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The Impact of Capacity on Price and Productivity Change: New Firm-Level Evidence

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Abstract

We find evidence for the capacity-constraint hypothesis in a newly constructed sample of firm-level data for the German non-life insurance market over an extended period (1954–2016). Moreover, we show that the impact of capacity on price is complex and depends on various exogenous factors (interest rate change, catastrophes, GDP growth, and regulation). We also find that decreased firm capacity has a negative impact on productivity change. The dual impact of capacity is important since price and productivity change determine firm profitability. Our results yield important implications for the understanding of underwriting cycles and re-emphasize the role of capacity in the business of insurance.

Keywords: Capacity-constraint hypothesis · Underwriting cycle · Productivity

JEL classification: D24 · E39 · G22 · L11

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1 Introduction

Extant literature shows that prices and productivity fluctuate over time. Cyclical price patterns in the insurance industry are termed *underwriting cycles*.[1] The capacity-constraint hypothesis of Gron (1994) and Winter (1994) states that the price fluctuations are caused by shocks to capital that constrain capacity. Economic theory suggests that capacity determines not only prices but also productivity (Schultze, 1963). Furthermore, previous literature mentions that capacity depends on various exogenous factors (Doherty & Garven, 1995; Weiss, 2007; Berry-Stölzle & Born, 2010; Bruneau & Sghaeier, 2015). Browne and Hoyt (1995) document the importance of exogenous market and economic factors in the context of insurer financial distress, which is also closely related to capital. Browne and Hoyt (1992) find a cycle in excess returns in the property-liability insurance sector, which is closely correlated with the underwriting cycle. Understanding the role of capacity is thus central, especially given that the interplay of price and productivity determines firm profitability (Grifell-Tatjé & Lovell, 2015).

To date, there is no definitive conclusion on the causes of underwriting cycles. While the capacity-constraint hypothesis has gained much empirical support using industry data, the evidence from firm-level data is both limited and ambiguous. Cummins and Danzon (1997) cannot support the capacity-constraint hypothesis using firm-level data of U.S. general liability insurers in 1976–1987; the results show the opposite impact than expected. In contrast, Weiss and Chung (2004) find evidence for the capacity-constraint hypothesis in a sample of large U.S. property-casualty reinsurers in 1991–1995. Besides the lack of firm-level analyses over long periods in the literature on underwriting cycles, there is a need to analyze the determinants of the capacity-price relationship. In addition, there is still a limited understanding of the drivers of productivity change in the insurance sector and to our knowledge, the role of capacity has not yet been analyzed.[2]

The purpose of this article is to analyze the impact of capacity on prices and productivity change using firm-level data so that we can then explore the role of exogenous factors. We use a new sample of hand-collected data on 251 insurance companies from the German non-life market (excluding health) for 1954–2016 (6,027 firm-year observations). Our sample encompasses numerous interest rate changes, years with high catastrophic losses, periods of business contraction and expansion, and two regulatory regimes (pre- and post-deregulation in 1994); all of these factors are derived from the literature as relevant moderators. Thus, our sample allows us to explore the role of capacity in greater depth. Our approach also allows us to analyze determinants of both price and productivity change in a common sample. In addition, this study is the first firm-level analysis of productivity over such a long period in the insurance sector.

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1 See Meier and Outreville (2006) for an overview of the analyzed triggers.

2 Cummins and Xie (2013) provide some first side-results for the capacity-productivity relationship. The authors find the premiums-to-capital ratio as significant driver of productivity change. However, the authors do not disentangle firm and industry capacity and do not separately control for financial quality/leverage (see Section 2). Thus, the results in Cummins and Xie (2013) may also reflect implications of the risky-debt hypothesis.

We find support for the capacity-constraint hypothesis and show that both firm and industry capacity are relevant price determinants. Our results suggest that if firm and/or industry capacity is reduced, insurers tend to increase prices in the next period, probably to replenish their capital (Gron, 1994; Winter, 1994). We also find that the capacity-price relationship is moderated by exogenous factors. Specifically, prices are more sensitive to decreased capacity following interest rate declines, years with catastrophic losses, and negative GDP shocks. With regards to regulation, our results suggest that the impact of capacity on price was greater pre-deregulation. In addition, we find support for the risky-debt hypothesis of Cummins and Danzon (1997) suggesting that safer insurers can charge higher prices. Firm capacity is also a significant driver of productivity change; however, industry capacity seems to play no role in productivity development.

This study demonstrates that exogenous factors may not only by themselves influence the underwriting cycle—as demonstrated by previous literature (see Cummins & Outreville, 2006, for an overview)—but also moderate the impact of capacity. This result highlights that the role of capacity is complex, a finding that is also relevant for the discussion on whether cycles can be forecast. As reflected in annual assessments produced each year by many business consultants, underwriting cycles in insurance remain a critical factor in forecasting insurance firm performance and to effects on insurance consumers (see, e.g., Marsh, 2017; Swiss Re, 2017; Deloitte, 2018). The importance of capital and the impact of exogenous factors such as those included in our study are also reflected in such business analysis.[3] This reinforces the contribution of our study not only to the academic literature on insurance cycles, but also to relevant and timely discussions in the business of insurance.

The remainder of the paper is organized as follows. In Section 2, we discuss the background and derive our hypotheses. Section 3 presents the variables and data used for later regression analyses. Section 4 presents our methodology. Section 5 discusses the empirical results and Section 6 concludes.

[3] Marsh (2017) and Deloitte (2018) state that the current soft insurance cycle appears to be "mainly due to an overabundance of capital." Reflecting the importance of exogenous factors, Deloitte (2018) also notes that insurers face "a wide range of challenges. Not all of them are within the industry's control, such as rising interest rates and catastrophe losses." Deloitte (2018) adds that "regulation and compliance requirements are important and seem ever-changing." Finally, reflecting the recognition that both capital and productivity are important, Deloitte (2018) concludes that "insurers can take advantage of growth opportunities, operational improvement, and expense reduction in 2018 if they can overcome a host of internal and external obstacles standing in their way."

2 Background and hypotheses development

Economic theory posits that capacity is related to capital and that it is a mutual determinant of price and productivity (Schultze, 1963; Grifell-Tatjé & Lovell, 2015). A common capacity measure in insurance is the premiums-to-capital ratio (Higgins & Thistle, 2000; Bruneau & Sghaier, 2015) and price is commonly proxied by the loss or combined ratio because premiums per exposure are usually not publicly available (Harrington, Niehaus, & Yu, 2013). Since productivity cannot be observed, the insurance literature generally has agreed on using Malmquist indices to measure productivity change (Cummins & Weiss, 2013). To our knowledge, other methodologies to measure productivity have not been applied since they require price information in order to weigh inputs and outputs in a multidimensional framework (Grifell-Tatjé & Lovell, 2015). This information is usually not publicly available at the firm level.

An important consideration in the discussion of capacity in the insurance sector is the assumption that capital does not freely flow into the industry because firms tend to face transaction costs for raising capital (Cummins & Danzon, 1991).[4] Furthermore, empirical evidence initially suggests that the impact of capacity in the insurance sector changes over time and depends on a variety of exogenous factors. Berry-Stölzle and Born (2010) provide evidence that the regulatory environment affects the role of capacity constraints. In their analysis, lagged capital changes have a significant negative impact on premium change post- but not pre-deregulation. In contrast, Bruneau and Sghaier (2015) find that capacity constraints were not binding in 1995–2010 in the French property-liability insurance sector, a period that encompassed various regulatory changes in the European Union (EU). Further, literature suggests that the interest rate development (Doherty & Garven, 1995), catastrophic losses (see Weiss, 2007, for a review), and the general business cycle (Berry-Stölzle & Born, 2010) interact with capacity. Specifically, if adverse exogenous "shocks" increase the need to replenish capital, a stronger price/productivity reaction is expected.[5]

In the following, we review prior literature, describe the relationship between capacity and price/productivity change, and discuss the moderating role of exogenous factors that are derived from previous literature. We focus on moderation (i.e., interaction) and do not consider mediation because, based on prior literature, we expect the relationship between capacity and price/productivity to vary depending on the severity of the exogenous factors (see, e.g., Doherty & Garven, 1995). By contrast, meditation would assume that the exogenous factors intervene

4 The main consideration here is that costs of financing generally increase with asymmetric information, thus making external capital more costly than internal capital (Myers & Majluf, 1984). Therefore, firms tend to prioritize internal capital, then debt, and finally equity.

5 One may also argue that firm-specific shocks to capital (e.g., firm-specific loss shocks) encourage the insurer to raise prices in order to increase its capital base (Cummins & Danzon, 1997). However, whether the insurer can increase prices also depends on whether its financial quality is impaired; if it is, the insurer is unlikely to achieve higher prices if competitors' financial quality is unchanged and customers can freely change companies.

in or interrupt the relationship between capacity and price/productivity change. Table 1 summarizes the hypotheses that we develop and test in later regression analyses.

Table 1 Overview of hypotheses

The impact of capacity on price	
H1a:	Firm capacity is negatively related to price.
H1b:	Industry capacity is negatively related to price.
H1c:	Interest rate change, catastrophic losses, GDP growth, and the regulatory environment moderate the capacity-price relationship.
The impact of capacity on productivity change	
H2a:	Firm capacity drives productivity change but the direction of impact is ambiguous.
H2b:	Industry capacity drives productivity change but the direction of impact is ambiguous.
H2c:	Interest rate change, catastrophic losses, GDP growth, and the regulatory environment moderate the capacity-productivity change relationship.

The impact of capacity on price

If capacity is reduced and transactions costs for raising new external capital exist, insurers may raise prices to replenish capital internally (see Weiss, 2007, for a review of literature). Insurers facing higher transaction costs (e.g., agency costs) may show stronger price responses (Cummins & Danzon, 1991).[6]

To date, two theories have formalized the relationship between capital and price in the insurance sector. The capacity-constraint hypothesis (Gron, 1994; Winter, 1994) posits that prices are inversely related to industry capacity. If capacity (industry capital) is reduced (e.g., through an industry-wide shock) insurers replenish capital via increased prices. The risky-debt hypothesis (Cummins & Danzon, 1997) posits that insurer-specific prices depend on financial quality of the insurer. Customers are willing to pay higher prices for coverage from safer insurers and, similar to risky debt, prices fall as default risk increases (Lei & Browne, 2017). Generally, the capacity-constraint and risky-debt hypotheses are consistent because the former hypothesis focuses on industry capital and the later on insurer-specific capital (Weiss & Chung, 2004; Weiss, 2007). Specifically, both hypotheses agree that overall capital supply affects pricing, but effects vary by firm such that better capitalized insurers benefit from their position by charging higher prices.

At the industry level, Gron (1994) finds that deviations in relative capacity (capital to Gross National Product, GNP) have an inverse relationship with underwriting profits in line with the capacity-constraint hypothesis (i.e., price increases if capacity is reduced). Winter (1994)

[6] Cummins and Danzon (1991) as well as Doherty and Garven (1995) show that observed prices deviate more from financial pricing models if the interest rate changes for insurers with higher transaction costs to raise new capital (i.e., private and/or smaller insurers and insurers with less access to reinsurance).

provides evidence that reduced capital is associated with lower loss ratios, in line with the capacity-constraint theory.

At the firm level, Cummins and Danzon (1997) disentangle firm from industry capacity and measure financial quality for a sample of 50 U.S. general liability insurers in 1976–1987. Cummins and Danzon (1997) find that price is positively related to financial quality (ratio of capital to liabilities) meaning that better-capitalized insurers can charge higher prices supporting their risky-debt hypothesis. However, Cummins and Danzon (1997) find contradictory results for the capacity-constraint hypothesis—the firm and industry capacity variables are positively related to price. Weiss and Chung (2004) analyze a sample of large U.S. property-casualty reinsurers in 1991–1995 and find evidence for both the capacity-constraint and risky-debt theory.

A distinction must therefore be made between firm and industry capacity while considering firm-specific financial quality as separate price determinant. Both firm and industry capacity should have the same coefficient sign (Cummins & Danzon, 1997): a decrease (increase) in capacity suggests a positive (negative) impact on price. Thus, we formulate our first two hypotheses.

Hypothesis 1a: Firm capacity is negatively related to price.
Hypothesis 1b: Industry capacity is negatively related to price.

The moderation of exogenous factors ("shocks") in the capacity-price relationship

a) Interest rate change

Wilson (1981), Doherty and Kang (1988), Fields and Venezian (1989), and Fung et al. (1998) emphasize the role of changes in interest rates for the underwriting cycle. The main consideration is that the equilibrium price changes in lagged response to changing interest rates (Doherty & Garven, 1995). Doherty and Garven (1995) combine the interest rate and capacity constraint models and show that interest rate changes affect prices both directly and indirectly through capital changes given the gaps in asset-liability duration. If the asset duration exceeds the duration of liabilities, negative interest rate changes, *ceteris paribus*, reduce capital. Consequently, insurers may raise their prices to replenish capital if raising external capital is more expensive (Weiss, 2007). Thus, interest rate changes may moderate the capacity-price relationship. If interest rates fall, capacity constraints may become more binding, increasing the incentive to raise prices for insurers. This implies a positive moderation of interest rate changes.

b) Catastrophic losses

As explained by capital shock theories, insurer capital is not only sensitive to interest rate movements but also to adverse loss shocks (Weiss, 2007). In line with the capacity-constraint hypothesis (Gron, 1994; Winter, 1994), insurers increase prices to replenish capital due to constrained capacity following loss shocks that reduce capital (Weiss, 2007)—thus, showing a similar response as explained for adverse interest rate movements. In this way, catastrophic losses may negatively moderate the capacity-price relationship.

c) The general business cycle (GDP growth)

Prior literature also emphasizes the importance of the general business cycle for the underwriting cycle (Grace & Hotchkiss, 1995; Lamm-Tennant & Weiss, 1997; Chen, Wong, & Lee, 1999). The general business cycle also influences capacity in various industries (Schultze, 1963; Kendrick & Grossman, 1980) and possible also in the insurance sector (Berry-Stölzle & Born, 2010). During (at the beginning of) upswings with increasing demand for insurance, capacity constraints may become more binding. If demand expectations are sustainable, insurers may raise prices to increase the capital basis. Excess capacity (Berry-Stölzle & Born, 2012) during downturns may be used to cut prices. This implies a positive moderation of GDP growth.

d) The regulatory environment

Bruneau and Sghaier (2015) demonstrate that different capacity regimes existed in the French property-liability industry in 1963–2010. Interestingly, the capacity constraint is binding if the premiums-to-capital ratio is less than 2.22.[7] This threshold was not undercut in France in 1995–2010 (Bruneau & Sghaier, 2015); the premiums-to-capital ratio has sharply decreased since 1995. This result suggests that capacity constraints have not played a role since then. The result is of particular interest since the period from 1995 onwards brought two major regime changes in the EU. In 1994, the third generation of non-life Insurance Directives designed to open and harmonize the European insurance markets was introduced (Rees & Kessner, 1999). The year 2007 saw the launch of the formal legislative process for an EU directive that codifies and harmonizes EU insurance capital adequacy (Solvency II).

While France had traditionally been subject to low insurance regulation, the German insurance industry was heavily regulated until 1994, when the EU Directives forced EU-wide deregulation and thus significantly influenced the German insurance market (Rees & Kessner, 1999; Flockton, Grout, & Yong, 2004). Berry-Stölzle and Born (2012) find that policy form regulation until 1994 did not increase aggregated prices (loss ratio) in the German property-liability insurance industry above competitive levels; however, in highly competitive (remaining) lines prices decreased (increased) post-deregulation. Berry-Stölzle and Born (2010) demonstrate that the 1994 deregulation changed the importance of internal and external factors for the premium-setting process in the German property-casualty sector. Although, Berry-Stölzle and Born (2010) do not find general support for the capacity-constraint hypothesis in their industry-level premium change model, it does find some evidence that lagged capital changes have a significant negative impact on premium change post-deregulation but not pre-deregulation. In addition, the evidence in Bruneau and Sghaier (2015) may

[7] In fact, Bruneau and Sghaier (2015) use the inverse premiums-to-capital ratio which relates to a threshold of 0.45.

emphasize that the impact of capacity is moderated by regulatory regimes. Thus, the impact of capacity on price may vary over time (e.g., due to different regulatory regimes).

Overall, based on our discussions we formulate our next hypothesis.

Hypothesis 1c: Interest rate change, catastrophic losses, GDP growth, and the regulatory environment moderate the capacity-price relationship.

The impact of capacity on productivity change

Capital is a central input factor of insurers (Cummins & Weiss, 2013). The relationship between capacity and productivity in the insurance sector has, to our knowledge, not yet been analyzed. Grifell-Tatjé and Lovell (2015) provide a general framework to decompose productivity change, which identifies change in capacity utilization as a central determinant. Consistent with Schultze (1963), the authors do not prejudge the direction of impact. Schultze (1963) emphasizes that the relationship between capacity and productivity in general is complex and, depends on such things as the stage of the business cycle.[8]

For the insurance sector, an increase in the premium-to-capital ratio may indicate that capacity is used more efficiently, suggesting high productivity in the current period (Kendrick & Grossman, 1980). If insurer capital is reduced due to a shock, *ceteris paribus*, this also leads to higher productivity in the current period. These arguments suggest a positive relationship between the premiums-to-capital ratio and current productivity in the insurance sector. However, the implications of an increase in the ratio for productivity change is not evident.

An increase in the premiums-to-capital ratio may indicate that capacity constraints become more binding (Higgins & Thistle, 2000). Without increasing the capital basis, the scope to increase output in the next period is limited. Thus, high premiums-to-capital ratios may delay or even hinder productivity growth. The capacity-constraint hypothesis suggests that the industry reduces supply after industry-wide capital shocks, while the demand for insurance remains constant. Thus, output quantity may decline but it is ambiguous to which extent in relation to the decreased capital input. In addition, it is ambiguous whether insurers adjust other input factors. Therefore, the net impact of the premiums-to-capital ratio on productivity change is not trivial. Cummins and Xie (2013) find that the premiums-to-capital ratio has an inverse relationship with productivity change in a firm-level analysis of the U.S. property-casualty industry from 1993–2009. This could be evidence that a decrease in capacity (increase in the premiums-to-capital ratio) has a negative impact on productivity change.[9] However, we also cannot preclude that the relationship is non-linear; where increases in the premiums-to-capital

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[8] During downturns, there is incentive to retain important input factors such as skilled employees because it is expensive to hire and train new employees. During upswings, if output reaches capacity, productivity grows more slowly as increasing the input base may have time lags because it depends on a long-term expectation. If capacity, especially in upswings, cannot be freely increased as is assumed in the insurance industry, the impact on productivity is ambiguous.

[9] A higher premiums-to-capital ratio may also indicate a higher default risk of insurers (Cummins & Xie, 2013). Thus, this result could be also seen as consistent with the implications of the risky-debt hypothesis. In our analyses, we will disentangle the impacts of firm/industry capacity from financial quality/leverage.

ratio increase productivity change up to a certain threshold after which the positive impact either mitigates or even turns into a negative one. Following the discussion above, we disentangle capacity into its firm and industry dimensions.

The exogenous factors outlined in this section also appear to be relevant for the capacity-productivity relationship. Specifically, Schultze (1963) outlines that during upswings productivity growth may slow down as capacity is fully exploited and increasing capacity has time delays. Also, Kendrick and Grossman (1980) state that the economic activity influences capacity utilization, thereby affecting productivity. To our knowledge, only the direct impact of exogenous factors on productivity change has been analyzed so far in the literature. Huang and Eling (2012) demonstrate that GDP growth and the interest rate level directly influence the productivity development in the non-life insurance sector of the BRIC (Brazil, Russia, India, China) countries. Based on our discussions, we formulate hypotheses regarding the impact of capacity on productivity. Despite the empirical evidence of Cummins and Xie (2013), we only hypothesize that firm and industry capacity determine productivity change and do not prejudge the direction of impact in line with Grifell-Tatjé and Lovell (2015).

Hypothesis 2a: Firm capacity drives productivity change but the direction of impact is ambiguous.

Hypothesis 2b: Industry capacity drives productivity change but the direction of impact is ambiguous.

Hypothesis 2c: Interest rate change, catastrophic losses, GDP growth, and the regulatory environment moderate the capacity-productivity relationship.

3 Variables and data

3.1 Variables

Capacity

We define capacity as net premiums written relative to capital (i.e., the premiums-to-capital ratio) (Higgins & Thistle, 2000; Bruneau & Sghaier, 2015). The advantage of this measure is that it gives an indication of whether capacity constraints are binding. Furthermore, it is consistent with the idea of capacity utilization (Schultze, 1963; Grifell-Tatjé & Lovell, 2015); a high (low) level may indicate that capacity is (not) extensively utilized meaning that the insurer has less (more) scope to accept new business.

In order to distinguish firm and industry capacity we follow the approach of Cummins and Danzon (1997) and decompose the premiums-to-capital ratio into two orthogonal components.[10] In detail, we run a pooled regression model with the firm-specific premiums-to-capital ratio as dependent variable and the corresponding annual industry value as regressor.

[10] Cummins and Danzon (1997) use firm-specific capital levels from the previous year in relation to the average level of the preceding five years. Besides the advantages of the premiums-to-capital ratio, a use of the alternative measure would shorten the sample period by six years.

Industry capacity is the predicted value from this regression and firm capacity is the residual. Thus, industry capacity varies over time but not cross-sectionally. The orthogonalization also removes a source of collinearity between the firm and industry capacity variables.

Price

We proxy price by the ratio of losses and operating expenses to earned premiums (i.e., the combined ratio) (Bruneau & Sghaier, 2015). Thus, the coefficient signs of predictors in later regression analyses must be interpreted as follows. A positive (negative) coefficient suggests a negative (positive) impact of that predictor on price. We do not use the inverse of the combined ratio because this transformation causes the variable to be highly skewed.

Inputs for Malmquist productivity analysis

We follow the literature (see Eling & Luhnen, 2010, for an overview) and 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, & Wirfs, 2016). The labor input is estimated by dividing net operating expenses by average annual wage rates.

Outputs for Malmquist productivity analysis

We follow the value-added approach to measure the risk-pooling/risk-bearing, intermediation, and financial services related to insured losses outputs of insurers (Cummins & Weiss, 2013). We proxy the first output (y_1) with the present value of losses paid adjusted for the change in the provision for outstanding claims (i.e., real incurred losses). To avoid negative numbers for this output (i.e., if the change in provisions is higher than the losses paid), this variable is shifted for the complete sample period (Biener et al., 2016). The intermediation output (y_2) is represented by the total investments value. The third service output is not modelled separately because it is highly correlated with the two other output variables (Eling & Luhnen, 2010).

Other firm characteristics and exogenous variables

In later regression analyses, we control for financial quality (capital/liabilities) to consider the risky-debt hypothesis (Cummins & Danzon, 1997; Weiss & Chung, 2004). We also account for firm size by the natural logarithm of total assets (Biener et al., 2016). We use two binary variables to control for the mutual and public organizational forms.

The insurance penetration ratio (total non-life premiums/GDP) is used to account for aggregated insurance demand (Harrington et al., 2013). The amount of competition is measured by the Herfindahl-Hirschman-Index (Elango, Ma, & Pope, 2008).[11] We account for the interest rate change by the annual differences between official discount rates. We account for years with

[11] Marsh (2017) notes that despite record-high catastrophic losses in 2017, prices did not increase in industrial property insurance due to the high level of competition.

catastrophic losses by a binary variable taking the value 1 if a year recorded an extraordinary increase in total market losses (increase of total market loss ratio by more than 4%) and 0 otherwise. The threshold was chosen based on a review of the loss ratio time series, which showed that years with increases in the loss ratio by more than 4% clearly stand-out from other years.[12] GDP growth rates proxy the general business cycle. We account for the pre- and post-deregulation periods with a binary variable that takes the value 1 until 1994 and 0 afterwards.[13]

3.2 Data

We hand collected data from annual publications of the *Hoppenstedt Versicherungsjahrbuch* for 1958–2010 (Luhnen, 2009; Mahlberg & Url, 2010; Braun, Schmeiser, & Rymaszewski, 2015) complemented by data from Bureau van Dijk's *orbis insurance focus* database. The final sample period is 1954–2016, which encompasses numerous interest rate changes, catastrophic years, contraction and expansion periods over the German business cycle, and two different regulatory regimes (pre- and post-deregulation in 1994). The sample comprises data from insurers that operate in the motor, casualty, liability, fire, transport, household, and homeowners insurance lines. The final sample includes 251 insurers and 6,027 firm-year observations. Over the entire period, the sample represents on average approximately 90% of total premiums written in the German non-life market (excluding health insurance).

The annual wage rates are computed based on monthly wage data for Industry and Services obtained from the German Federal Statistical Office. To our knowledge, no insurance-specific wage data is consistently and publicly available for the complete sample period. The total premium and loss data is obtained from the German Federal Financial Supervisory Authority. The GDP data also come from the German Federal Statistics Office. Discount rates are published by Deutsche Bundesbank. For comparative purposes, all firm-specific variables are inflated/deflated to 2010 using consumer price indexes based on inflation data from the Deutsche Bundesbank. All Saar Franc values in the database are converted to Deutsche Mark using the official exchange rate (0.008507) and all Deutsche Mark values are converted to Euro using the official exchange rate (0.511292). Saar Franc was the official currency of the Saarland until 1959 when it adopted the Deutsche Mark, two years after Saarland was incorporated into the Federal Republic of Germany. Deutsche Mark was the official currency of the Federal Republic of Germany until 2002, when the Euro was introduced. Table 2 presents summary statistics for the variables defined in chapter 3.1.

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[12] As a robustness test, we vary the threshold (5%, 6%, and 8%), leading to the same conclusions as presented later.

[13] The deregulation period post-1994 overlaps with efforts of increased solvency regulation in the German insurance sector (i.e., through the introduction of Solvency II) and thus the identification of effects may not be fully traceable to (de-) regulation. However, the variable still captures two different regulatory regimes in the German insurance sector.

Table 2 Summary statistics

Variable	Definition	Mean	Median	SD
Capacity				
Firm capacity	Residual from pooled regression of firm-specific premiums-to-capital ratio on the industry ratio	-0.0000	-0.2087	1.9365
Industry capacity	Predicted value from pooled regression of firm-specific premiums-to-capital ratio on the industry ratio	3.2033	2.9795	0.8232
Price				
Combined ratio	(Operating expenses+losses)/earned premiums	0.9213	0.9390	0.1840
Inputs for Malmquist productivity analysis				
x1	Labor input	2,146.5	738.1	4,247.3
x2	Equity capital input (in Mio. USD)	106.5	29.2	232.5
x3	Debt capital input (in Mio. USD)	532.2	123.7	1,499.4
Outputs for Malmquist productivity analysis				
y1	Losses output (in Mio. USD)	192.1	55.6551	404.1
y2	Investments output (in Mio. USD)	552.7	124.4128	1,516.4
Other firm characteristics				
Financial quality	Capital/liabilities	0.3069	0.2321	0.2478
Size	Log(total assets)	5.2127	5.0441	1.5232
Mutual	Dummy variable: 1 if insurer is mutual, 0 otherwise	0.1716	0	0.3770
Public	Dummy variable: 1 if insurer is public, 0 otherwise	0.1424	0	0.3494
Exogenous variables				
Insurance penetration	Total non-life premiums/GDP	0.0231	0.0243	0.0036
Competition	Herfindahl-Hirschman-Index	0.0374	0.0372	0.0093
ΔInterest rate	Discount rate_t-Discount rate_{t-1}	-0.0006	-0.0004	0.0124
Catastrophic year	1 if year is classified as catastrophe year; 0 otherwise	0.1599	0	0.3666
GDP	Growth in GDP	0.0271	0.0230	0.0243
Regulation	1 until 1994; 0 afterwards	0.6536	1	0.4759

4 Methodology

Productivity change measurement

Since productivity cannot be observed, we follow standard insurance literature and estimate input-oriented Malmquist indexes of total factor productivity (TFP) to proxy productivity change (Cummins & Weiss, 2013). We follow Simar and Wilson (1999, 2000) and use bootstrapping in order to obtain robust results.

Stationarity testing

We test all variables used in the regression analyses for stationarity using Fisher-type augmented Dickey–Fuller and Phillips–Perron panel unit-root tests (Choi, 2001). In case the null hypothesis that all the panels contain a unit root cannot be rejected, we also test the variable in first difference.

Price and productivity change models

For the specification of the price equation, we orient at Lamm-Tennant and Weiss (1997) who analyze premium change and Cummins and Danzon (1997) as well as Weiss and Chung (2004). Equation (1) illustrates how the price determinants are analyzed econometrically.

$$\begin{aligned} Price_{it} = {} & \alpha_1 + \alpha_2 \Delta Loss_{1,i,t} + \alpha_3 \Delta Loss_{2,i,t} + \alpha_4 \Delta Loss_{3,i,t} + \alpha_5 Firm\ capacity_{i,t-1} \\ & + \alpha_6 Industry\ capacity_{i,t-1} + \alpha_7 Financial\ quality_{i,t-1} + \alpha_8 \Delta TFP_{i,t-1} + \alpha_9 Size_{i,t-1} + \alpha_{10} Size^2_{i,t-1} \\ & + \alpha_{11} Mutual_{i,t-1} + \alpha_{12} Public_{i,t-1} + \alpha_{13} Insurance\ penetration_{t-1} + \alpha_{14} Competition_{t-1} + \\ & + \alpha_{15} \Delta Interest\ rate_{t-1} + \alpha_{16} Catastrophic\ year_{t-1} + \alpha_{17} GDP_{t-1} + \alpha_{18} Regulation_{t-1} + \varepsilon_{i,t}, \end{aligned} \tag{1}$$

where i denotes firm and t year. We consider firm- and year-fixed effects in Equation (1). The lagged loss variables ($\Delta Loss_{1,i,t} = \log(y1_{t-1}) - \log(y1_{t-2})$; $\Delta Loss_{2,i,t} = \log(y1_{t-2}) - \log(y1_{t-3})$; …) account for accounting and data collection lags in line with arbitrage theory (Cummins & Outreville, 1987; Lamm-Tennant & Weiss, 1997) as well as loss shocks (Cummins & Danzon, 1997). We include the financial quality variable (capital/liabilities) to control for the implications of the risky-debt hypothesis.

We orient at the regression model of Cummins and Xie (2013) to analyze the determinants of productivity change as shown in Equation (2).[14]

$$\begin{aligned} \Delta TFP_{i,t} = {} & \beta_1 + \beta_2 Firm\ capacity_{i,t-1} + \beta_3 Industry\ capacity_{i,t-1} + \beta_4 Financial\ quality_{i,t-1} \\ & + \beta_5 Price_{i,t-1} + \beta_6 Size_{i,t-1} + \beta_7 Size^2_{i,t-1} + \beta_8 Mutual_{i,t-1} + \beta_9 Public_{i,t-1} \\ & + \beta_{10} Insurance\ penetration_{t-1} + \beta_{11} Competition_{t-1} + \beta_{12} \Delta Interest\ rate_{t-1} \\ & + \beta_{13} Catastrophic\ year_{t-1} + \beta_{14} GDP_{t-1} + \beta_{15} Regulation_{t-1} + \varepsilon_{it}. \end{aligned} \tag{2}$$

[14] See Mahlberg and Url (2010) for a productivity change regression model for insurance group data.

We also consider dynamic interactions among price and productivity change in Equations (1) and (2) and use standard errors which are robust to heteroskedasticity and serial correlation for estimating both equations.[15]

Hypothesis testing

The testing of our hypotheses proceeds as follows. First, we estimate Equations (1) and (2) as presented. A negative coefficient for the firm capacity variable in Equation (1) would suggest that a positive increase in the deviation of the firm-specific capacity variable (premiums-to-capital ratio) from the industry average has a positive impact on price (H1a). A negative coefficient of the industry capacity variable suggests that an increase in the premium-to-capital ratio in the whole industry has a positive impact on price (H1b).

A negative (positive) coefficient for the firm capacity variable in Equation (2) would suggest that a positive increase in the deviation of the firm-specific ratio from the industry average has a negative (positive) impact on productivity change (H2a) suggesting "productivity-related capacity constraints" (a more efficient usage of capacity leading to greater productivity change). A negative (positive) coefficient of the industry capacity variable suggests that an increase in the premium-to-capital ratio in the whole industry has a negative (positive) impact on productivity change (H2b). To test for non-linearity, we also introduce quadratic terms of the capacity variables into Equation (2).

Second, we gradually introduce interaction terms between the (lagged) firm capacity variable and a) the variable accounting for changes in the interest rate, b) the catastrophic year variable, c) GDP growth, and d) the regulation variable (1 until 1994, 0 afterwards) in Equations (1) and (2). This approach measures the interaction of capacity that enters the new period subject to the (lagged) exogenous factors. Significant interactions are evidence for moderation (H1c, H2c).

We focus on the interaction between the firm capacity variable and the exogenous factors as the corresponding interaction term varies cross-sectionally and over time, which leads to a good identification of moderating effects; in contrast, interaction terms between the industry capacity variable and the exogenous variables vary over time but not cross-sectionally. Nevertheless, the interaction terms between the firm capacity variable and the exogenous variables capture the impact of industry-wide "shocks", as all firms are affected symmetrically (see, e.g., Winter, 1994) by, for example, interest rate changes. Thus, independent of the relative firm position in terms of capacity, all insurers experience the same impact of the exogenous factor on capacity while the relative capacity position is unaffected (see also Footnote 16).

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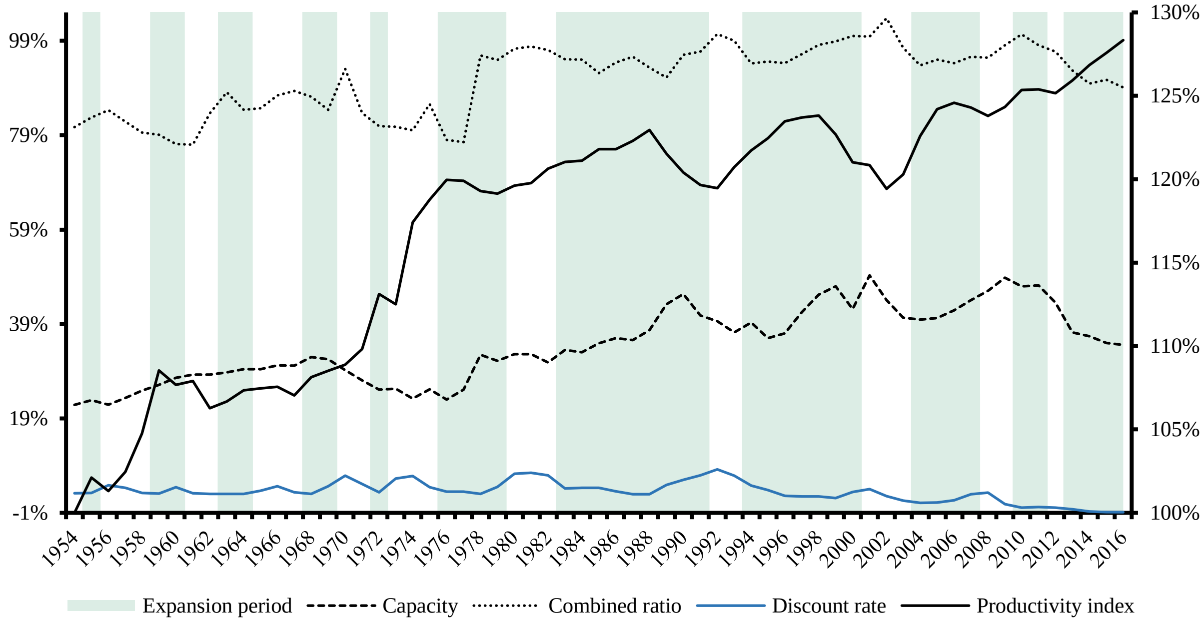
[15] We also specified and tested impulse response functions in a linear panel VAR framework to analyze the dynamic interactions among capacity, price, and productivity change (Appendix A). However, the interactions are extremely difficult to model so the modelling is based on various discretionary decisions. In addition, the paradigmatic analysis in Appendix A provides preliminary evidence that the interactions, if any, are weakly dynamic and may thus be rather contemporaneous. To our knowledge, there are no valid instruments for all three variables available to analyze the contemporaneous interactions.

In order to arrive at more meaningful interpretations of the interaction terms, we mean center all variables per panel that are used for constructing the terms. We also mean center variables before computing quadratic terms.

5 Empirical results

Figure 1 presents the development of capacity (premiums-to-capital ratio), price (combined ratio), and productivity in the German non-life market in 1954–2016. For illustrative purposes, the inverse of the capacity measure is given.

Figure 1 Development of inverse capacity (premiums-to-capital ratio), price (combined ratio), and productivity (secondary axis)



Notes: Productivity index is created by multiplying median annual TFP change rates with the preceding year index value (1954=100%). For illustrative purposes, the inverse of the capacity measure (premiums-to-capital ratio) is shown. For all other variables median values are presented. Expansion periods are defined as shown in Appendix B.

The inverse capacity measure has significantly increased during the sample period (Figure 1). While the median value is approximately 0.22 in 1954, it hovers around 0.35 in 2016 and even exceeds 0.49 in 2001. This trend resembles Bruneau and Sghaier's (2015) illustration of the capacity development in the French property-liability insurance sector, in which the inverse premiums-to-capital ratio increased from 0.18 in 1963 to 0.55 in 2010 at the aggregated level.

Figure 1 shows that the price proxy (underwriting ratio) moves in cycles during the sample period. Periods of increases in the underwriting ratio are usually followed by periods of sharp declines and vice versa. Prior literature has empirically verified the existence of the underwriting cycle in the German insurance market while documenting different cycle lengths depending on the analyzed period. Cummins and Outreville (1987) find an average cycle length of 7.76 years in 1957–1979, Lamm-Tennant and Weiss (1997) find an average cycle length of 6.45 years in 1965–1987, and Meier and Outreville (2006) find an average cycle length of 8.88 years in 1965–2001. Berry-Stölzle and Born (2010) demonstrate that by-line cycle periods differ in some lines pre- and post-deregulation. In Appendix D, we make a simple classification of hard and soft market periods based on the total loss ratio development that we use for an additional analysis of the price determinants in the two cycle phases later in this section.

Figure 1 illustrates that also productivity tends to be cyclical in the German non-life insurance sector, which is in line with findings for other industries (Kendrick & Grossman, 1980; Grifell-Tatjé & Lovell, 2015). The median productivity development mirrors Kendrick and Grossman's (1980) notion that productivity growth rates decelerate before business cycles peak (expansion periods are highlighted by the shaded areas). Appendix C presents further statistics for the productivity development; in line with Kendrick and Grossman (1980) we show median TFP change rates separately for expansion and contraction periods. Over the total sample period, we observe significant differences when using median (approximately 30% improvement in productivity) or mean values (approximately 100% improvement in productivity) to compute the productivity index. The index improvement in 1995–2006 based on the mean values (approximately 6% improvement) mirrors Luhnen's (2009) finding of approximately 8% improvement in the German property/liability sector. Mahlberg and Url (2010) find a significantly higher average increase of approximately 17.8% in 1991–2006 on group-level (life and non-life combined).

Price determinants

In Table 3, we investigate the relationship between the price proxy (underwriting ratio) and its determinants econometrically; a positive (negative) coefficient implies an inverse (positive) relationship of the regressor with price. The coefficients of the first two variables accounting for changes in losses are significantly different from zero in Table 3. Interestingly, the sign of all coefficients is positive. This result is counterintuitive given that insurers' premium calculations are based on discounted future losses plus additional loadings for risk bearing and administration costs. This suggests a negative coefficient since insurers should alter their forecasts based on historical loss experiences. Cummins and Danzon (1997) confirm an inverse relationship between prices and loss shocks consistent with their model. One possible explanation for this result is that, on average, the pricing in the German non-life market is oriented more to strategic (e.g., distribution and marketing considerations) than to actuarial aspects in competition for customers. For example, Eling and Luhnen (2008) show that German motor insurance historically has gone through several periods of intense competition.

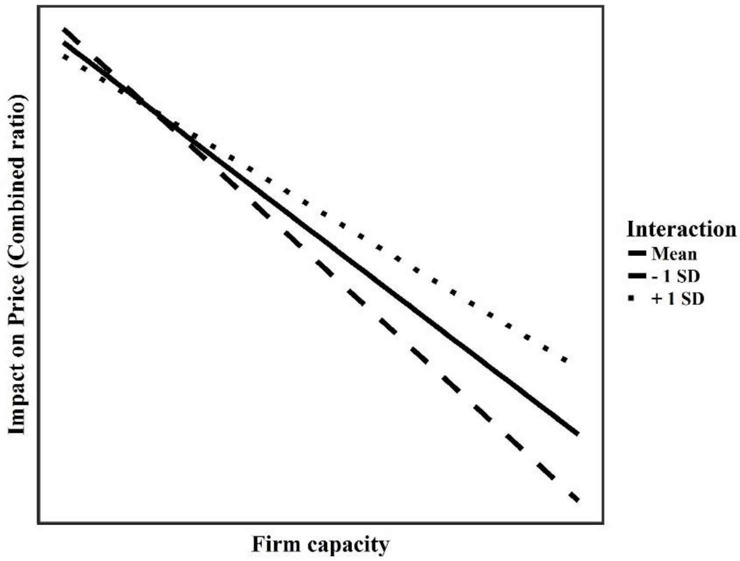
The premiums-to-capital ratio is the basis for our firm and industry capacity variables; an increase in these variables indicates less available capacity and more binding capacity constraints (Higgins & Thistle, 2000; Bruneau & Sghaier, 2015). Table 3 shows consistently significant and negative coefficients for both the firm and industry capacity variables in all models. Thus, we find empirical evidence for H1a and H1b suggesting that increases in the lagged capacity variables have a positive impact on price in line with the capacity-constraint hypothesis of Gron (1994) and Winter (1994). This result is also in line with the empirical findings of Weiss and Chung (2004) for a sample of U.S. property-casualty reinsurers.

Subsequent to the contradictory findings of Cummins and Danzon (1997), we can thus confirm the anticipated role of capacity in firm-level data of primary non-life insurers. In addition, Table 3 reports significant and negative coefficients of the financial quality variables in all models. This result lends support to the risky-debt hypothesis (Cummins & Danzon, 1997; Weiss & Chung, 2004) meaning that improved financial quality of the insurer (i.e., less leverage) has a positive impact on price.

Table 3 provides no evidence of a relationship between the lagged productivity change variable and the price proxy. Although theoretic considerations suggest interactions among price and productivity (Grifell-Tatjé & Lovell, 2015), these interactions may occur contemporaneously and not dynamically (Footnote 15). Other firm characteristics seem to play a minor role; only, the coefficient of the firm size variable is significant and positive in some of the models presented in Table 3.

Table 3 provides evidence for moderation of the capacity-price relationship by exogenous factors (H1c). In Model (8), the coefficient of the interaction term between the firm capacity and interest rate change variables is significant (positive moderation). Figure 2 illustrates that if ΔInterest rate$_{t-1}$ decreases by one standard deviation (SD) from its mean level, the line slope becomes steeper, meaning price is more sensitive to firm capacity. This is in line with the notion that a negative interest rate shock adversely affects all firms in the market, increasing the pressure to replenish capital via increased prices (Doherty & Garven, 1995).[16]

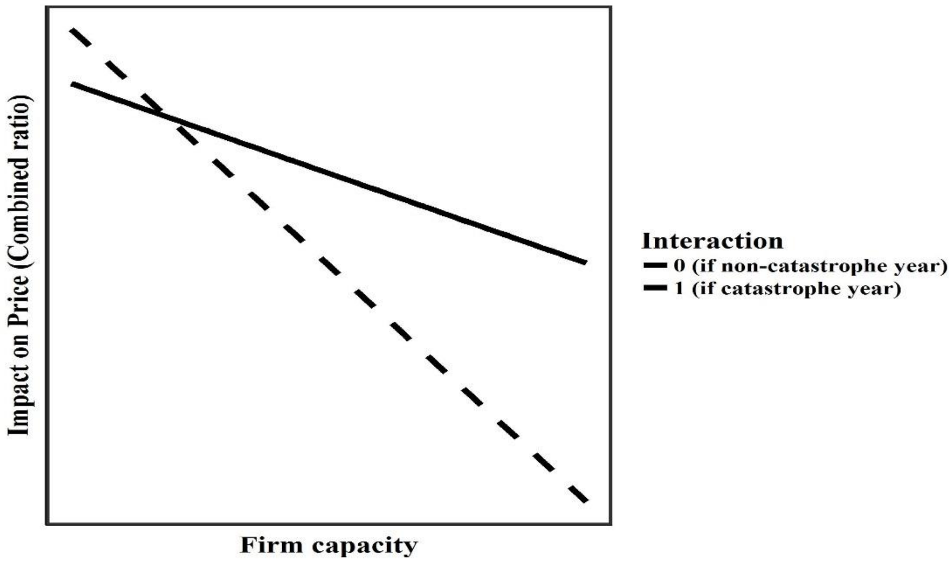
Figure 2 Interaction between interest rate change and firm capacity



16 Insurer capital is prone to interest rate changes if an asset-liability mismatch prevails (Weiss, 2007). Since all companies within a single market face the same change in the interest rate and given that asset-liability structures are similar, the relative position of the insurer in terms of its financial quality is unaffected by an interest rate change but the decrease in the interest rate leads, *ceteris paribus*, to a symmetric deterioration of the capital basis among all insurers.

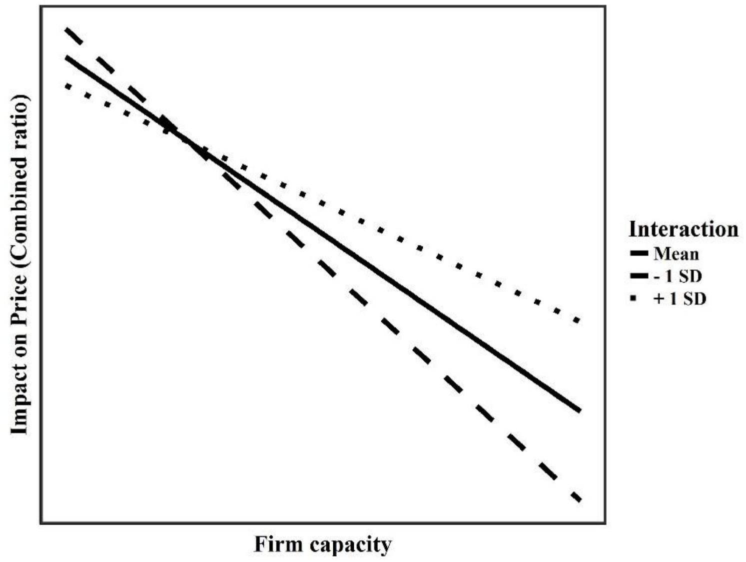
In Model (9), the coefficient of the interaction term between the firm capacity and catastrophic year variables is significant (negative moderation). Figure 3 shows that if a catastrophic year occurs (lagged catastrophic year variable takes value 1), the impact of the firm capacity variable on the combined ratio in the next year becomes more negative. This supports the expectation that following adverse market loss shocks, insurers increase prices in order to replenish capital (Gron, 1994; Winter, 1994; Weiss, 2007).

Figure 3 Interaction between catastrophe and firm capacity



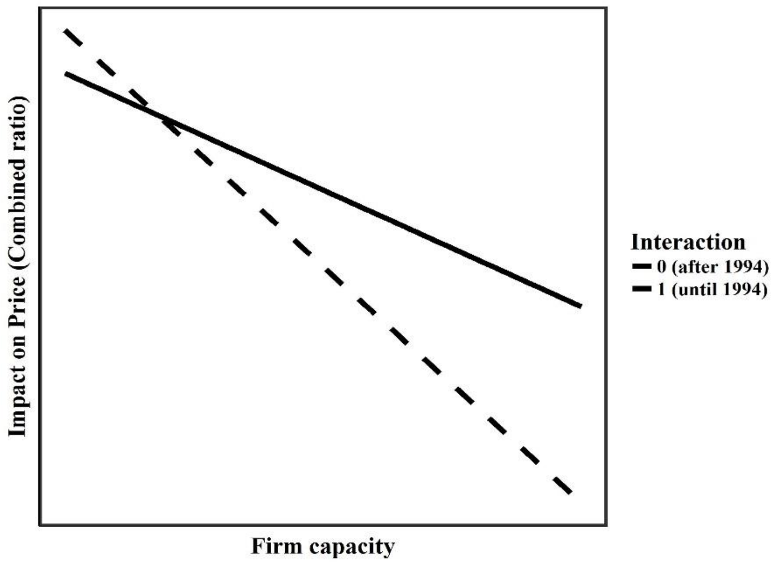
In Model (10), the coefficient of the interaction term between the firm capacity variable and GDP growth is significant (positive moderation). Figure 4 illustrates that if GDP growth falls (increases) by one SD below (above) its mean level, the line slope becomes steeper (less steep) meaning price is more (less) sensitive towards firm capacity in this situation. Thus, if GDP growth falls below (above) its mean level, the role of capacity constraints seem to become more (less) relevant for insurers' decisions to increase prices in the next year. This result contradicts our prior expectation of a more significant role of capacity constraints during expansion periods. One explanation for this result is that insurers with constrained capacity use particularly downturns to increase their capital basis for the next expansion period. The result may also be driven by the fact that capital might be less scarce and, therefore, cheaper during expansionary periods; conversely, insurers with constrained capacity may increase prices to build up internal capital during contraction periods with scarce and expensive capital.

Figure 4 Interaction between GDP growth and firm capacity



In Model (11), the coefficient of the interaction term between the firm capacity and regulation variables is significant (negative moderation). Figure 5 illustrates that the line slope is steeper pre-deregulation (and pre-Solvency II). This result could be related to the possibility that high levels of price regulation, as it was the case in Germany before 1994, limit the flow of capital to the insurance industry. Our result can be set in reference with Bruneau and Sghaier (2015), who also find that capacity constraints were a bigger concern in the French property-liability insurance sector prior to 1995; however, as noted above, France had already traditionally been subject to low insurance regulation. The post-deregulation period overlaps with the efforts of increased capital regulation starting with the launching of the formal legislative process for Solvency II in 2007. Thus, our result could also emphasize, that (firm-specific) capacity is a less important price determinant due to increased capital regulation.

Figure 5 Interaction between regulation and firm capacity



Appendix E shows the price regression models with the interaction effects separately for hard and soft market periods, which were defined according to Appendix E. The coefficients of the industry capacity variable are significant and negative in all models of the hard-market and soft-market samples. With only three exceptions, the coefficients of the firm-capacity variable are negative and significant in all models. In the hard-market sample, the coefficients of the interaction terms between the firm-capacity variable and the interest rate change as well as the catastrophic year variables are significant and show the expected signs. The coefficients of GDP growth and regulation interaction terms are insignificant. This result could emphasize that capacity constraints evolve at the end of soft market periods and decline at the end of hard market periods (Weiss, 2007); these transitions may not be modelled if hard markets are separated from soft markets. Interestingly, in the soft-market sample, the coefficients of the interest rate change and catastrophic year interaction terms show the opposite sign. This could indicate that different rules apply in soft-market periods.

Productivity change determinants

In Table 3, we investigate the relationship between productivity change and its determinants following Cummins and Xie (2013). The coefficients of the firm capacity variable are significant and negative in all regression models. However, all coefficients of the industry capacity variable are insignificant. In Model (3), we consider also quadratic terms of the two capacity variables but their coefficients are insignificant, rejecting the presence of a non-linear relationship. Thus, our results suggest that only firm-specific capacity determines productivity change; positive increases in the deviation of firm-specific capacity from the industry average have a negative impact on productivity change. This result is in line with Cummins and Xie (2013), who also find a negative impact of the premium-to-capital ratio. While the authors conclude that leverage penalties explain the negative impact, we disentangled the financial quality effect from capacity (Section 3.1).

Firms with high premiums-to-capital ratios appear constrained in their ability to increase the outputs-inputs ratio from one period to the other and may even experience negative productivity change. Thus, capacity constraints also seem to be relevant for productivity change, with high premiums-to-capital ratios indicating delayed, hindered, or even negative productivity growth. Grifell-Tatjé and Lovell (2015) formally show that the product of productivity change and price recovery (growth in output prices relative to the growth in input factor prices) together determine profitability change. Thus, given that capacity constraints may cause negative productivity change, insurers, *ceteris paribus*, also have to increase output prices to avoid profitability losses. This helps to explain why insurers raise their prices in times of constrained capacity. Overall, we find support only for H2a, not for H2b.

Interestingly, Table 3 shows statistically significant and negative coefficients for the financial quality variable in all models. Thus, an increase in this variable (reflecting less leverage) penalizes insurers in terms of productivity growth. This contradicts the expectation of the reverse impact, namely that decreased financial quality (increased leverage) negatively affects productivity change (Cummins & Xie, 2013) assuming that lower security levels of the insurer result in decreased output volume as policyholders penalize default risk (Wakker, Thaler, & Tversky, 1997; Epermanis & Harrington, 2006). In another regression model, we test for a non-linear impact of financial quality but the results are insignificant (the results are available upon request). Regarding other firm characteristics, Table 3 shows significant coefficients only for the firm size variable in some models, suggesting a positive impact of size. While Table 4 detects no interactions between the firm capacity and the exogenous variables, the coefficients of the regulation variable are significantly different from zero and have a positive sign in all models.[17] In contrast to Mahlberg and Url's (2010) finding of increased productivity on group level post-deregulation, this result suggests higher productivity change pre-deregulation.

[17] Huang and Eling (2013) demonstrate that various economic and industry factors determine productivity change in the non-life insurance industry of the BRIC countries in 2000–2008. Besides the sample differences, differences exist because their analysis relies on a multistage data envelopment analysis (DEA) model and focuses on contemporaneous impacts.

Table 3 Determinants of price (Equation 1)

Dependent variable: Price (Combined ratio)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
$\Delta Loss_{t-1}$	0.0418***	0.0463***	0.0465***	0.0467***	0.0463***	0.0466***	0.0473***	0.0475***	0.0457***	0.0473***	0.0461***
	(0.0100)	(0.0104)	(0.0104)	(0.0103)	(0.0104)	(0.0104)	(0.0104)	(0.0104)	(0.0104)	(0.0104)	(0.0104)
$\Delta Loss_{t-2}$	0.0272***	0.0310***	0.0312***	0.0305***	0.0311***	0.0314***	0.0314***	0.0316***	0.0301***	0.0314***	0.0300***
	(0.0089)	(0.0096)	(0.0096)	(0.0096)	(0.0097)	(0.0097)	(0.0096)	(0.0097)	(0.0094)	(0.0096)	(0.0095)
$\Delta Loss_{t-3}$	0.0101	0.0130	0.0131	0.0120	0.0132	0.0133	0.0129	0.0130	0.0119	0.0130	0.0121
	(0.0094)	(0.0098)	(0.0097)	(0.0098)	(0.0098)	(0.0098)	(0.0098)	(0.0098)	(0.0097)	(0.0098)	(0.0097)
Firm capacity$_{t-1}$	-0.0165***	-0.0172***	-0.0171***	-0.0171***	-0.0172***	-0.0172***	-0.0171***	-0.0163***	-0.0118***	-0.0162***	-0.0095**
	(0.0028)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0029)	(0.0034)	(0.0027)	(0.0039)
Industry capacity$_{t-1}$		-0.0811***	-0.0799***	-0.0797***	-0.0816***	-0.0807***	-0.0777***	-0.0776***	-0.0774***	-0.0772***	-0.0774***
		(0.0074)	(0.0078)	(0.0073)	(0.0075)	(0.0075)	(0.0078)	(0.0078)	(0.0077)	(0.0077)	(0.0077)
Financial quality$_{t-1}$	-0.0594**	-0.0583**	-0.0579**	-0.0571**	-0.0584**	-0.0582**	-0.0565**	-0.0549**	-0.0484*	-0.0533**	-0.0483*
	(0.0271)	(0.0270)	(0.0271)	(0.0270)	(0.0270)	(0.0270)	(0.0271)	(0.0266)	(0.0262)	(0.0267)	(0.0270)
ΔTFP_{t-1}	-0.0048	-0.0018	-0.0018	-0.0018	-0.0017	-0.0015	-0.0016	-0.0018	-0.0005	-0.0024	-0.0028
	(0.0070)	(0.0109)	(0.0109)	(0.0107)	(0.0109)	(0.0108)	(0.0106)	(0.0107)	(0.0107)	(0.0110)	(0.0107)
Size$_{t-1}$	0.0059	0.0149**	0.0152**	0.0163**	0.0142**	0.0120	0.0116	0.0116	0.0115	0.0118	0.0117
	(0.0098)	(0.0064)	(0.0064)	(0.0064)	(0.0063)	(0.0075)	(0.0074)	(0.0074)	(0.0075)	(0.0074)	(0.0075)
Size$^2_{t-1}$	-0.0033	-0.0032	-0.0027	-0.0034	-0.0035	-0.0041	-0.0043	-0.0044	-0.0039	-0.0043	-0.0045
	(0.0056)	(0.0055)	(0.0055)	(0.0055)	(0.0056)	(0.0055)	(0.0055)	(0.0055)	(0.0055)	(0.0056)	(0.0054)
Mutual$_{t-1}$	0.0177	0.0160	0.0147	0.0150	0.0172	0.0208	0.0214	0.0217	0.0208	0.0206	0.0219
	(0.0516)	(0.0517)	(0.0517)	(0.0517)	(0.0518)	(0.0510)	(0.0509)	(0.0508)	(0.0507)	(0.0511)	(0.0510)
Public$_{t-1}$	-0.0142	-0.0156	-0.0167	-0.0161	-0.0145	-0.0124	-0.0119	-0.0117	-0.0126	-0.0113	-0.0117
	(0.0165)	(0.0147)	(0.0147)	(0.0147)	(0.0148)	(0.0154)	(0.0154)	(0.0154)	(0.0151)	(0.0156)	(0.0151)
Insurance penetration$_{t-1}$		-1.4934	-1.1201	-2.3402	-2.0006	-1.2858	-2.3093	-2.3169	-2.1971	-2.3624	-2.2669
		(1.8594)	(1.9853)	(1.8905)	(2.0579)	(1.8515)	(2.0874)	(2.0883)	(2.0613)	(2.0931)	(2.0978)
Competition$_{t-1}$		-0.6055	-0.5614	-0.7641	-0.6989	-0.5966	-0.8424*	-0.8299*	-0.8071*	-0.8284*	-0.8291*
		(0.4737)	(0.4831)	(0.4678)	(0.4897)	(0.4713)	(0.4757)	(0.4758)	(0.4726)	(0.4758)	(0.4772)
ΔInterest rate$_{t-1}$			0.2080				0.3705	0.3600	0.3828	0.3672	0.3815*
			(0.1982)				(0.2286)	(0.2306)	(0.2347)	(0.2273)	(0.2279)
Catastrophic year$_{t-1}$				-0.0162***			-0.0160***	-0.0162***	-0.0161***	-0.0163***	-0.0159***
				(0.0049)			(0.0049)	(0.0049)	(0.0048)	(0.0049)	(0.0049)
GDP$_{t-1}$					-0.0978		-0.1791	-0.1809	-0.1753	-0.1913	-0.1821
					(0.1074)		(0.1242)	(0.1238)	(0.1254)	(0.1229)	(0.1241)
Regulation$_{t-1}$						-0.0072	-0.0099	-0.0103	-0.0101	-0.0096	-0.0098
						(0.0107)	(0.0108)	(0.0108)	(0.0108)	(0.0107)	(0.0108)
Firm capacity$_{t-1}$ × ΔInterest rate$_{t-1}$								0.2697*			
								(0.1623)			
Firm capacity$_{t-1}$ × Catastrophic year$_{t-1}$									-0.0192***		
									(0.0053)		
Firm capacity$_{t-1}$ × GDP$_{t-1}$										0.2392***	
										(0.0888)	
Firm capacity$_{t-1}$ × Regulation$_{t-1}$											-0.0097**
											(0.0043)
Unit dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	No	No	No	No	No	No	No	No	No	No
Observations	4,688	4,688	4,688	4,688	4,688	4,688	4,688	4,688	4,688	4,688	4,688

Notes: Robust (heteroskedasticity and serial correlation) standard errors in parentheses; ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively.

Table 4 Determinants of productivity change (Equation 2)

Dependent variable: ΔTFP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Firm capacity$_{t-1}$	-0.0085***	-0.0080***	-0.0071**	-0.0071***	-0.0080***	-0.0080***	-0.0081***	-0.0071***	-0.0076***	-0.0079***	-0.0069***	-0.0066**
	(0.0021)	(0.0021)	(0.0029)	(0.0023)	(0.0021)	(0.0021)	(0.0021)	(0.0023)	(0.0023)	(0.0016)	(0.0021)	(0.0028)
Industry capacity$_{t-1}$		0.0083	0.0005	0.0094	0.0081	0.0085	0.0070	0.0077	0.0077	0.0078	0.0077	0.0077
		(0.0092)	(0.0070)	(0.0099)	(0.0089)	(0.0095)	(0.0093)	(0.0096)	(0.0096)	(0.0095)	(0.0096)	(0.0096)
Financial quality$_{t-1}$	-0.0718***	-0.0650***	-0.0636***	-0.0676***	-0.0654***	-0.0649***	-0.0656***	-0.0681***	-0.0687***	-0.0690***	-0.0675***	-0.0676***
	(0.0212)	(0.0204)	(0.0214)	(0.0176)	(0.0205)	(0.0204)	(0.0204)	(0.0175)	(0.0169)	(0.0173)	(0.0169)	(0.0170)
Price$_{t-1}$	0.0435	0.0412	0.0430	0.0298	0.0412	0.0415	0.0423	0.0306	0.0314	0.0318	0.0317	0.0304
	(0.0300)	(0.0277)	(0.0277)	(0.0290)	(0.0277)	(0.0280)	(0.0276)	(0.0294)	(0.0295)	(0.0289)	(0.0299)	(0.0291)
Size$_{t-1}$	0.0045	-0.0023	-0.0044	-0.0021	-0.0026	-0.0018	0.0074*	0.0044	0.0046	0.0044	0.0044	0.0044
	(0.0053)	(0.0038)	(0.0044)	(0.0037)	(0.0039)	(0.0038)	(0.0040)	(0.0040)	(0.0040)	(0.0039)	(0.0040)	(0.0040)
Size$^2_{t-1}$	-0.0041	-0.0068	-0.0084	-0.0043	-0.0067	-0.0067	-0.0041	-0.0022	-0.0022	-0.0023	-0.0023	-0.0022
	(0.0058)	(0.0057)	(0.0072)	(0.0076)	(0.0056)	(0.0056)	(0.0058)	(0.0074)	(0.0075)	(0.0071)	(0.0075)	(0.0076)
Mutual$_{t-1}$	-0.0333	-0.0218	-0.0202	-0.0226	-0.0215	-0.0225	-0.0360	-0.0325	-0.0331	-0.0325	-0.0323	-0.0325
	(0.0266)	(0.0285)	(0.0287)	(0.0246)	(0.0283)	(0.0287)	(0.0266)	(0.0233)	(0.0234)	(0.0234)	(0.0234)	(0.0233)
Public$_{t-1}$	-0.0090	-0.0028	-0.0006	-0.0047	-0.0026	-0.0035	-0.0135*	-0.0118*	-0.0120*	-0.0117	-0.0120*	-0.0118*
	(0.0067)	(0.0078)	(0.0072)	(0.0070)	(0.0076)	(0.0084)	(0.0074)	(0.0070)	(0.0070)	(0.0072)	(0.0071)	(0.0069)
Insurance penetration$_{t-1}$		0.5874	0.5419	1.7444	0.7272	0.9783	-0.2618	1.3029	1.2571	1.2651	1.3036	1.3047
		(1.5664)	(1.5751)	(1.6899)	(1.5745)	(1.9034)	(1.5724)	(2.0278)	(2.0308)	(2.0528)	(2.0256)	(2.0318)
Competition$_{t-1}$		-0.2424	-0.0066	0.0961	-0.2242	-0.1629	-0.3152	0.0794	0.0617	0.0727	0.0784	0.0800
		(0.4624)	(0.4101)	(0.5109)	(0.4396)	(0.4597)	(0.4696)	(0.4748)	(0.4717)	(0.4747)	(0.4745)	(0.4753)
Firm capacity$^2_{t-1}$			-0.0002									
			(0.0003)									
Industry capacity$^2_{t-1}$			0.0072									
			(0.0073)									
ΔInterest rate$_{t-1}$				0.2967*				0.2206	0.2192	0.2172	0.2223	0.2213
				(0.1653)				(0.1843)	(0.1827)	(0.1804)	(0.1831)	(0.1819)
Catastrophic year$_{t-1}$					0.0037			0.0063	0.0064	0.0063	0.0065	0.0063
					(0.0098)			(0.0103)	(0.0103)	(0.0103)	(0.0104)	(0.0104)
GDP$_{t-1}$						0.0690		0.0006	0.0022	0.0006	0.0017	0.0005
						(0.1664)		(0.1919)	(0.1918)	(0.1919)	(0.1926)	(0.1915)
Regulation$_{t-1}$							0.0240***	0.0176***	0.0180***	0.0176***	0.0174***	0.0176***
							(0.0073)	(0.0066)	(0.0066)	(0.0067)	(0.0067)	(0.0067)
Firm capacity$_{t-1}$ × ΔInterest rate$_{t-1}$									-0.2360			
									(0.1533)			
Firm capacity$_{t-1}$ × Catastrophic year$_{t-1}$										0.0029		
										(0.0071)		
Firm capacity$_{t-1}$ × GDP$_{t-1}$											-0.0894	
											(0.0890)	
Firm capacity$_{t-1}$ × Regulation$_{t-1}$												-0.0007
												(0.0051)
Unit dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	No	No	No	No	No	No	No	No	No	No	No
Observations	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654	5,654

Notes: Robust (heteroskedasticity and serial correlation) standard errors in parentheses; ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively.

6 Conclusions

We analyze the impact of capacity on price and productivity change in a newly constructed firm-level sample for the German non-life market over the 1954–2016 period. This sample period is much longer than previous studies of insurance cycles. Additionally, we specifically control for insurance demand which has not typically been done in prior studies of insurance cycles. This has been a common criticism of previous analyses of insurance market cycles. Our results support the capacity-constraint hypothesis and emphasize that both firm and industry capacity are relevant price determinants. The impact of capacity on price is complex and depends on exogenous factors (interest rate change, catastrophic years, GDP growth, and regulation). Our results also show that decreased firm capacity has a negative impact on productivity change. Since price and productivity change together determine profitability, insurers may also increase prices to account for negative productivity change as a result of constrained capacity.

Our results yield important implications for the understanding of underwriting cycles and re-emphasize the role of capacity in this context. The impact of capacity is more complex than previously documented and depends on several exogenous factors. The pressure to increase prices due to capacity constraints is reinforced during interest rate declines, catastrophic years, and GDP drops. These results illustrate that the causes of underwriting cycles are even more diverse than previously assumed and highlight that different hard-market phases may have different causes. As described above, these findings represent not only important contributions to the academic literature on insurance cycles, but also to the business of insurance.

The analyses presented here offer numerous directions for future research. The analyses could be expanded to by-line cross-sectional data, which would yield interesting insights about idiosyncrasies of certain business lines. Also, contemporaneous interactions among capacity, prices, and productivity could be analyzed if appropriate instruments are available. In addition, it is of interest whether industry-shocks have the same price/productivity impact or whether differences among (group of) firms can be observed (e.g., by means of a factor augmented vector autoregression). It also could be worthwhile to compare the estimated cycle length using industry data compared to using firm-level data. Like previous literature, this study lacks accurate price data and thus relies on the combined ratio as proxy.

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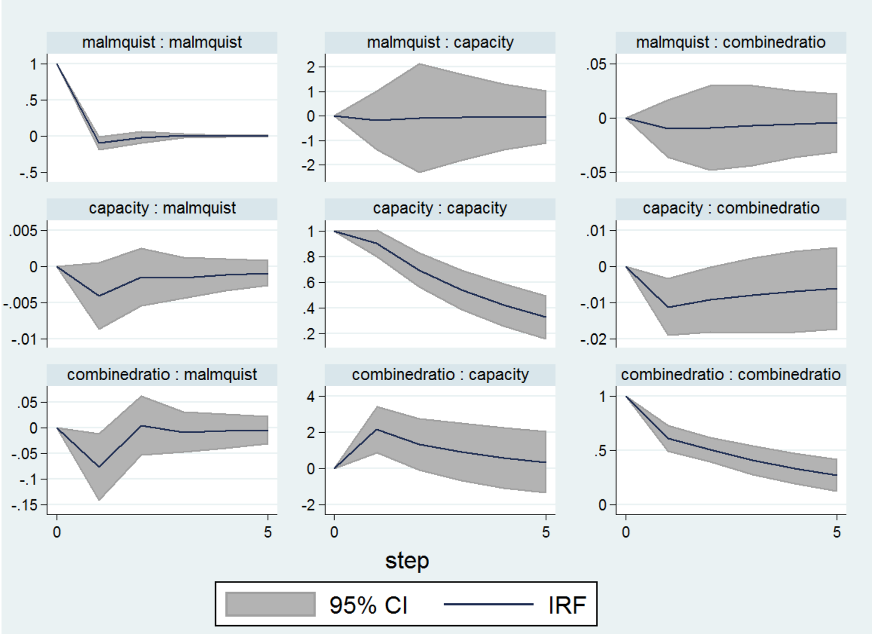
Appendix A

Impulse response functions estimated from linear panel VAR model



Notes: The impulse response functions stem from a linear panel VAR model which analyzes the short-term dynamic interactions among capacity, price and productivity. The model was specified following Bruneau and Sghaier (2015), which analyzes the short-term dynamic interactions between the capacity and the combined ratio at the industry level. We extended this framework by considering also ΔTFP. The model specification is shown in Equation (A1). The model was based on the Arellano-Bond estimator (Arellano & Bond, 1991). The lines illustrated the responses from all variables in the model to a (positive) one standard deviation shock in the impulse variable.

$$X_{i,t} = \alpha_0 + \sum_{i=1}^{P} \alpha_{1,i} X_{i,t-1} + \sum_{i=1}^{P} \alpha_{2,i} X_{i,t-2} + \varepsilon_{i,t}, \tag{A1}$$

where $X_{i,t} = (Capacity, Combined\ Ratio, \Delta TFPs)$.

Appendix B

Definition of expansion and contraction periods

Reference	Cycle	Trough	Beginning Quarter Expansion	Peak	Beginning Quarter Contraction	Expansion (Trough–Peak)	Contraction (Peak–Trough)
Heilemann & Schuhr (2008)				1955-II (4)	1956-II (9)	1954–1955	1956–1958
	1958-III–1962-IV (18)	1958-III (4)	1959-III (3)	1960-II (5)	1961-III (6)	1959–1960	1961–1962
	1963-I–1966-IV (16)	1963-I (1)	1963-II (6)	1964-IV (3)	1965-III (6)	1963–1964	1965–1967
	1967-I–1971-I (17)	1967-I (4)	1968-I (6)	1969-III (2)	1970-I (5)	1968–1969	1970–1971
	1971-I–1974-I (12)	1971-II (4)	1972-II (2)	1972-IV (2)	1973-II (4)	1972–1972	1973–1975
	1974-II–1982-I (32)	1974-II (7)	1976-I (13) *1975-IV (14)*	1979-II (4)	1980-II (8)	1976–1979	1980–1982
	1982-II–1994-I (48)	1982-II (6) *1982-IV (3)*	1983-IV (27) *1983-II (28)*	1990-III (6)	1992-I (9) *1991-IV (9)*	1983–1991	1992–1993
	1994-II–2001-IV (31)	1994-II (1)	1994-III (23)	2000-II (5) *2000-I (5)*	2001-III (2)	1994–2000	2001–2003
	2002-I–2004-II (10)	2002-I (7) 2001-IV (8)	2003-IV (3)	*2008-I (3)*		2004–2007	2008–2009
Döhrn (2014)	*2008-IV–2012-III*	*2008-V (5)*	*2010-I (6)*	*2011-III (3)*	*2012-II (2)*	2010–2011	2012–2012
	2012-IV	*2012-IV (2)*				2013–2016	

Notes: Döhrn's (2014) results are italicized. Numbers in parentheses show duration of cycle phase in quarters.

Appendix C

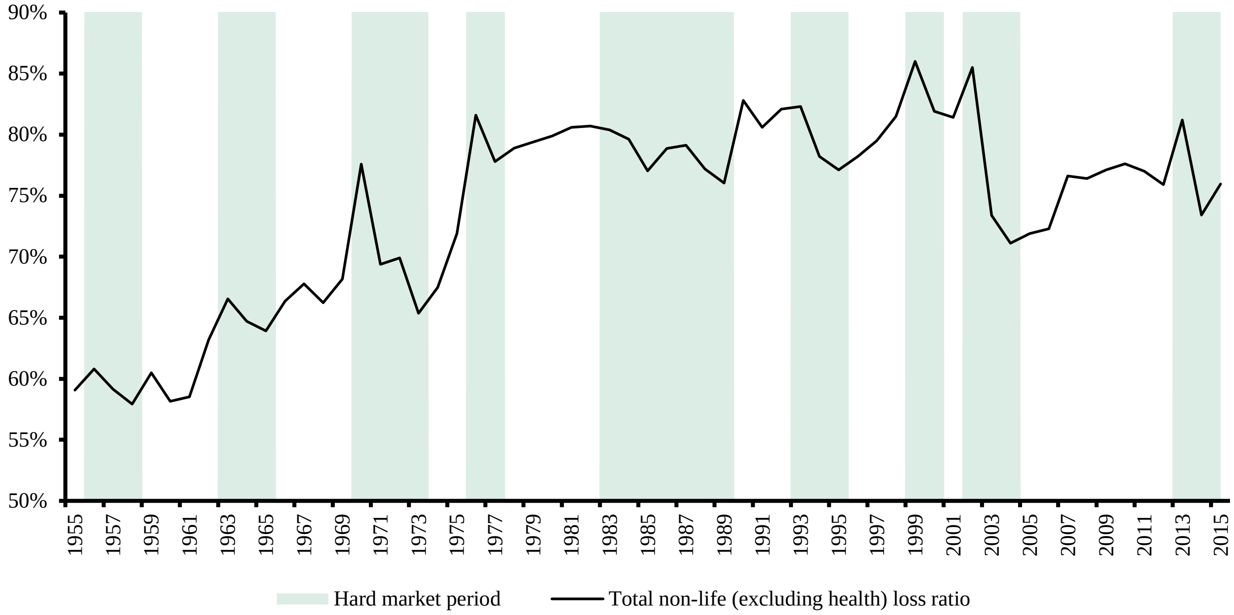
Median annual productivity change rates over the German business cycle

Period	Median ΔTFP	Period	Median ΔTFP
Expansion (Trough–Peak)		Contraction (Peak–Trough)	
1954–1955	1.0211	1956–1958	1.0061
1959–1960	1.0127	1961–1962	0.9966
1963–1964	1.0056	1965–1967	0.9993
1968–1969	1.0062	1970–1971	1.0060
1972–1972	1.0299	1973–1975	1.0099
1976–1979	0.9989	1980–1982	1.0040
1983–1991	1.0014	1992–1993	1.0037
1994–2000	1.0014	2001–2003	0.9974
2004–2007	1.0068	2008–2009	1.0016
2010–2011	1.0057	2012–2012	0.9981
2013–2016	1.0059		1.0029
Total	1.0030	Total	1.0029
Complete period			
1955–2016	1.0032		

Notes: Kendrick and Grossman (1980) find that during expansion (contraction) periods, productivity shows stronger (weaker) growth in various U.S. industries. Appendix C replicates their analysis for the German non-life insurance sector using the business cycle phase definitions from Table Appendix B. Based on the results, we cannot confirm these findings of Kendrick and Grossman for the German non-life insurance sector; the median TFP change rates are only marginally different. However, Appendix C shows that negative TFP change is more common in contraction periods than in expansion periods.

Appendix D

Definition of hard market periods



Notes: Appendix D shows the development of the loss ratio for the complete German non-life sector (excluding health). Data is obtained from the annual reports of the German Federal Financial Supervisory Authority; the loss ratio is used since expenses data are available only after 1975. Hard market phases start at the peak of the loss ratio development and end at the trough. Furthermore, the loss ratio must have decreased by more than 3% in this period in order to be classified as hard market period.

Appendix E

Price determinants in soft and hard market periods

Dependent variable: Price (Combined ratio)	Hard market periods					Soft market periods				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\Delta Loss_{t-1}$	0.0084	0.0093	0.0082	0.0081	0.0083	0.0379**	0.0385***	0.0380**	0.0378**	0.0378**
	(0.0076)	(0.0076)	(0.0075)	(0.0075)	(0.0076)	(0.0149)	(0.0148)	(0.0149)	(0.0149)	(0.0149)
Firm capacity$_{t-1}$	-0.0076***	-0.0060**	0.0022	-0.0061**	-0.0060	-0.0136***	-0.0151***	-0.0194***	-0.0135***	-0.0074
	(0.0029)	(0.0028)	(0.0031)	(0.0028)	(0.0039)	(0.0029)	(0.0036)	(0.0049)	(0.0031)	(0.0062)
Industry capacity$_{t-1}$	-0.0522***	-0.0524***	-0.0512***	-0.0520***	-0.0522***	-0.0474***	-0.0485***	-0.0481***	-0.0473***	-0.0470***
	(0.0088)	(0.0087)	(0.0084)	(0.0088)	(0.0088)	(0.0076)	(0.0077)	(0.0077)	(0.0076)	(0.0076)
Financial quality$_{t-1}$	0.0188	0.0141	0.0281	0.0246	0.0196	-0.0220	-0.0322	-0.0323	-0.0212	-0.0147
	(0.0216)	(0.0216)	(0.0220)	(0.0221)	(0.0213)	(0.0397)	(0.0426)	(0.0423)	(0.0406)	(0.0414)
ΔTFP_{t-1}	0.0010	0.0014	0.0052	0.0006	0.0008	-0.0526	-0.0494	-0.0495	-0.0528	-0.0541
	(0.0092)	(0.0093)	(0.0090)	(0.0094)	(0.0093)	(0.0357)	(0.0350)	(0.0350)	(0.0355)	(0.0365)
Size$_{t-1}$	0.0055	0.0047	0.0040	0.0056	0.0056	0.0217***	0.0224***	0.0217***	0.0217***	0.0218***
	(0.0103)	(0.0102)	(0.0101)	(0.0104)	(0.0103)	(0.0077)	(0.0078)	(0.0077)	(0.0077)	(0.0077)
Size$^2_{t-1}$	-0.0043	-0.0039	-0.0016	-0.0046	-0.0043	0.0032	0.0033	0.0026	0.0032	0.0030
	(0.0055)	(0.0056)	(0.0057)	(0.0055)	(0.0055)	(0.0052)	(0.0052)	(0.0053)	(0.0052)	(0.0052)
Mutual$_{t-1}$	0.0009	0.0023	0.0003	0.0016	0.0009	0.0176	0.0159	0.0180	0.0175	0.0182
	(0.0511)	(0.0514)	(0.0512)	(0.0513)	(0.0511)	(0.0368)	(0.0369)	(0.0372)	(0.0368)	(0.0367)
Public$_{t-1}$	-0.0238	-0.0221	-0.0250	-0.0239	-0.0238	-0.0247	-0.0243	-0.0233	-0.0247	-0.0244
	(0.0165)	(0.0165)	(0.0165)	(0.0165)	(0.0165)	(0.0242)	(0.0245)	(0.0242)	(0.0242)	(0.0244)
Insurance penetration$_{t-1}$	-7.2900**	-7.2948**	-6.4759**	-7.2850**	-7.3051**	6.5726***	6.4519***	6.3135***	6.5770***	6.6629***
	(3.2235)	(3.1929)	(3.0429)	(3.2323)	(3.2254)	(2.2235)	(2.2497)	(2.2787)	(2.2219)	(2.2195)
Competition$_{t-1}$	-1.8590***	-1.8861***	-1.7025***	-1.8452***	-1.8561***	-1.2310**	-1.3235**	-1.2730**	-1.2281**	-1.2181**
	(0.5901)	(0.5899)	(0.5819)	(0.5944)	(0.5916)	(0.5768)	(0.5984)	(0.5948)	(0.5788)	(0.5781)
ΔInterest rate$_{t-1}$	0.0717	0.0064	0.1206	0.0798	0.0748	-0.6809**	-0.7651***	-0.6728***	-0.6803**	-0.6770**
	(0.3319)	(0.3233)	(0.3460)	(0.3347)	(0.3346)	(0.2714)	(0.2681)	(0.2561)	(0.2722)	(0.2711)
Catastrophic year$_{t-1}$	-0.0372***	-0.0375***	-0.0370***	-0.0371***	-0.0371***	0.0232***	0.0229***	0.0236***	0.0232***	0.0234***
	(0.0069)	(0.0067)	(0.0064)	(0.0068)	(0.0069)	(0.0068)	(0.0064)	(0.0066)	(0.0068)	(0.0068)
GDP$_{t-1}$	-0.5153*	-0.5039*	-0.5262*	-0.5105*	-0.5189*	-0.2540**	-0.2399*	-0.2684**	-0.2536**	-0.2484*
	(0.3039)	(0.3029)	(0.3019)	(0.3032)	(0.3072)	(0.1293)	(0.1301)	(0.1291)	(0.1289)	(0.1295)
Regulation$_{t-1}$	-0.0396***	-0.0401***	-0.0410***	-0.0407***	-0.0396***	0.0261**	0.0296**	0.0258**	0.0260**	0.0259**
	(0.0131)	(0.0131)	(0.0131)	(0.0133)	(0.0131)	(0.0118)	(0.0121)	(0.0117)	(0.0118)	(0.0119)
Firm capacity$_{t-1}$ × ΔInterest rate$_{t-1}$		0.7109***					-0.6820***			
		(0.1731)					(0.2051)			
Firm capacity$_{t-1}$ × Catastrophic year$_{t-1}$			-0.0355***					0.0196***		
			(0.0066)					(0.0065)		
Firm capacity$_{t-1}$ × GDP$_{t-1}$				-0.1750					0.0193	
				(0.1273)					(0.0744)	
Firm capacity$_{t-1}$ × Regulation$_{t-1}$					-0.0019					-0.0071
					(0.0045)					(0.0054)
Unit dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year dummies	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Observations	2,635	2,635	2,635	2,635	2,635	2,384	2,384	2,384	2,384	2,384

Notes: Robust (heteroskedasticity and serial correlation) standard errors in parentheses; ∗∗∗, ∗∗, and ∗ represent significance at the 1%, 5%, and 10% levels, respectively.