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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 envelopment analysis in samples for the U.S. and EU from 2002 to 2015. This result may emphasize that, contrary to findings of previous literature, the dominance of the two organizational forms declines over time. Recent changes in the economic environment (for example, elimination of state aids for the mutual organizational form and introduction of risk-based capital standards) may explain this result. Unlike previous studies focusing on the expense preference and efficient structure hypotheses, I consider the dynamics of stock and mutual insurers' technology and efficiency.

Keywords: Organizational form · Efficiency · Metafrontier data envelopment analysis · Insurance

JEL classification: D23 · G22 · L23

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1 Introduction

The efficiency implication of the organizational form is a subject of great interest in the literature. Particularly in a long-term perspective, this question is important because the coexistence of both forms is presumably advantageous for the market as a whole (Michie & Llewellyn, 2010; Broek, Buiskool, Grijpstra, & Plooij, 2011); for example, mutual insurers are assumed to perform better during crises. In the past, some states in the United States (US) and some countries in the European Union (EU) even supported mutual insurers by requiring less capital and offering tax incentives (Zanjani, 2007; Broek et al., 2011). Prior insurance literature (see, e.g., Braun, Schmeiser, & Rymaszewsk (2015) for a recent review) found much empirical support during the 1980s and 1990s for the hypothesis that the stock and mutual organizational forms are each dominant in different market segments, leading to the conclusion that the two forms apply different production technologies (i.e., the efficient structure hypothesis, or ESH).[1] Conversely, the hypothesis that the stock organizational form is—in direct comparison with the mutual form—dominant in terms (cost) efficiency (i.e., the expense preference hypothesis, EPH) has not gained much empirical support.

Since the 1990s, the economic context for stock and mutual insurers has changed in the two largest insurance markets—the U.S. and EU—giving rise to expect changes particularly in the way mutual insurers operate (Broek et al., 2011). The EU has begun to eliminate state aids (e.g., tax incentives, lower capital requirements) for the mutual organizational form in 2000. Also, the U.S. has largely aligned the solvency regulations for the two organizational forms (Zanjani, 2007). These actions were taken to level the organizational playing field. Furthermore, the increased focus on risk-based capital requirements—in place in the U.S. since the early 1990s—in the EU under Solvency II gives insurers incentives 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 economies of scale and scope. Moreover, the operating environment, especially in the EU, has become more homogenous due to reduced trade barriers through the European Internal Market (Cummins, Rubio-Misas, & Zi, 2016). In addition, developments such as low interest rates and market saturation have 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 use of stock and mutual insurers with special attention to the relevant developments in the operating environment. By considering the changed economic environment, I hypothesize that mutual

[1] *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'Donnell, Rao, & Battese, 2008).

and stock insurers' production processes converge over time (i.e., the convergence hypothesis). In samples for the U.S. 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, Rao, & Battese, 2008; Cummins et al., 2016). Metatechnology efficiency is the ratio of efficiency measured against a common benchmark (the metafrontier) constituting insurers from both organizational forms to the efficiency measured against a group-specific benchmark. If efficiency levels from both frontiers are equal, the metatechnology ratio is 1, indicating that stock and mutual insurers use the same technologies. Conversely, levels lower than 1 indicate technology differences. β-convergence econometrically 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).

During the sample period, stock and mutual insurers on average close the gap between individual group frontiers and the common frontier particularly in the EU, revealing some support for my expectation of converging stock and mutual insurers' technologies. In the U.S. sectors, average 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 levels tend to persist until the end of the sample period. Nevertheless, the econometric results (β- and σ-convergence) suggest convergence in both the U.S. and EU. However, these results also indicate 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). Nevertheless, a significant degree of convergence as documented in this study might be the inevitable consequence of risk-based capital standards and the elimination of state protection of the mutual organizational form.

This study contributes a new hypothesis on how stock and mutual insurers operate in the insurance market; it also explains why both organizational forms continue to coexist. While existing theories can explain temporary variations in efficiency across organizational forms in the 1980s and 1990s, in the current operating environment the organizational forms may inevitably have to converge. Analyzing efficiency trends paints a more sustainable picture of firm efficiency because efficiency is not a 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. The remainder of the paper is organized as follows. In Section 2, I review the background and present my hypotheses. Section 3 presents the data and methodology. Section 4 discusses the empirical results and Section 5 concludes.

2 Background and hypothesis development

Prior literature has argued for the dominance of organizational forms in terms of efficiency subject to different reasoning.[2] The EPH states that mutual insurers will be less (cost) efficient than stock insurers due to their weaker control mechanisms of the firm management (Cummins et al., 2004). Whilst the EPH is appealing from a theoretical point of view, it has not gained much empirical support. Evidence for this hypothesis is rather scarce (see, e.g., Cummins, Weiss, & Zi, 1999; Erhemjamts & Leverty, 2010) and most of the literature either finds no support (see, e.g., Gardner & Grace, 1993; Cummins & Zi, 1998; Cummins et al., 2004; Biener & Eling, 2012) or 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 explain 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). The two organizational forms arguably produce different insurance outputs and 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 (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 (Cummins et al., 1999). In contrast to the EPH, the ESH has 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 U.S. property/liability (p/c) insurers from 1981 to 1991. Cummins et al. (2004) also find support for the hypothesis in a sample of all licensed Spanish insurers from 1989 to 1997: the authors therefore conclude that stock and mutual insurers tend to operate on separate production, cost, and revenue frontiers.

If stock and mutual insurers continue to produce different outputs (e.g., dominance in different market segments continues in line with the ESH), I do not expect convergence but rather the dominance of different technologies, which is my initial hypothesis (H1a):

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

[2] Agency theory has been the central consideration for the efficiency discussion of insurers 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 (Biener & Eling, 2012).

Although the ESH has gained much empirical support in early studies, in more recent samples for the Northern American and European markets for 2002–2006, Biener and Eling (2012) can find support only 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). 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. Since the 1990s, 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 contribute to convergence of the two organizational forms (Broek et al., 2011).[3] Table 1 provides an overview of the most important changes for the two largest insurance markets—the EU and US. These changes will be discussed in more detail.

3 The goal of this paper is not to identify the direct causes (economic changes) of convergence trends, if any, as, to my knowledge, no methodological framework is available to realize this. Rather, as previous literature on convergence (e.g., Casu & Girardone, 2010; Cummins et al., 2016), the goal is to detect convergence trends and to present theoretical considerations that may explain convergence in a specific period. However, this also means that if any convergence trends can be observed, the direct causes/importance of the causes remain undetected, which is one of the main limitations of this analysis. Since it is also difficult to assess how the presented arguments affect individual states/countries and how this in turn affects the results for the US and EU, I consider country-fixed effects in all econometric analyses (see also Footnote 4).

Table 1 Overview of Changing Economic Context

Change	Specification
Alignment of legislation for mutual and stock insurers to create a level playing field for every organizational form.	US: Gradual elimination of solvency requirement differentials between stock and mutual insurers. By 2000, only two states in the U.S. still had preferential solvency requirements for mutual insurers (Zanjani, 2007). EU: Harmonization of legislation at the EU level and various rulings to eliminate state aids for the mutual organizational form since the turn of the millennium (e.g., tax advantages, less rigorous solvency regulation) which were previously granted by national laws (Broek et al., 2011).
Introduction of risk-based capital requirements to promote diversification of investments and lines of businesses.	US: Introduction of the Risk-Based Capital (RBC) system for life insurers in 1993, p/c insurers in1994, and health insurers in 1998. EU: Launching of the formal legislative process for Solvency II in 2007 with a transition period starting in 2016.
Creation of a unified European market to increase competition, diversification, enhance products and services, and increase pressure on prices and profit margins.	EU: Introduction of the EU Internal Market in 1993, which has caused convergence in the European market (Cummins et al., 2016).

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

[4] For example, France, Luxembourg, and Belgium had significantly favored mutual insurers over stock insurers (Broek et al., 2011). All three countries account for a major part of the insurance business written by mutual insurers in the EU (ICMIF, 2016). Since information for other countries are hard to obtain and/or the situation may differ among countries, I control for country fixed effects in the later econometric analyses.

Probably the most important action was the elimination of preferential solvency requirements for mutual insurers (Mossialos & Thomson, 2009; Broek et al., 2011).[5] Similar to the EU case, the latest capital regulations in the U.S. have largely ceased to differentiate between organizational forms (for a detailed 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 the same operating conditions.

The aspiration to create a level playing field is expected to have significant implications for mutual insurers' operations. Zanjani (2007) shows that the evolution of the organizational forms in the U.S. life insurance sector depended on the solvency regulation in place. The mutual form could only dominate in states where the capital requirements were favorable. Because equity capital is one of the central inputs in insurer efficiency measurement (Cummins & Weiss, 2013), lower capital requirements represent a major efficiency advantage. Thus, mutual insurers could *ceteris paribus* even afford managerial slack (e.g., due to expense preference behavior) without being identified as an inefficient organizational form. However, this advantage has been eliminated and mutual insurers can now be benchmarked with stock insurers and are consequently exposed to their competition.

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 (Broek et al., 2011). However, particularly due to Solvency II, for which the formal legislative process was launched in 2007 and which took effect in January 2016, a specialization only one or a few 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 must hold more equity than diversified insurers.[8] In addition, the RBC system in the U.S. promotes diversification by assuming correlations among business lines less than one. Given that diversified insurers must hold 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 that mutual insurers are especially eager to expand their businesses (e.g., mergers & acquisitions (M&A), strategic

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5 For example, mutual insurers in France had operated under the special Code de la Mutualité, which generally led 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 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 insurers 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 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 Companies D and E together which have only 100 premium income in motor and liability, respectively.

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.) to offer competitive prices and to attain attractive and healthy output (Broek et al., 2011), especially since 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 skim off 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, a convergence of the production technologies of both organizational forms can be expected (Broek et al., 2011). Such a process would go hand in hand with the 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 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 with a different economic context (see, e.g., Zanjani, 2007), they may have to either demutualize or orient towards stock insurers' operations to cope with the changed economic context and to avoid being crowded out of the market (Broek et al., 2011). A.M. Best (2012) shows that the performance of stock and mutual insurers in the U.S. p/c sector was directionally aligned in 2001–2011; insurers stood out in terms of operating performance and capitalization regardless of the organizational form. Today, not all mutual insurers are small-scaled and niche-market players—some mutual insurers have large organizations offering a broad range of products and services (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., International Cooperative and Mutual Insurance Federation (ICMIF), 2016; Federal Insurance Office, 2016). Based on this discussion, H1a may subside over time in the new economic context.

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9 Expanding business is also important for mutual insurers to raise capital as they are limited in using capital markets (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.

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.

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 global insurance markets. Hence, I consider life and non-life insurers that are domiciled in the U.S. and the EU (including countries from the European Economic Area and Switzerland). Merging the U.S. and EU life and non-life samples yields samples for the global insurance markets (Biener & Eling, 2012).[12] I extract data for 2002–2015 from two sources for accounting information. The data for the U.S. 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); the data for these insurers is lopsided in the ISIS database for a significant part of the sample period.[13] Due to data availability, the Czech Republic, Greece, Hungary, Iceland, Latvia, Lithuania, Luxembourg, Poland, Slovakia, and Slovenia cannot be considered. Due to data availability, Canada cannot be considered; this would have allowed a creation of a Northern American sample as in Biener and Eling (2012). 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 and only firms, which do not change their organizational form during the sample period are considered.[14] All absolute values in the samples are 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.

I differentiate the sample insurers by organizational form (stock or mutual). Additionally, 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 whose organizational form is unknown. Furthermore, I exclude insurers in run-off,

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[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 assumes 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] In fact, the data for 2002–2013 is directly obtained from A.M. Best and the data for 2014 and 2015 stems from Bureau van Dijk's orbis insurance focus database, which relies on A.M. Best as data provider. The data is matched by the A.M. Best identification number.

[14] Otherwise, the results could be biased by stock/mutual insurers, which leave the market or prepare for (de)mutualization. For example, a mutual insurer that cannot catch-up to the common benchmark and either leaves the market or demutualizes would bias the results towards convergence; McNamara and Rhee (1992) show that increased efficiency can be the result of demutualization. In a robustness test, I also run the econometric analyses for an unbalanced sample, the results of which are consistent with the conclusions presented in this paper and are available from the author upon request.

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 detailed in the following—as well as key firm characteristics.

Table 1 Summary statistics

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
U.S.																			
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 of the choice of inputs for efficiency analyses (Eling & Luhnen, 2010). I therefore 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 state-specific wage rates from the U.S. Department of Labor. The wage rates are provided separately 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 wage 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 approaches are frequently used in the insurance literature (Cummins & Weiss, 2013). The main advantage of the nonparametric approach is that it is less vulnerable to specification errors (Biener et al., 2016). Consequently, 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:

$$TE_j = \min \theta_j \text{, s.t. } \lambda_j X \le \theta_j x_j \text{ , } \lambda_j Y \ge y_j \text{ , } \lambda_j \ge 0 \; (j = 1,2,3......N) \text{ .} \qquad (1)$$

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):

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

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., between the stock and mutual organizational forms) and depicts the level of homogeneity between them (Cummins et al., 2016).[15] MTE ratios of 1 suggest that the efficiency of stock and mutual insurers is not affected by the choice of the frontier (i.e., common vs. group frontier) indicating that the two organizational forms use identical technologies. Because differences in efficiency between the individual stock and mutual frontiers may be attributable to different sample sizes, I follow Cummins et al. (2004) and Biener and Eling (2012) to build size-stratified samples. Thus, each year I sort stock and mutual insurers into small, medium, and large quantiles and then randomly draw several stock insurers from the complete sample that equals the number of mutual insurers in each size quantile. To ensure robust findings, I run 200 iterations of the random selection of stock insurers (Biener & Eling, 2012). Because the econometric analyses in 3.2.2 involve the usage of lagged values, I calculate average values per year and firm based on the iterations.

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[15] One requirement for the metatechnology efficiency methodology is that the groups of firms can 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 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).

3.2.2 Trends in technology usage

I analyze trends in technology usage (i.e., the methods and processes to produce outputs from inputs) over time by analyzing the developments of stock and mutual insurers' MTE ratios based on three criteria (Casu & Girardone, 2010; Cummins et al., 2016). These 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). The advantage of these concepts is that they consider the underlying dynamics of technology development during the sample period from which projections for the out-of-sample development could also be drawn. β-convergence is analyzed, as illustrated in Equation (3):

$$\Delta E_{j,t} = \alpha_0 + \alpha_1 Mutual + \beta_1(\ln MTE_{j,t-1}) + \beta_2(\ln MTE_{j,t-1}) \times Mutual + \rho\Delta E_{j,t-1} + \varepsilon_{j,t}\,. \tag{3}$$

$\Delta E_{j,t} = \ln(MTE_{j,t}) - \ln(MTE_{j,t-1})$, $MTE_{j,t}$ ($MTE_{j,t-1}$) is the MTE ratio of insurer j at time t $(t-1)$, $Mutual$ is a binary variable taking the value 1 if insurer j is a mutual and 0 if it is a stock, $\varepsilon_{j,t}$ 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 the tendency of convergence. To control for differences among stock and mutual insurers, Equation (3) considers an interaction term. I estimate Equation (3) with and without a lagged dependent variable (Casu & Girardone, 2010).

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

$$\Delta V_{j,t} = \alpha_0 + \alpha_1 Mutual_j + \sigma_1 V_{j,t-1} + \sigma_2 V_{j,t-1} \times Mutual_j + \rho\Delta V_{j,t-1} + \varepsilon_{j,t}\,. \tag{4}$$

$V_{j,t} = \ln(MTE_{j,t}) - \ln(\overline{MTE_t})$, $\overline{MTE_t}$ 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 value of this parameter implies convergence; the greater the value the greater is the rate of convergence. I also estimate Equation (4) with and without the 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 Appendix A):

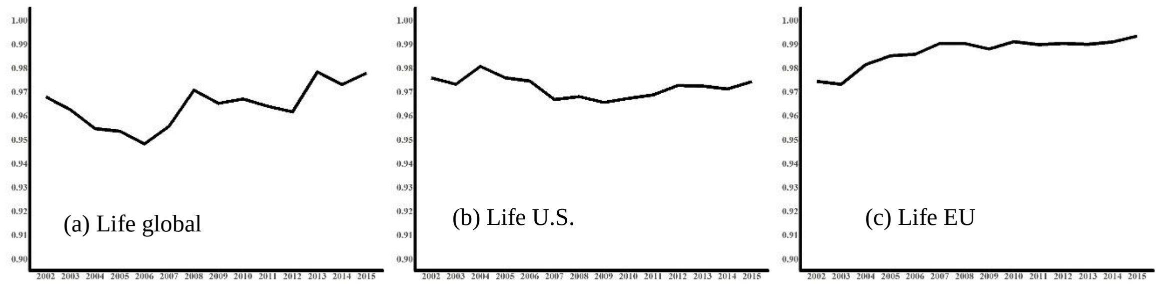
$$MTE_{j,t} = \gamma_1 + \gamma_2 Mutual_j + \gamma_3 MTE_{j,t-1} + \gamma_4 MTE_{j,t-1} \times Mutual_j + \varepsilon_{j,t}\,. \tag{5}$$

$\delta_S = (1-\gamma_3)$ for stock insurers and $\delta_M = (1-\gamma_3-\gamma_4)$ for mutual insurers, which capture the adjustment rate towards the state of identical production processes. The higher the value of δ, the greater the rate of convergence. Conversely, a lower or negative value implies lack of convergence or persistence of differences (Casu & Girardone, 2010; Lin & Kao, 2014).

4 Empirical results

Figure 1 presents the development of mean MTE ratios for 2002–2015 in the life sector. Figure 2 presents those ratios in the non-life sector. Appendices B and C 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 offer several important insights. First, although the MTE ratios are lower than 1, they are considerably high, indicating only minor technology differences between stock and mutual insurers during the sample period. Cummins et al. (2016), for example, document 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. In the U.S. life sample, the yearly mean MTE ratios seem to remain high except for minor fluctuations. Interestingly, in 2005, the MTE ratios in the EU exceeded the levels for the U.S. sample.

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



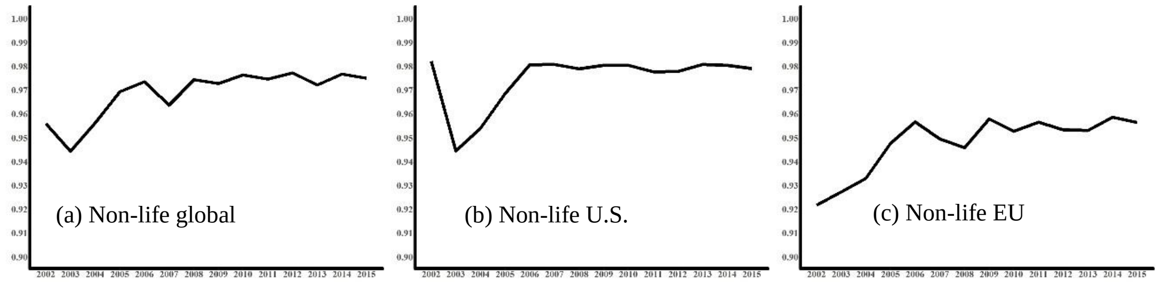
Notes: Figure 1 shows the mean MTE ratios for 2002–2015 in the life sector.

For the non-life sector, Figure 2 reveals that the MTE ratios tend to hover around 0.98 in the US sample apart from a drop in 2003–2005. The drop is traceable to a disproportionate increase, mainly in the labor input factor of the mutual insurers compared to the stock insurers in the sample. A.M. Best (2012) documents a significant divergence in stock and mutual insurers' expense ratios and net written premiums, which is relevant for the calculation of the labor input, during this period; output change remained comparable between the two organizational forms.

In the EU sample, the ratios throughout the sample period are significantly lower but increase considerably. Likewise, the MTE ratios increase in the global non-life sample; the drop in 2003–2005 in this sample seems to have been driven by the US insurers. The effect in the global sample in 2002 appears to be more intense as it captures both the convergence of EU non-life insurers and the temporary divergence of US insurers in the MTE measurement.

The results from the US market might be regarded as a 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 were present in this market since the early 1990s and the MTE ratios do not change much during the sample period, except for the mentioned drop. This would suggest that convergence might not be perfectly (i.e., MTE ratios of 1) attributable to persistent differences between stock and mutual insurers—for example, the speed of raising new capital.

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



Notes: Figure 2 shows the mean MTE ratios for 2002–2015 in the non-life sector.

Taken together, the results from the graphical analysis are first preliminary evidence of some convergence 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 the tests for 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_1	-0.1791***	-0.2210***	-0.3679***	-0.1586***	-0.1885***	-0.3999***
	(0.0072)	(0.0115)	(0.0122)	(0.0072)	(0.0125)	(0.0103)
β_2	-0.0748	0.1603	0.2256***	-0.0011	0.1505	0.2715***
	(0.2204)	(0.1003)	(0.0723)	(0.2085)	(0.1007)	(0.0542)
ρ				-0.2113***	-0.1359***	-0.0533***
				(0.0132)	(0.0187)	(0.0126)
α_0	-0.0024	-0.0070***	0.0002	-0.0018	-0.0059***	0.0008
	(0.0115)	(0.0009)	(0.0058)	(0.0111)	(0.0009)	(0.0043)
α_1	-0.0748	0.1603	0.2256***	-0.0011	0.1505	0.2715***
	(0.2204)	(0.1003)	(0.0723)	(0.2085)	(0.1007)	(0.0542)
N	5,590	2,910	2,671	5,159	2,683	2,462
Adj. R^2	0.0977	0.1124	0.2554	0.1642	0.1279	0.4123
Non-life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
β_1	-0.4710***	-0.4891***	-0.3512***	-0.4745***	-0.4895***	-0.2907***
	(0.0079)	(0.0105)	(0.0113)	(0.0053)	(0.0070)	(0.0123)
β_2	0.3878***	-0.0043	0.1069***	0.3797***	-0.0062	0.0984***
	(0.0210)	(0.0466)	(0.0307)	(0.0125)	(0.0273)	(0.0301)
ρ				0.0370***	0.0425***	-0.2304***
				(0.0053)	(0.0069)	(0.0141)
α_0	-0.0311***	-0.0171***	-0.0495***	-0.0321***	-0.0122***	-0.0371***
	(0.0073)	(0.0007)	(0.0078)	(0.0044)	(0.0004)	(0.0077)
α_1	0.0139***	0.0120***	0.0063**	0.0058***	0.0069***	0.0031
	(0.0012)	(0.0012)	(0.0027)	(0.0007)	(0.0008)	(0.0027)
N	11,830	7,139	4,421	10,915	6,509	4,017
Adj. R^2	0.2295	0.2429	0.1887	0.4718	0.4960	0.2452

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 stock insurers (β_1) in the global sample as well as in the individual US and EU samples. This result holds for the life and non-life sector and is also robust across the two models (i.e., Equation (3) with and without lagged dependent variable). Table 2 suggests differences in β-convergence among stock and mutual insurers in the EU non-life sample as well as the global and EU life samples as the coefficient of the interaction term (β_2) is significant in the respective regression models. The corresponding β-coefficients for mutual insurers $(\beta_1 + \beta_2)$ are still negative in all cases but are lower than the ones for stock insurers. Overall, the results provide evidence for β-convergence suggesting that stock and mutual insurers that have the largest gaps in MTE ratios show higher catch-up growth than insurers with smaller technology gaps (see, e.g., Cummins et al., 2016). Thus, the analysis of β-convergence supports H1b; especially, lagging stock and mutual insurers (probably, small niche players) catch up to the common frontier. However, the results also show that mutual insurers have lower β-convergence than stock insurers in some market segments. Thus, in a longer-term perspective the identified convergence trend could produce a dominance situation if stock insurers on average show consistently higher catch-up effects than mutual insurers. The differences in β-convergence may also indicate the persistence of some differences among organizational forms.

Table 3 shows the results for σ-convergence, which measures whether stock and mutual insurers' MTE ratios converge towards the common average. Table 3 reports a consistently negative and significant σ-coefficient for stock insurers (σ_1) in all samples (global, US, EU) for the life and non-life sectors and for the two models. For mutual insurers, a different σ-coefficient (as indicated by a significant σ_2) is revealed only in the EU life and in the global and EU non-life samples. Although the corresponding coefficients $(\sigma_1 + \sigma_2)$ are lower than for stock insurers, they are all still negative, providing evidence for convergence. Thus, the results suggest that the dispersion of MTE ratios around the common averages decreased during the sample period. This reduced dispersion also supports the expectation of converging technologies of stock and mutual insurers (H1b). However, as discussed for β-convergence, the lower σ-coefficient of mutual insurers in some market segments suggests the need for further monitoring.

Table 3 σ-convergence of MTE

Coefficients	Equation (4) without lagged dependent variable			Equation (4)		
Life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
σ_1	-0.1799***	-0.2199***	-0.3758***	-0.1596***	-0.1877***	-0.3977***
	(0.0072)	(0.0114)	(0.0124)	(0.0072)	(0.0125)	(0.0106)
σ_2	0.0325	0.1582	0.2232***	0.0594	0.1456	0.2092***
	(0.1283)	(0.0994)	(0.0597)	(0.1203)	(0.0994)	(0.0468)
ρ				-0.2110***	-0.1356***	-0.0512***
				(0.0132)	(0.0187)	(0.0127)
α_0	0.0014	-0.0006	0.0038	0.0007	-0.0005	0.0042
	(0.0114)	(0.0008)	(0.0057)	(0.0110)	(0.0008)	(0.0043)
α_1	0.0018	0.0004	0.00004	-0.0011	0.0003	-0.0008
	(0.0035)	(0.0031)	(0.0011)	(0.0033)	(0.0032)	(0.0008)
N	5,590	2,910	2,671	5,159	2,683	2,462
Adj. R^2	0.0988	0.1118	0.2578	0.1649	0.1273	0.4027
Non-life	*Global*	*US*	*EU*	*Global*	*US*	*EU*
σ_1	-0.4731***	-0.4793***	-0.3530***	-0.4686***	-0.4879***	-0.2847***
	(0.0081)	(0.0106)	(0.0115)	(0.0057)	(0.0072)	(0.0124)
σ_2	0.3495***	-0.0179	0.1115***	0.3350***	0.0415*	0.0894***
	(0.0187)	(0.0380)	(0.0298)	(0.0118)	(0.0231)	(0.0293)
ρ				0.0134**	0.0253***	-0.2343***
				(0.0057)	(0.0071)	(0.0141)
α_0	-0.0179***	-0.0040***	-0.0334***	-0.0231***	-0.0021***	-0.0248***
	(0.0068)	(0.0006)	(0.0077)	(0.0044)	(0.0004)	(0.0076)
α_1	0.0028***	0.0121***	0.00003	-0.0052***	0.0062***	-0.0024
	(0.0011)	(0.0012)	(0.0024)	(0.0007)	(0.0008)	(0.0024)
N	11,830	7,139	4,421	10,915	6,509	4,017
Adj. R^2	0.2269	0.2381	0.1864	0.4405	0.4841	0.2432

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.

Despite the evidence for β- and σ-convergence, I analyze whether the MTE ratios converge towards 1 as this result would indicate that stock and mutual insurers come to use 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_3-coefficients for stock insurers in all samples of the life and non-life sectors. For the US and EU non-life as well as the global and EU life samples, Table 4 reports a significant coefficient of the interaction term (γ_4) indicating differences between stock and mutual insurers. The corresponding coefficients for mutual insurers $(\gamma_3 + \gamma_4)$ are still positive but higher than for stock insurers; in the partial adjustment model, a higher coefficient indicates slower adjustment. Nevertheless, the coefficients for both stock and mutual insurers correspond to positive δ-values $(\delta_S = 1 - \gamma_2; \delta_M = 1 - \gamma_2 - \gamma_3)$ consistently indicating convergence towards 1 but the higher δ_S-values suggest higher convergence rates of stock insurers (refer to Appendix D). In addition, although the results from partial adjustment model propose convergence towards identical production processes (i.e., MTE ratios of 1), observations from the graphical analysis and theoretical arguments suggest 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	0.1623***	0.1982***	0.3449***	0.4190***	0.4395***	0.2850***
	(0.0107)	(0.0108)	(0.0126)	(0.0095)	(0.0100)	(0.0116)
γ_2	0.0905	-0.1401	-0.1975***	-0.3372***	0.0405	-0.0942***
	0.0905	-0.1401	-0.1975***	-0.3372***	0.0405	-0.0942***
γ_3	0.8356***	0.7958***	0.6555***	0.5534***	0.5456***	0.6741***
	(0.0068)	(0.0111)	(0.0118)	(0.0078)	(0.0103)	(0.0110)
γ_4	-0.0888	0.1441*	0.2001***	0.3490***	-0.0304	0.0997***
	(0.1632)	(0.0873)	(0.0637)	(0.0208)	(0.0416)	(0.0300)
N	5,590	2,910	2,671	11,830	7,139	4,421
Adj. R^2	0.7434	0.6452	0.5779	0.3946	0.3326	0.5359

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.

As a whole, the econometric results provide evidence for the convergence hypothesis (H1b) that the technologies of stock and mutual insurers converge over the long term 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. Whilst the average MTE ratios are high in the life sector throughout the sample period, they are notably lower in the EU non-life sector. The differences between life and non-life may be due to more degrees of freedom in the non-life sector (Huang & Eling 2013; Eling & Schaper, 2017). In addition, in some market segments the convergence rates differ among stock and mutual insurers. This may be because of some inherent differences between the organizational forms. In the EU, differences in the legal opportunities for M&A and cross-border activities 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; see, e.g., Biener & Eling, 2012). Thus, dominance/convergence among stock and mutual insurers should be further monitored and analyzed. 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 compelled to progressively operate like stock insurers (e.g., takeover 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 efficiency levels for 2002–2015 in sectors of the US and EU insurance markets. These results suggest that in the changed operating environment (particularly, elimination of state aid for the mutual organizational form and introduction of risk-based capital standards) the two organizational forms converge. Especially, mutual insurers may have to orient towards the stock organizational form, which may increase the homogeneity among stock and mutual insurers.

However, as initially discussed, the direct causes of the convergence trends cannot be identified, which is a central limitation of many convergence studies. Particularly, the documented differences in the convergence movements among the organizational forms, geographical areas, as well as the life/non-life sectors, offer a variety of directions for future research. The relationship between the amount of competition, capital requirements and the development of efficiency could be analyzed across industries and countries (see, e.g., Matousek, Rughoo, Sarantis, & Assaf, 2015; Cummins et al., 2016). The study could be also expanded to analyze convergence in other insurance lines. Similar to other studies, the results presented here are limited by lack of data. Thus, it would be interesting to continue monitoring the development of stock and mutual insurers' efficiency once additional firm-year data becomes available. It would also be 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).

This analysis also emphasizes that future research should 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 regard, future research could, for example, analyze the resilience and response to endogenous/exogenous turmoil of stock and mutual insurers to arrive at further insights on situational dominance (see, e.g., Fukuyama, 1997; Tsionas, Assaf, & Matousek, 2015).

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Appendix A

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 full efficiency (Casu & Girardone, 2010):

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

Equation (A2) considers no disturbance term because it represents an equilibrium relation which renders the disturbance term redundant (Cheng & Weiss, 2012). Cheng and Weiss (2012) define partial adjustment models to analyze the adjustment speeds of stock and mutual insurers to desired capital structure. Equation (A3) recognizes that adjustment costs prevent each insurer from immediately achieving the desired level of efficiency. Thus, improving efficiency (i.e., eliminating inefficiency) is an adjustment process:

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

Equation (A3) considers a disturbance term as the adjustment process may be imperfect (Cheng & Weiss, 2012). $\delta = 1$ means that the insurer instantaneously adjusts to the desired efficiency level 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, must trade adjustment costs against the costs of operating inefficiently 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 of insurer i at time t is determined:

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

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:

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

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

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:

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

$\delta = (1-\gamma_2)$, $\delta_s = (1-\gamma_2-\gamma_4)$, and D_M is a binary variable which takes the value 1 if insurer j operates as mutual insurer. If γ_4 is significantly different from zero, mutual insurers adjust to the desired level of efficiency at different speed. If $\gamma_4 < 0$ then mutual insurers adjust more quickly to the desired level of efficiency. Equation (A5) can also be adopted to analyze convergence towards MTE ratios of 1.

Appendix B

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
U.S.	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
U.S.															
U.S.	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

Appendix C

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
U.S.	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
U.S.															
U.S.	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

Appendix D

Convergence towards 1 with different rates of adjustment (δ)