in losses (due to an environmental catastrophe or a terrorist attack) would be considered an increase in output quantity and, therefore, would result in efficiency enhancement of the respective company. The "intermediation approach", which was believed to be best to evaluate financial institutions (Berger & Humphrey (1997)) and which was recently adopted by Brockett et al. (2004) and Brockett, Cooper, Golden, Rousseau & Wang (2005), tries to overcome these shortfalls by treating an insurance company like a financial intermediary and by selecting input and output variables accordingly. Brockett et al. (2005) specify outputs as a combination of certain variables that are related to the goals of all stakeholders of the company: claims paying ability (being in policyholders' interests), return of investment (for shareholders or, generally, company owners) and solvency scores (for public benefit). As shown below, we adopt the framework of Brockett et al. (2005) for selecting a combination of output variables. However, the variable of solvency was omitted, since the majority of the German life insurers are not rated by any of the large rating companies (like A.M.Best, Fitch or Standard and Poor's).

Outputs
Insurers' output consists primarily of services provided to policyholders.[6] The principal contribution to social welfare of an insurance company is to insure value. Consistent with recent insurance efficiency studies, services provided by life insurers can be divided into risk bearing (assuming risk to decrease potential personal losses), risk pooling (collecting funds from policyholders and redistributing money to those policyholders who incurred losses) and financial intermediation (borrowing funds from policyholders and investing them in financial assets until they are paid back at policy expiration date). We assume the amount of gross premium provided by a company to be a good proxy for these services, since all of them are related to this key figure. Risk bearing as well as risk pooling can be measured in terms of insurance coverage, and the level of financial intermediation services depends heavily on the level of funds brought in by policyholders. This in turn is strongly related to the amount of gross premiums. From the company owner's point of view, the main objective of an insurer is to achieve a certain profit goal, e.g. a required rate of return. Therefore, net income is chosen as output variable as well.

Input and Prices
Consistent with traditional efficiency literature we define four inputs for life insurance companies: labor, business services, financial debt capital and equity capital.

The quantity of labor input is defined as administration costs divided by the average monthly wage of an employee in the German insurance industry for the respective years (provided by the German Statistisches Bundesamt (German Federal Statistical Office). The average monthly wage of an insurance employee can be interpreted as the price of labor input. Since a good portion of business services in the life insurance industry are outside services such as agent activities and broker commissions, we use acquisition costs as an input, while input prices of business services are defined by using a price index for insurance services (provided by the German Statistisches Bundesamt). Cost of capital for each year is defined by the average return of the German prime equity index DAX calculated for a period of five years preceding the respective fiscal year. Cost of debt is defined similarly using

[6]For a general discussion on output measurement and productivity of life insurance companies, see Weiss (1986).

the representative cross-section index of German government bonds REX. Input and output prices were deflated to the base year 2002 by the German Consumer Price Index.

4.3 Summary Statistics

Table 1 presents summary statistics. It can be seen that the level of gross premiums and the amount of insurance coverage is significantly higher for stock firms (840.3 and 26132.3) than for mutual (523.3 and 19427.4) and public insurers (230.5 and 7915.6). Return on assets (measured as net financial profits to total assets) is highest for mutual insurers (4.9 vs. 4.7 and 4.5), although the differences are not statistically significant. Acquisition costs and operational expenses (as compared to gross premiums) are lowest for public firms, with stock firms being the most expensive insurance vehicle (although differing from mutual insurers' expenses only slightly). Furthermore, public firms perform best when it comes to cancellation rates (i.e. ratio of policies surrendered by policyholders to total number of policies in force), although differences in values are not significant. The policyholders' complaints ratio (measured as the ratio of complaints obtained from Federal Financial Supervisory Authority (BAFin) to the total number of policies in force) is much higher for mutual firms as compared to stock and public insurers. However, these results should be interpreted cautiously, since numbers of complaints were only available from quite a few public firms. Summary statistics also show that stock firms are significantly larger than mutuals or public ones in terms of input (columns 9 and 10) and output (columns 11–14) quantities.

5 Efficiency Results

To test the efficient structure hypothesis, i.e. that stock, mutual and public firms operate on separate frontiers, we first estimate the pooled production frontier and the pooled cost frontier as well as the group-specific frontiers for stock, mutual and public firms and check if pooled and group-specific frontiers are different. Table 2 presents sample mean values for technical efficiency, cost efficiency and allocative efficiency for all three groups with reference to the pooled data set as well as to the group-specific data set. Results show that the mutual and public specific frontiers for technical

Table 1: Descriptive Statistics

	Sample means													
	Number[7]	Prem.	RoA	Cost1	Cost2	Comp.	Can1	Can2	Ins.	net income	Labor	Service	Equity	Debt
all	356	741.0	4.7	13.3	4.1	0.605	16.1	4.1	23734.0	342.5	7193.9	1.2	1.6	54.4
firm level														
mutual	73	523.3	4.9	12.9	3.7	2.735	16.3	3.9	19427.4	276.7	5.1.2	0.8	1.2	41.6
stock	263	840.3	4.7	13.6	4.3	0.007	16.3	4.2	26132.3	379.9	8.1.8	1.3	1.7	60.8
public	20	230.5	4.5	10.5	2.6	0.005	13.4	3.9	7915.6	90.0	1.7	0.3	0.7	16.6
t-tests														
M vs. S		***			**				**		***	***	**	**
M vs. P		***		**	***				***	***	***	***	*	***
S vs. P		***		***	***				***	***	***	***	***	***

Note:
Prem.: gross premiums (mm EUR)
RoA: Return on Assets (ratio of net profits to total assets) calculated as arithmetic mean for each firm over the observed time period.
Cost1: acquisition costs to gross premiums
Cost2: operational expenses to gross premiums
Comp.: complaints ratio (filed complaints to total number of policies)
Can1: early cancellation rate
Can2: midterm/late cancellation rate
Ins.: amount of insurance coverage(mm EUR)
Labor, services, equity and debt mm EUR
All values are means averaged over the sample period 2002-2005
*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

[6] Complaints ratios were available only for:
mutual: 69; stock: 240; public: 6 (firm level);
mutual stock: 71; pure stock: 147; public stock: 23;
Cancellation rates were available only for:
mutual: 73; stock: 261; public: 18 (firm level);
mutual stock: 81; pure stock: 155; public stock: 25

efficiency are significantly different from the pooled production frontier (based on the input distance function results). Moreover, at least the cost frontier for public companies is not coinciding with the "general" cost frontier calculated with respect to the pooled data set. Our tests did not reject the hypothesis that the stock specific frontiers differ from the pooled ones. Nevertheless, the significant difference between pooled and individual results for mutual and public firms strongly indicates that comparisons of at least technical efficiency should rather be based on results calculated from group-specific frontiers. However, when doing so, a problem arises with allocative efficiency, which can be interpreted as the ratio of cost and technical efficiency scores: using pooled cost efficiency values together with the more appropriate group-specific technical efficiency scores would lead to an allocative efficiency mismatch because two different reference sets would be used for creating a single efficiency measure. Therefore, we decide to abstract away from pooled frontier results and use only individual reference sets instead.[8]

[8] Individual frontier efficiency scores cannot be compared *per se* because of the use of different reference sets. A smaller sample size of the respective benchmark / reference set will, by nature, on average lead to higher DEA efficiency scores. Therefore, the use of separate production and cost frontiers reflecting different production technologies for stock, mutual and public firms necessitates an X-efficiency analysis.

Table 2: Mean values of efficiency scores for the reference set of all insurers and for reference sets based on the organizational form of the companies

	Sample means		
	M	P	S
Technical efficiency			
All insurers	0.715	0.703	0.730
Subgroups	0.767	0.915	0.745
t-test	***	***	
Cost efficiency			
All insurers	0.360	0.353	0.391
Subgroups	0.361	0.740	0.380
t-test		***	
Allocative efficiency			
All insurers	0.505	0.491	0.536
Subgroups	0.469	0.805	0.505
t-test	***	***	

Note:

*** significant at the 0.01 level,

Cross-frontier efficiencies are calculated to test whether each form of ownership is dominant in producing its group-specific outputs. The results are shown in table 3. Remember that a certain production technology, e.g. mutual technology, dominates competing technologies for a specific input/output combination of a mutual insurer if the group-specific efficiency value of this combination is smaller than cross-efficiency measures, e.g. if $T_m(y_m, x_m) < T_s(y_m, x_m)$ and $T_m(y_m, x_m) < T_p(y_m, x_m)$ for any mutual DMU with y_m and x_m, respectively.

In the face of the efficient structure hypothesis we compare technical efficiency first. The results reported in the first row of table 3 suggest that mutual technology dominates public technology in producing mutual firms' output (0.767 vs. 1.013)[9], but is dominated significantly by stock technology (0.507). The average efficiency values for public firms with respect to their group-specific frontier (0.915) are significantly larger than stock and mutual scores (0.475 and 0.679, respectively), leading to the conclusion that pub-

[9]Sample mean values larger than 1 indicate that it is not feasible to replicate the input/output combination of mutual firms with public technology.

lic technology is inferior in producing its group-specific input/output mix compared to stock and mutual technology. Finally, stock technology significantly dominates both mutual and public technology in producing stock companies' input/output combination (0.747 vs. 0.941 and 1.383, resp.). In view of the efficient structure hypothesis, these findings are surprising, since at least public insurers seem to be highly inefficient in producing their specific input/output mix. In contrast, stock technology is superior not only in producing stock specific outputs but also dominates mutual and public firms with respect to their group-specific production.

Comparing X-efficiency scores for cost efficiency (row 2 of table 3), it can be seen that mutual firms are predominantly cost-efficient as compared to public companies for producing mutual input/output combinations (0.361 vs. 0.715) and do even better (although insignificantly) than stock insurers (0.373). With respect to public input/output matrices, public firms are significantly dominated by both stock and mutual companies (0.740 vs. 0.350 and 0.570, resp.). Finally, the results show that stock insurers seem to operate in a highly *cost-efficient* way (0.380) when compared to mutual (0.728) and public ones (0.922) in producing stock specific outputs. Although these findings are generally in accordance with the traditional cost efficiency hypothesis, the X-cost efficiency scores for mutual insurers which show a relatively high degree of cost efficiency are noteworthy.

To sum up the results for allocative efficiency (row 3 of table 3), one can see that both mutual and stock insurers allocate their resources efficiently when producing group-specific outputs (for mutual firms: 0.469 vs. 0.780 and 0.762, resp.; for stock firms: 0.508 vs. 0.801 and 0.729, resp). These differences in means are highly significant and large in size. For producing public input/output combinations, public firms show a slightly (insignificantly) higher degree of allocative efficiency than mutual firms (0.805 vs. 0.831) and are a little less efficient than stock firms (0.805 vs. 0.723), although the differences in means are significant at the 0.1 level only.

Table 3: Mean values of efficiency scores and X-efficiency scores for three groups of insurers, i.e. stock (S), mutual (M) and public (P)

	Sample means			t-tests	
	$T_m(y_m, x_m)$	$T_p(y_m, x_m)$	$T_s(y_m, x_m)$	$T_m : T_p$	$T_m : T_s$
M	0.767	1.013	0.507	***	***
	$T_p(y_p, x_p)$	$T_m(y_p, x_p)$	$T_s(y_p, x_p)$	$T_p : T_m$	$T_p : T_s$
P	0.915	0.679	0.475	***	***
	$T_s(y_s, x_s)$	$T_m(y_s, x_s)$	$T_p(y_s, x_s)$	$T_s : T_m$	$T_s : T_p$
S	0.747	0.941	1.383	***	***
	$C_m(y_m, x_m)$	$C_p(y_m, x_m)$	$C_s(y_m, x_m)$	$C_m : C_p$	$C_m : C_s$
M	0.361	0.715	0.373	***	
	$C_p(y_p, x_p)$	$C_m(y_p, x_p)$	$C_s(y_p, x_p)$	$C_p : C_m$	$C_p : C_s$
P	0.740	0.570	0.350	***	***
	$C_s(y_s, x_s)$	$C_m(y_s, x_s)$	$C_p(y_s, x_s)$	$C_s : C_m$	$C_s : C_p$
S	0.380	0.728	0.922	***	***
	$A_m(y_m, x_m)$	$A_p(y_m, x_m)$	$A_s(y_m, x_m)$	$A_m : A_p$	$A_m : A_s$
M	0.469	0.780	0.762	***	***
	$A_p(y_p, x_p)$	$A_m(y_p, x_p)$	$A_s(y_p, x_p)$	$A_p : A_m$	$A_p : A_s$
P	0.805	0.831	0.723		*
	$A_s(y_s, x_s)$	$A_m(y_s, x_s)$	$A_p(y_s, x_s)$	$A_s : A_m$	$A_s : A_p$
S	0.508	0.801	0.729	***	***

Note:

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

To analyze cross-efficiency results further, we use the frontier difference functions DF defined above. Results are shown in table 4, where values smaller than 0 indicate that the stock frontier dominates the mutual frontier, and values larger than 0 indicate that mutuals dominate stocks.

To test if efficiency results are influenced by firm size we split each group sample into quartiles and calculate frontier differences for the respective subgroups sorted by size. Since the subsample of public firms is small and quartile results would be heavily biased by firm-specific results, we only compare the subsamples of stock and mutual firms. Again, results in column 1 indicate that stock technology by and large dominates mutual technology for

producing stock outputs. However, sorting our samples into quartiles allows for more insight into our previous findings: it becomes obvious that the production frontier distance is largest for the smallest quartile (-0.784), thus, the predominance of stock insurers seems to be present especially with small firms. Mid-sized stock companies still significantly dominate mutual technology in producing stock specific outputs, but the differences are now smaller (-0.158 and -0.203). Surprisingly, we now find that mutual technology significantly dominates stock technology for the largest quartile. To conclude, the superiority of stock technology as presented in table 3 seems to stem from the technical efficiency of smaller stock insurers. When looking at production frontier differences for mutual inputs/outputs, column 2 shows the highly significant dominance of stock firms over mutual ones. The frontier differences are relatively large and decreasing with size, leading to the overall conclusion that small stock firms generally show a higher degree of technical efficiency than large stock companies (compared to the respective mutual firms).
Cost frontier differences (columns 5 and 6) indicate that stock firms operate more efficiently than mutual ones in producing stock specific outputs. The difference is by far largest for the smallest quartile (-1.376), roughly the same for mid-sized stock insurers (-0.896 and -0.910), and clearly smallest for the last quartile (-0.446). All values are significant at the 0.01 level. In contrast, mutual firms' cost frontier dominates the stock cost frontier for all quartiles when producing mutual outputs. Although all differences are significant at least at the 0.05 level, they are very small in size (from 0.099 to 0.033).

By sorting allocative efficiency scores by size (columns 3 and 4), we find overall predominance of stock firms over mutual firms when producing stock outputs, with the smallest difference for the smallest quartile (-0.443) and roughly the same values for the remaining quartiles (-0.674, -0.670 and -0.698, resp.). On the other hand, mutual firms significantly dominate stock firms for all quartiles when producing mutual outputs. Here, in contrast to allocative differences for producing stock outputs, differences are smaller and decreasing with size (from 0.453 to 0.333).

Table 4: Frontier differences for stock and mutual insurers sorted by size

		Production frontiers		Cross-allocative		Cost frontiers	
		S	M	S	M	S	M
		$1-\frac{T_m(y_s,x_s)}{T_s(y_s,x_s)}$	$1-\frac{T_m(y_m,x_m)}{T_s(y_m,x_m)}$	$1-\frac{A_m(y_s,x_s)}{A_s(y_s,x_s)}$	$1-\frac{A_m(y_m,x_m)}{A_s(y_m,x_m)}$	$1-\frac{C_m(y_s,x_s)}{C_s(y_s,x_s)}$	$1-\frac{C_m(y_m,x_m)}{C_s(y_m,x_m)}$
Quartile 1	Mean	-0.784	-0.679	-0.443	0.453	-1.376	0.099
	t-test	***	***	***	***	***	**
Quartile 2	Mean	-0.158	-0.578	-0.674	0.378	-0.896	0.037
	t-test	**	***	***	***	***	***
Quartile 3	Mean	-0.203	-0.575	-0.670	0.370	-0.910	0.041
	t-test	***	***	***	***	***	**
Quartile 4	Mean	0.139	-0.505	-0.698	0.333	-0.446	0.033
	t-test	***	***	***	***	***	**

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

6 Influence of the Form of Ownership of the Holding Company on Firm's Efficiency

Many of the life insurance companies in Germany are part of a holding company. The legal structure of the holding company is in some cases different from the structure at the firm level. In this sequence we follow the hypothesis that a firm acts the same way as its holding company does. This assumption is based on the idea that a stock firm that is 100% owned by a mutual or public firm acts in a similar way as its mother company does.

Therefore, we restructured our data set into three groups depending on the form of ownership of the highest firm level (if there is no holding, the ownership form of the firm is taken into account). Then we analyze the equivalent questions as done in the previous section. The newly structured data set consists of 156 data points for a stock insurance holding (about 40 companies in the observed time period 2002-2005), 155 data points for firms with a mutual holding (or 40 companies) and 45 with a public holding (11 companies).

In table 5 we present the results of the differences in efficiency between the pooled and the individual samples.

We observe significant differences for technical efficiency just for the public firms. No significant differences between the pooled mean of technical efficiency and the mean on their own frontier could be found for mutual and stock insurers. Therefore, in this reorganized sample, we can only be sure that public firms act on their own technical frontier. The situation is different at the cost and allocative frontier, where we can find a significant deviation of the pooled from the individual sample in all three categories. But as already stated before, the differences between the efficiency frontiers can be seen best when calculating the X-efficiencies.

In table 6 we compare the own efficiency frontier of each group with the cross frontier. To test once more the efficient structure hypothesis in this environment, we compare technical efficiency first (remember that a smaller value means that the technology dominates the higher value). In the first row, mutual firms are measured on their own frontier with an average of 0.720 efficiency score compared to 0.892 on the public and 0.610 on the stock frontier, deviations are significant. This means that mutual technology

Table 5: Pooled vs. own frontier on holding level

	Sample means		
	Mutual	Public	Stock
Technical efficiency			
Pooled	0.718	0.715	0.736
Individual	0.720	0.833	0.747
t-test		***	
Cost efficiency			
Pooled	0.379	0.338	0.398
Individual	0.431	0.618	0.436
t-test	***	***	***
Allocative efficiency			
Pooled	0.533	0.464	0.540
Individual	0.603	0.740	0.585
t-test	***	***	***

Note:

*** significant at the 0.01 level,

** significant at the 0.05 level,

* significant at the 0.1 level

dominates public's in producing mutual outputs. Stock technology, however, significantly dominates mutual technology regarding mutual outputs.

In the second row, we have firms with a public holding, their mean performance was 0.833 on their own frontier. Estimated on the mutual frontier an average of 0.567 and on the stock frontier an average of 0.571 was estimated for public inputs and outputs. The difference is only significant for the stock frontier. As a result, we find that stock technology dominates the technology of firms with a public holding.

In the third row the same estimations were done for stock insurers. In their own technology, stock insurers are as efficient as measured on the frontier of firms with a mutual holding (0.747 vs. 0.735) and even more efficient in the technology of public insurers (1.141).

The efficient structure hypothesis that each form of ownership acts most efficiently on its own frontier must be denied. Stock insurers operate on a more efficient frontier. The results for technical efficiency at the the holding level are very much the same as the results at the firm level (cf. table 3).

The expense preference hypothesis, which says that stock firms are most efficient concerning their cost structure because of dealing better with manager/owner conflicts, could be confirmed in this setting. Estimating the cost efficiency (second part of table 6) shows that the cost efficiency frontier of insurers with a stock holding is dominated by firms with a mutual or public holding. Evidence for a dominance of firms with a mutual holding over firms with a public holding could be found as well, but was not as explicit as the dominance of stock insurers over public insurers.

The third part of table 6 presents the results for allocative efficiency. It is shown, that firms with a mutual or stock holding are most efficient in their own technology, only public firms are dominated by stock technology for public inputs and outputs.

Table 6: Efficiency results on holding level

	Sample means			T-tests	
	$T_m(y_m, x_m)$	$T_p(y_m, x_m)$	$T_s(y_m, x_m)$	$T_m : T_p$	$T_m : T_s$
Mutual	0.720	0.892	0.610	***	***
	$T_p(y_p, x_p)$	$T_m(y_p, x_p)$	$T_s(y_p, x_p)$	$T_p : T_m$	$T_p : T_s$
Public	0.833	0.567	0.571		***
	$T_s(y_s, x_s)$	$T_m(y_s, x_s)$	$T_p(y_s, x_s)$	$T_s : T_m$	$T_s : T_p$
Stock	0.747	0.735	1.141		***
	$C_m(y_m, x_m)$	$C_p(y_m, x_m)$	$C_s(y_m, x_m)$	$C_m : C_p$	$C_m : C_s$
Mutual	0.431	0.661	0.422	***	***
	$C_p(y_p, x_p)$	$C_m(y_p, x_p)$	$C_s(y_p, x_p)$	$C_p : C_m$	$C_p : C_s$
Public	0.618	0.403	0.309	***	***
	$C_s(y_s, x_s)$	$C_m(y_s, x_s)$	$C_p(y_s, x_s)$	$C_s : C_m$	$C_s : C_p$
Stock	0.436	0.521	0.877	***	***
	$A_m(y_m, x_m)$	$A_p(y_m, x_m)$	$A_s(y_m, x_m)$	$A_m : A_p$	$A_m : A_s$
Mutual	0.603	0.811	0.735	***	***
	$A_p(y_p, x_p)$	$A_m(y_p, x_p)$	$A_s(y_p, x_p)$	$A_p : A_m$	$A_p : A_s$
Public	0.740	0.707	0.672		**
	$A_s(y_s, x_s)$	$A_m(y_s, x_s)$	$A_p(y_s, x_s)$	$A_s : A_m$	$A_s : A_p$
Stock	0.585	0.754	0.828	***	***

Note:

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

To analyze cross-efficiency results further, we use, as already done in the last section, the frontier difference function DF[10]. Results are shown in table 7. Table 7 consists of three parts. In the first part, DF was calculated for firms with a stock or mutual holding, respectively (values larger than 0 indicate that mutuals dominate stocks and vice versa). In the second part, firms with a stock holding are compared to firms with a public holding (values larger than 0 indicate that publics dominate stocks and vice versa). In the third part, mutuals and publics are compared; values bigger than 0 indicate that publics dominate mutuals and vice versa. The firms are divided into four quartiles by size (smallest in the first quartile). In order to test for size effects, we sort the three subgroups into quartiles and calculate frontier differences, which are represented in table 7.

In the very first column of table 7 we see that for the small and medium-sized firms (1st-3rd quartile) the stock frontier dominates the mutual as regards stock in- and output. Only for the large firms we get a similar result as in the previous chapter for firm level, namely that firms with a mutual holding dominate the firms with a stock holding. As regards the frontier differences of mutual in- and output, values for all quartiles are negative, which is evidence for a domination of the stock technology, but the values of the frontier differences are not significant and very close to zero. Therefore, no statistically relevant domination can be stated.

Results for allocative efficiency (second column, first part of table 7) show that each production frontier seems to be more efficient for the respective in- and outputs.

The cost efficiency hypothesis can be confirmed for the ownership structure of the holding company as well, stock technology dominates mutual for stock in- and output. For big companies the distance to the frontier is very small.

In the second part of table 7 we compare firms with a public holding to firms with a stock holding. The results are very clear, for all three forms of efficiency stocks dominate the publics. Especially stock insurers are apparently much more cost-efficient than public firms, which corresponds to most of the theory.

The third part of table 7 compares firms with a mutual holding to firms with a public one. Dominance of the mutual over the public is given on almost all quartiles and efficiency measures, but values are not as high as values comparing public to stock insurers.

[10]Recall that DF is the distance function, defined by

$$DF_T = 1 - \frac{T_M(x_s, y_s)}{T_S(x_s, y_s)}.$$

A distance value < 0 would imply that stock technology dominates mutual technology for the respective input/output combination, a distance value > 0 would show dominance of mutual technology .

Table 7: Frontier holding level

		Production frontiers		Cross-allocative		Cost frontiers	
		Stock	Mutual	Stock	Mutual	Stock	Mutual
		$1-\frac{T_m(y_s,x_s)}{T_s(y_s,x_s)}$	$1-\frac{T_m(y_m,x_m)}{T_s(y_m,x_m)}$	$1-\frac{A_m(y_s,x_s)}{A_s(y_s,x_s)}$	$1-\frac{A_m(y_m,x_m)}{A_s(y_m,x_m)}$	$1-\frac{C_m(y_s,x_s)}{C_s(y_s,x_s)}$	$1-\frac{C_m(y_m,x_m)}{C_s(y_m,x_m)}$
Quartile 1	Mean	-0.222	-0.292	-0.223	0.112	-0.369	-0.117
	t-test	**	***	***	***	***	***
Quartile 2	Mean	-0.005	-0.316	-0.304	0.188	-0.216	-0.053
	t-test		***	***	***	***	
Quartile 3	Mean	0.102	-0.214	-0.288	0.158	-0.101	0.008
	t-test	**	***	***	***	***	
Quartile 4	Mean	0.235	-0.164	-0.363	0.080	-0.027	-0.016
	t-test	***	***	***	*	**	

		Production frontiers		Cross-allocative		Cost frontiers	
		Stock	Public	Stock	Public	Stock	Public
		$1-\frac{T_p(y_s,x_s)}{T_s(y_s,x_s)}$	$1-\frac{T_p(y_p,x_p)}{T_s(y_p,x_p)}$	$1-\frac{A_p(y_s,x_s)}{A_s(y_s,x_s)}$	$1-\frac{A_p(y_p,x_p)}{A_s(y_p,x_p)}$	$1-\frac{C_p(y_s,x_s)}{C_s(y_s,x_s)}$	$1-\frac{C_p(y_p,x_p)}{C_s(y_p,x_p)}$
Quartile 1	Mean	-1.247	-0.533	-0.228	-0.151	-1.464	-0.771
	t-test	***	***	***	***	***	***
Quartile 2	Mean	-0.538	-0.462	-0.421	-0.101	-1.083	-0.604
	t-test	***	***	***	***	***	***
Quartile 3	Mean	-0.218	-0.632	-0.501	-0.191	-0.773	-0.953
	t-test	***	***	***		***	***
Quartile 4	Mean	-0.010	-0.377	-0.539	-0.085	-0.545	-0.475
	t-test		***	***	**	***	***

		Production frontiers		Cross-allocative		Cost frontiers	
		Mutual	Public	Mutual	Public	Mutual	Public
		$1-\frac{T_p(y_m,x_m)}{T_m(y_m,x_m)}$	$1-\frac{T_p(y_p,x_p)}{T_m(y_p,x_p)}$	$1-\frac{A_p(y_m,x_m)}{A_m(y_m,x_m)}$	$1-\frac{A_p(y_p,x_p)}{A_m(y_p,x_p)}$	$1-\frac{C_p(y_m,x_m)}{C_m(y_m,x_m)}$	$1-\frac{C_p(y_p,x_p)}{C_m(y_p,x_p)}$
Quartile 1	Mean	-0.415	-0.468	-0.198	-0.077	-0.563	-0.577
	t-test	***	***	***	**	***	***
Quartile 2	Mean	-0.086	-0.370	-0.452	-0.131	-0.543	-0.524
	t-test	**	***	***	***	***	***
Quartile 3	Mean	-0.182	-0.702	-0.364	0.045	-0.512	-0.612
	t-test	***	***	***		***	***
Quartile 4	Mean	-0.227	-0.453	-0.335	-0.047	-0.517	-0.502
	t-test	***	***	***		***	***

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

Results for cost efficiency show a clear order between the different forms of ownership of the holding company: stock dominates mutuals and mutuals dominate public firms. All the results are constrained to the chosen in- and output.

7 Holding Companies of Stock Insurers

For further research, it is interesting to specify stock firms according to their ownership structure. In the next section, we analyze stock firms as to whether their holding structure is organized as a stock, as a mutual or as a public. As mentioned above, only stock insurers can be owned by a holding company. We assume that a stock insurer owned by a mutual holding company (mutual stock insurer, henceforth) and a stock insurer owned by a public holding company (public stock insurer, henceforth) tend to act like a mutual insurer and a public insurer, respectively. These hybrid forms of ownership lack the typical properties of a stock company. Mutual stock insurers are not able to use any of the control mechanisms of stock companies listed before, since the sole owner is a mutual body. Public stock insurers may face the same uneconomic decisions by political representatives of their public owner as "pure" public companies do. Therefore, it seems reasonable to re-run our efficiency analysis after dividing stock insurers into three groups based on the structure of the respective holding company.

Redefined by the corporate structure of the respective holding companies, the 263 stock firms can be split into 156 stock insurers owned by a stock holding company ("pure" stock insurers), 82 stock insurers owned by a mutual holding (mutual stock insurers) and 25 stock insurers owned by a public holding (public stock insurers).

In table 8 the descriptive statistics are summarized, but also include the data at the firm level. Now comparison between, for example,"pure" mutuals and mutuals is easier. It can be seen that mutual stock insurers are the smallest in terms of gross premium, amount of insurance coverage, etc. and are even smaller than "pure" mutual and public companies. On the other hand, public stock insurers are larger than "pure" public companies and "pure" mutual ones. By all means, "pure" stock insurers (i.e. stock insurers owned by stock holdings) are the largest with respect to gross premium, amount of insurance coverage and all input and output quantities.

Table 8: Descriptive Statistics

	Sample means													
	Number[11]	Prem.	RoA	Cost1	Cost2	Comp.	Can1	Can2	Ins.	Net income	Labor	Service	Equity	Debt
All	356	741.0	4.7	13.3	4.1	0.605	16.1	4.1	23734.0	342.5	7193.9	1.2	1.6	54.4
Firm level														
Mutual	73	523.3	4.9	12.9	3.7	2.735	16.3	3.9	19427.4	276.7	5.1.2	0.8	1.2	41.6
Stock	263	840.3	4.7	13.6	4.3	0.007	16.3	4.2	26132.3	379.9	8.1.8	1.3	1.7	60.8
Public	20	230.5	4.5	10.5	2.6	0.005	13.4	3.9	7915.6	90.0	1.7	0.3	0.7	16.6
T-tests														
M vs. S		***			**				**		***	***	**	**
M vs. P		***		**	***				***	***	***	***	*	***
S vs. P		***		***	***				***	***	***	***	***	***
Stock firms														
Mutual stock	82	212.0	4.8	13.2	4.4	0.008	17.3	4.0	8 652.8	93.9	1.9	0.2	0.6	15.9
Pure stock	156	1152.1	4.7	14.5	4.6	0.006	16.3	4.4	35 502.5	523.8	11.7	1.9	2.2	81.3
Public stock	25	955.2	4.3	9.4	2.6	0.004	13.0	3.3	24 994.7	419.9	6.6	1.1	1.8	80.8
T-tests														
S_S vs. S_M		***				*				***	***	***	***	***
S_M vs. S_P		***		***	***	***	*	*	**	***	***	***	***	***
S_S vs. S_P			*	***	***	*	**	**	***		**	***		

Note:
Prem.: Gross premiums (in mm EUR)
RoA: Return on Assets (ratio of net profits to total assets) calculated as arithmetic mean for each firm over the observed time period.
Cost1: acquisition costs to gross premiums
Cost2: operational expenses to gross premiums
Comp.: complaints ratio (filed complaints to total number of policies)
Can1: early cancellation rate
Can2: mid-term/late cancellation rate
Ins.: amount of insurance coverage(in mm EUR)
Labor, services, equity and debt in mn EUR
All values are means averaged over the sample period 2002-2005
*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

[6] Complaints ratios were available only for:
mutual: 69; stock: 240; public: 6 (firm level);
mutual stock: 71; pure stock: 147; public stock: 23
Cancellation rates were available only for:
mutual: 73; stock: 261; public: 18 (firm level);
mutual stock: 81; pure stock: 155; public stock: 25

Table 9 shows the differences in means for technical, allocative and cost efficiency for all three subgroups. For technical efficiency, no significantly different scores can be found between the three subgroups of stock insurers. However, the subgroup of public stock insurers S_P do significantly worst in terms of allocative (0.442 vs. 0.540 and 0.558, resp.) and cost efficiency (0.326 vs. 0.398 and 0.395) compared to "pure" stock firms S_S and mutual stocks S_M. These findings suggest to take a further look on efficiency differences among the three subgroups of stock insurers.

Table 9: Mean values of efficiency scores for the three subgroups of stock insurers, i.e. "pure" stocks (S_S), mutual stocks (S_M) and public stocks (S_P)

	Sample means			T-tests		
	Pure stock	Mutual stock	Public stock	S_S vs. S_M	S_M vs. S_P	S_S vs. S_P
Pooled						
Technical efficiency	0.736	0.720	0.724			
Allocative efficiency	0.540	0.558	0.442		***	***
Cost efficiency	0.398	0.395	0.326		***	***

Note:
*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

To gain further insight into differences of stock insurers that are owned by a differently organized holding company, we first calculate separate frontiers for technical, cost and allocative efficiency for all three subgroups and compare the results with efficiency scores that were computed with reference to the set of all stock insurers. Table 10 presents mean efficiency scores for different reference sets. It can be seen clearly that technical efficiency values for mutual stocks and public stocks are significantly different and measured against their respective subgroup-specific reference set. The results for allocative and cost efficiency are even more striking. Differences in means are significant at the 0.01 level for all three subgroups of stock insurers. These findings strongly support our hypothesis that the organizational form of the holding company has significant influence on the corporate behavior of the respective stock subsidiary which, in turn, differences leads to different degrees of efficiency.

Table 10: Mean values of efficiency scores for the reference set of all stock insurers and for reference sets based on the organizational form of the holding company

	Sample means		
	S_M	S_P	S_S
Technical efficiency			
All stock insurers	0.720	0.724	0.736
Subgroup based on holding company	0.768	0.867	0.747
t-test	**	***	
Cost efficiency			
All stock insurers	0.395	0.326	0.398
Subgroup based on holding company	0.476	0.642	0.436
t-test	***	***	***
Allocative efficiency			
All stock insurers	0.558	0.442	0.540
Subgroup based on holding company	0.558	0.734	0.585
t-test	***	***	***

Note:

*** significant at the 0.01 level,

** significant at the 0.05 level,

* significant at the 0.1 level

To examine whether there is any dominance of one subgroup of stock insurers over the other ones, we compute X-efficiency scores for all three subgroups and compare them with efficiency values calculated with respect to the subgroup-specific reference sets. The results are given in table 11. Comparing the technical efficiency of the three subgroups of stock insurers, row 1 shows that mutual stocks are significantly dominated by "pure" stocks (0.767 vs. 0.623), but dominate public stocks (0.767 vs. 1.014) when producing their subgroup-specific outputs. For producing public stock insurers input/output combinations, public stocks are significantly dominated by both mutual stock and "pure" stock companies (0.867 vs. 0.748 and 0.591, resp.). Finally, "pure" stock insurers are technically predominant in producing their specific outputs (0.747 vs. 0.860 and 1.194). To sum up, neither of the hybrid forms of ownership is technically superior to "pure" stock insurers for producing their subgroup-specific input/output combinations. Exactly the same results can be found for X-cost efficiencies (see row 2 of table 13)). Our findings regarding allocative efficiency of the three subgroups of stock insurers are slightly different. Here, not only "pure" stock firms but also mutual stock insurers most efficiently allocate their resources for producing their respective subgroup-specific outputs. However, public stock firms do worst compared to "pure" stock and mutual stock insurers (0.736 vs. 0.644 and 0.563, resp.), although the difference between public stocks and "pure" stocks is significant at the 0.1 level only.

Table 11: Mean values of efficiency scores and X-efficiency scores for all three subgroups of stock insurers, i.e. "pure" stocks (S_S), mutual stocks (S_M) and public stocks (S_P)

	Sample means			T-tests	
	$T_m(y_m, x_m)$	$T_p(y_m, x_m)$	$T_s(y_m, x_m)$	$T_m : T_p$	$T_m : T_s$
S_M	0.767	1.014	0.623	***	***
	$T_p(y_p, x_p)$	$T_m(y_p, x_p)$	$T_s(y_p, x_p)$	$T_p : T_m$	$T_p : T_s$
S_P	0.867	0.748	0.591	***	***
	$T_s(y_s, x_s)$	$T_m(y_s, x_s)$	$T_p(y_s, x_s)$	$T_s : T_m$	$T_s : T_p$
S_S	0.747	0.860	1.194	***	***
	$C_m(y_m, x_m)$	$C_p(y_m, x_m)$	$C_s(y_m, x_m)$	$C_m : C_p$	$C_m : C_s$
S_M	0.476	0.738	0.420	***	***
	$C_p(y_p, x_p)$	$C_m(y_p, x_p)$	$C_s(y_p, x_p)$	$C_p : C_m$	$C_p : C_s$
S_P	0.642	0.422	0.389	***	***
	$C_s(y_s, x_s)$	$C_m(y_s, x_s)$	$C_p(y_s, x_s)$	$C_s : C_m$	$C_s : C_p$
S_S	0.436	0.556	0.934	***	***
	$A_m(y_m, x_m)$	$A_p(y_m, x_m)$	$A_s(y_m, x_m)$	$A_m : A_p$	$A_m : A_s$
S_M	0.625	0.799	0.722	***	***
	$A_p(y_p, x_p)$	$A_m(y_p, x_p)$	$A_s(y_p, x_p)$	$A_p : A_m$	$A_p : A_s$
S_P	0.736	0.563	0.644	***	*
	$A_s(y_s, x_s)$	$A_m(y_s, x_s)$	$A_p(y_s, x_s)$	$A_s : A_m$	$A_s : A_p$
S_S	0.585	0.695	0.844	***	***

Note:

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

In order to test for size effects, we sort the three subgroups into quartiles and calculate frontier differences, which are presented in table 12. The first section shows that "pure" stock insurers generally dominate mutual stock firms for producing "pure" stock as well as mutual stocks output, and the distance between production frontiers is significant for all quartiles. When producing stock outputs, the difference is decreasing with size (from -0.335 to 0.066). However, mutual stock technology is significantly dominant for the largest quartile, although the difference is small in size (0.066). A significant dominance of "pure" stock insurers can also be found with cost frontier differences.[12]Again, there is a decreasing tendency of dominance with size (for stock outputs: from -0.457 to -0.101; for mutual outputs: from -0.222 to -0.130). The differences in allocative efficiency suggest that "pure" stocks are efficient for producing "pure" stock outputs, and mutual stock firms are dominant in producing their specific input/output mix. However, mutual stock insurers' allocative dominance is not significant for the smallest and the largest quartile, and is only small in size. Comparing "pure" stock firms and public stock insurers, we see that the latter are significantly dominated by "pure" stocks in terms of technical and cost efficiency for all quartiles and for producing both "pure" stock and public stock outputs. Moreover, "pure" stock firms dominate public stock firms even with respect to allocative efficiency, by all means, although the differences are hardly significant for mid-sized companies producing public stock outputs (-0.415 and -0.129). Finally, section 3 of table 12 shows the significant dominance of mutual stock insurers over public stock insurers for technical, allocative and cost efficiencies for all quartiles and all sorts of input/output combinations.

The previous results provide evidence that the holding company plays an important role in classifying firms due to these criteria. Therefore, we finally investigate the differences between "pure" mutual and mutual stock and "pure" public and public stock. One would assume that a mutual and a stock 100% owned by a mutual would act similarly concerning their agency conflicts. The same argument might be true for public and public stock. In table 13 we compare their individual and pooled frontiers to see if there are significant differences.

[12]Only the difference for mutual stock outputs at quartile 3 is not significant.

Table 12: Frontier differences for all three subgroups of stock insurers, sorted by size

		Production frontiers		Cross-allocative		Cost frontiers	
		S_S	S_M	S_S	S_M	S_S	S_M
		$1-\frac{T_m(y_s,x_s)}{T_s(y_s,x_s)}$	$1-\frac{T_m(y_m,x_m)}{T_s(y_m,x_m)}$	$1-\frac{A_m(y_s,x_s)}{A_s(y_s,x_s)}$	$1-\frac{A_m(y_m,x_m)}{A_s(y_m,x_m)}$	$1-\frac{C_m(y_s,x_s)}{C_s(y_s,x_s)}$	$1-\frac{C_m(y_m,x_m)}{C_s(y_m,x_m)}$
Quartile 1	Mean	-0.335	-0.363	-0.182	0.062	-0.457	-0.222
	t-test	***	***	***		***	***
Quartile 2	Mean	-0.195	-0.416	-0.209	0.162	-0.298	-0.176
	t-test	*	***	***	***	***	***
Quartile 3	Mean	-0.088	-0.294	-0.156	0.071	-0.177	-0.157
	t-test		***	***		***	**
Quartile 4	Mean	0.066	-0.209	-0.211	0.011	-0.101	-0.130
	t-test	**	***	***		***	**

		Production frontiers		Cross-allocative		Cost frontiers	
		S_S	S_P	S_S	S_P	S_S	S_P
		$1-\frac{T_p(y_s,x_s)}{T_s(y_s,x_s)}$	$1-\frac{T_p(y_p,x_p)}{T_s(y_p,x_p)}$	$1-\frac{A_p(y_s,x_s)}{A_s(y_s,x_s)}$	$1-\frac{A_p(y_p,x_p)}{A_s(y_p,x_p)}$	$1-\frac{C_p(y_s,x_s)}{C_s(y_s,x_s)}$	$1-\frac{C_p(y_p,x_p)}{C_s(y_p,x_p)}$
Quartile 1	Mean	-1.343	-0.540	-0.254	-0.105	-1.601	-0.697
	t-test	***	***	***	**	***	***
Quartile 2	Mean	-0.608	-0.650	-0.449	-0.415	-1.213	-1.348
	t-test	***	***	***		***	**
Quartile 3	Mean	-0.279	-0.441	-0.563	-0.129	-0.904	-0.594
	t-test	***	***	***	*	***	***
Quartile 4	Mean	-0.064	-0.501	-0.567	-0.060	-0.657	-0.588
	t-test	***	***	***	**	***	***

		Production frontiers		Cross-allocative		Cost frontiers	
		S_M	S_P	S_M	S_P	S_M	S_P
		$1-\frac{T_p(y_m,x_m)}{T_m(y_m,x_m)}$	$1-\frac{T_p(y_p,x_p)}{T_m(y_p,x_p)}$	$1-\frac{A_p(y_m,x_m)}{A_m(y_m,x_m)}$	$1-\frac{A_p(y_p,x_p)}{A_m(y_p,x_p)}$	$1-\frac{C_p(y_m,x_m)}{C_m(y_m,x_m)}$	$1-\frac{C_p(y_p,x_p)}{C_m(y_p,x_p)}$
Quartile 1	Mean	-0.526	-0.021	-0.143	-0.466	-0.581	-0.495
	t-test	***		**	***	***	***
Quartile 2	Mean	-0.216	-0.299	-0.288	-0.307	-0.531	-0.631
	t-test	***	*	***	***	***	***
Quartile 3	Mean	-0.229	-0.254	-0.386	-0.211	-0.578	-0.510
	t-test	**	***	***	***	***	***
Quartile 4	Mean	-0.266	-0.176	-0.326	-0.297	-0.536	-0.516
	t-test	***	***	***	***	***	***

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

Table 13: Mean values of efficiency scores of firms with mutual holding compared with pure mutual and mutual stock and public holding with pure public and public stock firms

	Sample means			T-tests		
Mutual	pooled	pure	mixed	po/pu	po/mi	pu/mi
Technical efficiency	0.720	0.767	0.768	***	***	
Cost efficiency	0.431	0.361	0.476	***	***	
Allocative efficiency	0.603	0.469	0.625	***	**	
Public	pooled	pure	mixed	po/pu	po/mi	pu/mi
Technical efficiency	0.830	0.915	0.867	***	*	
Cost efficiency	0.618	0.739	0.642	***		
Allocative efficiency	0.739	0.806	0.736			

Note:

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

po/pu stands for pooled vs. pure, po/mi for pooled vs. mixed

In table 13 we see that there is a significant difference in cost and allocative efficiency for mutual firms. For public firms we observe significant differences in technical efficiency. These results are not unambiguous, thus we decide to calculate cross frontier for these two groups. The results are shown in table 14

Table 14: Mean values of cross efficiency scores of firms with a pure form of ownership and a mixed form of ownership

	Cross efficiency of pure vs. mixed				T-tests	
	$T_M(x_m, y_m)$	$T_{S_M}(x_m, y_m)$	$T_{S_M}(x_{S_m}, y_{S_m})$	$T_M(x_{S_m}, y_{S_m})$	$M : S_M$	$S_M : M$
Means	0.767	0.651	0.768	0.786	***	
	$C_M(x_m, y_m)$	$C_{S_M}(x_m, y_m)$	$C_{S_M}(x_{S_m}, y_{S_m})$	$C_M(x_{S_m}, y_{S_m})$	$M : S_M$	$S_M : M$
Means	0.361	0.449	0.476	0.614	***	***
	$A_M(x_m, y_m)$	$A_{S_M}(x_m, y_m)$	$A_{S_M}(x_{S_m}, y_{S_m})$	$A_M(x_{S_m}, y_{S_m})$	$M : S_M$	$S_M : M$
Means	0.469	0.719	0.625	0.798	***	***
	$T_P(x_p, y_p)$	$T_{S_P}(x_p, y_p)$	$T_{S_P}(x_{S_p}, y_{S_p})$	$T_P(x_{S_p}, y_{S_p})$	$P : S_P$	$S_P : P$
Means	0.915	0.796	0.867	1.166	***	***
	$C_P(x_p, y_p)$	$C_{S_P}(x_p, y_p)$	$C_{S_P}(x_{S_p}, y_{S_p})$	$C_P(x_{S_p}, y_{S_p})$	$P : S_P$	$S_P : P$
Means	0.739	0.685	0.642	0.698		
	$A_P(x_p, y_p)$	$A_{S_P}(x_p, y_p)$	$A_{S_P}(x_{S_p}, y_{S_p})$	$A_P(x_{S_p}, y_{S_p})$	$P : S_P$	$S_P : P$
Means	0.806	0.853	0.736	0.606		**

Note:

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

The results in table 14 provide evidence that mutual and mutual stock firms operate on different frontiers and that, except for technical efficiency, each form of ownership is more efficient in its own environment. As a conclusion, we find that, on average, mutual stock firms produce a higher output level with same input quantities than the pure mutual and that they operate on different cost frontiers, but that each is efficient in its own environment. For pure public and public stock firms, we find a similar but stronger result with respect to technical efficiency: public stock firms are more efficient than pure public firms. On the other hand, we do not find statistically significant results concerning cost efficiency. The evidence showing that pure public firms and public stock firms operate on different frontiers is not as strong as for mutual firms.

8 Determinants of Efficiency and Policyholder Concerns

Finally, we examine the hypothesis that firms which are efficient within their specific group can be identified by certain characteristics and key figures observable by stakeholders of the respective companies. We regress technical efficiency and cost efficiency measures for all firms (calculated with reference to their group-specific data set) on a set of independent variables such as market, cancellation rate, etc. (all explanatory variables are listed and described below). Tobit's regression results for technical and cost efficiency are represented in table 15. Tobit's regression was chosen because of the assumption of a latent (unobservable) dependent variable. This assumption might be helpful to correct for the parametric DEA model (see Tobin (1958)). Tobit's regression is defined as:

$$y_i = \begin{cases} y_i^* & y_i^* > 0 \\ 0 & y_i^* \leq 0 \end{cases}$$

Explanatory variables are:
Size: total assets
$Size^2$: squared size to control for non-linear effects in total assets
Can1: early cancellation rate
Can2: later cancellation rate
Lev: equity to debt
Assets/Ins: total assets to amount of insurance coverage
M: dummy variable (=1 for mutual firms; =0 for stock or public firms)
P dummy variable (=1 for public firms; =0 for others)

We estimated the following regression equations (with technical efficiency and cost efficiency as dependent variables), first, regarding the firm level, later regarding the holding level.[13]:

$T(x,y) = \alpha + \beta_1\ Size + \beta_2\ Size^2 + \beta_3\ Can1 + \beta_4\ Can2 + \beta_5\ Lev + \beta_6\ Assets/Ins + \beta_7\ M + \beta_8 P$
$C(x,y) = \alpha + \beta_1\ Size + \beta_2\ Size^2 + \beta_3\ Can1 + \beta_4\ Can2 + \beta_5\ Lev +$

[13]Estimations were made with the econometrics software EViews.

$\beta_6\ Assets/Ins + \beta_7\ M + \beta_8 P$

Table 15: Tobit's regression analysis on technical and cost efficiency

Independent Variables	Technical efficiency coefficient	signif.	Cost efficiency coefficient	signif.
C	0.7566	***	0.3584	$***$
$Size$	0.4789		0.4490	$**$
$Size^2$	$1.93E-11$	$***$	$2.31E-11$	$***$
$Can1$	-0.0012	$***$	$-4.4E-05$	
$Can2$	-0.0063	$***$	-0.00012	
Lev	0.0005	$***$	-0.0001	$***$
$Assets/Ins$	-0.5638	***	-0.5396	$***$
M_f	0.0424	$***$	0.1920	$***$
P_f	0.1573	***	0.2391	$***$
N	344		344	
R^2	0.4615		0.7083	
adjusted R^2	0.4437		0.6986	

Note:
*** significant on the 0.01 level,
** significant on the 0.05 level, * significant on the 0.1 level
Coefficients are corrected by White's heteroskedasticity test

Summarizing the results, we can observe that technical efficiency is, as might be expected, negatively related to both cancellation rates. Furthermore, technically efficient firms show a lower ratio of all assets to total insurance coverage. This might be an indication that these firms have relatively more liabilities toward policyholders. Efficient firms have a significantly higher leverage, although the coefficient does not differ much from zero. The dummies for corporate structure show the expected sign and are highly significant both for technical as well as for cost efficiency. Firms operating nearer to their group-specific cost frontiers also have a lower ratio of total assets to insurance coverage. Moreover, cost efficiency is increasing with market share, which is evidence for economies of scale. In contrast to technical efficiency, cancellation rates do not show significant explanatory power for cost efficiency.

In a next step towards policyholder concerns, we want to find out whether there is a correlation between the return on asset (RoA) and the individual technical efficiency results for each firm. We analyze this by using Spearman's and Kendall's rank correlation test as defined in Kendall & Smith (1939) and Spearman (1904) for each subgroup. The results are summarized in table 16.

Table 16: Spearman's and Kendall's rank correlation results

	Spearman's ρ	Kendall's τ	p-values	
Mutual				
Technical efficiency	0.646	0.481	0^{***}	$1.80E-09^{***}$
Cost efficiency	0.806	0.6446	0^{***}	$7.47E-16^{***}$
Allocative efficiency	0.4436	0.3174	$1.00E-04^{***}$	$7.28E-05^{***}$
Stock				
Technical efficiency	0.5839	0.4331	0^{***}	$1.25E-25^{***}$
Cost efficiency	0.7758	0.6082	0^{***}	$6.74E-49^{***}$
Allocative efficiency	0.3211	0.2252	$1.20E-07^{***}$	$5.29E-08^{***}$
Public				
Technical efficiency	0.2647	0.1684	0.2584	0.3189
Cost efficiency	0.7053	0.5368	$7.32E-04^{***}$	$6.38E-04^{***}$
Allocative efficiency	0.7504	0.5895	$2.10E-04^{***}$	$1.42E-04^{***}$

Note:

*** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level

Obviously, there is a strong correlation between cost efficient firms and the RoAs. This is true for stock, public and mutual firms. Allocative efficiency (which for given in- and output says that the allocation of the input is efficient) was also linear correlated to the RoA for all types of ownership. For mutual and stock firms, we still find a relatively high correlation between technical efficiency and the RoA, but not for public firms. We once more observe that public firms work differently from private firms.

In the next paragraph, we focus on the determinants of efficiency at the holding level. We run the same regression analysis for the results of technical and cost efficiency on the holding level. Results are presented in table 17.

Our findings concerning explanatory variables for technical efficiency are very similar to the estimations at the firm level. Differences can be found in the significance of market share and of the mutual dummy, both are not significant at the holding level. Regarding cost efficiency, the results are very similar, too.

Table 17: Tobit's regression analysis on technical and cost efficiency

Independent Variables	Technical efficiency coefficient	z-value	Cost efficiency coefficient	z-value
C	0.8480	50.156^{***}	0.4966	32.257^{***}
$Size$	$-1.25E-06$	-1.176	$-1.85E-06$	-2.605^{***}
$Size^2$	$2.63E-11$	2.795^{***}	$2.51E-11$	4.161^{***}
$Can1$	-0.0011	-3.155^{***}	0.0002	0.687
$Can2$	-0.0081	-3.029^{***}	-0.0007	-0.323
Lev	0.0006	4.086^{***}	-0.0002	-2.176^{**}
$Assets/Ins$	-0.3450	-6.304^{***}	-0.3497	-8.271^{***}
M	0.0340	2.635^{***}	-0.0097	0.877
P	0.1650	11.835^{***}	0.3487	9.218^{***}
N	350		350	
R^2	0.2625		0.5539	
adjusted R^2	0.2340		0.5421	

*** significant at the 0.01 level

Note:

** significant at the 0.05 level, * significant at the 0.1 level

Summarizing our estimation results in this section, we find that firms which show a high level of technical efficiency when measured against their group-specific frontiers also offer other features which seem to be favorable for policyholders like, for instance, lower cancellation rates (which can be considered a proxy for policyholder satisfaction). For cost efficiency, we find a high correlation with market share, which provides evidence for economies of scale.

9 Conclusion

In this thesis two agency hypotheses concerning different forms of ownership are tested: the efficient structure hypothesis, which claims that firms with a different form of organizational structure operate on separate frontiers and therefore use different technologies to produce their group-specific input/output combinations efficiently, and the expense preference hypothesis, which claims that mutual and public firms are less cost-efficient due to weaker mechanisms for managerial control.

Using a data set of German life insurance companies accounting for more than 90% of the total market share over the period 2002-2005, we found evidence that stock, mutual and public insurers do not operate on a joint production frontier and joint cost frontier. Although different forms of ownership use distinct technologies, the efficient structure hypothesis, which states that each group has a comparative advantage in producing its specific output vectors, is rejected for mutual and public firms. Both forms of ownership are not superior in producing their specific input/output combinations, but are dominated by stock ownership.

Comparing companies by size, we also showed that the superiority of stock insurers is present especially with smaller companies, which show a higher degree of technical dominance over smaller mutual firms than larger stock insurers over larger mutual firms. In terms of cost efficiency, our results suggest that stock insurers as well as mutual insurers operate efficiently in producing their specific outputs, while public companies do worst. Although the latter is in line with the expense preference hypothesis, it is surprising that mutual firms produce their specific outputs at least as efficiently as stock insurers could do, even though pure stock insurers seem to represent the most efficient form of ownership. Moreover, our findings suggest that stock and mutual companies allocate their resources efficiently, with limited evidence for public firms.

Especially our findings regarding the lacking efficiency of public insurers are in line with most parts of the theory on public ownership. As often argued, firms which operate inefficiently should be expelled from the market, but this may not be true for public firms because of political interests. Since efficiency is measured herein by a 4-inputs/2-outputs model, our findings regarding public insurers may be limited. Public insurers in Germany arrogate other types of outputs and objectives which are certainly in contrast to “normal” profit maximizing behavior, like, for example, playing an important role in local employment opportunities and in the promotion of arts, sciences, sports and other social activities. These outputs are not comparable to traditional outputs of profit maximizing organizations and can hardly be quantified, although these activities may contribute to societal and political goals.

The traditional efficient structure hypothesis seems to be unable to capture the hybrid form of public life insurers, which on the one hand have to compete in the market with privately owned, profit maximizing rivals, and on the other hand are constrained by their public owners to non-core activities, which might be judged as not efficiency enhancing. As a consequence, the analysis of the social outputs of public firms and, therefore, the reconciliation with the efficient structure hypothesis is left to further research.

Furthermore, this thesis gives an insight into the importance of the ownership structure of the holding level. We observed that, in terms of efficiency, firms with a stock holding dominate firms with a mutual or public holding.

We tested the potential influence of a holding company on the efficiency of its differently organized subsidiary by splitting the sample of stock insurers into subgroups based on the corporate structure of the respective holding company. Our results suggest that hybrid forms (i.e. stock insurers owned by a mutual or public holding company) are clearly inferior compared to pure stock companies (i.e. stock insurers owned by a stock holding company) in terms of technical and cost efficiency. Moreover, stock insurers owned by a mutual holding show a significantly higher degree of both technical and cost efficiency than stock insurers owned by a public company. Generally speaking, the advantage of pure stock insurers over hybrid forms and the advantage of mutual stock insurers over public stock insurers is greater for smaller companies. The lower degree of efficiency of hybrid forms leads to the conclusion that the difference in organizational structures between an insurance company and its holding company may lead to frictions that cause inefficiencies. These frictions do obviously not exist with a uniformly organized group of companies.

Finally, we test the hypothesis that firms which are efficient within their specific group can be identified by some characteristics and key figures observable by stakeholders of the respective companies. We ran a regression analysis and could observe that our results indicate that firms which show a high level of technical efficiency when measured against their group-specific frontiers also offer other features which seem to be favorable to policyholders like, for instance, lower cancellation rates (which can be considered a proxy for policyholder satisfaction).

Appendix A

The Malmquist Index

The Malmquist Index as described, for instance, in Caves, Christensen & Diewert (1982) or in Fare, Grosskopf & Lovell (1994) reflects the efficiency improvement from one time period to the next. It is defined as:

$$M(x_{t+1}, y_{t+1}, x_t, y_t) = \sqrt{\Big[\frac{T^t(x_{t+1}, y_{t+1})}{T^t(x_t, y_t)} \times \frac{T^{t+1}(x_{t+1}, y_{t+1})}{T^{t+1}(x_t, y_t)}\Big]},$$

with T^t being the technical efficiency frontier as defined above at time t, and with x_t and y_t being the input and/or output vectors at time t. The Malmquist Index is the geometrical mean of the efficiency of the data point (x_t, y_t) under the technology of $t + 1$ and of the efficiency of (x_{t+1}, y_{t+1}) under the technology of t. This is analogous to the X-efficiency, but instead of measuring one technology on another production frontier, the technology is measured on the frontier of the previous time period. A value greater than one indicates an improvement in the technology and vice versa. In these last estimations, we want to find out whether the technology improvement for firms with different forms of ownership was/is noticeable over the observed time period. The time period from 2002 to 2005 allows only three data points for the Malmquist Index, which is insufficient for general statements.

The data consist of 81 insurance companies for each year, thereof 60 stock, 17 mutual and 4 public insurers. The ownership with regard to the highest firm level was 38 stock, 35 mutual and 8 public insurers.

Table 18: Mean values of the Malmquist Index at the firm and the holding level and t-test for differences in mean

	Mean value				t-test		
	All	Mutual firms	Stock firms	Public firms	M:S	M:P	S:P
2002/2003	1.094	1.077	1.075	1.423		**	**
2003/2004	0.982	0.983	0.992	0.918		*	*
2004/2005	1.154	1.162	1.119	1.203			
	All	Mutual holdings	Stock holdings	Public holdings	M:S	M:P	S:P
2002/2003	1.094	1.119	1.047	1.205			
2003/2004	0.982	0.987	0.983	0.952			
2004/2005	1.154	1.136	1.150	1.256			*

Note:

*** significant at the 0.01 level

** significant at the 0.05 level, * significant at the 0.1 level

The estimation results of the Malmquist Index show that the technical efficiency of the overall German life insurance industry improved slightly in 2003 with a mean value of 1.094, decreased in 2004 (0.982) and improved in 2005 with an estimated mean value of 1.154. In 2002, the public insurers improved most (1.423) with regard to the technology of the previous year. They improved significantly more than stock (1.077) and mutual (1.075) insurers did. However, in 2004, technical efficiency of public firms changed most strongly for the worse as compared to public and mutual firms. In 2005, an overall improvement, but no significant differences corresponding to the ownership could be observed. For the holding level, results are very similar, but less significant differences were found. The results of this thesis show that the public insurers were acting less efficiently than mutual and stock insurers. The estimations of the Malmquist Index could not prove that the technology improvement of public insurers is less than with other forms of ownership even if, as already mentioned, the time sample is too small to show long-term developments. This would be interesting for further research based on a longer time period.

Appendix B

Bootstrapping Results

In Appendix B we present bootstrapping results for the technical efficiency.

Table 19: Mean values, mean values corrected by bootstrapping and confidence interval of technical efficiency scores for the reference set of all insurers and for reference sets based on the organizational form of the companies

	Technical efficiency: Mutual		
	sample means	corrected means	95 confidence interv.
Pooled	0.756	0.715	[0.685,0.750]
Individual subgroup	0.823	0.767	[0.716,0.818]
	Technical efficiency: Public		
	sample means	corrected means	95 confidence interv.
Pooled	0.740	0.703	[0.672,0.734]
Individual subgroup	0.956	0.915	[0.853,0.955]
	Technical efficiency: Stock		
	sample means	corrected means	95 confidence interv.
Pooled	0.784	0.730	[0.688,0.778]
Individual subgroup	0.801	0.745	[0.703,0.795]

Table 20: Mean values, mean values corrected by bootstrapping and confidence interval of technical efficiency scores for the reference set of all insurers and for reference sets based on the organizational form of the holding company

	Technical efficiency: Mutual		
	sample means	corrected means	95 confidence interv.
Pooled	0.764	0.718	[0.683,0.757]
Individual subgroup	0.793	0.720	[0.662,0.786]
	Technical efficiency: Public		
	sample means	corrected means	95 confidence interv.
Pooled	0.759	0.715	[0.679,0.752]
Individual subgroup	0.897	0.833	[0.762,0.893]
	Technical efficiency: Stock		
	sample means	corrected means	95 confidence interv.
Pooled	0.793	0.736	[0.692,0.786]
Individual subgroup	0.821	0.747	[0.683,0.816]

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2003-2005:	CCEFM (Center for Central European Financial Markets) joint doctoral program in finance at the Vienna University of Business Administration, University of Vienna, and Vienna University of Technology.

Employment record:

1996-1997:	External lecturer at the faculty of mathematics
1996-2001:	Mathematics teacher (high school)
2003-2007:	Research Assistant at the Department of Finance, University of Vienna
since 2007:	Analyst at the Department of Financial Markets Analysis and Surveillance Division, Österreichische Nationalbank

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