Stock versus mutual insurers: Long-term convergence or dominance?

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Abstract: I find evidence for convergence of stock and mutual insurers in an analysis of metatechnology efficiency estimated by data development analysis in the US and EU in 2002–2015. This result may emphasize that even though the organizational forms tended to dominate in different market segments in the past as documented by extant literature, due to recent changes in the economic context (particularly, elimination of state aids for the mutual organizational form and introduction of risk-based capital standards) the production processes inevitably converge over time. Different to previous studies focusing on the expense preference and efficient structure hypotheses, I explicitly consider the dynamics of stock and mutual insurer's technology and efficiency.

Keywords: Organizational Form, Ownership Structure, Efficiency, Metafrontier Data Envelopment Analysis

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1 Introduction

The efficiency implication of the organizational form is subject of great interest in the literature. Particularly in a long-term perspective, this question is important as a coexistence of both forms is generally regarded to be advantageous for the overall market (Michie & Llewellyn, 2010; Broek, Buiskool, Grijpstra, & Plooij, 2011). In the past, some states in the United States (US) and some countries in the European Union (EU) had even aided mutual insurers by requiring lower capital levels and by offering tax incentives (Zanjani, 2007; Broek et al., 2011). Prior insurance literature (see, e.g., Braun, Schmeiser, & Rymaszewski, 2015 for a recent review) has found much support for the hypothesis that the stock and mutual organizational forms are dominant in different market segments and subsequently apply different production

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technologies during the 1980s and 1990s (i.e., the efficient structure hypothesis, ESH).[1] Conversely, the hypothesis that the stock organizational form is—in a direct comparison with the mutual form—dominant in terms (cost) efficiency (i.e., the expense preference hypothesis, EPH) has not gained much empirical support.

During the last two decades, the economic context for stock and mutual insurers has changed in the two largest insurance markets (i.e., the US and the EU) giving raise to expect particularly changes in the way mutual insurers operate. In the EU, state aids for the mutual organizational form were eliminated throughout the 2000s. Also, the US has meanwhile to a great extent aligned the solvency regulations for the two organizational forms. These actions were mainly taken to create a level playing field for every organizational form. Furthermore, the increased focus on risk-based capital requirements—already in place in the US since the beginning of the 1990s—in the EU through the implementation of Solvency II incentivizes firms to diversify across various lines of business. Subsequently, niche-players or specialized insurers will most likely face competition from larger and diversified insurers that attain capital economies of scale and scope. Moreover, the operating environment, particularly in the EU, has overall become more homogenous due to reduced trade barriers such as the European Internal Market (Cummins, Rubio-Misas, Zi, 2016). In addition, developments such as low interest rates and market saturation have further increased the pressure to improve efficiency in the insurance sector (see, e.g., Eling & Schaper, 2017). A relevant question is how stock and mutual insurers operate over the long-term in this changed environment.

The purpose of this article is to analyze long-term trends in the technology usage of stock and mutual insurers particularly taking into account relevant developments of the operating environment. By considering the changed economic environment, I hypothesize that mutual and stock insurers' production processes inevitably converge over time (i.e., the convergence hypothesis). In samples for the US and EU markets, I analyze trends of metatechnology efficiency estimated by data envelopment analysis (DEA) in 2002–2015 using the concepts of β- and σ-convergence (O'Donnell et al., 2008; Cummins et al., 2016).[2] This analysis reveals some support for my expectation of converging stock and mutual insurers' technologies. During the sample period, stock and mutual insurers on average close the gap between individual group frontiers and a

[1] The production technology is defined as the operational practices (i.e., the management activities subject to other factors such as available human capital and economic infrastructure) that determine how inputs are transformed into outputs. It is derived from the firms within a group that have the highest input-output combinations, thus constituting also the efficient frontier, and highlights what is feasible for all firms in this group. Efficiency measures the productivity of a firm in the group relative to the efficient frontier. Technologies across groups of firms (e.g., different industries, regions or countries) can differ because each group may face different production opportunities (which could be simply because they operate in different environments) and consequently uses different input-output combinations (O'Donnel, Rao, & Battese, 2008).

[2] Metatechnology efficiency is the ratio of efficiency measured against a common benchmark (the metafrontier) constituting firms from various groups to the efficiency measured against a group-specific benchmark. If both efficiency levels are equal the metatechnology ratio is 1 which indicates that the groups of firms use the same technologies. β-convergence measures the catch-up effect of insurers with the highest technology gaps and σ-convergence measures the dispersion of technologies across insurers (Casu & Girardone, 2010; Cummins et al., 2016).

common frontier particularly in the EU life and non-life sectors. In the corresponding US sectors, the metatechnology efficiency levels are already quite high at the beginning of the sample period suggesting only minor production differences between the stock and mutual organizational form. The metatechnology efficiency persists at high levels until the end of the sample period. As the results for the US market could be seen as a benchmark for the degree of convergence that is attainable since the mentioned changed have occurred in this market considerably earlier than in the EU, it could be concluded that convergence may not be perfect. This conclusion is intuitive given that inherent differences among the organizational forms continue to exist (e.g., the speed to raise capital) but a significant degree of convergence as documented in this study might be the inevitable consequence of risk-based capital standards and eliminated state protection of the mutual organizational form.

This study contributes a new hypothesis how stock and mutual insurers operate in the insurance market also addressing why both organizational forms continue to coexist. While existing theories were capable to explain temporary efficiency variations across the organizational forms in the 1980s and 1990s, in the current operating environment the organizational forms inevitable have to converge to some extent. The analysis also emphasizes that analyzing efficiency trends gives a more sustainable picture of firm efficiency as efficiency is no steady state (see, e.g., Viswanathan & Cummins, 2003). In other words, when assessing efficiency only over a certain period, the corresponding temporal context (e.g., the conditions of the operating environment) should be considered. Otherwise, the efficiency analysis may reveal a biased picture. For example, mutual insurers are generally assumed to perform better during crisis periods (Michie & Llewellyn, 2010; Broek et al., 2011). The remainder of the paper is organized as follows. In Section 2, I review the background and present my hypotheses. Section 3 presents my data and methodology. Section 4 discusses my empirical results and Section 5 concludes.

2 Background and hypothesis development

Prior literature has argued for dominance of the organizational forms in terms of efficiency subject to different assumptions.[3] The EPH states that mutual insurers will be less (cost) efficient than stock insurers due to their weaker control mechanisms of the firm management (see, e.g., Cummins et al., 2004). Whilst the EPH is appealing from a theoretic point of view, it has not gained much empirical support. Evidence for

[3] Agency theory has been generally the central consideration for the efficiency discussion of companies with different organizational forms. In line with agency theory, the stock and mutual forms both have inherent costs and benefits that determine the financial and operational performance. The inherent disadvantage of the mutual form are less effective control mechanisms of managers because policyholders control less effectively compared to stockholders (Jeng, Lai, & McNamara., 2007). As a consequence, managers of mutual companies may exhibit expense preference behavior (Mester, 1989) and hence may indulge in excessive expenditures on unnecessary staff, emoluments, and other perquisites (Williamson, 1963). Due to this managerial opportunism, mutual companies may choose suboptimal input/output combinations or employ outdated technologies (Cummins, Rubio-Misas, & Zi, 2004). Although mutual insurers have lower control over the manager/owner conflict, they tend to have more control over the customer/owner conflict as mutual insurers unify both roles and thus eliminate any costs related to this conflict (see, e.g., Biener & Eling, 2012).

this hypothesis is rather in the minority (see, e.g., Cummins, Weiss, & Zi, 1999; Erhemjamts & Leverty, 2010) and most of the extant literature finds no support (see, e.g., Gardner & Grace, 1993; Cummins & Zi, 1998; Cummins et al., 2004; Biener & Eling, 2012) or even finds mutual insurers to be more efficient than stock insurers (see, e.g., Biener, Eling, & Wirfs, 2016; Eling & Schaper, 2017). Furthermore, the EPH does not address why both organizational forms coexist on the market.

The ESH predicts that stock and mutual insurers coexist because they perform well in different market segments due to different requirements of managerial discretion and access to capital (Biener & Eling, 2012). It is argued that the two organizational forms produce different insurance outputs and that the stock production technology dominates the mutual production technology for producing stock output and vice-versa. Mutual insurers are expected to succeed in less complex and less risky lines of business which require less managerial discretion and thus less control (see, e.g., Biener & Eling, 2012). Moreover, it is argued that mutual insurers have a competitive advantage in lines of business with relatively long payout periods due to lower incentives to exploit policyholders' interests (see, e.g., Cummins et al., 1999). Different to the EPH, the ESH has previously gained much empirical support. Cummins et al. (1999) find support for the ESH in an analysis of technical and cost efficiency for a sample of US property/liability (p/c) insurers from 1981–1991. Also, Cummins et al. (2004) find support for the hypothesis in a sample of all licensed Spanish insurers in the 1989–1997 period: the authors conclude that stock and mutual insurers tend to operate on separate production, cost, and revenue frontiers. Different to these early studies, in more recent samples for the Northern American and European markets for 2002–2006, Biener and Eling (2012) can only find support for the ESH in a combined world frontier and some selected market segments (i.e., European life production frontier, Northern American non-life cost frontier).

Nevertheless, if dominance in different market segments of the two organizational forms in line with the ESH holds over time, we do not expect convergence but rather dominance of both the stock and mutual technologies, which is my initial hypothesis (H1a):

H1a: Over the long term, different technologies among stock and mutual insurers dominate.

Although the ESH has gained much empirical support by early studies, to the best of my knowledge no study has so far assessed whether a state of different production technologies is persistent or changes over time. During the last two decades, the economic context for stock and mutual insurers has changed, which may affect particularly the practices of mutual insurers for producing insurance outputs and which may overall contribute to convergence of the two organizational forms. Table 1 provides an overview of the most important changes for the two largest insurance markets (i.e., the EU and US) which will be discussed in more detail in the following.

Table 1 Overview of changing economic context

Affected market	Change	Intended effect
EU	Harmonization of legislation on the EU level and various rulings to eliminate state aids for mutual insurers since the turn of the millennium (e.g., tax advantages and less rigorous solvency regulation) which were previously granted by national laws (Broek et al., 2011).	Creation of a level playing field for all organizational forms.
US	Gradual elimination of solvency requirement differentials between stock and mutual insurers. By 2000, only two States in the US still had preferential solvency requirements for mutual insurers (Zanjani, 2007).	Creation of a level playing field for every organizational form.
EU	Introduction of risk based capital requirements according to Solvency II. Launching of the formal legislative process in 2007 with a transition period and finally effective from 2016.	Diversification of investments and lines of businesses.
US	Introduction of the Risk-Based Capital (RBC) system for life insurers in 1993, property-casualty insurers in1994, and health insurers in 1998.	Diversification of investments and lines of businesses.
EU	Introduction of the EU Internal Market in 1993 (see, e.g., Cummins et al., 2016).	Creation of a unified European market to increase competition, diversification, enhance products and services, and increase pressure on prices and profit margins.

Because of the EU-wide insurance legislation (e.g., the Directives 2002/83/EC and 88/357/EEC for life and non-life insurers, respectively) various competitive advantages previously granted by national laws in some member countries for the mutual organizational form were identified as state aid and accordingly eliminated (see, e.g., Broek et al., 2011). These actions by the EU ruling bodies were mainly taken to establish a level playing field within the insurance business for all organizational forms. One important action contributing to an equal treatment of both organizational forms was the gradual elimination of mutual insurers' preferential tax treatments throughout the 2000s (Mossialos & Thomson, 2009; Broek et al., 2011).[4] Another and probably the most important action was to eliminate preferential solvency requirements for mutual insurers (Mossialos & Thomson; Broek et al., 2011).[5]

4 For example, France, Luxembourg, and Belgium had traditionally favored mutual insurers over commercial insurers.

5 For example, mutual insurers in France had operated under the special 'Code de la Mutualité' which in generally lead to less rigorous solvency requirements. Following a ruling of the European Court of Justice in 1999 and infringement proceedings of the European Commission resulted in tightened solvency requirements for mutual insurers in accordance with European rules

The ambition to create a level playing field is expected to have significant implications on mutual insurers' operations. For example, Zanjani (2007) shows that the evolution of the organizational forms in the US life insurance sector depended significantly on the solvency regulation in place. The mutual form could only dominate in states where it was favored regarding the capital requirements. Because equity capital is one of the central inputs in insurer efficiency measurement (see, e.g., Cummins & Weiss, 2013), lower capital requirements represent also a major efficiency advantage. Thus, mutual insurers could ceteris paribus even afford managerial slacks (e.g., due to expense preference behavior) without being identified as an inefficient organizational form. However, as mentioned, this advantage has been eliminated and mutual insurers can now be benchmarked with stock insurers and are consequently exposed to their competition. Similar to the EU case, the latest capital regulations in the US have for the most part stopped to differentiate between the organizational forms (for a detailed and recent overview of the state legislatures see National Association of Insurance Commissioners (NAIC), 2010).[6] Thus, under the latest capital regulations in the EU and US, stock and mutual insurers have equal operating conditions probably increasing the pressure to operate efficiently in general.

In line with the ESH, many mutual insurers in the EU had tended to focus on niche markets or specialize in undertaking selective types of risks in the past (see, e.g., Broek et al., 2011). However, particularly due to the introduction of Solvency II which was finally effective from January 2016 (but was likely anticipated from 2007, the launching of the formal legislative process) a specialization on only one/some segments becomes difficult.[7] This is because Solvency II calls not only for higher solvency margins but also promotes increased risk diversification. Consequently, specialized insurers have to hold relatively more equity than diversified insurers.[8] Also, the RBC system in the US promotes diversification by assuming correlations among business lines less than one. Given that diversified insurers have to hold relatively less equity capital, they may have a competitive advantage to enter new market segments which were traditionally dominated by, for example, specialized mutual insurers which puts additional pressure on these insurers to defend their existence. Winter (1991) highlights that changes in the dominance of the organizational forms can occur quickly in the insurance industry. Thus, as a consequence of risk based capital standards, it can be expected

on the Internal Market and competition (Mossialos & Thomson, 2009). Similar rulings occurred in Belgium in 2008 and Ireland in 2008/2009.

[6] By 1990, only two US states had favorable capital requirements for mutual insurers (Zanjani, 2007).

[7] Excluded from the Solvency II regulation are very small insurer with premium income not exceeding 5 million euros.

[8] In the EU and the US, a diversified insurer (in terms of underwriting) has to hold relatively less capital than a specialized insurer because the correlations between the insurance business lines are assumed to be less than one (in the EU according to the Solvency II standard formula). For example, company A which has 100 premium income in both motor and liability, ceteris paribus, has to hold relatively less equity capital than companies B and C which have 200 premium income only in motor and liability, respectively. Also, company A has to hold less equity than company D and E together which have only 100 premium income in motor and liability, respectively.

that especially mutual insurers try to expand their businesses (e.g., mergers & acquisitions (M&A), strategic alliances, new products, and new markets) to attain capital economies of scale and scope to avoid being crowded out of the insurance business (Broek et al., 2011).[9] Entering markets traditionally dominated by the other organizational form probably requires applying the same rules (pricing, risk selection, pooling, handling of agency conflicts, etc.) in order to offer competitive premiums and to attain attractive and healthy output, especially given the fact that none of the organizational forms has competitive advantages regarding the amount of inputs anymore.[10][11] Otherwise, the more efficient organizational form may be able to cream-skim customers in these segments.

Because of the level playing field for both organizational forms (in terms of taxation and solvency margins) and the introduction of risk based capital standards, it could be expected that the production technologies of both organizational forms converge (see also Broek et al., 2011). Such a process would go hand in hand with the general trend of an increasingly uniform European (i.e., due to the Internal Market and increased competition; see, e.g., Cummins et al., 2016) insurance market. Cummins et al. (2016) empirically document that higher competition in the EU life insurance sector has promoted inter-country convergence in 1998–2007 leading to more homogeneity among insurers. Because today's mutual insurers tend to be a product of a bygone era in which the economic context was different (see, e.g., Zanjani, 2007), they may have only two options to cope with the changed economic context to avoid being crowded out of the market (Broek et al., 2011): demutualization or orientation towards stock insurers. Today, not all mutual insurers are small-scaled and niche-market players anymore—some mutual insurers have built large organizations offering a broad range of products and services already (e.g., Crédit Agricole Assurances in France, Achmea in the Netherlands, R + V Versicherung in Germany, Liberty Mutual in the US; for more details see, e.g., Amice, 2017; Federal Insurance Office, 2016). Based on this discussion H1a may subside over time in the new economic context and consequently I formulate the "convergence hypothesis" that the technologies of stock and mutual insurers converge over the long term guaranteeing the survival of both organizational forms (H1b):

H1b: Over the long term, stock and mutual insurers' technologies converge.

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[9] Expanding business is anyway important for mutual insurers anyway in order to raise capital as they are limited in using capital markets (see, e.g., Harrington & Niehaus, 2002).

[10] Braun et al. (2015) show that mutual insurers could charge higher prices than stock insurers. However, policyholders of mutual insurers are less aware of their voting rights and rational agents would not pay for the nonrealizable component of the equity stake. In an empirical analysis of German motor vehicle liability insurance sector in 2000-2006, the authors document that prices of stock and mutual insurers are not significantly different.

[11] Although the same capital requirements apply to stock and mutual insurers, differences still remain with regards to how capital is raised. Mutual insurers cannot use capital markets but are also less dependent on external fund raising compared to stock insurers, a fact that could be especially valuable during crises. These idiosyncrasies may encourage both organizational forms to hold additional capital buffers. However, the differences may likely cause different speeds in capital structure changes.

3 Data and methodology

3.1 Data

The selection of the samples is oriented toward Biener and Eling (2012) and focuses on the life and non-life sectors of the two central insurance markets. Hence, I consider life and non-life insurers that are domiciled in US and the EU (including non-EU countries from the European Economic Area and Switzerland). Merging the US and EU life and non-life samples yields samples for the global insurance market (Biener & Eling, 2012).[12] I extract data for 2002–2015 from two sources for accounting information. The data for the US markets stems from Bureau van Dijk's Global Insurance Company Database (ISIS) (see, e.g., Cummins et al., 2016). The data for the EU insurers is extracted from the Insurance Reports database of A.M. Best (see, e.g., Eling & Schaper, 2017) as the data for these insurers is highly unbalanced in the ISIS database for a significant part of the sample period. Due to data availability the Czech Republic, Greece, Hungary, Iceland, Latvia, Lithuania, Luxembourg, Poland, Slovakia, and Slovenia cannot be considered.[13] Observations with missing or extreme data, such as zero or negative total asset values, were eliminated from the samples. Furthermore, only firms for which data is available for every year are included in the final samples. All absolute values in the samples were deflated to 2002 and converted to US dollars (USD) using consumer price indexes from the World Bank and exchange rates from the European Central Bank, respectively.

I differentiate the sample firms by the organizational form (stock or mutual). In addition, I classify all insurers in the database with the organization type reciprocal exchange, non-profit company, friendly society, fraternal benefit organization, and cooperative as mutual insurers (Smith & Stutzer 1995; Swiss Re, 2016). I exclude Lloyd's insurers, pool or insurance trusts, and insurers with unknown organizational form. Furthermore, I exclude insurers in run-off, insurers which stopped underwriting insurance business during the sample period, and insurers for which either only group accounts or unreliable financials are available. The final global samples consist of 431 life insurance companies (6,023 firm years) and 918 non-life insurance companies (12,758 firm years). Table 1 presents summary statistics for the inputs, input prices, and outputs—which are used for the later efficiency analyses and which are introduced in more detail in the following—as well as key firm characteristics.

[12] The efficiency results strongly depend on the selected group of insures which shall be evaluated against each other. For example, a combined frontier of both US and EU insurers presumes that insurers from both regions are in direct competition (Biener & Eling, 2012). However, it is also reasonable to assume that competition exists only within the US market and only within the EU.

[13] Due to data availability also Canada cannot be considered which would have allowed a creation of a Northern American sample as in Biener and Eling (2012).

Variables	Unit	Stock and mutual insurers pooled						Stock insurers separately						Mutual insurers separately					
		Mean	Min	25%	50%	75%	Max	Mean	Min	25%	50%	75%	Max	Mean	Min	25%	50%	75%	Max
US																			
Life																			
Labor(x1)	1,000s	3.90	0.00	0.46	1.32	4.13	76.93	3.72	0.00	0.44	1.29	4.03	76.93	6.16	0.19	0.75	1.90	11.17	28.69
Debt capital (x2)	bn $	12.45	0.01	0.67	2.23	8.89	225.16	11.62	0.01	0.67	2.30	8.53	225.16	22.52	0.14	0.71	1.87	15.27	164.79
Equity capital (x3)	bn $	1.34	0.01	0.16	0.41	1.30	29.40	1.24	0.01	0.16	0.40	1.24	29.40	2.53	0.03	0.09	0.64	2.34	16.31
Losses (y1 not shifted)	bn $	1.34	-0.36	0.08	0.26	1.09	27.37	1.27	-0.36	0.08	0.26	1.03	27.37	2.18	0.02	0.09	0.23	1.47	15.09
Total investments (y2)	bn $	8.64	0.02	0.65	1.76	6.71	178.12	7.74	0.02	0.63	1.73	6.69	178.12	19.56	0.16	0.92	1.94	6.75	154.44
Assets	bn $	16.44	0.03	1.02	3.20	12.30	309.10	15.34	0.03	1.01	3.21	11.73	309.10	29.92	0.19	1.15	2.62	19.22	238.54
Equity to assets	%	0.18	0.01	0.09	0.13	0.21	0.95	0.19	0.01	0.09	0.14	0.22	0.95	0.16	0.05	0.07	0.11	0.15	0.60
Non-life																			
Labor(x1)	1,000s	2.90	0.00	0.25	0.56	1.47	1,701.66	3.05	0.00	0.23	0.55	1.52	1,701.66	2.56	0.02	0.27	0.57	1.40	112.15
Debt capital (x2)	bn $	1.07	0.00	0.08	0.18	0.57	379.69	1.16	0.00	0.08	0.18	0.61	379.69	0.86	0.00	0.08	0.17	0.49	44.77
Equity capital (x3)	bn $	1.02	0.00	0.08	0.16	0.48	265.03	1.08	0.01	0.08	0.17	0.52	265.03	0.87	0.00	0.07	0.14	0.39	62.71
Losses (y1 not shifted)	bn $	0.43	-3.82	0.03	0.07	0.21	114.51	0.42	-3.82	0.03	0.07	0.21	114.51	0.44	-0.01	0.04	0.08	0.20	26.68
Total investments (y2)	bn $	1.80	0.00	0.14	0.28	0.91	536.67	1.92	0.01	0.14	0.29	0.96	536.67	1.51	0.00	0.14	0.26	0.77	99.26
Assets	bn $	2.51	0.01	0.19	0.40	1.26	802.79	2.69	0.01	0.20	0.42	1.35	802.79	2.06	0.03	0.19	0.36	1.13	138.80
Equity to assets	%	0.49	0.03	0.38	0.47	0.58	1.00	0.50	0.07	0.39	0.48	0.60	1.00	0.46	0.03	0.37	0.45	0.54	0.97
EU																			
Life																			
Labor(x1)	1,000s	1.82	0.00	0.10	0.54	1.82	134.94	2.19	0.00	0.18	0.65	2.01	134.94	0.90	0.00	0.01	0.18	1.13	7.32
Debt capital (x2)	bn $	7.49	0.00	0.37	2.11	8.06	195.09	8.43	0.00	0.46	2.11	9.16	195.09	5.15	0.00	0.14	2.12	5.82	46.53
Equity capital (x3)	bn $	0.24	0.00	0.02	0.07	0.26	4.88	0.24	0.00	0.02	0.07	0.25	4.88	0.26	0.00	0.01	0.06	0.28	4.59
Losses (y1 not shifted)	bn $	1.30	-83.50	0.04	0.31	1.24	137.04	1.44	-83.50	0.07	0.34	1.35	137.04	0.94	-2.06	0.01	0.17	1.03	14.07
Total investments (y2)	bn $	7.19	0.00	0.37	2.06	7.93	182.65	8.00	0.00	0.45	2.03	8.92	182.65	5.17	0.00	0.14	2.11	5.71	45.82
Assets	bn $	8.68	0.00	0.44	2.41	9.35	234.63	9.73	0.00	0.54	2.44	10.72	234.63	6.07	0.00	0.17	2.40	6.86	56.49
Equity to assets	%	0.07	0.00	0.02	0.04	0.06	0.95	0.07	0.00	0.02	0.04	0.07	0.95	0.07	0.00	0.02	0.04	0.06	0.79
Non-life																			
Labor(x1)	1,000s	2.30	0.00	0.12	0.44	2.09	138.96	2.62	0.00	0.15	0.60	2.39	138.96	0.73	0.00	0.05	0.18	0.43	10.05
Debt capital (x2)	bn $	1.71	0.00	0.04	0.21	0.99	82.25	1.94	0.00	0.05	0.27	1.11	82.25	0.57	0.00	0.02	0.07	0.46	8.00
Equity capital (x3)	bn $	0.56	0.00	0.02	0.07	0.33	59.90	0.61	0.00	0.02	0.08	0.37	59.90	0.29	0.00	0.02	0.05	0.15	3.78
Losses (y1 not shifted)	bn $	0.43	-6.15	0.02	0.06	0.30	30.07	0.48	-6.15	0.02	0.08	0.36	30.07	0.20	-0.03	0.01	0.03	0.13	3.64
Total investments (y2)	bn $	1.65	0.00	0.05	0.20	0.95	106.77	1.83	0.00	0.05	0.23	1.04	106.77	0.72	0.00	0.03	0.09	0.49	7.44
Assets	bn $	2.53	0.00	0.08	0.34	1.57	143.27	2.85	0.00	0.09	0.42	1.75	143.27	0.97	0.00	0.05	0.14	0.65	11.21
Equity to assets	%	0.33	0.01	0.19	0.27	0.42	0.99	0.31	0.01	0.18	0.26	0.40	0.99	0.40	0.05	0.25	0.36	0.52	0.95

3.1.1 Inputs selection

In the insurance literature, there is broad acceptance regarding the choice of inputs for efficiency analyses (Eling & Luhnen, 2010). I use labor (x_1), debt capital (x_2), and equity capital (x_3) as input variables. The business and materials input of insurers (Cummins & Weiss, 2013) cannot be modelled separately due to data limitations and is therefore integrated into the labor input (Biener & Eling, 2012; Biener et al., 2016). The labor input (i.e., number of employees) is estimated by dividing the net operating expenses of each insurer by annual country-specific average wage rates. For insurers domiciled in the US, I obtain the wage rates from the US Department of Labor. The wage rate is provided individually for life (North American Industry Classification System (NAICS) class 524113) and non-life insurers (NAICS class 524126). For all insurers domiciled in the EU, I obtain the wage rates for insurance activities from the International Labor Organization. The few missing values were either approximated by wages rates for financial intermediation activities or linear interpolation.

3.1.2 Output selection

I follow the value-added approach to measure the intangible service outputs of insurers (Cummins & Weiss, 2013). The three value-adding services of insurers are risk-pooling/risk-bearing, intermediation, and financial services related to insured losses. As a proxy for the first service (y_1), I use the present value of losses paid adjusted for the change in the provision for outstanding claims for non-life insurers (i.e., real incurred losses) and benefits paid adjusted for the change in the provision for outstanding claims for life insurers. To avoid negative numbers for this output (i.e., if the change in provisions is higher than the losses paid/claims paid in one year) I shift this variable for the complete sample period (Biener et al., 2016). The intermediation service of insurers (y_2) is represented by the total investments value. I do not model the third service output because y_1 and y_2 are highly correlated with the financial services output of insurers (Eling & Luhnen, 2010).

3.2 Methodology

3.2.1 Efficiency measurement

Efficiency can be measured following a parametric (econometric) or nonparametric (mathematical programming) approach, both are frequently used in the insurance literature (Cummins & Weiss, 2013). The inherent advantage of the nonparametric approach is that it is less vulnerable to specification errors (see, e.g., Biener et al., 2016). Therefore, I choose data envelopment analysis (DEA) originated by Charnes, Cooper, and Rhodes (1978) to determine firm technical efficiency based on firm productivity relative to the productivity of best-practice firms.

I estimate input-oriented frontiers based on the inputs and outputs defined in section 3.1 with constant returns to scale to determine technical efficiency. Equation (1) illustrates the linear programming problem to determine technical efficiency:

$$TE_j = \min \theta_j \text{, s.t. } \lambda_j X \leq \theta_j x_j \text{, } \lambda_j Y \geq y_j \text{, } \lambda_j \geq 0 \ (j = 1,2,3......N) . \tag{1}$$

TE represents Farrell's (1957) measure of technical efficiency for DMU j ($j = 1,2,...N$), N denotes the number of decision making units (DMU; i.e., insurers), M and K are the number of inputs and outputs, respectively, θ is a scalar providing a radial distance estimate, X is a $M \times N$ matrix of all inputs used, Y is a $K \times N$ matrix of all outputs produced, x_j is an $M \times 1$ input vector for DMU j, y_j is a $K \times 1$ output vector for DMU j, and λ_j is an $N \times 1$ intensity vector.

Based on the DEA methodology, I estimate metatechnology technical efficiency (MTE) for stock and mutual insurers as illustrated in Equation (2) to analyze the technology usage of stock and mutual insurers (O'Donnell et al., 2008):

$$MTE_{j,t} = \frac{Efficiency_{j,t}}{Efficiency_{j,t}^k} \text{, } k\{stock\ frontier; mutual\ frontier\} . \tag{2}$$

MTE is the metatechnology technical efficiency ratio of firm j, $Efficiency$ is the metafrontier efficiency ratio (i.e., efficiency measured against a common frontier for stock and mutual insurers), and $Efficiency^k$ represents efficiency measured against a frontier constituting only stock (mutual) insurers if firm j is a stock (mutual) insurer. This concept allows for different production "environments" among groups of firms (i.e., among the stock and mutual organizational form) and depicts the level of homogeneity between these environments (Cummins et al., 2016).[14] MTE ratios of 1 suggest that the efficiency of stock and mutual

[14] One requirement for the metatechnology efficiency methodology is that the groups of firms are able to change their production environments (i.e., switch to one of the other groups; O'Donnell et al., 2008). I believe that this is the case for the groups of stock and mutual insurers—where the production environment superficially refers to the inherent costs and benefits of each ownership types—because (1) they can technically (i.e., from a legal perspective) operate in the same market segments exposing them to the same production conditions (in reality, stock and mutual insurers jointly serve several market segments), (2) mutual insurers are able to choose a mutual holding company (MHC) structure which enables them to benefit from advantages of the stock charter (see, e.g., Erhemjamts & Leverty, 2010; NAIC, 1998), (3) stock and mutual insurers can exercise legal structure

insurers are not affected by the choice of the frontier (i.e., common vs. group frontier) indicating that both organizational forms use identical technologies. Because differences in the efficiency levels from the individual stock and mutual frontiers may be due to different sample sizes, I follow Cummins et al. (2004) as well as Biener and Eling (2012) and build size-stratified samples. Thus, each year I sort stock and mutual insurers into three size quantiles (small, medium, and large) and then randomly draw a number of stock insurers from the complete sample that equals the number of mutual insurers in each size quantile. To ensure robust findings, I compute average efficiency values based on 200 iterations of the random selection of stock insurers (Biener & Eling, 2012).

3.2.2 Trends in technology usage

I analyze trends in technology usage (i.e., the methods and processes to produce outputs from inputs on which efficiency can be assessed) over time by analyzing the developments of stock and mutual insurers' MTE ratios on the basis of three criteria (Casu & Girardone, 2010; Cummins et al., 2016). The three criteria comprise *β*-convergence and *σ*-converge which are also discussed in economic growth theory (Barro & Sala-i-Martin, 1995) and the convergence towards identical production processes (i.e., MTE ratios of 1). Advantageous of these concepts is that they consider the underlying dynamics of technology development during the sample period from which also projections for the out-of-sample development could be drawn. *β*-convergence is analyzed as illustrated in Equation (3):

$$\Delta E_{j,t} = \alpha + \beta(\ln MTE_{j,t-1}) + \rho \Delta E_{j,t-1} + \varepsilon_{j,t} . \tag{3}$$

$\Delta E_{j,t} = \ln(MTE_{j,t}) - \ln(MTE_{j,t-1})$, $MTE_{j,t}$ ($MTE_{j,t-1}$) is the MTE ratio of stock or mutual insurer j at time t $(t-1)$, $\varepsilon_{j,t}$ is the error term, and α, β, and ρ are the parameters to be estimated. β captures the catch-up effect and a negative value of this parameter implies convergence; the greater the value the greater is the tendency of convergence. I estimate Equation (3) with and without lagged dependent variable (Casu & Girardone, 2010).

I analyze *σ*-convergence as shown in Equation (4):

$$\Delta V_{j,t} = \alpha + \sigma V_{j,t-1} + \rho \Delta V_{j,t-1} + \varepsilon_{j,t} . \tag{4}$$

$V_{j,t} = \ln(MTE_{j,t}) - \ln(\overline{MTE_t})$, $\overline{MTE_t}$ is the mean metatechnology technical efficiency ratio of all insurers at time t, $\Delta V_{j,t} = V_{j,t} - V_{j,t-1}$, $MTE_{j,t}$ and $\varepsilon_{j,t}$ are defined as before. α, σ, and ρ are the parameters to be estimated. σ represents the rate of convergence towards the mean MTE ratios of all insurers and a negative

conversions and switch to the other ownership form, and (4) mutual insures can adopt stock insurer practices, increase the scale of operation, operate as full service provider, and diversify geographically as already existent in the US or some EU markets (see, e.g., Broek et al., 2011).

value of this parameter implies convergence; the greater the value the greater is the rate of convergence. Again, I estimate Equation (4) with and without lagged dependent variable.

Equation (5) shows how the convergence towards MTE ratios of 1 (i.e., homogenous production processes of stock and mutual insurers) is analyzed (refer also to Equations A1–A5 in the Appendix):

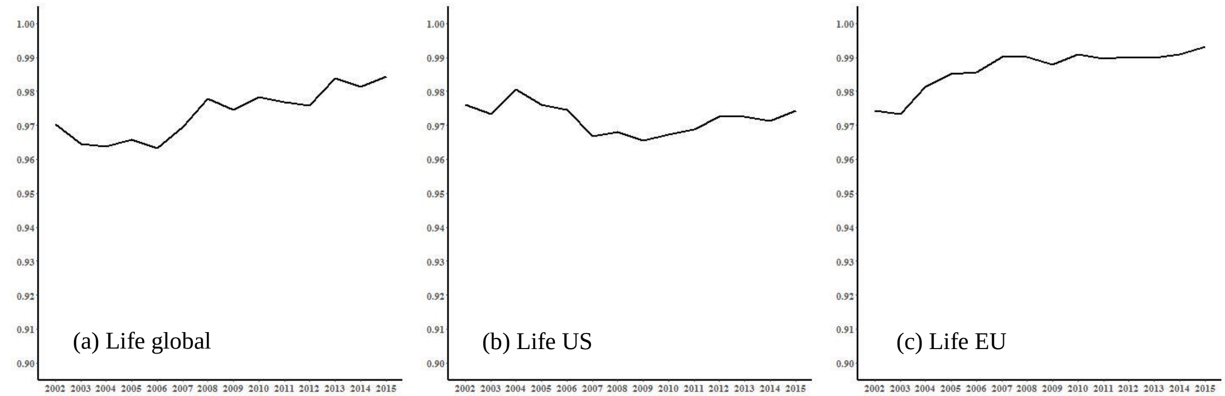
$$MTE_{j,t} = \gamma_1 + \gamma_2 MTE_{j,t-1} + \varepsilon_{j,t} \,. \tag{5}$$

$\delta = (1 - \gamma_2)$ and captures the adjustment rate towards the state of identical production processes. The higher the value of δ is, the greater is the rate of convergence—vice versa, a lower or negative value implies lack of convergence or persistence of differences (Casu & Girardone, 2010; Lin & Kao, 2014).

4 Empirical results

Figures 1 and 2 present the development of mean MTE ratios for 2002–2015 in the life and non-life sectors, respectively. Tables A1 and A2 in the Appendix show the annual mean MTE ratios for all samples. All mean levels are consistently lower than 1 (representing conformity of stock and mutual insurers' technologies) throughout the sample period indicating differences in the efficiency measurement according to the metafrontier and the individual stock/mutual frontiers. This result may be set in reference with the initial hypothesis suggesting that stock and mutual insurers use different technologies and are each dominant in producing their respective outputs (Cummins et al., 1999b; Cummins et al., 2004; Biener & Eling 2012). However, Figures 1 and 2 highlight two aspects providing important insights. First, although the MTE ratios are lower than 1, they are considerable high indicating only minor technology differences between stock and mutual insurers during the sample period. Cummins et al. (2016), for example, document considerably lower cost and revenue metatechnology levels in an analysis of cross-country differences in the EU life insurance sector. Second, Figures 1 and 2 emphasize that the differences between stock and mutual insurers are subject to changes over time. For the global and EU life sectors, Figure 1 reveals an increase of the mean MTE ratios from 2002–2015. However, in the US sample, the yearly mean MTE ratios seem to persist at their high level except for minor fluctuations. Interestingly, the MTE ratios in the EU already overtake the levels for the US sample in 2005.

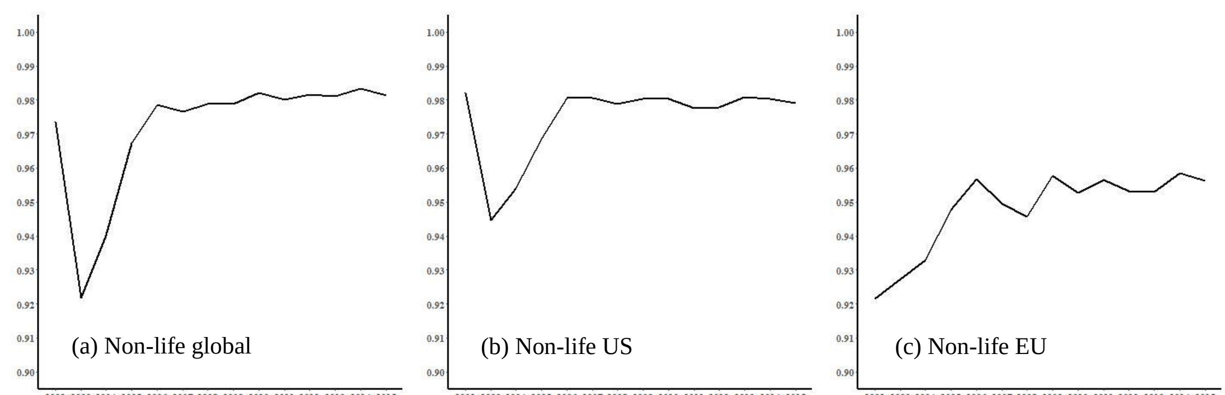
Figure 1 Development of MTE in the life sector from 2002–2015



Notes: Figure 1 shows the mean MTE ratios for the 2002–2015 period.

For the non-life sector, Figure 2 reveals that the MTE ratios tend to persist around 0.98 in the US sample apart from a drop off in 2003–2005. In the EU sample, the ratios are throughout the sample period significantly lower but they increase considerably. Likewise, the MTE ratios increase in the global non-life sample. The results from the US market might be regarded as benchmark for the degree of convergence that could be expected for stock and mutual insurers in the non-life sector. This is because the changes in the operating conditions outlined in chapter 2 have been present in this market already since the early 1990s and the MTE ratios do not change much during the sample period—apart for the mentioned drop off. This would suggest that convergence might not be perfectly (i.e., MTE ratios of 1) due to differences between stock and mutual insurers that continue to exist—for example, the speed of capital raising.

Figure 2 Development of MTE in the non-life sector from 2002–2015



Notes: Figure 2 shows the mean MTE ratios for the 2002–2015 period.

Overall, the results from the graphical analysis are first preliminary evidence that some convergence trends can be observed in parts of the insurance industry. To dig deeper into the development of stock and mutual insurers' technology usage from an econometric perspective, I present the results for my tests of β-convergence (Equation 3) and σ-convergence (Equation 4) in Tables 2 and 3, respectively.

Table 2 β-convergence of MTE

Coefficients	Equation (3) without lagged dependent variable			Equation (3)		
Life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
β	-0.1778***	-0.2185***	-0.3579***	-0.1584***	-0.1861***	-0.3886***
	(0.0072)	(0.0114)	(0.0119)	(0.0071)	(0.0124)	(0.0101)
ρ				-0.2114***	-0.1365***	-0.0554***
				(0.0132)	(0.0187)	(0.0127)
α	-0.0024	-0.0068***	0.0004	-0.0018	-0.0057***	0.0009
	(0.0115)	(0.0009)	(0.0058)	(0.0111)	(0.0009)	(0.0044)
N	5,590	2,910	2,671	5,159	2,683	2,462
Adj. R^2	0.0976	0.1121	0.2522	0.1645	0.1277	0.4065
Non-life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
β	-0.4113***	-0.4657***	-0.3359***	-0.4135***	-0.4722***	-0.2770***
	(0.0074)	(0.0101)	(0.0105)	(0.0051)	(0.0067)	(0.0114)
ρ				0.0195***	0.0334***	-0.2298***
				(0.0055)	(0.0069)	(0.0141)
α	-0.0278***	-0.0130***	-0.0475***	-0.0286***	-0.0097***	-0.0352***
	(0.0074)	(0.0006)	(0.0078)	(0.0046)	(0.0004)	(0.0077)
N	11,830	7,139	4,421	10,915	6,509	4,017
Adj. R^2	0.2058	0.2311	0.1867	0.4267	0.4883	0.2436

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. Country dummy variables are included but not reported.

Table 2 shows a negative and significant β-coefficient for the global sample as well as for the individual US and EU samples. This result holds for the life as well as for the non-life sector and is also robust across the two models (i.e., Equation 3 with and without lagged dependent variable). Thus, the evidence for β – convergence of MTE ratios suggests that stock and mutual insurers which have the highest technology gaps regarding the common frontier, show higher catch-up growth than stock and mutual insurers with smaller technology gaps (see, e.g., Cummins et al., 2016). Thus, the analysis of β-convergence supports the expectation of convergence. In particular, lagging stock and mutual insurers (probably, small niche players) catch up to a common frontier.

Table 3 reports a negative and significant σ-coefficient in all samples (i.e., global, US, and EU) consistently for the life and non-life sectors as well as for the two models. The coefficient measures whether stock and mutual insurers' MTE ratios converge towards the common average. Table 3 suggests that the dispersion of MTE ratios around the common averages decreases during the sample period (Casu & Girardone, 2010). Thus, also the reduced dispersion supports the expectation of converging technologies of stock and mutual insurers (Cummins et al., 2016).

Table 3 σ-convergence of MTE

Coefficients	Equation (4) without lagged dependent variable			Equation (4)		
Life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
σ	-0.1784***	-0.2175***	-0.3624***	-0.1592***	-0.1853***	-0.3855***
	(0.0071)	(0.0114)	(0.0120)	(0.0071)	(0.0124)	(0.0102)
ρ				-0.2111***	-0.1361***	-0.0544***
				(0.0132)	(0.0187)	(0.0127)
α	0.0014	-0.0004	0.0039	0.0007	-0.0004	0.0042
	(0.0114)	(0.0008)	(0.0057)	(0.0110)	(0.0008)	(0.0043)
N	5,590	2,910	2,671	5,159	2,683	2,462
Adj. R^2	0.0987	0.1116	0.2534	0.1651	0.1272	0.3981
Non-life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
σ	-0.4034***	-0.4556***	-0.3358***	-0.3998***	-0.4663***	-0.2715***
	(0.0073)	(0.0100)	(0.0106)	(0.0053)	(0.0068)	(0.0114)
ρ				-0.0029	0.0158**	-0.2339***
				(0.0058)	(0.0071)	(0.0141)
α	-0.0161**	-0.0006	-0.0321***	-0.0212***	-0.0001	-0.0237***
	(0.0069)	(0.0005)	(0.0077)	(0.0045)	(0.0003)	(0.0076)
N	11,830	7,139	4,421	10,915	6,509	4,017
Adj. R^2	0.2025	0.2256	0.1841	0.3985	0.4760	0.2417

Notes: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. Country dummy variables are included but not reported.

Although I find evidence for β- and σ-convergence, I also have to analyze whether the MTE ratios converge towards 1 as this result would indicate that stock and mutual insurers use more and more the same technologies. In other words, β- and σ-convergence without evidence for convergence towards 1 could mean that the MTE ratios become closer in the sample but still persist at values smaller than 1 (i.e., differences in the technologies persist). To analyze convergence of MTE ratios towards 1, I estimate Equation (4) and present the results in Table 4.

Table 4 presents significant and positive γ_2 -coefficients for all samples in the life and non-life sectors. These coefficients correspond to positive δ -values ($\delta = 1 - \gamma_2$) consistently indicating convergence towards 1. Generally, a smaller γ_2 -coefficient corresponding to a higher δ -value suggests higher convergence rates (refer to Figure A1 in the Appendix). While the convergence rates for the life sector appear reasonable with regard to the graphical analysis, the relatively high values for the non-life sector—in particular for the global and US samples—do not consistently fit to Figure 2. One explanation for this is the sharp short-term downward movement which is followed by a longer period of upward movement in these samples. The partial adjustment model (Equation 5) may not be capable to consider this pattern as it approximates only a constant rate of convergence (see, e.g., Lin & Kao, 2014). Thus, the results for the US samples and consequently also for the global samples should be considered with caution. Likewise, although the results from partial adjustment model propose convergence towards identical production processes (i.e., MTE ratios of 1), there are also the observations from the graphical analysis and theoretical arguments suggesting convergence may not be perfect.

Table 4 Convergence of MTE towards 1

Coefficients	Equation (5)			Equation (5)		
	Life			*Non-life*		
	Global	*US*	*EU*	*Global*	*US*	*EU*
γ_1	0.1608***	0.1958***	0.3348***	0.3679***	0.4194***	0.2723***
	(0.0107)	(0.0107)	(0.0123)	(0.0092)	(0.0095)	(0.0111)
γ_2	0.8371***	0.7983***	0.6658***	0.6073***	0.5693***	0.6885***
	(0.0067)	(0.0110)	(0.0115)	(0.0073)	(0.0098)	(0.0102)
N	5,590	2,910	2,671	11,830	7,139	4,421
Adj. R^2	0.7434	0.6451	0.5761	0.3789	0.3216	0.5348

Notes: ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively; the numbers in parentheses are robust standard errors clustered at the firm level. Country dummy variables are included but not reported.

Overall, my results provide some evidence for the convergence hypothesis (H1b) that over the long term the technologies of stock and mutual insurers converge in the changed economic context. However, although the econometric results are distinct, the results also emphasize not only differences between the life and non-life sector but also between the US and EU market. Whilst the MTE ratios are relatively high in the life sector during the complete sample period, they are particularly lower in the EU non-life sector. The differences between life and non-life may be due to relatively more degrees of freedom in the non-life sector (see, e.g., Huang & Eling 2013; Eling & Schaper, 2017). Furthermore, whilst the MTE ratios seem to persist in the US life and non-life sectors in which significant changes in the operating conditions have occurred already since the 1990s as outlined in chapter 2, particularly the EU market shows high convergence movements. In this market, changes in the operating conditions for particularly mutual insurers have occurred more recently (i.e., elimination of state aids, introduction of risk-based capital standards). If the US market is regarded as benchmark for the degree convergence, it becomes obvious that minor differences among stock and mutual insurers (i.e., MTE ratios lower than 1) tend to persist due to unchanged and inherent differences between the organizational forms. In the EU case, differences may be also due to differences in the legal opportunities for M&A and cross-border activities which still exist in some member countries (Broek et al., 2011). Furthermore, although diversification among different insurance lines can be excepted from the introduction of risk-based capital standards, it is still ambiguous whether stock and mutual insurers continue to serve different clients (e.g., commercial vs. non-commercial clients; see, e.g., Biener & Eling, 2012). In reference to the ESH, my results suggest that the dominance of the organizational forms in different market segments may decline. Mutual insurers may be enforced to progressively operate like stock insurers (e.g., take over characteristics, pricing mechanisms, and management techniques).

5 Conclusions

I propose and empirically test the convergence hypothesis (i.e., convergence of stock and mutual insurers' technologies). I find evidence for β- and σ-convergence of stock and mutual insurers' metatechnology technical and cost efficiency levels for the 2002–2015 period in sectors of the US and EU insurance markets. These results suggest that due to significant changes in the operating conditions during the last two decades (particularly, elimination of state aids for the mutual organizational form and introduction of risk-based capital standards) especially mutual insurers started to orient towards the stock organizational form. This orientation-imitation effect may lead to more homogeneity among stock and mutual insurers.

However, I document differences in the convergence movements among geographical areas and the life/non-life sectors which offers various directions for future research. In particular, the relationship between the competition degree as well as capital requirements and the efficiency development could be further analyzed across industries and countries (see, e.g., Matousek, Rughoo, Sarantis, & Assaf, 2015; Cummins et al., 2016). The study could be also expended to study convergence in different insurance lines. Similar to other studies also the presented results are limited due to data availability. Thus, it would be interesting to further monitor the efficiency development of stock and mutual insurers once additional firm-year data becomes available. It would be also interesting to analyze the development of cost (revenue) efficiency over time if data for individual prices of stock and mutual insurers' inputs (outputs) are available. Furthermore, it may be interesting to study mutual firm behavior in terms of size and group structure (i.e., the mutual holding company structure) and link this to efficiency (see, e.g., Cummins & Xie, 2013). On the methodological side, it could be interesting to analyze the development with models which are capable to study large convergence fluctuations (see, e.g., Lin, 1986; Lin & Kao, 2014).

Overall, my analysis also emphasizes that future research should further focus on dynamic efficiency settings while considering the operating environment (see, e.g., Zanjani, 2007; Huang & Eling, 2013; Eling & Schaper, 2017) in order to better understand firm behavior. In this regards, future research could, for example, study the efficiency resilience and response to endogenous/exogenous turmoil of stock and mutual insurers to get further insights on situational dominance (see, e.g., Fukuyama, 1997; Tsionas, Assaf, & Matousek, 2015).

Appendix

Equations A1–A5 Specification of partial adjustment model

I specify partial adjustment models to analyze the association between organizational form and evolution of efficiency. Equation (A1) illustrates a standard partial adjustment model for panel data (see, e.g., Pesaran, 2015):

$$Y^{*}_{j,t} = a_j + bX_{j,t} + \varepsilon_{j,t}\,. \tag{A1}$$

Y^{*} is the desired level of any decision making variable of firm j at time t, a is a constant term, X is a vector of factors related to costs and benefits of operating at the desired level for firm j at time t, b is a vector of coefficients, and ε is the disturbance term. In general, the desired level is not observable and may also change over time. However, in the efficiency context the desired level is known because all companies pursue to become fully efficient (Casu & Girardone, 2010):

$$Efficiency^{*}_{j,t} = Efficiency_{\max}\,. \tag{A2}$$

Equation (A2) considers no disturbance term because it represents an equilibrium relation which makes the disturbance term redundant (Cheng & Weiss, 2012).[15] Equation (A3) recognizes that adjustment costs prevent each insurer to achieve the desired efficiency level immediately. Thus, improving efficiency (i.e., eliminating inefficiency) is an adjustment process:

$$Efficiency_{j,t} - Efficiency_{j,t-1} = \delta\left[Efficiency^{*}_{j,t} - Efficiency_{j,t-1}\right] + \varepsilon_{j,t}\,,\ 0 < \delta \leq 1. \tag{A3}$$

Equation (A3) considers a disturbance term as the adjustment process may be imperfect (Cheng & Weiss, 2012). $\delta = 1$ means that the insurer adjusts to the desired efficiency level instantaneously in the specified period. Usually, insurers only partially ($0 < \delta < 1$) close the gap between the actual and desired efficiency level due to technological rigidities, habit inertia, resource constraints, institutional controls, regulations, and adjustment costs (Lin, 1986). Thus insurers, have to trade the adjustments-costs against the costs of operating at an inefficient level over time (Casu & Girardone, 2010). Substituting Equation (A2) into Equation (A3) and applying some simplifications yields the following model which shows how the observed efficiency level of insurer i at time t is determined:

$$Efficiency_{j,t} = \delta Efficiency_{\max} + (1-\delta)Efficiency_{j,t-1} + \varepsilon_{j,t}\,. \tag{A4}$$

[15] Cheng and Weiss (2012) define partial adjustment models to analyze the adjustment speeds of stock and mutual insurers to desired capital structure.

To account for different adjustment speeds of stock (s) and mutual (m) insurers in the model, I differentiate Equation (A4) according to the organizational form:

$$Efficiency_{s,j,t} = \delta_s Efficiency_{\max} + (1-\delta_s) Efficiency_{s,j,t-1} + \varepsilon_{s,j,t}, \quad \text{(A4.1)}$$

$$Efficiency_{m,j,t} = \delta_m Efficiency_{\max} + (1-\delta_m) Efficiency_{m,j,t-1} + \varepsilon_{m,j,t}. \quad \text{(A4.2)}$$

Merging Equations (A4.1) and (A4.2) and replacing $Efficiency^*$ by the value 1 in line with the efficiency measurement according to Farrell (1957) who defines efficiency on]0;1], where unity represents full efficiency, yields the following pooled model:[16]

$$Efficiency_{j,t} = \gamma_1 + \gamma_2 Efficiency_{j,t-1} + \gamma_3 D_s + \gamma_4 D_s Efficiency_{j,t-1} + \varepsilon_{j,t}. \quad \text{(A5)}$$

$\delta = (1-\gamma_2)$, $\delta_s = (1-\gamma_2-\gamma_4)$, and D_s is a binary variable which takes the value 1 if insurer j operates under the stock charter. If γ_4 is significantly different from zero, stock insurers adjust to the desired efficiency level at different speed. In particular, if $\gamma_4 < 0$ then stock insurers adjust more quickly toward the desired efficiency level.

[16] Equation (6) does not consider that insurers in the sample may have a different ownership form than stock or mutual. However, without allowance for other ownership forms Equation (6) cannot be estimated. I recognize this in Equation (7).

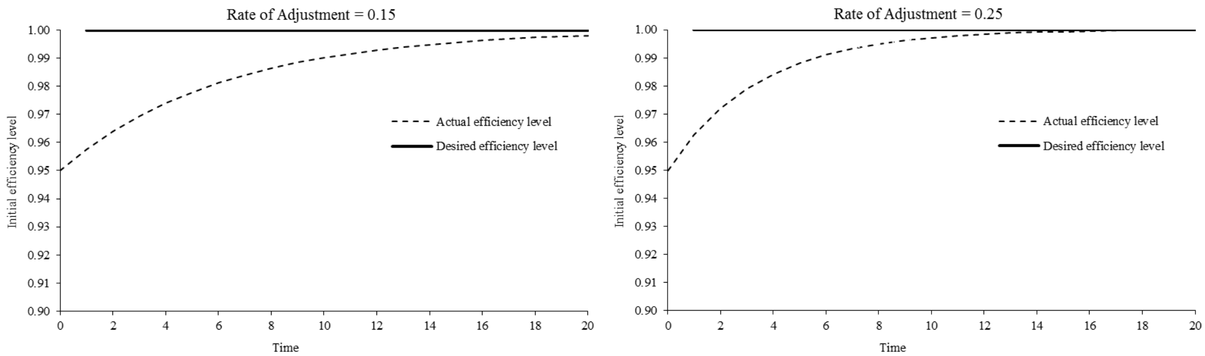
Table A1 Mean metatechnology technical efficiency life

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2002–2015
Global															
Austria	0.9845	0.9823	0.9780	0.9796	0.9841	0.9804	0.9863	0.9761	0.9808	0.9831	0.9873	0.9884	0.9884	0.9931	0.9837
Belgium	0.9516	0.8412	0.8598	0.9185	0.8551	0.9730	0.9227	0.9271	0.9027	0.9784	0.9338	0.9142	0.9776	0.9707	0.9233
Denmark	0.9897	0.9791	0.9877	0.9861	0.9896	0.9938	0.9958	0.9948	0.9966	0.9970	0.9984	0.9995	0.9974	0.9984	0.9931
Finland	0.9897	0.9782	0.9788	0.9815	0.9884	0.9886	0.9882	0.9902	0.9910	0.9896	0.9956	0.9906	0.9866	0.9877	0.9875
France	0.9864	0.9879	0.9845	0.9879	0.9875	0.9859	0.9884	0.9889	0.9903	0.9875	0.9898	0.9904	0.9891	0.9920	0.9883
Germany	0.9699	0.9649	0.9724	0.9798	0.9811	0.9869	0.9896	0.9876	0.9925	0.9931	0.9929	0.9931	0.9930	0.9945	0.9851
Ireland	0.9768	0.9565	0.9593	0.9565	0.9003	0.9024	0.9387	0.9512	0.9596	0.9519	0.9640	0.9594	0.9710	0.9683	0.9511
Italy	0.9881	0.9691	0.9700	0.9687	0.9739	0.9699	0.9696	0.9750	0.9881	0.9917	0.9915	0.9902	0.9899	0.9918	0.9805
Netherlands	0.9816	0.9778	0.9744	0.9682	0.9694	0.9906	0.9924	0.9916	0.9950	0.9957	0.9955	0.9944	0.9940	0.9956	0.9869
Portugal	0.9900	0.9812	0.9810	0.9865	0.9831	0.9956	0.9932	0.9991	1.0000	1.0000	0.9999	0.9991	0.9984	0.9987	0.9933
Spain	0.9770	0.9746	0.9767	0.9823	0.9853	0.9890	0.9776	0.9749	0.9907	0.9904	0.9889	0.9836	0.9904	0.9918	0.9838
Switzerland	0.9609	0.9602	0.9582	0.9583	0.9592	0.9696	0.9675	0.9750	0.9860	0.9779	0.9814	0.9841	0.9840	0.9761	0.9713
United Kingdom	0.9193	0.8757	0.9828	0.9825	0.9850	0.9926	0.9933	0.9897	0.9777	0.9796	0.9761	0.9633	0.9277	0.9440	0.9635
US	0.9679	0.9626	0.9548	0.9536	0.9483	0.9556	0.9707	0.9652	0.9671	0.9640	0.9617	0.9783	0.9730	0.9778	0.9643
Total	0.9703	0.9645	0.9637	0.9658	0.9634	0.9697	0.9779	0.9746	0.9783	0.9769	0.9758	0.9839	0.9813	0.9845	0.9736
US															
US	0.9301	0.9291	0.9377	0.9284	0.9240	0.9198	0.9359	0.9461	0.9414	0.9442	0.9404	0.9471	0.9408	0.9399	0.9361
Total	0.9301	0.9291	0.9377	0.9284	0.9240	0.9198	0.9359	0.9461	0.9414	0.9442	0.9404	0.9471	0.9408	0.9399	0.9361
EU															
Austria	0.9158	0.9392	0.9968	0.9962	0.9983	0.9991	0.9957	0.9899	0.9900	0.9873	0.9915	0.9935	0.9921	0.9956	0.9844
Belgium	0.8771	0.8238	0.8966	0.9237	0.8975	0.9833	1.0000	0.9120	0.9590	0.9949	0.9838	0.9611	0.9958	0.9977	0.9433
Denmark	0.9897	0.9827	0.9898	0.9873	0.9905	0.9942	0.9972	0.9954	0.9964	0.9970	0.9978	0.9985	0.9974	0.9982	0.9937
Finland	0.9955	0.9952	0.9909	0.9963	0.9955	0.9940	0.9937	0.9883	0.9867	0.9893	0.9904	0.9904	0.9954	0.9869	0.9920
France	0.9893	0.9853	0.9845	0.9904	0.9879	0.9883	0.9899	0.9879	0.9878	0.9877	0.9880	0.9883	0.9901	0.9941	0.9885
Germany	0.9700	0.9719	0.9811	0.9844	0.9844	0.9904	0.9923	0.9909	0.9936	0.9933	0.9937	0.9936	0.9942	0.9958	0.9878
Ireland	0.9797	0.9703	0.9573	0.9636	0.9929	0.9634	0.9644	0.9560	0.9653	0.9518	0.9636	0.9572	0.9739	0.9675	0.9662
Italy	0.9720	0.9777	0.9876	0.9926	0.9884	0.9859	0.9784	0.9761	0.9755	0.9648	0.9600	0.9637	0.9694	0.9938	0.9776
Netherlands	0.9878	0.9833	0.9816	0.9789	0.9747	0.9913	0.9953	0.9958	0.9971	0.9956	0.9939	0.9961	0.9965	0.9875	0.9897
Portugal	0.9895	0.9858	0.9826	0.9850	0.9935	0.9958	0.9954	1.0000	0.9995	0.9965	0.9999	1.0000	0.9979	0.9984	0.9943
Spain	0.9916	0.9794	0.9815	0.9856	0.9904	0.9935	0.9856	0.9838	0.9913	0.9896	0.9904	0.9912	0.9904	0.9948	0.9885
Switzerland	0.9768	0.9789	0.9742	0.9822	0.9786	0.9862	0.9818	0.9787	0.9815	0.9718	0.9742	0.9708	0.9730	0.9703	0.9771
United Kingdom	0.9165	0.9009	0.9827	0.9824	0.9859	0.9938	0.9904	0.9792	0.9811	0.9835	0.9821	0.9645	0.9569	0.9628	0.9689
Total	0.9744	0.9732	0.9814	0.9851	0.9857	0.9903	0.9902	0.9878	0.9909	0.9898	0.9902	0.9898	0.9908	0.9933	0.9866

Table A2 Mean metatechnology technical efficiency non-life

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2002–2015
Global															
Austria	0.9661	0.9621	0.9452	0.9482	0.9753	0.9411	0.9535	0.9381	0.9484	0.9611	0.9532	0.8897	0.9390	0.9108	0.9451
Belgium	0.9777	0.9375	0.9698	0.9803	0.9833	0.9712	0.9723	0.9810	0.9780	0.9848	0.9853	0.9826	0.9918	0.9900	0.9773
Denmark	0.9764	0.9304	0.9509	0.9870	0.9912	0.9738	0.9871	0.9758	0.9683	0.9728	0.9867	0.9783	0.9839	0.9891	0.9751
Finland	0.9649	0.9330	0.9530	0.9714	0.9806	0.9605	0.9823	0.9787	0.9818	0.9808	0.9758	0.9680	0.9756	0.9819	0.9706
France	0.9334	0.9235	0.9443	0.9728	0.9744	0.9640	0.9750	0.9781	0.9816	0.9787	0.9780	0.9756	0.9754	0.9758	0.9665
Germany	0.9602	0.9425	0.9577	0.9693	0.9768	0.9637	0.9738	0.9731	0.9785	0.9771	0.9786	0.9698	0.9780	0.9757	0.9696
Ireland	0.9516	0.9384	0.9469	0.9120	0.9155	0.9226	0.9475	0.9425	0.9476	0.9608	0.9608	0.9451	0.9529	0.9720	0.9440
Italy	0.9568	0.9486	0.9505	0.9885	0.9938	0.9875	0.9943	0.9943	0.9945	0.9921	0.9881	0.9598	0.9852	0.9808	0.9796
Netherlands	0.9618	0.9526	0.9428	0.9759	0.9808	0.9438	0.9706	0.9626	0.9616	0.9445	0.9621	0.9579	0.9707	0.9779	0.9618
Portugal	0.9609	0.9573	0.9755	0.9966	0.9910	0.9687	0.9869	0.9820	0.9905	0.9936	0.9926	0.9943	0.9967	0.9944	0.9844
Spain	0.9681	0.9704	0.9693	0.9825	0.9850	0.9812	0.9848	0.9852	0.9848	0.9810	0.9770	0.9842	0.9768	0.9737	0.9789
Sweden	0.9797	0.9743	0.9827	0.9876	0.9855	0.9758	0.9831	0.9865	0.9892	0.9799	0.9814	0.9809	0.9846	0.9828	0.9824
Switzerland	0.9561	0.9578	0.9698	0.9864	0.9820	0.9808	0.9852	0.9794	0.9863	0.9751	0.9909	0.9770	0.9899	0.9826	0.9785
United Kingdom	0.9313	0.9231	0.9401	0.9495	0.9519	0.9467	0.9610	0.9577	0.9639	0.9641	0.9709	0.9744	0.9709	0.9663	0.9552
US	0.9845	0.9077	0.9301	0.9659	0.9818	0.9845	0.9818	0.9827	0.9857	0.9835	0.9846	0.9869	0.9874	0.9854	0.9737
Total	0.9735	0.9218	0.9402	0.9672	0.9786	0.9765	0.9789	0.9789	0.9821	0.9800	0.9817	0.9812	0.9833	0.9813	0.9718
US															
US	0.9343	0.9368	0.9242	0.9013	0.9118	0.8990	0.9127	0.9112	0.9086	0.8825	0.9003	0.8967	0.9025	0.8919	0.9082
Total	0.9343	0.9368	0.9242	0.9013	0.9118	0.8990	0.9127	0.9112	0.9086	0.8825	0.9003	0.8967	0.9025	0.8919	0.9082
EU															
Austria	0.9032	0.8479	0.8881	0.8840	0.9460	0.9070	0.8327	0.8437	0.8634	0.8834	0.8661	0.8843	0.9088	0.8737	0.8809
Belgium	0.9288	0.9014	0.9111	0.9454	0.9356	0.9468	0.9258	0.9579	0.9602	0.9733	0.9633	0.9583	0.9625	0.9590	0.9446
Denmark	0.9317	0.9090	0.9547	0.9578	0.9720	0.9614	0.9785	0.9653	0.9701	0.9698	0.9600	0.9646	0.9673	0.9746	0.9601
Finland	0.9622	0.9734	0.9621	0.9694	0.9782	0.9744	0.9831	0.9590	0.9598	0.9524	0.9605	0.9454	0.9495	0.9646	0.9638
France	0.9198	0.9369	0.9308	0.9414	0.9581	0.9610	0.9619	0.9650	0.9588	0.9637	0.9595	0.9561	0.9623	0.9623	0.9526
Germany	0.9141	0.9174	0.9239	0.9381	0.9466	0.9475	0.9422	0.9566	0.9520	0.9563	0.9521	0.9537	0.9583	0.9580	0.9441
Ireland	0.9305	0.9130	0.9107	0.8961	0.9124	0.9204	0.8917	0.9582	0.9414	0.9500	0.9045	0.9059	0.9174	0.9245	0.9196
Italy	0.9043	0.8863	0.9260	0.9660	0.9832	0.9691	0.9705	0.9837	0.9799	0.9885	0.9692	0.9580	0.9750	0.9846	0.9601
Netherlands	0.9364	0.9513	0.9369	0.9470	0.9558	0.9114	0.9175	0.9267	0.9141	0.9129	0.9340	0.9312	0.9284	0.9430	0.9321
Portugal	0.8837	0.9199	0.9326	0.9700	0.9696	0.9785	0.9764	0.9706	0.9585	0.9683	0.9655	0.9696	0.9781	0.9775	0.9585
Spain	0.9484	0.9672	0.9591	0.9755	0.9813	0.9794	0.9718	0.9738	0.9684	0.9655	0.9580	0.9651	0.9630	0.9561	0.9663
Sweden	0.9473	0.9516	0.9671	0.9731	0.9519	0.9432	0.9341	0.9523	0.9459	0.9494	0.9565	0.9837	0.9885	0.9588	0.9572
Switzerland	0.9438	0.9497	0.9656	0.9840	0.9843	0.9880	0.9831	0.9841	0.9796	0.9888	0.9909	0.9710	0.9882	0.9816	0.9771
United Kingdom	0.8965	0.9136	0.9173	0.9347	0.9489	0.9194	0.9237	0.9401	0.9339	0.9380	0.9485	0.9444	0.9527	0.9458	0.9329
Total	0.9216	0.9272	0.9329	0.9476	0.9566	0.9495	0.9457	0.9578	0.9527	0.9565	0.9533	0.9530	0.9586	0.9563	0.9478

Figure A1 Convergence towards 1 with different rates of adjustment (δ)



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