The hazard of merger by absorption: Why some Knappschaften merged and others not, 1861-1920

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Abstract: By the mid-19th century, German miners' mutual insurance funds adopted social insurance character due to the Prussian mining reform. Against the background of observable demographic and structural ageing processes, this paper investigates the determinants of mergers by absorption among 19th and early 20th century Prussian miners' social insurance funds. In a competing risk setting, the influence of a set of both time-invariant and time-varying explanatory variables on the conditional probability of exit by absorption compared to that of closure is estimated. We apply, on the one hand, Cox's semiparametric proportional hazards model to explain KV exit and, on the other hand, Fine and Gray's proportional subhazards model to explain exit by absorption in particular. The latter model allows for correlation among exit modes.

Keywords: Competing Risks, Cox Regression; Duration Analysis; Financial Distress; Knappschaft; Mergers; Proportional Subhazards Model; Social Insurance
JEL classification: C41; G22; G23; I31; N33

I. Introduction

This paper wants to assess the determinants of mergers among 19th and early 20th century Prussian miners' social insurance funds (called Knappschaften or Knappschaft funds). Focusing on the period 1861 to 1920, the formative period of German social insurance, this investigation is motivated by two important stylized facts. First, absolute and relative concentration among Knappschaft funds (henceforth abbreviated with KV for *Knappschaftsverein*), which provided pay-as-you-go financed compulsory insurance against life risks, increased steadily since the 1870s. Second, the concentration process was driven by unequal internal growth as well as liquidations and, in particular, external growth via mergers. Aside from the fact that we are able to observe that KVs merged, we do not know the motives behind the decisions. Yet the economics literature proposes and investigates a variety of motives firms, in general, and insurers, in particular, could have to take over another firm or volunteer as target for absorption. Motives might be to increase the market share, diversify risks, exploit

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economies of scale and scope, reach minimum efficient size, and also to avoid insolvency.[1]

With respect to contemporary sources, two distinct motives come into question. On the one hand, it may have been financially distressed KVs that were subject to absorptions, and the even more financially distressed ones were subject to closure. Thus, mergers may have aimed at preventing financially unviable KV from running out of resources, hence preventing insurants of financially distressed funds from loss of acquired entitlements. We call this the rescue-hypothesis which is in the following our baseline hypothesis. Contemporary researchers, KV officials, and the state debated into the early 20th century the issue of why and to what extent KVs were financially distressed. This historical debate in the literature was in its core actuarial, and the main argument was that sustainable operation of the KVs' pension benefit schemes required some kind of (not further specified) minimum efficient size. Especially smaller KVs were said to be more vulnerable to unforeseen events like accidents or otherwise caused variations in the number of contributors and pensioners so that they would not be able to provide sustainable pension finance.[2] Beyond that, KVs early experienced increasing system dependency ratios regarding their collectives of insured miners with parallels to the more familiar demographic challenge of social security systems of the second half of the 20th century. On the other hand, mergers by absorption may have been simply part of the growth strategy of the absorber KVs. We call this the self-interest hypothesis. Clearly, the rescue-hypothesis puts the absorbed KVs into focus, while the self-interest-hypothesis emphasizes the potential economic advantage for the absorber KVs that, then, had only absorbed attractive targets.

[1] Ronald E. Shrieves/Donald L. Stevens, *Bankruptcy avoidance as a motive for merger*, in: Journal of Financial and quantitative Analysis 14 (1979), 501-515; Michael C. Jensen, *Takeovers: Their Causes and Consequences*, in: Journal of Economic Perspectives 2 (1988), 21-48; Roland Eisen, *Market Size and Concentration: Insurance and the European Internal Market 1992*, in: The Geneva Papers on Risk and Insurance 16 (1991), 263-281; Ran BarNiv/John Hathorn, *The Merger or Insolvency Alternative in the Insurance Industry*, in: The Journal of Risk and Insurance 64 (1997), 89-113; J. David Cummins/Maria Rubio-Misas, *Deregulation, Consolidation, and Efficiency: Evidence from the Spanish Insurance Industry*, in: Journal of Money, Credit and Banking 38 (2006), 323-356.

[2] Tobias A. Jopp, *Ein risikoreiches Geschäft? Internes und externes Wachstum als risikopolitische Instrumente im preußischen Knappschaftswesen, 1854-1923*, in: Berufliches Risiko und soziale Sicherheit. Beiträge zur Tagung „Vergangenheit und Zukunft sozialer Sicherungssysteme am Beispiel der Bundesknappschaft und ihrer Nachfolger" im Deutschen Bergbau-Museum Bochum, 8. und 9. Oktober 2009, ed. by Christoph Bartels, Bochum 2010, 189-224, 189-192; compare Timothy W. Guinnane/Jochen Streb, *Moral hazard in a mutual health-insurance system: German Knappschaften, 1867-1914*, in: Economics Department Working Paper No. 70, Yale University, and *Ruhr Economics Papers* No. 163, Rheinisch-Westfälisches Institut für Wirtschaftsforschung for testing the contemporaries' argument that sickness funds should be small to allow for intense social control of simulation behaviour.

Against this background, this paper carries out an indirect quantitative test of the rescue-hypothesis that says mergers among Prussian KVs were, first and foremost, an insolvency alternative. The test is indirect because it cannot prove by whom the decisions to merge were precisely made. For a problem connected with KV management and regulation is that we cannot directly observe the decision-making process on the micro-level leading to a merger, a liquidation or continuation of operation. Principally, for some reason either (a) the state via its mining administration had promoted mergers or (b) the absorbing KV had proposed their targets a merger or (c) the absorbed KVs had proposed mergers to potential absorber KVs. However, by means of duration analysis, we examine the effect of KV-specific determinants on survival time before absorption occurred. Thereby, we intend to gain some new insights into the motives of mergers. This approach requires estimates of the conditional probability of absorption at a particular point in time, given survival until that point in time. We first focus on Cox's (1972) semiparametric proportional hazards model to explain simply KV exit. Secondly, in a competing risk setting, the influence of a set of both time-invariant and time-varying explanatory variables on the conditional probability of absorption compared to that of closure is estimated. Therefore we apply Fine and Gray's (1999) proportional subhazards model that allows for correlation among exit modes.

Economists and economic historians have meanwhile generated a variety of applications of duration analysis, a convenient statistical tool to examine time-to-event data. Early applications focus in particular on the relationship between time spent in unemployment and the conditional probability of getting employed.[3] More recent economic applications, this investigation is in some way related to, deal with the determinants of firm survival and financial distress prediction.[4] Recent applications with respect to economic history study, for example, demographics and the du-

[3] Nicholas M. Kiefer, *Economic Duration Data and Hazard Functions*, in: Journal of Economic Literature 26 (1988), 646-679, for an overview.

[4] Asger Lunde/Allan Timmermann/David Blake, *The hazards of mutual fund underperformance: A Cox regression analysis*, in: Journal of Empirical Finance 6 (1999), 121-152; Howard F. Turetsky/Ruth Ann McEwen, *An Empirical Investigation of Firm Longevity: A Model of the Ex Ante Predictors of Financial Distress*, in: Review of Quantitative Finance and Accounting 16 (2001), 323-343; Adrian Gepp/Kuldeep Kumar, *The Role of Survival Analysis in Financial Distress Prediction*, in: International Research Journal of Finance and Economics 16 (2008), 13-34; Chae Woo Nam/Tong Suk Kim/Nam Jung Park/Hoe Kyung Lee, *Bankruptcy Prediction Using a Discrete-Time Duration Model Incorporating Temporal and Macroeconomic Dependencies*, in: Journal of Forecasting 27 (2008), 493-506.

ration of the interwar gold-exchange standard.[5] We add an economic application focusing on one of the important historical pioneers of social insurance in Germany.

Findings suggest that the burden with pensioners, measured by the invalids- and survivors-to-contributors ratios, plays a significant role in driving the conditional probability of absorption up. Besides, also the young contributors-to-old contributors ratio and the entrepreneurs' financing share regarding total claims costs are identified as drivers of the hazard of merger by absorption. The sick days-to-contributors ratio and the degree of a KV's diversification across different mining subsectors are in contrast inversely related to the hazard rate, and an increase in these variables significantly reduces the hazard of merger by absorption. While size plays no significant role with respect to exit by absorption, it does play with respect to exit by closure in that increases in size reduce the hazard rate. Even if evidence on the invalids- and survivors-to-contributors ratios support the rescue-hypothesis, findings on the other variables do support the self-interest-hypothesis.

The analysis unfolds in the following steps. Section 2 presents the data sources. Section 3 provides a quantitative description of Knappschaft insurance and the concentration process. Section 4 deals with the econometric model. Section 5 discusses the empirical results. Finally, Section 6 concludes the paper.

II. Data sources

This analysis draws upon a data set newly constructed from the *Statistik der Knappschaftsvereine des preussischen Staates*, henceforth shortly labeled KV statistics, which the Prussian ministry of trade and commerce originally compiled and first published in 1854, thereby reporting data on 1852.[6] Volumes were then published regularly since 1862 reporting annual data on the preceding year. For the years 1921 and 1922, information is not at hand. In 1923, all German KVs merged into the

[5] Timothy W. Guinnane, *Economics, History, and the Path of Demographic Adjustment: Ireland after the Famine*, in: Research in Economic History 13 (1991), 147-198; Chulhee Lee, *Socioeconomic Background, Disease, and Mortality among Union Army Recruits: Implications for Economic and Demographic History*, in: Explorations in Economic History 34 (1997), 27-55; Kirsten Wandschneider, *the stability of the Interwar Gold Exchange Standard: Did Politics Matter?*, in: Journal of Economic History 68 (2008), 151-181; Nikolaus Wolf, *Scylla and Charybdis. Explaining Europe's exit from gold, January 1928-December* 1936, in: Explorations in Economic History 45 (2008), 383-401; Louis Cain/Sok Chul Hong, *Survival in 19th century cities: The larger the city, the smaller your chances*, in: Explorations in Economic History 46 (2009), 450-463.

[6] Bavarian Knappschaften were excluded because the Bavarian Knappschaft statistics is officially published not before 1884. Saxonian Knappschaften were excluded since there were too few mergers conducted.

Reichsknappschaft, which marks the endpoint of this investigation. Data compiled cover the entire population of 103 Prussian KVs that were in operation within the period 1861-1920 and provide a broad range of information on memberships, revenues and expenditures. The data set is divided into three samples. The basic sample consists of the cohort of KVs that were still in operation in 1920, thus survived over the observation period. Sample two is made of all KVs that ceased operation before 1920 because of absorption by another KV. Sample three covers the remainder of KVs that exited the market because of terminal closure and, hence, liquidation. Appendix 1 lists all KVs by code, name, location (mining administration region), years of operation and sample linkage.

Information on mergers conducted within the observation period are taken from Jopp (2010) who provides a basic overview of 20 mergers (name of involved KVs and their location, year of merger, their size and pensioners-to-contributors ratio in the year prior to the merger, and as appropriate the name of the newly created KV). In particular, he distinguishes two types of mergers. The former (type A) was the more frequent and happened when one or more KVs were merged into another fund that had already existed before the merger and continued existence after merger.[7] The latter (type B) happened when two or more KVs merged into a newly created fund. Appendix 1 also indicates into which funds the absorbed KVs merged.

III. Stylized facts on concentration and ageing

The first mutual aid schemes related to German miners were formed in the Middle Ages. Later, these associations became known as Knappschaft funds. Their members benefited in terms of income replacement from several sources: Daily sick pay in the case of temporary sickness, medical treatment, invalidity pensions in the case of permanent incapacitation to work, and survivorship pensions in the case of the breadwinner's death.[8] Until the mid-19th century, however, financing was based at first on charity (until absolutism) and later on patronage by the sovereign (during

[7] Jopp, *Ein risikoreiches Geschäft?* (cf. n. 2).
[8] Königreich Preußen, *Gesetz, betreffend die Vereinigung der Berg-, Hütten- und Salinen- und Aufbereitungs-Arbeiter in Knappschaften, für den ganzen Umfang der Monarchie, vom 10. April* 1854, Essen 1855; Rudolf Klostermann, *Das Allgemeine Berggesetz für die preußischen Staaten vom 24. Juni 1865, nebst Einleitung und Kommentar*, Berlin 1866; Christoph Bartels et al., *Vergangenheit und Zukunft sozialer Sicherungssysteme am Beispiel der Bundesknappschaft und ihrer Nachfolger. Ein Forschungsprojekt der Leibniz-Gemeinschaft*, in: Jahrbuch für Wirtschaftsgeschichte (2009), 195-217.

absolutism).[9] The reform of the Prussian mining legislation between 1851 and 1865 then shaped the KVs' benefit scheme towards occupational social insurance.[10] While miners' funds operated with mandatory contributions by themselves and their employers even before, the Knappschaft law of 1854 introduced legal claims and, therefore, some kind of actuarial relationship between contributions and benefits.[11] While miners and their employers ran the KVs via self-management, the mining administration had supervisory competences. Moreover, KVs could have either operated a benefit scheme for a particular area for which, then, no other KV was allowed to compete or a particular company. Naturally, KV areas were tantamount to smaller or larger mining areas exhibiting resource deposits of various types (hard coal, brown coal, iron ore, other ores, salt, stone). In addition, KVs insured also employees of steelworks and related processing plants provided owners had chosen to join Knappschaft insurance.[12]

Let us now turn to a quantitative description of the KVs. Table 1, to begin with, displays aggregate membership information on contributing miners and pension recipients as well as aggregate expenditure information on the main cost items daily sick pay, medical treatment and pensions for the invalids and survivors.[13] Columns (1) and (2) show the long-term expansion of the collective of insurants of Prussian KVs, which in turn reflects the rapid growth of the mining sector as a whole. Comparing 1861 and 1920, the contributor base, i.e. the financial power of the KVs, increased by about 753 percent whereas the number of pensioners to be financed increased at an even higher pace implying an increasing financing burden put on the average contributor. As Jopp shows, the pensioners-to-contributors ratio (PCR) as an indicator of this burden was highest and more volatile among smaller KVs. Nonetheless, even large KVs had to deal with increasing PCRs. The average PCR of smallest-sized KVs up to 200 contributors was at least 50 pensioners per 100 contributors since 1873 and not below 22 between 1861 and 1872. For larger KVs, historical PCRs ranged between 12 to 26 in 1861 and 25 to 48 in 1920, hence nearly doubled on average. Table 1 as well shows that the proportion of invalids in all pension recipients was – on the

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[9] Wilhelm Bülow, *Das Knappschaftswesen im Ruhrkohlenbezirk bis zum allgemeinen preußischen Berggesetz vom 24. Juni 1865*, Borna-Leipzig 1905, 32-65.
[10] A prominent exception not taken into account here is the Kingdom of Saxony which went not the Prussian way what most other territorial states did.
[11] Klaus Tenfelde, *Die Knappschaftsversicherung und die Wurzeln der Sozialversicherung in Deutschland*, in: 150 Jahre Preußisches Knappschaftsgesetz, ed. by Bundesknappschaft, Bochum 2004; Tobias A. Jopp, *The Welfare State Evolves: German Knappschaften, 1854-1923*, in: FZID Discussion Paper Series, No. 16 (2010).
[12] Jopp, *The Welfare State Evolves* (cf. n. 7).
[13] Note that Bismarckian insurance introduced survivorship pensions as early as in 1911.

aggregate, not necessarily for each KV – rather low, about 20 to 23 percent in the first decade depicted, but increased towards the First World War to 40 percent. However, while there were always more survivors than invalidity pensioners, invalids were far more costly as a look at column (7) shows. At the minimum, about 47 to 50 percent of pension expenditure was spent for invalidity pensions. Consulting KV-level data explicitly proves that average widows' (orphans') pensions predominantly ranged between 50 and 60 (10 to 20) percent of those. Yet the great expansion of social spending within the KVs' benefit scheme in all claims categories including sickness-related benefits is evident from the data, even if especially size-contingent differentials across KVs persistently existed.[14]

Table 1: Prussian Knappschaften from an aggregate perspective, selected years

Year	(1) Contributors	(2) Pensioners	(3) Invalids in % of (2)	(4) Sick Pay	(5) Health Care	(6) Pensions	(7) Invalids in % of (6)
1861	118.9	21.0	23.1	564	661	1,298	47.8
1866	159.3	29.7	22.0	763	907	1,927	48.5
1871	226.8	48.3	20.4	1,043	1,304	3,170	47.2
1876	260.9	67.3	23.2	1,727	1,839	6,317	51.5
1881	289.4	86.8	24.1	1,520	1,988	8,293	53.6
1886	328.7	110.1	25.3	2,667	2,529	11,288	54.1
1891	429.1	132.1	28.4	3,962	3,575	13,982	57.7
1896	469.1	153.8	31.4	5,012	3.956	17,350	60.4
1901	636.7	156.3	39.0	10,681	6,299	23,147	61.7
1906	729.3	183.4	40.0	11,605	11,248	29,272	62.2
1911	683.9	206.8	40.3	17,026	17,244	37,428	69.0
1916	773.3	292.4	30.2	14,639	18,386	47,469	61.7
1920	1,013.9	327.6	27.8	126,376	155,758	57,725	56.2

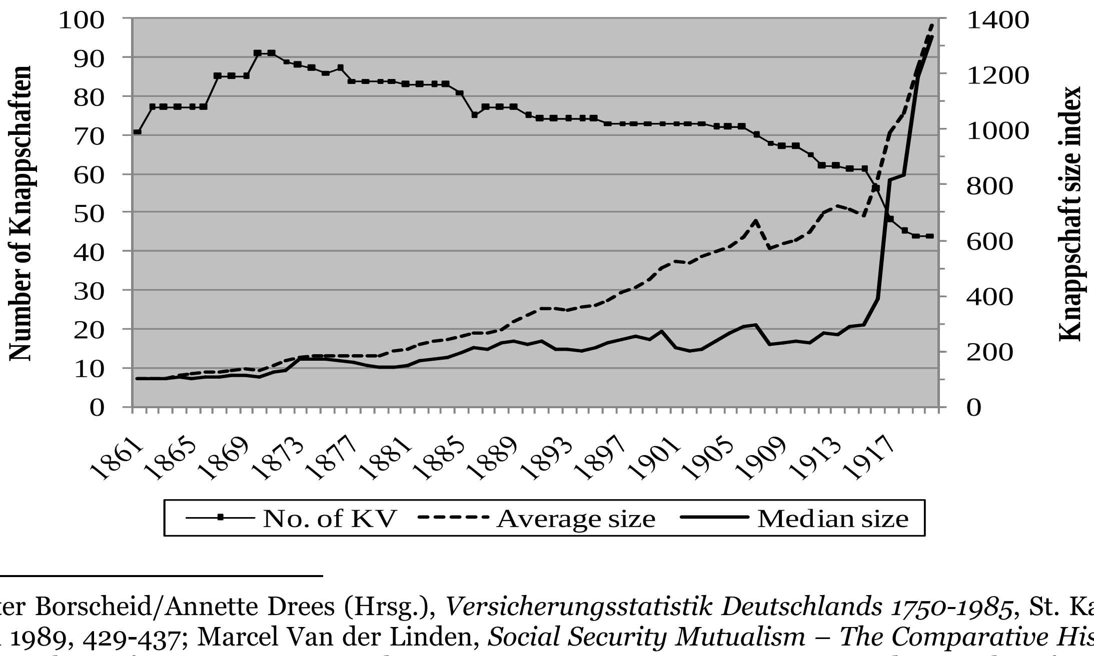
Note: (1) and (2) are in 1,000 insurants. (1) includes established and unestablished miners. From 1908 on, contributors are those of the pension section. (2) includes invalids, widows and orphans. (4), (5) and (6) are in 1,000 marks. For the year before 1876, one Taler is converted into three marks.
Source: Ministerium für Handel und Gewerbe (1862-1922), Statistik der Knappschaftsvereine des preussischen Staates, *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, 10-70.

As mentioned above, the benefit scheme for miners was run by 103 different KVs. Figure 1 first depicts the distribution of KVs across observed years. From 71 in 1861, the number of operating funds rose to 91 in 1870/71, the absolute maximum

[14] Jopp, *The Welfare state Evolves* (cf. n. 7).

and a rather low number of insurance carriers per year compared to other sorts of existing German social insurance (especially sickness) funds and friendly societies in Britain and other countries at the time, which often ranged in the high hundreds or even thousands per year.[15] Since 1871 absolute concentration as regards the number of existing KVs decreased by more than 50 percent to yet 44 in 1920. The figure moreover displays indices of two proxy measures of minimum efficient size proposed in the literature, namely average and median size, and data stress excess growth of the first over the latter.[16] Not only in growth terms did average KV size exceed median KV size, but also in absolute terms. Being aware of different approaches to measuring the size of an insurance fund, for example by memberships or monetary variables like premium income, we measure KV size in terms of contributing miners, not in terms of overall membership that includes pensioners. This is because the number of contributors better reflects the true financing potential of which a KV could dispose. Average size in 1861 amounted to 1,675 contributors while median size was 449. From the observation that median size is far smaller than the average, it is straightforward to identify the annual KV size distribution as clearly positively skewed.

Figure 1: Number of Prussian Knappschaften and indices of average and median Knappschaft size (1861=100), 1861-1920



[15] Peter Borscheid/Annette Drees (Hrsg.), *Versicherungsstatistik Deutschlands 1750-1985*, St. Katharinen 1989, 429-437; Marcel Van der Linden, *Social Security Mutualism – The Comparative History of Mutual Benefit Societies*, Bern et al. 1996; Margarete Wagner-Braun, *Zur Bedeutung berufsständischer Krankenkassen innerhalb der privaten Krankenversicherung in Deutschland bis zum Zweiten Weltkrieg – Die Selbsthilfeeinrichtungen der katholischen Geistlichen*, Stuttgart 2002, 58 and 87; E. Peter Hennock, *The Origin of the Welfare State in England and Germany, 1850-1914*, Cambridge 2007, 160-164.
[16] Eisen, *Market Size and Concentration* (cf. n. 8), 270-271.

Note: Knappschaft size is measured in terms of contributing miners. From 1908 on, contributors are those of the pension section.
Source: See Table 1.

To detail the picture, Table 2 reports for selected years and each sample the absolute frequency of KV size according to six size classes. Data exemplarily show that small KVs up to 999 contributors were persistently relatively large in number. Though, the relative frequency of large funds steadily increased. Note that in 1920 92 percent of contributors were insured in 14 KVs larger than 10,000 contributors each. In addition, the data indicate that especially absorbed as well as closed KVs predominantly operated on the lower end of the size distribution.

Table 2: Knappschaft size distribution for 1861, 1891 and 1920

Size classes	**Survivors (sample A)**			**Absorbed (sample B)**		**Closed (sample C)**		***Share in contributors by size class (in %)***		
	1861	**1891**	**1920**	**1861**	**1891**	**1861**	**1891**	***1861***	***1891***	***1920***
1 to 199	8	9	9	4	1	8	5	*1.2*	*0.3*	*0.1*
200 to 999	9	8	7	11	6	8	8	*10.6*	*2.6*	*0.3*
1,000 to 4,999	7	14	5	8	7	3	2	*32.7*	*11.4*	*1.3*
5,000 to 9,999	1	4	9	-	2	-	-	*4.3*	*9.9*	*6.4*
10,000 to 49,999	3	5	10	2	1	-	-	*51.2*	*24.1*	*22.4*
50,000 +	-	2	4	-	-	-	-	-	*51.7*	*69.6*

Note: Knappschaft size is measured in terms of contributing miners. From 1908 on, contributors are those of the pension section.
Source: See Table 1.

Following Figure 1, Table 3 displays the number of absorbed, closed and newly entering KVs by phases. In all, 20 mergers took place whereby 37 KVs were absorbed by 13 different other KVs, and additionally 5 type-B-merger were conducted formally creating new funds. While half of all closures occurred during World War I, absorptions took especially place during three phases, 1869-1877, 1885-1891 and 1907-1913. It is hard to say what could have made these phases special for merging activity. We actually know from the one type-B-merger in 1885-1891, conducted precisely in 1890 between the *Märkischer KV*, *Essen-Werden'scher KV* and the *Mülheimer KV*, that it was done in the Ruhr area as a direct response to the implementation of Bismarckian invalidity and old age insurance in 1889 (into force since 1891). For some reason this is probably the single most important merger conducted. The *Märkischer KV* (*Essen-*

Werden'scher KV) was the largest (third-largest) KV at the time with about 86,000 (36,300) contributors. Recently Lauf, for example, argues that they conducted the merger for the one and only reason to take over Reich insurance in addition to their own Knappschaft benefit scheme as a *besondere Kasseneinrichtung* (special insurer) which legally required a certain minimum KV size.[17] The amending law of 1906, moreover, installed the possibility for the regulator to formally force mergers or closures on KVs (§177a and b).[18] This is not to say he did not do so before, but there was actually no paragraph in the laws of 1854 and 1865 saying he could. Nonetheless, the main argument of this investigation is that KV were merged (or even closed) because of financial distress. Clearly, from the perspective of the absorbing KV, rescuing a financially distressed KV, however small it was, requires (or would show) some sense of solidarity among miners and mining entrepreneurs.

Table 3: Absorbed, closed and newly entering Knappschaften, 1862-1920

Phases	(1) Absorbed KV	(2) Closed KV	(3) Entering KV	(4) Remarks
1862-1868	-	-	13	
1869-1877	10	4	13	Two type-B-merger in (3)
1878-1884	-	1	-	
1885-1891	10	2	3	One type-B-merger in (3)
1892-1906	1	1	-	
1907-1913	10	2	2	Two type-B-merger in (3)
1914-1918	6	11	-	
1919-1920	-	1	-	
Sum	*37*	*22*	*31*	

Source: Jopp, *Ein risikoreiches Geschäft?* (cf. n. 9).

Finally, ageing among KVs has to be addressed. Basically, an economic concept of ageing stresses economic dependency of the retired elderly on yet working individuals.[19] On the one hand, this definition allows modeling ageing processes among many present day economies that are characterized by threshold ages specifying when an individual officially enters the fraction of elderly (old age). Such an age usually lies

[17] Ulrich Lauf, *Der Allgemeine Knappschaftsverein zu Bochum (1890-1923) – Mythos und Wirklichkeit*, Bochum 2009, 14-21.
[18] Otto Steinbrinck, *Gesetz vom 19. Juni, betreffend die Abänderung des Siebenten Titels im Allgemeinen Berggesetze für die preußischen Staaten 24. Juni 1865, nebst Kommentar*, Berlin 1908, 152-158.
[19] Richard R. Verdugo, *Workers, workers' productivity and the dependency ratio in Germany: analysis with implications for social policy*, in: Population Research & Policy Review 25 (2006), 547-565, 548.

between 60 and 65 and equals legal retirement age, thus is the result of the societal-political discourse. On the other hand, this definition even allows modeling ageing in a society where threshold ages to retirement are much lower than those we are familiar with today. Since KVs provided invalidity and survivorship insurance, earliest effective retirement ages lay between 20 and 26. Clearly, a permanently incapacitated miner of that young age cannot be labeled as aged in a pure biological sense. From the perspective of the insurance system, however, his retirement constituted long-term economic dependency via "social" ageing.[20]

Basic measures of a society's age structure and ageing processes include median age, age or respectively support ratios (e.g. the old-age dependency ratio) and death rates, and the measures' respective changes over time.[21] Our first measure of ageing among KVs ties to the concept of old-age dependency which reflects the potential economic burden connected with ageing. Since KVs were social insurance funds, we are interested in system, not old-age, dependency, a concept that reflects the factual economic burden for the insurance scheme connected with ageing. The measure to be evaluated is the pensioners-to-contributors ratio already introduced above. It is of decisive importance if a benefit scheme is pay-as-you-go financed like that of KVs because the PCR directly enters the pay-as-you-go equation, and changes in the PCR trigger changes in the contribution rate, pension level, degree of subsidization or eligibility.[22] Our second measure of ageing is observed average pension duration with respect to invalidity pensions. Clearly, as with the PCR, average pension duration is not fully exogenous to KV. However, data on larger KV for which amplitudes of fluctuation were naturally smaller than for smaller KVs show a, by and large, constant effective retirement age regarding invalidity. So average pension durations, if increasing over time, should be a reasonable indicator of the underlying ageing process. Our third measure, lastly, refers to the fraction of contributors exclusively. We may not only define ageing among KVs in terms of increasing system dependency, but also in terms of a relatively ageing contributor base. According to the KV statistics, which reports five age groups of established contributors since 1867 and 10 since 1889, we

[20] There might arise some confusion with long-term unemployment that effectively constitutes economic dependency as well. The emphasis in the KV case, however, lies on the fact that an invalid miner officially retires from the perspective of the system.
[21] Peter Uhlenberg, *Demography of Aging*, in: Handbook of Population, ed. by Dudley L. Poston and Michael Micklin, New York 2006, 143-167, 161-162; Randall Wray, *Social Security in an Aging Society*, in: Review of Political Economy 18 (2006), 391-411, 393.
[22] Winfried Schmähl, *Umlagefinanzierte Rentenversicherung in Deutschland – Optionen und Konzepte sowie politische Entscheidungen als Einstieg in einen grundlegenden Transformationsprozeß*, in: Soziale Sicherungssysteme und demographische Herausforderungen, ed. by Winfried Schmähl and Volker Ulrich, Tübingen 2001, 124-204, 149-150.

compute the number of younger established miners per 100 older established miners.[23] The ratio (P) is equal to P = [(miners aged 16 to 25) + (miners aged 26 to 35)] / [miners aged 36 and more] for 1867 to 1920.

Table 4 displays estimates of the three measures of ageing. The PCR is decomposed into the invalids-to-contributors ratio (ICR) and the survivors-to-contributors ratio (SCR). Unfortunately, the average pension duration for the various KVs is reported as early as since 1900 by the KV statistics. The young contributors-to-old contributors ratio can be computed from 1867 on since the statistics lacks age group data before. For each measure and displayed year, the minimum, median and maximum of all operating KVs are reported. The long term increase of the median ICR towards the First World War as well as of the SCR towards 1890 substantiates increasing system dependency. Note that the median ICR increased by 500 percent from 1861 to 1911. In addition, the median average pension duration with respect to invalidity pensions increased from 7.0 in 1901 to 9.6 years in 1920, which corresponds to an overall growth of 27 percent. According to Jopp, available data on the Saarbrücker KV, one of the largest KV throughout the sampling period, point to an increase in the average pension duration by 198 percent, from 5.0 years in 1879 to 14.9 years in 1920. Interestingly, the young contributors-to-old contributors ratio does not indicate ageing of the contributor base from an aggregate perspective. On the whole, many KVs were growing over the observation period according to the growth of the mining area they were tied to, and thus they experienced a relatively growing proportion of pensioners while they could also recruit many young miners.

Table 4: Indicators of ageing among Knappschaften, selected years

Year	Invalids-to-con-tributors ratio			Survivors-to-con-tributors ratio			Average pension duration			Young-to-old ratio		
	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max
1861	0	2	38	1	13	94	-	-	-	-	-	-
1866	0	3	41	1	12	100	-	-	-	-	-	-
1871	0	3	83	3	16	103	-	-	-	2	50	80
1876	0	5	200	5	20	326	-	-	-	4	49	84
1881	0	5	125	2	20	205	-	-	-	4	49	77
1886	0	6	74	3	24	94	-	-	-	7	50	68
1891	0	6	77	5	20	136	-	-	-	3	50	76
1896	1	8	82	4	22	177	-	-	-	0	49	76

[23] As regards the distinction into established and, consequently, unestablished miners see Jopp, *The Welfare State Evolves* (cf. n. 7).

1901	0	9	55	3	19	95	0	7.0	24.0	8	52	75
1906	0	10	94	3	19	400	0	6.5	17.8	6	51	74
1911	0	12	63	5	24	129	0	8.2	22.5	12	61	78
1916	0	11	60	10	24	95	0	9.0	26.0	9	59	78
1920	0	9	38	7	25	63	0	9.6	15.4	11	61	80

Note: The invalids-to-contributors ratio indicates invalids per 100 contributors. The other two ratios are to be interpreted analogously. The annual average pension duration refers to the fraction of invalids that died during the observed year. Until 1907, the young-to-old ratio refers to established miners exclusively.
Source: See table 1.

IV. Econometric framework

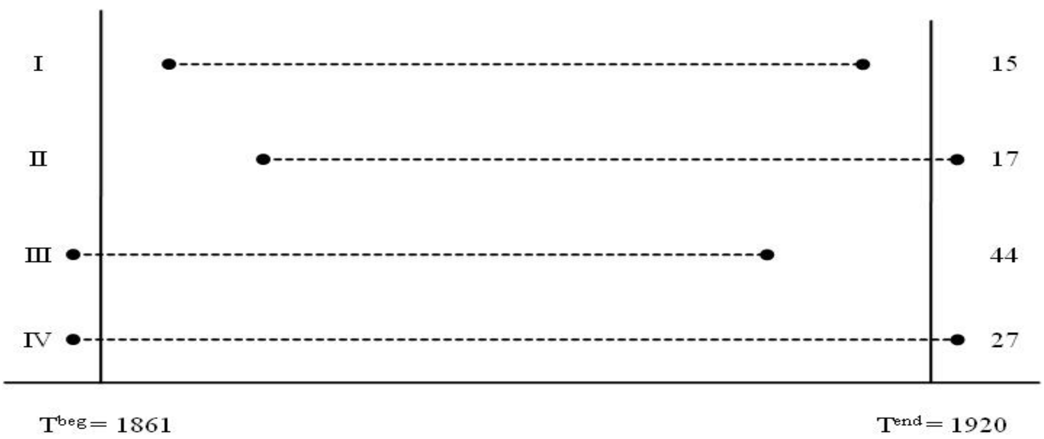
Survival time

This investigation studies time-to-event data from Prussian KVs. The nature of the data requires application of duration analysis tools. The basic elements of the empirical merger model to be tested are hereinafter established.

To start with, let index i denote the n observed KVs, i = 1, ..., n. Let further the survival time of a KV be defined as the time elapsed from its foundation to its market exit. The previous Section has shown that KVs either exited the market due to the event "merger" (i.e. "absorption") or due to the event "closure". Thus, let T^{ME*} and T^{CL*} be two nonnegative random variables representing uncensored survival time till these events occurred. Furthermore, let t denote the years in which KV_i is observed, $t \in [t^{beg}, t^{end}]$, where t^{beg} and t^{end} mark the beginning and end of the study, and t^{ME*} and t^{CL*} denote the periods in which the event of interest took place. It would be ideal to observe for each KV uncensored survival times. This requires being able to observe a KV from its known start-up year, t^S, until the particular event of interest whereby it holds that $t^{beg} \leq t^S \leq t^{ME*}$ (t^{CL*}) $\leq t^{end}$.

As with many duration data studies, having incomplete observations because of censoring or truncation is a problem that matters here, too. As regards censoring mechanisms, right- and left-censoring are general challenges for this empirical framework. Right-censoring occurs if KV_i was still in operation in the end year of the study, 1920, and the event of interest potentially occurred sometime thereafter, t^{ME*} (t^{CL*}) > t^{end}. Hence, KV_i did not die because of merger or closure, but because of right-censoring. Given $t^S \geq t^{beg}$, the observed duration is then the minimum of the duration until merger (closure) and right-censoring. A particular advantage of duration data models is that they explicitly allow for right-censored durations so that this form of censoring can be handled relatively easy. Left-censoring, in contrast, is a problem for which, to the best of my knowledge, no systematic correction procedure is at hand. It occurs if KV_i did not came into existence in 1861 or later, but before, $t^S < t^{beg}$. The obvious problem with this setting is that the observed duration from t^{beg} to t^{ME*} (t^{CL*}) or t^{end}, respectively, is biased in that it is too short compared to the true survival time. As mentioned above, the observation period is definitely limited to 1861-1920 because of data (un-)availability. Moreover, regarding all KVs for which the first observed period is 1861, it is not possible to infer from the KV statistics or other sources their precise start-up year. True survival time is, hence, unknown, and the survival time observed is best labeled as "minimum survival time". [24]

Figure 2: Censoring summary



Source: Figure according to Kiefer, *Economic Duration Data* (cf. n. 1), 647.

Figure 2 summarizes the censoring issue for KVs. Case I indicates the full uncensored case. The cases II and III highlight right-censoring and (potential) left-censoring. Case IV is equal to double-censoring. Shown on the right-hand side, in addition, is the number of KVs that fall into the respective categories.

Competing risk models

In the presence of multiple modes of failure or exit, respectively, the appropriate time-to-event model is a competing risk model allowing KV_i to cease operation due to

[24] Kiefer, Economic Duration Data (cf. n. 1), 647; Jeffrey M. Wooldridge, *Econometric Analysis of Cross Section and Panel Data*, Cambridge 2002, 695-696; David W. Hosmer/Stanley Lemeshow/Susanne May, *Applied Survival Analysis – Regression Modeling of Time-to-Event Data*, Hoboken 2008, pp. 6-9.

the occurrence of one out of j = 1, …, k different events. The random variable C_j then indicates the event by numerical value where right-censoring is indicated by $C_j = 0$.

An issue of crucial importance when multiple modes of failure are involved is potential correlation between the j exit modes. As regards the underlying fundamental assumption about the correlation between competing risks, two alternative ways of handling are possible. On the one hand, one might assume that exit modes are independent of each other so that, in fact, the likelihood function is additively separable, and each survival time T has its own distribution. This is a strong assumption that rules out much of the econometric challenges linked with competing risks. Based on this assumption, event-(or cause-)specific effects of covariates can then be obtained in separate regressions treating in turn all other events as right-censored. On the other hand, however, one might allow for the possibility of dependence between risks and solve for event-specific effects of covariates simultaneously in one regression. This requires focusing on the joint distribution of survival times T_j. In the following, we build two models, the one based directly on Cox regression (1972) ignoring that there were two exit modes to consider and the other based on Fine and Gray (1999) allowing for correlation between the competing risks of absorption and closure. The former approach follows the usual way of analysis researchers take in investigating firm survival. They predominantly do not model more than one mode of exit. Thus, in the latter approach we explicitly take into account that there were two potentially correlated risks of exit regarding KV. The influence of explanatory variables on each is evaluated.[25]

Starting from a single-exit mode setting, assume T has a cumulative probability distribution F(t) with corresponding probability density f(t), and the survivor function S(t) with S(t) = 1 – F(t). F(t) states the probability that a KV exits before t, F(t) = Pr(T ≤ t). Accordingly, S(t) yields the unconditional probability that a KV reaching t will not exit. Let the instantaneous hazard rate, i.e. the conditional probability that a KV will exit shortly after t given it survived until t, be defined as h(t) = f(t) / S(t), which can be also expressed in terms of equation (1):[26]

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[25] Bo E. Honoré/Adriana Lleras-Muney, *Bounds in competing risks models and the war on cancer*, in: Econometrica 74 (2006), 1675-1698, 1679; Melania Pintile, *Analysing and interpreting competing risk data,* in: Statistics in Medicine 26 (2007), 1360-1367; Miguel C. Manjón-Antolín/Josep-Maria Arauzo-Carod, *Firm survival: methods and evidence*, in: Empirica 35 (2008), 1-24, 15.
[26] Wooldridge, *Econometric Analysis* (cf. n. 25), 692.

$$h[t; X(t)] = \lim_{\Delta t \to \infty} \frac{\Pr[t \le T < t + \Delta t, |T > t, X(t)]}{\Delta t}. \quad (1)$$

The widely applied Cox-model to assess the effect of covariates on the hazard of exit, regard-less by which mode, is then given by

$$h[t; X(t)] = h_0(t) * \exp[X(t)'\beta], \quad (2)$$

where $h_0(t)$ is a baseline hazard that only depends on time. It is a basic feature of semiparametric duration models that they do not provide estimates of the baseline hazard explicitly. Yet, given some additional assumptions, the baseline hazard can be recovered from the estimates. Maximization is done via maximum partial likelihood.[27]

In the bivariate case with j = 2 mutually exclusive exit modes (j = 1: merger; j = 2: closure), basic quantities have to be generalized to the multiple-exit setting and the two alternative approaches. According to Hosmer et al. (2008), generalization of the hazard function according to (1) yields

$$h_j[t; X(t)] = \lim_{\Delta t \to \infty} \frac{\Pr[t \le T < t + \Delta t, C = j|T > t, X(t)]}{\Delta t}. \quad (3)$$

The cause-specific effect of covariates on either exit mode can be assessed by fitting the regression equation

$$h_j[t; X(t)] = h_{0j}(t) * \exp[X(t)'\beta_j]. \quad (4)$$

Event-specific effects can either be derived by separately fitting for each exit mode assuming the other mode, in turn, as right-censored, which reduces (4) to (2), or simultaneously by use of a data duplication method, where data are replicated j times

[27] David R. Cox, *Regression Models and Life-Tables*, Journal of the Royal Statistical Society B 34 (1972), 187-220; David R. Cox, *Partial Likelihood*, Biometrika 62 (1975), 269-276; Glenn T. Sueyoshi, *Semiparametric proportional hazards estimation of competing risks models with time-varying covariates*, Journal of Econometrics 51(1992), 25-58; the model to be introduced is also called proportional risks model in the literature; see Hosmer/Lemeshow/May, *Applied Survival Analysis* (cf. n. 25), 335.

and additional indicator variables must be created. Lunn and McNeil (1995) and Hosmer (2008), for example, describe the method.[28]

However, assuming independent risks might be a too strong assumption regarding particularly KV or generally firm exit. We therefore fit a model allowing for correlation that is given if the event "closure" either prevents the event "absorption" from happening since it happened first or whose presence at least alters the probability of occurrence of absorption ex ante. Against this background, we make use of STATA's ability to accommodate competing risk models without data replication via Fine and Gray's (1999) proportional subhazards model allowing for a joint distribution $F(T_1, T_2)$. Technically, this model does not tie to the event-specific hazard as if there were no other risks, but to the respective hazard of the subdistribution, which is a function of both hazards.[29] The subdistribution for event j is also called the cumulative incidence function (CIF_j). Regarding our two exit modes, Fine and Gray's proportional subhazards model generalizes (3) to

$$h_j[t; X(t)] = \lim_{\Delta t \to \infty} \frac{\Pr[t \le T < t + \Delta t, C = 1 | (T > t \text{ or } (T \le t \text{ and } C \ne 1)), X(t)]}{\Delta t} \quad (5)$$

and expresses the conditional probability of exit by absorption in the presence of the risk of exit by closure. The difference between (3) and (5) stems from the condition in brackets concerning T. It not only says that event j = 1 did not happen until t, but in particular states that KV_i might have exited because of j = 2. Hence, the incidence of j = 1 depends on the incidence of j = 2. The regression equation to be estimated from the data corresponds to (4), where the competing risk is included into the likelihood function via a weighting-technique.

Finally, two important issues involved in almost every empirical investigation are to be tackled. The first is unobserved heterogeneity.[30] We do not think that our set of explanatory variables described in the subsequent subsection covers all characteristics that might be of importance. We therefore experimented with models with shared frailty, which is equal to introducing group-specific random effects into equation (4). From a practical viewpoint, such models can be estimated within the Cox-

[28] Mary Lunn/Don McNeil, *Applying Cox Regression to Competing Risks*, Biometrics 51 (1995), 524-532; Hosmer/Lemeshow/May, *Applied Survival Analysis* (cf. n. 25), 335-336.
[29] Jason P. Fine/Robert J. Gray, *A proportional Hazards Model for the Subdistribution of a Competing Risk*, in: Journal of the American Statistical Association 94 (1999), 496-509.
[30] Aaron Han/Jerry A. Hausman, *Flexible Parametric Estimation of Duration and Competing Risk Models*, in: Journal of Applied Econometrics 5 (1990), 1-28.

approach only. Unfortunately, the software applied cannot accommodate frailty models within the proportional subhazards approach of Fine and Gray. Shared frailty models predominantly yield no better estimates than the models reported below, so we do not display them here.

The second issue concerns a piecewise-constant model structure which allows coefficients to vary across some defined sub periods while constant within.[31] Even if relaxing the assumption of constant coefficients would introduce more flexibility into the models, we do not consider some kind of structural break model further, since we suppose that the number of observations and, in particular, the number of events that happened are not sufficient to model, for example, coefficients for 1861-1890 and 1881-1920 separately.

Explanatory variables

This investigation draws upon a set of both time-invariant and time-varying covariates on the KV-level that are hypothesized to influence the hazard rates. For an overview of abbreviated variable names and variable definitions consult Appendix 2. In the following, the set is presented and main hypotheses concerning the covariates' influence on hazard rates are formulated. We assume therefore that differences between the j events regarding covariate x express in different magnitudes of the effect. This allows for the formulation of one, not two, hypothesis per covariate. The regressions below will then show whether event-specific effects regarding mergers are significantly different from those regarding closures. Note that all time-varying variables are observed year by year.

In the firm survival literature, firm size is among the central variables applied to explain post-entry performance and exit.[32] In the context of KVs, size is hypothesized to play a major role in explaining exit because, as Jopp states, many absorbed as well as closed KVs were (extremely) small.[33] This evidence, along with the historical debate on the appropriate KV size and insurance theory, raises the question of whether these KV were too small to be able to provide a stable benefit scheme. From an insurance economic perspective, Albrecht (1982) establishes theoretically a negative relationship between the size of an insurer's collective of insurants and both the

[31] H. L. Van Kranenburg/F. C. Palm/G. A. Pfann, *Exit and Survival in a Concentrating Industry: The Case of Daily Newspapers in the Netherlands*, in: Review of Industrial Organization 21 (2002), 283-303.
[32] Manjón-Antolín/Arauzo-Carod, *Firm survival* (cf. n. 26), 1-24.
[33] Jopp, *Ein risikoreiches Geschäft?* (cf. n. 9).

variance of the average claim size and the probability of ruin. Both a decrease in the variance and a decrease in the probability of ruin are associated with diminishing actuarial risk.[34] We therefore incorporate several controls with respect to size in our models. First, start-up size, the size a KV had when founded, is a time-invariant variable equaling the size KV_i had in the first year of observation (STARTUPSIZE). In fact, start-up size refers to either t = 1861, even if true foundation happened before, or t > 1861. Another time-invariant variable is the geometrically averaged mean growth rate of size with which we model long-term growth patterns (AVGROWTHSIZE). A negative average growth rate implies, by tendency, long-term shrinkage and, correspondingly, a positive one long-term expansion. In order to allow for different combinations of start-up size and post-entry growth patterns, we incorporate an interaction between start-up size and average growth. Moreover, SIZE is a time-varying variable referring to current size and measured by the sum of established and unestablished contributors. Our last measure of size effects is RATIOMES, which is the ratio of a KV's size to the average size of all KV in the particular year. Several empirical approximations of minimum efficient size (MES) of an insurer are established in the literature. Average firm size, in comparison to the midpoint firm size index and the top fifty percent index, is said not to be linked with the problem of overstating minimum efficient size, which is the reason that we have chosen it here.[35] Using this measure, we are able to identify below-minimum-efficient-size KV and, consequently, above-minimum-efficient-size ones. In fact, this alternative is a measure of relative size.

> H1: KV with small start-up size face a higher conditional risk of exit than medium- or large-sized ones.
> H2: Size or growth size, respectively, positively affects KV survival.
> H3: Falling short of minimum efficient size increases the conditional probability of exit.

While the relationship between size and the conditional probability of either absorption or closure gives an indirect indication of pressure on finances and, correspondingly, of absorptions as potential insolvency alternatives, several variables are employed that serve as more explicit measures of financial distress. Again, if we found

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[34] Peter Albrecht, *Gesetze der großen Zahlen und Ausgleich im Kollektiv – Bemerkungen zu Grundlagen der Versicherungsproduktion*, Zeitschrift für die gesamte Versicherungswissenschaft 71 (1982), 501-538; Jopp, *Ein risikoreiches Geschäft?* (cf. n. 9), ties to Albrecht's framework and assesses the relationship between a KV's size and its exposure to actuarial risk empirically.
[35] Eisen, *Market Size and Concentration* (cf. n. 8), 271-272.

significant positive effects of absorption-specific financial distress variables on hazard rates (in the presence of the risk of closure), this would support the hypothesis that absorptions were a rescue measure, not a measure that necessarily favored absorbing KV from an (insurance) economic perspective. We employ as the main measures of financial distress the two components of the pensioners-to-contributors ratio (PCR), namely the invalids-to-contributors ratio (ICR) and the survivors-to-contributors ratio (SCR). The inclusion of system dependency follows directly from the functioning of the pay-as-you-go mechanism. Basically, the contribution rate is a function of the pensioners-to-contributors ratio, the gross pension level and the degree of subsidization from the outside. By definition, a pay-as-you go financed benefit scheme, where current contributors finance current pensioners, is balanced ex post for each period. A ceteris paribus increase in the PCR inevitably triggers adjustments via the other quantities.[36] Assuming the potential of subsidization from the outside is exploited, either the contribution rate must increase or the gross pension level must decrease or both must be done simultaneously. Depending on the development of wages, hence productivity, the additional financing burden on contributors might reduce disposable income and lifetime implicit rates of return, which we assume is not preferred, and/or lowering the gross pension level might be equal to reduce the welfare level of pensioners and, again, lifetime implicit rates of return, which we assume is also not preferred. While ICR and SCR vary with time, the start-up invalids-to-contributors ratio and the start-up survivors-to-contributors ratio as measures of the initial burden with pension recipients are constant (STARTUPICR, STARTUPSCR). Analogously to size, we also incorporate the geometric mean growth rate of the ICR and SCR over the observation period (AVGROWTHICR, AVGROWTHSCR) together with interactions with the start-up burden. In order to allow the effect of start-up size to vary with the initial burden with pensioners, we lastly examine interactions of STARTUPSIZE with the respective variables for pensioners.

H4: Both the invalids- and survivors-to-contributors ratios are positively related to the conditional probability of exit.

H5: KV with a high start-up burden with pensioners face a higher conditional risk of exit than those less burdened initially.

H6: Having experienced long-term shrinkage (expansion) with respect to both pensioners-to-con-tributors ratios decreases (increases) the hazard of exit.

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[36] Schmähl, *Umlagefinanzierte Rentenversicherung* (cf. n. 23), 149-150.

Further time-varying financial distress variables are the contribution rate (CR) and the gross pension level (GPL) itself as well as their interaction. The logic is that a high contribution rate implies an above-average need for financial resources which must originate in greater demographic or structural problems. Accordingly, the more a KV's gross pension level falls short of its initial level over time, the less is a KV able of ensuring a minimum welfare standard. In addition to these measures that refer to the pay-as-you-go equation, we experiment with two other measures of financial distress from the insurance literature. These are the probability of ruin and the risk loading of the average contribution first employed in economic history by Emery (1996) and Emery and Emery (1999).[37] Precisely, we include ex-post estimates of the probability of ruin with respect to both the pension and sickness section (RUINPROBPENS, RUINPROBSICK). We consider pure probability of ruin, i.e. without taking into accounting financial reserves, which states the probability that a KV could have been ruined from extraordinary high claims in a given year. Despite we actually model the probability of exit mainly conditional on processes in a KV's pension section, this is an opportunity to control for processes in the sickness section as well. The other mentioned measure, the risk loading of the average contribution, is derived under the straightforward assumption that a KV's average contribution should not only cover expected average claims costs, but also allow for a positive risk surcharge covering potential excess costs.[38] The logic behind these variables is simple. First, the higher a KV's probability of ruin is, the more is it financially distressed and the sooner should it be absorbed by a financially viable KV. Second, a positive risk loading implies risk-adequate pricing, whereas negative loading implies the opposite. We herewith control for the pricing behavior.

H7: An increasing (decreasing) contribution rate (gross pension level), decreases the duration of operation.

H8: The probability of ruin (risk loading) positively (negatively) affects hazard rates.

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[37] J. C. Herbert Emery, *Risky Business? Nonactuarial Pricing Practices and the Financial Viability of Fraternal Sickness Insurers*, in: Explorations in Economic History 33 (1996), 195-226; George N. Emery/J. C. Herbert Emery, *A young man's benefit: the Independent Order of Odd Fellows and sickness insurance in the United States and Canada, 1860-1929*, Montreal 1999. Other applications include Nicholas Broten, *From Sickness to Death: The Financial Viability of the English Friendly Societies and Coming of the Old Age Pensions Act, 1875-1908*, in: Department of Economic History Working Paper 135/2010, London School of Economics, and Jopp, *Ein risikoreiches Geschäft?* (cf. n. 9).

[38] Jopp, *Ein risikoreiches Geschäft?* (cf. n. 9), 202-204.

Finally, we incorporate few more time-varying controls to capture part of the heterogeneity among KV. ESTAB is a variable that measures the proportion of established contributors among all contributors. Established contributors were in general more costly than unestablished ones in that they often received higher benefits given equal contribution payments. Against the background of an increasing ICR or SCR, respectively, a decreasing proportion of established miners may release the KV from some financial pressure. Indeed, a decreasing proportion may also indicate structural problems since ever fewer miners obviously had applied for established status, hence had decided to enter into a long-term relationship with the KV. In order to capture this, we include an interaction between ESTAB and both the ICR and SCR. FIRMSHARE is equal to the proportion of claims costs that employers' contributions financed. YOUNG equals the ratio between established contributors aged 16 to 35 and those aged 36 and more. This is a proxy measure for a KV's age structure. A continuously diminishing ratio can be interpreted as a hind at structural ageing of the contributor base. Analogous to the ICR and SCR, the sick days-to-contributors ratio (SDAYSRATIO) measures the financing burden on contributors that arises from the sickness section. The more sick days the average contributor has to finance, the more financially distressed is the KV assumed to have been. Our last variable is DIVERSIFICATION which is intended to be a proxy measure of how strong a KV diversified insurants-at-risk over different mining subsectors (hard coal, brown coal, iron ore, other ores, halite, stone, salt) and related industries (steel production, ore processing). Denote relevant subsectors with q, q = 1, ..., Q, and number of insurants with Z. We constructed a Herfindahl index per year with respect to subsector shares within a KV's collective of insurants,

$$\text{DIVERSIFICATION} = \sum_{q=1}^{Q} \left(\frac{Z_q}{\sum_{Z} Z_q} \right)^2 . \tag{6}$$

The KV statistics reports subsector shares for each KV and year since 1867 and differentiates into 12 subsectors. If a KV insured miners employed in only one subsector, DIV equals one. If insurants were equally distributed over all subsectors, DIV equals 0.083. Hence, the closer DIVERSIFICATION is to the latter quantity, the less concentrated were a KV's insurants in one subsector.

H9: The proportion of established contributors in all contributors is inversely related to the hazard of exit.

H10: The employers' financing share and the conditional probability of exit are inversely related.

H11: The lower the proportion of young miners in all miners, the higher is the hazard of exit.

H12: The sick days-to-contributors ratio positively affects the conditional probability of exit.

H13: Diversification lowers the hazard of exit.

Table 5 provides summary statistics on durations by sample and explanatory variables. Minimum start-up size, for example, was only 9 contributors which is doubtlessly extremely small. Moreover, KV grew at the mean by 1.14 percent per year. Mean growth rates regarding the invalids- and survivors-to-contributors ratio amounted to more than 3 and 4.5 percent. Regarding both probability of ruin measures, the mean security level was about 48 percent, which is appears to be rather low.

Table 5: Summary statistics of survival time and covariates

Variable	**Minimum**	**Mean**	**Median**	**Maximum**	**St. dev.**
Duration until absorption	5.0	31.1	29.0	56.0	17.7
Duration until closure	12.0	43.5	54.0	58.0	16.4
Right-Censorings	9.0	53.5	60.0	60.0	12.1
STARTUPSIZE	9	2,612	521	136,314	11,727
STARTUPICR	0	4.3	2.6	37.5	6.2
STARTUPSCR	0	12.0	7.3	93.7	13.5
AVGROWTHSIZE	-49.04	1.14	1.53	17.79	3.94
AVGROWTHICR	-10.85	4.63	3.09	116.64	8.22
AVGROWTHSCR	-8.84	3.19	1.89	94.25	6.82
SIZE	0	6,071.9	828	411,585	25,268.6
RATIOMES	0	0.99	0.01	31.1	3.0
ICR	0	10.8	25.6	1,600*	33.0
SCR	0	25.2	6.9	4,600*	95.7
RUINPROBPENS	0	0.49	0.46	1.00	0.32
RUINPROBSICK	0	0.49	0.47	1.00	0.29
RISKLOADING	-1	0.16	0.01	32.06*	1.33
CR	0	4.62	3.66	64.83*	3.33
GPL	0	15.6	14.7	178.6*	9.5
ESTAB	0	0.68	0.69	1.00	0.26
FIRMSHARE	0	0.44	0.46	5.1	0.21
YOUNG	0.1	0.51	0.53	1.00	0.16
SDAYSRATIO	0	7.4	6.8	468*	8.7
DIVERSIFICATION	0.16	0.86	1.00	1.00	0.21

Note: Number of observations is 4,448. Outliers denoted with * were dropped in the regressions.

IV. Empirical results

Proportional hazards models of KV exit

To fix ideas on KV survival, we begin presentation of results for exit in general. Consider therefore Figures 3 and 4 first. For two alternative groupings, the former shows the standard Kaplan-Meier (KM) product-limit estimator of the survivor function, S(t), if we focus for the moment simply on the hazard of exit. The latter depicts a smoothed estimate of the hazard function. As regards grouping alternative one, we grouped KV according to variable AVGROWTHSIZE. Four groups were created for KV whose average annual growth rate of the contributor base was below -1.0, between -1.0 and 0.0, between 0.0 and 1.0, and more than 1.0 percent. As regards grouping alternative two, we grouped KV according to variable STARTUPSIZE. We created groups for five classes of start-up size, namely for 1 to 199, 200 to 999, 1,000 to 4,999, 5,000 to 9,999, and 10,000 and more contributors.

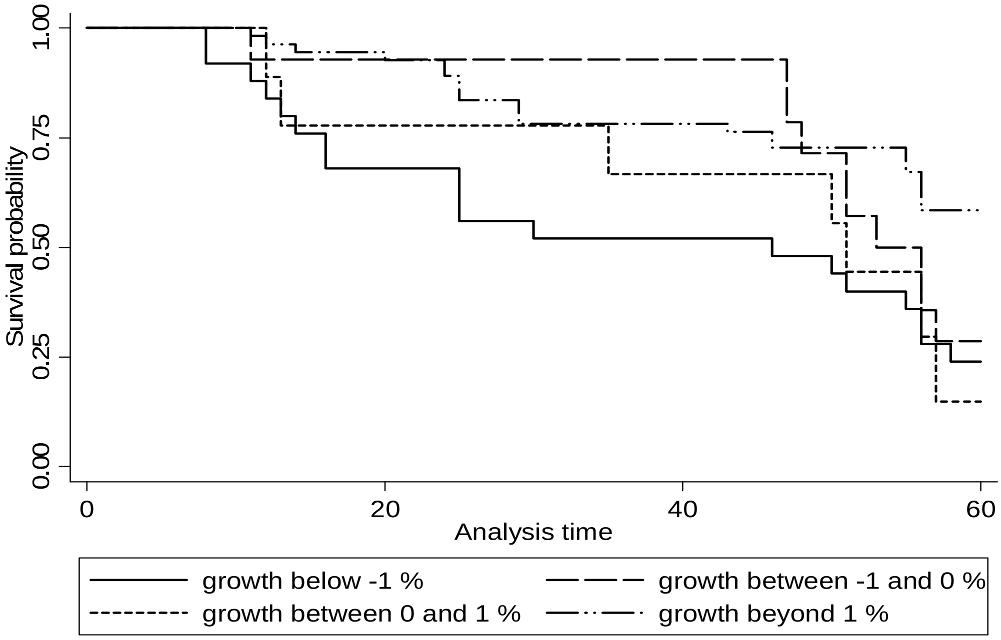
Both the survivor and hazard functions are derived without taking into account the influence of covariates and, thus, serve as baseline descriptions of KV survival. KM estimates imply, for example, that KV that were subject to severe shrinkage from a long-term perspective – i.e. they exhibited a high negative growth rate – died faster than all other KVs. Panel A of figure 3 shows that 50 percent of exceptionally shrinking KV had already exited after 30 years. In comparison, of the KV that exceptionally grew by more than 1.0 percent per year 25 percent ceased operation after 30 years. Astonishingly, the relatively best survival performance show KVs that shrank at an annual rate between -1.0 and 0.0 percent. Of these, only one-fourth had exited after about 50 years. Regarding grouping alternative two, KV with start-up size below 1,000 contributors exhibited a comparatively worse survival performance than larger ones. Of these KV, 25 percent exited before they could enter into year 26 of operation. 50 percent had exited after about 54 year.

The kernel-smoothed hazard function estimates for the two grouping alternatives are intended to give an alternative visual impression of the survival process. They not provide precise pointwise estimates. With respect to long-term growth patterns, hazard rates predominantly lie between 0 and 3.5 percent. A hazard rate of one percent indicates that one out 100 KV fails to survive the year under observation conditional on the fact that it has survived so long. Indeed, smoothed hazard rates appear to be rather low. However, they sharply increase for KVs subject to modest shrinkage or growth, respectively, at some point in time. With respect to grouping by start-up size, panel B of Figure 4 indicates that hazard rates vary between zero and two percent. While the hazard rate for start-up size classes one, three and four are firstly quite constant and then increase, hazard rates for classes two and five show a different pattern in that they firstly increase and then remain constant or respectively decrease.

As regards Cox regression models of KV exit, Table 5 displays estimated coefficients, log-pseudo-likelihoods and Wald Chi-square statistics for the joint significance of coefficients. Since we estimate exponential models, coefficients have to be interpreted as semi-elasticities that indicate the percentage change in the log hazard rate due to a one-unit change in the respective covariates. Hazard ratios that report the percentage change in the hazard rate given a one-unit change in the independent variable can be obtained from the expression $\exp(\hat{\beta})$. If we want to know how a change in the covariate by c units affects the hazard rate, we can simply calculate $\exp(c^* \hat{\beta})$. Finally, a positive coefficient implies a hazard ratio larger than one and thus an increase in the hazard rate.

Figure 3: Kaplan-Meier estimates of the survivor function assuming a single-risk model

Panel A: Grouping by long-term growth performance classes



Panel B: Grouping by start-up-size classes

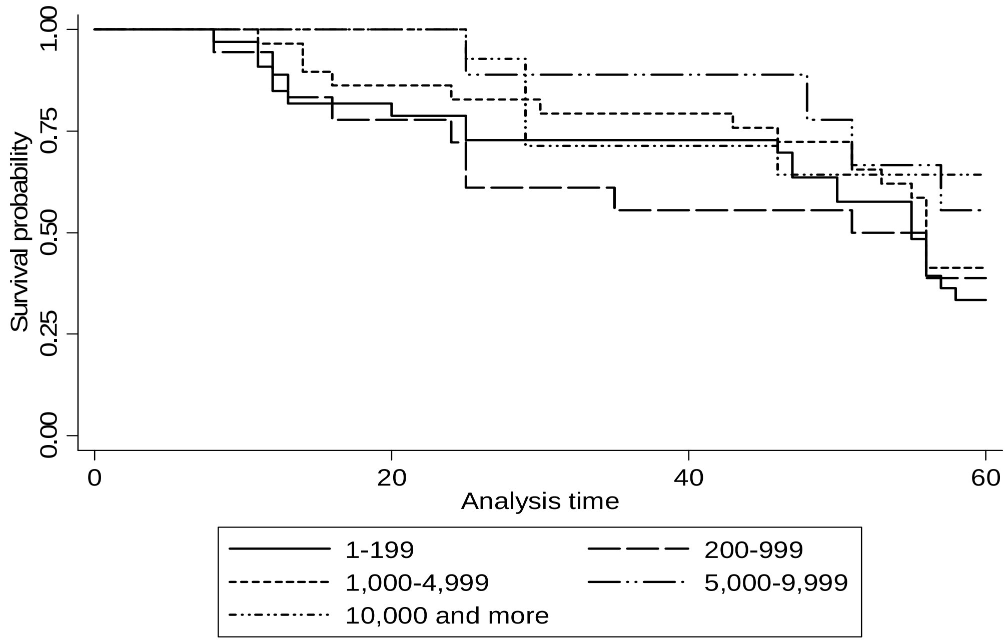
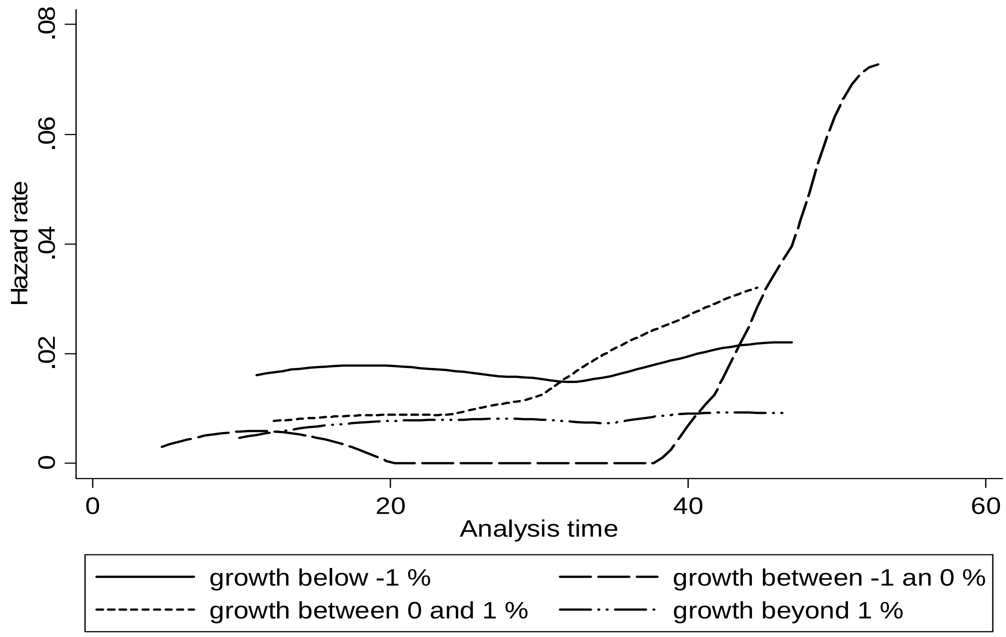
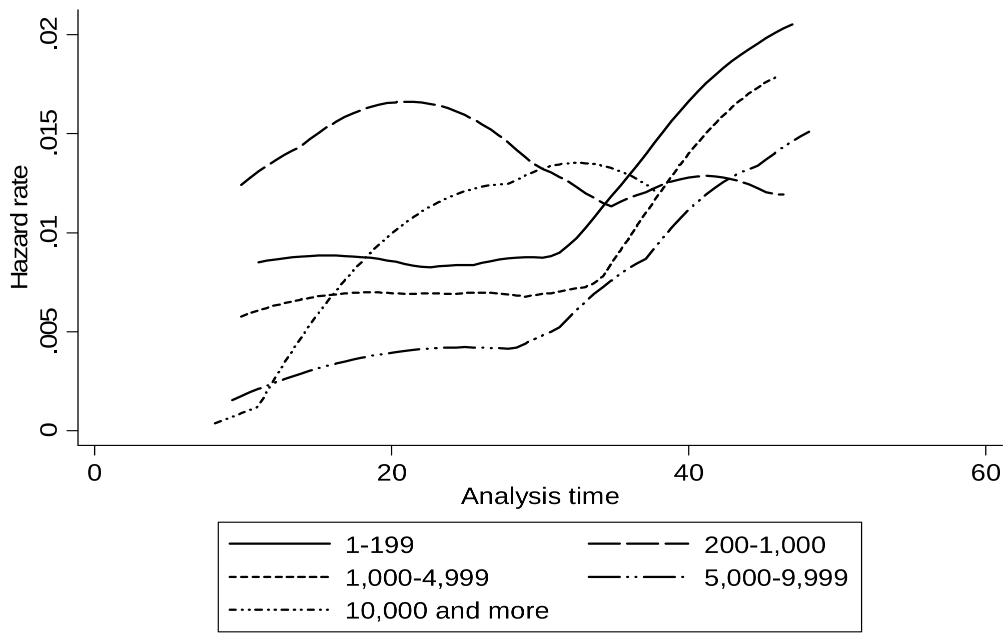


Figure 4: Smoothed hazard estimates assuming a single-risk model

Panel A: Grouping by long-term growth performance classes



Panel B : Grouping by start-up size classes



Displayed are six models that differ, on the one hand, in the time-varying financial distress variable applied. Time-invariant measures concerning our main financial distress variables, the invalids- and survivors-to-contributors ratios, are additionally included in all models except for 1 and 4, where we check for potential significance of the contribution rate, gross pension level, ruin probabilities and risk loading. On the other hand, models differ in that models 4 to 6 are stratified over classes of START-UPSIZE and AVGROWTHSIZE, whereas models 1 to 3 are not. KVs with equal values of the these variables are assumed to belong to the same stratum. Each stratum has its own baseline hazard. It is important to note that coefficients are assumed to be equal across stratums.

With respect to the coefficients in the unstratified models, the first result of interest is the insignificance of the invalids-to-contributors ratio in model 1. Statistically, there seems to be no strong relationship between this variable and the log hazard rate, given the variable SCR is zero. However, the survivors-to-contributors ratio, given ICR is zero, is highly statistically significant and implies that a rising burden with survivorship pensioners increases the hazard of exit per se. The hazard ratio for an increase in the SCR by 10 survivors per 100 contributors is 1.0037 meaning that the hazard rate increases by approximately 0.4 percent. As we can also see from Table 5, the interaction between ICR and SCR is significant on the five percent level. Thus, the effect of ICR on the hazard is modified if SCR is not zero. Hence, taking into account the interaction, an increase in the burden with invalidity pensioners increases the conditional probability of exit.

Beyond that, the estimation results suggest that our alternative financial distress variables do not have statistically significant explanatory power except for the probability of ruin with respect to the pension section. Interestingly, on the ten percent level, an increase of the ruin probability by 5 percentage points drives the hazard rate up by about 10.5 percent.

The coefficients of the additionally included average growth rates of the KVs' ICR and SCR, which give an impression of post-entry demographic-structural development, are also highly significant. A high positive average growth rate of the ICR is associated with in increase in the hazard rate and, consequently, a negative long-term growth rate is associated with a decrease in the hazard. We can interpret the coefficient of 0.06569 in model 2 such that an increase in the long-term annual growth rate across KV by one (five, ten) percent increases the hazard of merger by absorption by 7.0 (38.0, 91.0) percent.

As regards the remaining independent variables, the statistically significant coefficients of start-up size show a positive sign, which seemingly contradicts the hypothesized negative relationship to the hazard of exit. The higher the start-up size, the higher is ceteris paribus the hazard of exit (models 2 and 3). Though, one has to note that in the presence of interactions with the initial pension burden variables, the effect of start-up size is evaluated at a start-up ICR and SCR of zero, not at an average level of these variables.

The time-varying variable SIZE which measures current KV size is in contrast statistically insignificant in all three models and cannot explain exit. Obviously, it was not a matter of size per se that certain KVs ceased operation.

Another interesting outcome is that the entrepreneurs' share in total claims costs was also of statistical importance as a determinant of the conditional probability of exit per se. The coefficients' signs are positive in models 2 and 3 indicating that a KV with high cost sharing by entrepreneurs was ceteris paribus more likely to exit conditional on time elapsed and the covariate's level. In model 2, for example, the coefficient of FIRMSHARE corresponds to a hazard ratio of 1.0629. Consequently, a rise in the entrepreneurs' cost share by one percentage point increases the hazard rate by 6.29 percent. Yet, a ten percentage point increase causes the hazard rate to increase by 84 percent.

Table 5: Competing risk regression I – the hazard of exit

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Unstratified			Stratified over classes of STARTUP-SIZE and AVGROWTHSIZE		
STARTUPSIZE	0.00004	**0.00013****	**0.00013***	-0.00005	-0.00001	-0.00007
	(0.00007)	(0.00006)	(0.00008)	(0.00016)	(0.00016)	(0.00018)
STARTUPICR	-0.00775	-0.00193	-0.01079	-0.03112	-0.05829	-0.09518
	(0.06181)	(0.08717)	(0.07547)	(0.06905)	(0.08010)	(0.08039)
STARTUPSCR	-0.00850	0.02985	0.03181	0.02519	**0.07051****	**0.08375****
	(0.02413)	(0.03482)	(0.02923)	(0.02884)	(0.03570)	(0.03541)
STARTUPSIZE*STARTUPICR	-0.00001	-0.00002	-0.00001	-0.00001	-0.0000001	-0.000001
	(0.00001)	(0.00001)	(0.00001)	(0.00003)	(0.00003)	(0.00003)
STARTUPSIZE*STARTUPSCR	0.000002	0.000002	-0.0000006	0.0000004	-0.00001	-0.00001
	(0.00001)	(0.000005)	(0.00001)	(0.00001)	(0.00001)	(0.00001)
AVGROWTHICR		**0.06569*****	**0.05497*****		**0.08040****	**0.07846****
		(0.01509)	(0.01418)		(0.03774)	(0.03350)
AVGROWTHSCR		0.04091	**0.06743*****		0.05734	**0.08548****
		(0.02622)	(0.02435)		(0.05515)	(0.04059)
AVGROWTHICR*STARTUPICR		0.00519	**0.01283***		0.00007	0.01383
		(0.00917)	(0.00788)		(0.01459)	(0.01808)
AVGROWTHSCR*STARTUPSCR		0.00107	-0.00057		0.00372	0.00069
		(0.00231)	(0.00211)		(0.00424)	(0.00387)
ICR	0.00028			**0.00120***		
	(0.00035)			(0.00069)		
SCR	**0.00037*****			0.00095		
	(0.00008)			(0.00037)		
ICR*SCR	**-0.000003****			**-0.00001***		
	(0.000001)			(0.000005)		
CR		-0.00002			-0.00141	
		(0.00367)			(0.00518)	
GPL		-0.00108			-0.00156	
		(0.00074)			(0.00141)	

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
CR*GPL		0.00002			0.00018	
		(0.00015			(0.00029)	
RUINPROBPENS			**0.01993***			0.02268
			(0.01235)			(0.02362)
RUINPROBSICK			0.01236			0.00819
			(0.01065)			(0.01989)
RISKLOADING			-0.00086			-0.00418
			(0.00175)			(0.00961)
SIZE	-0.0000004	-0.0000005	-0.000001	0.0000001	0.0000002	0.0000005
	(0.0000004)	(0.0000005)	(0.0000005)	(0.000001)	(0.000001)	(0.000001)
YOUNG	0.01962	0.01574	0.02157	**0.16502*****	**0.08815****	**0.11689****
	(0.01959)	(0.01898)	(0.02137)	(0.05264)	(0.04461)	(0.05065)
ESTAB	-0.04339	0.00637	-0.02219	**-0.13656*****	-0.04567	-0.05459
	(0.03741)	(0.03784)	(0.03428)	(0.04386)	(0.04258)	(0.03685)
FIRMSHARE	0.03038	**0.06109****	**0.06305****	0.03032	0.05239	**0.10965***
	(0.02420)	(0.03079)	(0.02536)	(0.05031)	(0.06092)	(0.06637)
SDAYSRATIO	0.00061	-0.00113	-0.00036	0.00025	-0.00209	-0.00145
	(0.00089)	(0.00073)	(0.00074)	(0.00106)	(0.00137)	(0.00119)
DIVERSIFICATION	-0.00201	-0.00979	-0.01913	0.01514	-0.01101	-0.02434
	(0.01429)	(0.01435)	(0.01297)	(0.02024)	(0.01911)	(0.02113)
Number of observations	4,337	4,282	4,276	4,337	4,282	4,276
Log-pseudolikelihood	-214.05	-186.96	-193.94	-72.03	-60.91	-59.86
Wald χ^2 (*LR* χ^2)	96.49	65.66	83.06	*28.42*	*32.58*	*46.19*
Prob > χ^2	0.00	0.00	0.00	0.01	0.02	0.00

Note: Dependent variable is the log hazard rate. Displayed are coefficients, not hazard ratios. Standard errors in brackets are robust. For ties, the Breslow method is used. ***, ** and * denote statistical significance on the one, five and ten percent level.

With respect to stratified models, some changes in basic implications occur. First, start-up size is insignificant. Second, the initial survivors-to-contributors ratio is now of significant importance. If a KV was burdened with ten survivorship pensioners per 100 contributors more than another KV, it faced at least a 102 percent higher hazard of exit. In comparison, the initial burden with invalids has no explanatory power. Furthermore, the effects of long-term growth patterns of the ICR and SCR are higher than in the unstratified models, and the time-varying variable ICR is now significant, but not the SCR. Moreover, the young contributors-to-old contributors ratio plays a statistically significant role as a determinant of the conditional probability of exit. In all three models, the coefficients have positive signs and the magnitude of the effect is quite large. Depending on the model, an increase in the young-to-old ratio by 1 causes the hazard rate to increase by between 9.2 and 17.9 percent. The statistical evidence is counter-intuitive. We expected to find, if any, a negative relationship which would have fitted to the consideration that, first, an ageing contributor base is a sign of declining attractiveness of employment in a particular mining area, hence a sign of structural decline. Second, if occupational morbidity was positively related to age, then the probability of claiming an invalidity pension due to incapacitation for work would have been the higher, the older a contributor was. Hence, the more old contributors existed, the more likely a KV could run into financial distress due to disproportionately high claim rates.[39] The share of established contributors in all contributors is only significant with respect to model 4. A one percentage point increase in this share is associated with a 0.136 percent decrease in the log hazard rate. Finally, the entrepreneurs' cost share is only significant in model 6, but the coefficient has also a positive sign.

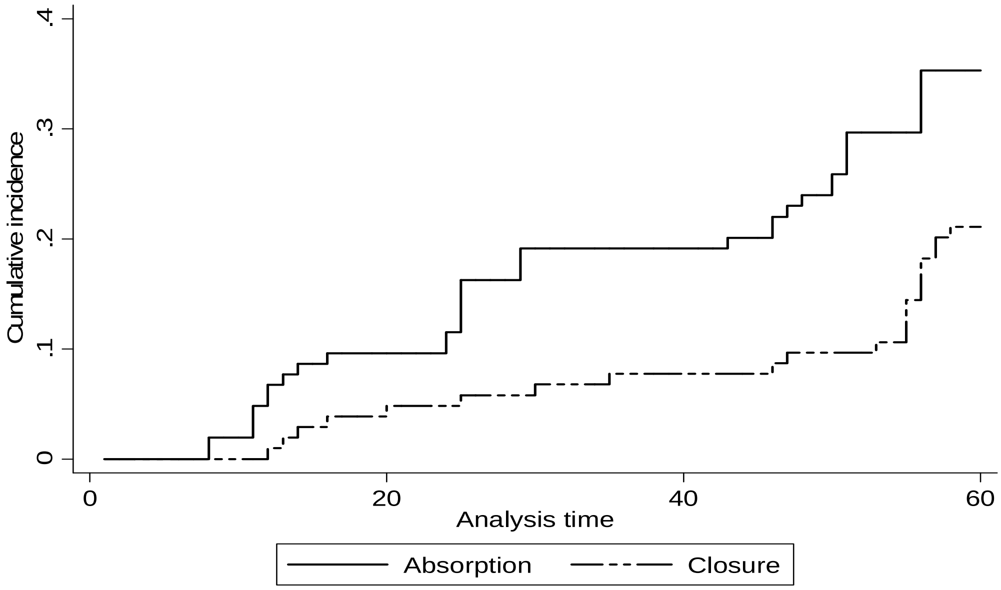
A final remark on the alternative size measure RATIOMES is necessary. We only display results for SIZE because using the deviation from minimum efficient size in the regressions does not alter the implications of the estimation results.

Proportional subhazards approach assuming dependent exit modes – baseline models

[39] Gorsky et al. find evidence for a positive relationship between age and both the frequency and duration of sick claims in the Hampshire Frinedly Society; Martin Gorsky/Bernard Harris/Andrew Hinde, *Age, Sickness, and Longevity in the Late Nineteenth and the Early Twentieth Centuries*, in: Social Science History 30 (2006), 571-600.

Now we present estimation results derived under allowance for dependency of exit modes. We begin with introducing the cumulative incidence functions for our exit events where $CIF_{j=1}$ takes into account the incidence of closure and vice versa.

Figure 5: Cumulative incidence functions



Note: Assumed are dependent risks.

As regards absorption, the figure indicates that a KV was absorbed with cumulative probability of approximately 10 percent after one-third of the observation period and with 25 percent after approximately 50 years. The CIF for closure runs flatter. It implies that merely about 6 or 7 percent of KV had closed after 20 years. Furthermore, merely 9 percent had ceased operation at the onset of World War I. With the beginning of war the probability of failure leading to closure sharply increases.

With respect to the determinants of the hazard of merger by absorption in the presence of the exit alternative closure, Tables 5 and 6 contain the main results. Firstly, Table 5 shows a number of interesting outcomes. In the presence of the hazard of closure, we are now able to specify the statistical importance of the ICR and SCR in driving the hazard of merger by absorption up. As from the perspective of exit per se, the ICR is significant and positive if we take account the interaction with the SCR. In particular, both the ICR and SCR, our main financial distress variables, have no significant explanatory power regarding closures. Indeed, in model 2, the average annual growth rate of the ICR is significant, but only on the ten percent level. In contrast, there is clear statistical relationship between (log) hazard rate and the average annual growth rate of the ICR even in the time-invariant case. A ceteris paribus increase in the average annual growth rate of the ICR impacts positively on the conditional probability of absorption. These findings support the view that absorptions served as insolvency alternative if the burden with invalidity and survivorship pensioners increased to a level that could threaten sustainable financing.

As in models 2 and 3 in the previous subsection, start-up size gains statistical importance. Since we incorporated interactions with the initial burden with pensioners, the effect of start-up size is evaluated at zero values of interacted variables. Consequently, the larger initial size was, the higher was the hazard of merger by absorption (models 2 and 3) as well as the hazard of closure (models 1 and 2). Note that the magnitude of the effect is higher with respect to closure. We interpret this as showing that a KV was more likely to be closed rather than absorbed at every level of start-up size. In fact, this effect appears to be counter-intuitive compared to the working hypothesis formulated in Section IV. Possibly, this result reflects the fact that strikingly many small KV survived the observation period, although they were claimed to be under constant financial pressure (see Section III). The literature proposes the explanation that those small surviving KV were predominantly works-related ones, and the one entrepreneur saw in a small KV the ability to control his workforce optimally. Consequently, absorptions were often rejected.[40]

It is also important to emphasize that the absorption-specific effect of the interaction between start-up size and start-up ICR is significantly negative implying an effect modification on both the start-up size and start-up ICR variables. In all models, the effect of STARTUPSIZE remains positive, thus indicating that in the presence of non-zero start-up ICR the conditional probability of merger by absorption is slightly lower than in the zero-case if start-up size increases. Especially, if start-up size is non-zero, the effect of STARTUPICR is modified as well and significantly positive meaning that the higher the initial burden with invalidity pensioners was, the higher was the conditional probability of absorption. Moreover, size played a significant role as a driver of the hazard of closure. More precisely, the larger current size was, the lower was the conditional proba-

[40] Heinrich Imbusch, *Das deutsche Knappschaftswesen,* Köln 1910, 72.

Table 6: Competing risk regression II – the hazard of exit by event j=1 (j=2) in the presence of the hazard of exit by event j=2 (j=1)

Variable	Model 1		Model 2		Model 3	
	Absorption	Closure	Absorption	Closure	Absorption	Closure
STARTUPSIZE	0.0001	**0.00045***	**0.00014***	**0.00044****	**0.00017***	0.00033
	(0.0001)	(0.00023)	(0.00007)	(0.00022)	(0.00009)	(0.00022)
STARTUPICR	0.03236	-0.10604	0.07449	-0.08881	0.05502	-0.12803
	(0.07138)	(0.15546)	(0.0827)	(0.1994)	(0.07412)	(0.15515)
STARTUPSCR	-0.01486	0.03615	-0.00047	0.07313	0.00289	0.08103
	(0.03135)	(0.05377)	(0.0369)	(0.07435)	(0.03348)	(0.05593)
STARTUPSIZE*STARTUPICR	**-0.00002***	0.00001	**-0.00003****	-0.00004	**-0.00003***	0.00001
	(0.00001)	(0.00006)	(0.00001)	(0.00007)	(0.00001)	(0.00008)
STARTUPSIZE*STARTUPSCR	0.000004	-0.00007	0.000005	0.0000003	-0.0000001	-0.00003
	(0.000007)	(0.00006)	(0.000008)	(0.00003)	(0.000008)	(0.00006)
AVGROWTHICR			**0.06673*****	**0.08888***	**0.06446*****	-0.01294
			(0.01243)	(0.0473)	(0.01227)	(0.03107)
AVGROWTHSCR			0.03067	0.05168	0.03066	0.13703***
			(0.02847)	(0.09734)	(0.02846)	(0.03504)
AVGROWTHICR*STARTUPICR			0.00472	-0.00504	0.00896	0.01092
			(0.00834)	(0.01859)	(0.00824)	(0.01325)
AVGROWTHSCR*STARTUPSCR			0.00218	0.00413	0.00194	-0.00318
			(0.00226)	(0.00701)	(0.00205)	(0.00413)
ICR	0.00013	-0.00008				
	(0.00035)	(0.00091)				
SCR	**0.00037*****	0.00001				
	(0.00009)	(0.00019)				
ICR*SCR	**-0.000002****	-0.000001				
	(0.000001)	(0.000003)				
CR			0.00456			
			(0.00404)			
GPL			0.00011			
			(0.00117)			

	Absorption	Closure	Absorption	Closure	Absorption	Closure
CR*GPL			-0.00027			
			(0.00027)			
RUINPROBPENS					0.00986	0.03031
					(0.01957)	(0.0416)
RUINPROBSICK					0.01952	0.02991
					(0.0183)	(0.02542)
RISKLOADING					-0.00078	**0.00274***
					(0.00167)	(0.00153)
SIZE	-0.0000001	**-0.00001***	-0.0000002	**-0.00001****	-0.0000001	**-0.00001***
	(0.0000002)	(0.000004)	(0.0000003)	(0.000006)	(0.0000003)	(0.000007)
YOUNG	**0.0582****	-0.00829	**0.05092****	-0.00553	**0.06057****	-0.01927
	(0.02756)	(0.03269)	(0.02468)	(0.0344)	(0.0259)	(0.02795)
ESTAB	-0.0264	0.03522	-0.03162	**0.47209****	-0.02605	0.06905
	(0.02683)	(0.04719)	(0.03469)	(0.18682)	(0.02664)	(0.05001)
FIRMSHARE	**0.05851*****	0.00056	**0.07972*****	-0.06442	**0.0762*****	0.00004
	(0.02101)	(0.05532)	(0.02542)	(0.08763)	(0.02548)	(0.04203)
SDAYSRATIO	**-0.00228***	**0.00239****	**-0.0031****	0.00082	**-0.00344*****	**0.00271****
	(0.00123)	(0.00112)	(0.00125)	(0.00084)	(0.00126)	(0.00119)
DIVERSIFICATION	**-0.043****	0.03535	**-0.04349****	0.04268	**-0.05583*****	0.03271
	(0.01836)	(0.03762)	(0.01761)	(0.0467)	(0.01765)	(0.04419)
Number of observations	4,337	4,337	4,282	4,282	4,276	4,276
Log-pseudolikelihood	-133.98	-71.94	-124.66	-56.07	-124.81	-62.87
Wald χ^2	123.53	28.70	97.36	40.96	78.22	110.93
Prob > χ^2	0.00	0.01	0.00	0.00	0.00	0.00

Note: Event j=1 is absorption, event j=2 is closure. Dependent variables are the log hazard rates with respect to these events. Displayed are coefficients, not hazard ratios. Standard errors in brackets are robust. For ties, the Breslow method is used. ***, ** and * denote statistical significance on the one, five and ten percent level.

bility of closure. However, there is no significant relationship between current size and the hazard of absorption in the presence of the exit alternative closure. This is to say, in retrospective, a KV that was closed was very likely to have been closed because it was too small. A KV that was absorbed was very likely not to have been absorbed simply because of its large or small size.

Of the alternative financial distress variables, only the risk loading measure is significant, but only on the ten percent level and with respect to closure. The coefficient implies a positive relationship between the risk loading of the average contribution and the hazard of closure. In other words, an increase in the risk loading factor causes the hazard rate to increase. This is counter-intuitive insofar as an increase is principally compatible with a policy towards risk-adequate pricing, irrespective of whether the risk loading itself is negative or positive. At the moment, we have no compelling explanation at hand for this effect.

As regards the effect of the young contributors-to-old contributors ratio, we are now able to specify the seemingly counter-intuitive implications of our stratified Cox model from above. Precisely, the effect is statistically significant in all three models with respect to absorption. A ceteris paribus increase in the ratio made an absorption more likely. Even if we expected to find a negative relationship between this variable and the (log) hazard rate, which would have then implied that such a KV would have been an obvious target for an insolvency avoidance merger, we can interpret the finding. Apparently, a high share of young contributors appears to improve a KV's attractiveness as target since it reflects the growth potential of the respective mining area. This finding clearly contradicts our baseline hypothesis because it is more compatible with self-interested absorber KVs that wanted to ensure a steady inflow of young insurants to stabilize the revenue side than compatible with the insolvency avoidance assumption underlying the baseline hypothesis.

The share of established contributors in all contributors only plays a significant role in model 2 regarding closure. Here, the coefficient is positive and implies that an increase in the share increases the hazard of closure. An explanation why KV closure might have been more likely in the case unestablished miners were substituted for established miners could be that the latter were comparatively much costlier than former so that, other being having been equal (especially the relative pricing of the average established and unestablished miner's insurance contracts) a cost shock or a sequence of such shocks occurred that could not be handled.

On the basis of our competing risk model, we are now also able to specify that the entrepreneurs' financing share in total claims costs is a statistical significant determinant of the conditional probability of absorption, but not of the closure alternative. In particular, a rising entrepreneurs' cost share increases the hazard of absorption. We consider two alternative explanations. On the one hand, a rise in the entrepreneurs' cost share could have signaled growing financial distress. Given contributors were already sufficiently burdened with the financing of costs, entrepreneurs had to inject additional financing resources in order to prevent the KV from being underfunded. Hence, an insolvency avoidance merger was principally required. On the other hand, irrespective of how financially distressed a KV was, a rise in its cost share could have been interpreted by potential absorber KVs as a signal of prosperity in the respective mining area, which allowed entrepreneurs to unburden insurants out of additional profits. Hence, a merger by absorption then served to improve first and foremost the position of the absorber KV thereby contradicting our hypothesis.

Finally, two other KV characteristics are of significant importance. First, the sick days-to-contributors ratio as an analogue to the ICR and SCR is significant with respect to absorption in all models where the sign implies that an increase in the number of paid sick days per 100 contributors reduces the hazard of merger by absorption. This finding suggests that, other things being equal, a KV was the less attractive as target, the more sick days per contributor were claimed and financed. Since we interpret a rise in the ratio as a sign of growing financial distress, possibly due to worsening geological conditions that increasingly depressed the miners' organism or due to simulation, an inverse relationship does not support our hypothesis. Besides that, it is striking that the closure-specific effect is significantly positive in models 1 and 3. This means, an increasing sick days-to-contributors made a closure more likely, but eliminated absorption as an alternative. Here, our baseline hypothesis does definitely not work.

Second, controlling for the degree of a KV's diversification of among different mining subsectors reveals that it is now always significant on the one or five percent level regarding absorption, but is statistically irrelevant in the case closures are examined. Coefficients imply an inverse relationship between a change in the covariate and the conditional probability of absorption. Specifically, the less a KV was diversified, the less was it likely to become a target for absorption. This may be interpreted as evidence on the fact that correlation of insurance risks on the subsector level plays a role. Consider that if a KV had only employed hard coal miners, a large accident regarding this single most dangerous mining activity, had caused correlated claims. This then contradicted one fundamental principle of insurance, namely independence between insured risks, and possibly resulted in extraordinary high claim rates, hence pressure on finances. In contrast, if a KV's insurants distributed among at least two different subsectors, whereby the one could be associated with a lower baseline hazard of accident or occupational disease than the other, the problem of correlation among insured risks had not disappeared, but was comparatively less severe. We interpret results on the variable diversification as supporting the opposing hypothesis that absorber KVs saw in the absorption of other KVs the ability to improve their position as insurers.

V. Conclusion

By means of econometrics, this paper aims at assessing the determinants of mergers among Prussian Knappschaft funds within 1861 to 1920 from the perspective of absorbed KVs. This is the first approach of that kind in the literature. We introduce the hypothesis that absorptions were an alternative to insolvency due to increased financial distress and conduct an indirect test of this hypothesis. In a competing risk setting, we model the hazard of merger by absorption as dependent on a set of both time-invariant and time-varying covariates and in distinction to the hazard of closure. Within a Cox proportional hazards framework, we first consider the determinants of exit per se. Taking, then, Fine and Gray's proportional subhazards approach, we explicitly consider absorption and closure as two competing and possibly correlated exit modes.

Part of our findings supports the baseline hypothesis that mergers were a rescue measure. We expected to find a significant positive relationship between financial distress variables and the hazard of absorption and no such statistically relevant relationship with respect to the hazard of closure. Yet the components of the pensioners-to-contributors ratio as a central variable for a pay-as-you-go financed pension scheme, namely the invalids- and survivors-to-contributors ratio, stand out as having significant explanatory power with respect to the hazard of merger by absorption. We find that an increase in both ratios can be associated with an increase in the conditional probability of absorption. Hence, we interpret this as an indirect hint at the fact that mergers are likely to have been conducted in order to prevent financially distressed KV from financial collapse.

Besides, findings suggest importance of a number of other controls. First, the higher both the ratio of young established contributors to old contributors and the entrepreneurs' financing share in total claims costs were, the higher was ceteris paribus the hazard of absorption. Second, the more consequent a KV was diversified over mining subsectors, the higher was the hazard of absorption. Astonishingly, in the presence of closure as an exit alternative, current size does not play a significant role as a determinant of the conditional probability of absorption. Though, size is an important determinant of the hazard of closure in that shrinkage increased the hazard. Finally, while a rising sick days-to-contributors ratio increased the hazard of closure, too, it reduced at the same time the hazard of absorption. These findings together support the opposing self-interest-hypothesis which implies that absorber KVs especially absorbed the more attractive targets, but not necessarily the financially distressed ones. From this it follows that unattractive, financially distressed KVs faced no alternative to closure.

Appendix 1: Population of Prussian Knappschaften

Code	KV Name	Observation	Duration	Sample	Absorbed by
1	Arnsberg KV	1861-1916	56	B	39
2	Brilon KV	1861-1916	56	B	39
3	Brühl KV	1861-1920	60	A	
4	Burbacher Hütte KV	1861-1920	60	A	
5	Cottenheim KV	1862-1916	55	C	
6	Deutz KV	1861-1916	56	C	
7	Dillinger Hütten KV	1861-1920	60	A	
8	Eifel KV	1861-1910	50	B	3
9	Emser KV	1867-1911	45	B	21
10	Eschweiler Pümpchen KV	1861-1917	57	C	
11	Eschweiler KV	1861-1917	57	C	
12	Goffontaine KV	1861-1872	12	C	
13	Günnersdorf KV	1861-1885	25	C	
14	Halberg KV	1861-1920	60	A	
15	Heller KV	1861-1916	56	B	39
16	Hohenzollern'sche Lande KV	1861-1920	60	A	
17	Holzappeler KV	1867-1911	45	B	21
18	Hostenbach KV	1861-1915	55	B	38
19	Ichenberg KV	1861-1873	13	B	11
20	Krupp KV	1867-1871	5	B	29
21	Lahn KV	1912-1920	9	A	
22	Lendersdorf KV	1861-1876	16	C	
23	Mariahütte KV	1861-1920	60	A	
24	Mayen KV	1862-1920	59	A	
25	Meinerzhagen KV	1861-1907	47	B	3
26	Mosel KV	1862-1910	49	B	3
27	Münster am Stein KV	1861-1920	60	A	
28	Müsen KV	1861-1916	56	B	39
29	Allgemeiner KV Nassau	1869-1911	43	B	21
30	Neunkirchen KV	1861-1920	60	A	
31	Niedermendingen KV	1862-1916	55	C	
32	Oberbergischer KV	1861-1884	24	B	36
33	Olpe KV	1861-1916	56	B	39
34	Quinter KV	1861-1920	60	A	
35	Rheinböller Hütte KV	1861-1915	55	C	
36	Rheinischer KV	1861-1920	60	A	
37	Rheinpreussen KV	1867-1920	54	A	
38	Saarbrücken KV	1861-1920	60	A	
39	Siegen KV	1861-1920	60	A	
40	Stolberger KV	1861-1920	60	A	
41	Stromberger Hütte KV	1861-1915	55	C	
42	St. Goar KV	1861-1915	55	C	
43	St. Wendel KV	1861-1906	46	C	
44	Theodorshalle KV	1887-1920	34	A	
45	Thommer KV	1876-1920	45	A	
46	Werl KV	1861-1918	58	C	
47	Westernkotten KV	1861-1920	60	A	
48	Wetzlar KV	1861-1911	51	B	21
49	Wied KV	1861-1880	20	C	
50	Wittgenstein KV	1861-1920	60	A	
51	Wurm KV	1861-1920	60	A	
52	Muskau KV	1861-1884	24	B	53
53	Niederschlesischer KV	1861-1920	60	A	
54	Oberschlesischer KV	1861-1920	60	A	
55	Plesser KV	1862-1920	59	A	
56	Cassel KV	1870-1920	51	A	
57	Clausthal KV	1870-1920	51	A	

Code	KV Name	Observation	Duration	Sample	Absorbed by
58	Hannover KV	1874-1885	12	B	57
59	Hessischer KV	1870-1885	16	B	57
60	Hohenstein KV	1870-1885	16	B	57
61	Ilseder Hütte KV	1873-1920	48	A	
62	Schaumburg KV	1870-1885	16	B	57
63	Schmalkalden KV	1870-1885	16	B	57
64	Unterharzischer KV	1873-1920	48	A	
65	Allgemeiner KV Bochum	1890-1920	31	A	
66	Altenbeken KV	1861-1895	35	C	
67	Borgloh-Oesede KV	1867-1890	34	C	
68	Essen-Werden'scher KV	1861-1889	29	B	65
69	Georgs-Marien-Hütte KV	1867-1920	51	A	
70	Gottesgabe KV	1861-1920	60	A	
71	Ibbenbüren KV	1861-1920	60	A	
72	Königsborn KV	1861-1876	16	B	73
73	Märkischer KV	1861-1889	29	B	65
74	Minden-Ravensberg KV	1861-1920	60	A	
75	Mülheim KV	1861-1889	29	B	65
76	Neusalzwerk KV	1861-1920	60	A	
77	Piesberg KV	1867-1903	37	B	69
78	Rothenfelde KV	1867-1920	51	A	
79	Salzkotten KV	1861-1907	47	C	
80	Sassendorf KV	1861-1920	60	A	
81	Artern KV	1861-1876	16	C	
82	Brandenburgischer KV	1872-1920	49	A	
83	Brandenburg-Pommern KV	1861-1871	11	B	82
84	Berlin KV	1861-1873	13	C	
85	Dürrenberg KV	1861-1908	48	B	90
86	Erfurt KV	1861-1872	12	B	95
87	Werke am Finowkanal KV	1861-1915	55	C	
88	Halberstadt KV	1861-1920	60	A	
89	Saline Halle KV	1861-1913	53	C	
90	Hallescher KV	1907-1920	14	A	
91	Henneberg KV	1861-1868	8	B	102
92	Kamsdorf KV	1861-1868	8	B	102
93	Lauchhammer KV	1861-1920	60	A	
94	Mansfeld KV	1861-1920	60	A	
95	Neupreussen KV	1861-1906	40	B	90
96	Niederlausitz KV	1861-1871	11	B	82
97	Rüdersdorf KV	1861-1916	56	C	
98	Saalkreis KV	1861-1906	40	B	90
99	Schönebeck KV	1861-1874	14	B	88
100	Stolberg KV	1862-1872	11	B	88
101	Tangerhütte KV	1861-1920	60	A	
102	Thüringen KV	1869-1920	49	A	
103	Wernigerode KV	1887-1920	34	A	

Note: KV with code 1 to 51 (52 to 55, 56 to 64, 65 to 80, 81 to 103) were located in the mining administration region of Bonn (Breslau, Clausthal, Dortmund, Halle). Sample A consists of right-censored KV. Sample B consists of KV subject to event 1. Sample C consists of KV subject to event 2

Source: See Table 1 and Jopp, *Ein risikoreiches Geschäft?* (cf. n. 9).

Appendix 2: Explanatory variables

Variable Name	**Definition**
A. Time-invariant variables:	
STARTUPSIZE	Equals the number of contributors a KV had in the first year it was observed
STARTUPICR	Equals the pensioners-to-contributors ratio a KV had in the first year it was observed
STARTUPSCR	Equals the pensioners-to-contributors ratio a KV had in the first year it was observed
AVGROWTHSIZE	Equals the geometric mean of annual growth rates of size
AVGROWTHICR	Equals the geometric mean of annual growth rates of the ICR
AVGROWTHSCR	Equals the geometric mean of annual growth rates of the SCR
B. Time-varying variables:	
SIZE	Equals the sum of established and unestablished contributors
RATIOMES	Equals the ratio of a KV's size to minimum efficient size measured by the average size of all KV
ICR	Equals the invalids-to-contributors ratio measured by the ratio of invalidity pension recipients to all contributors
SCR	Equals the survivors-to-contributors ratio measured by the ratio of survivorship pension recipients to all contributors
CR	Equals the contribution rate measured as average contribution divided by the sum of average net wage and average contribution
GPL	Equals the gross pension level measured as average invalidity pension divided by average gross wage
RUINPROBPENS	Equals the probability of ruin with respect to the pension section without incorporation of financial reserves
RUINPROBSICK	Equals the probability of ruin with respect to the sickness section without incorporation of financial reserves
RISKLOADING	Equals the risk loading of the average contribution
ESTAB	Equals the share of established contributors in all contributors
FIRMSHARE	Equals the ratio of employers' contributions to total costs
YOUNG	Equals the ratio of established contributors aged 16 to 35 to those aged 36 and more
SDAYSRATIO	Equals the sick days-to-contributors ratio measured by the ratio of paid sick days to all contributors
DIVERSIFICATION	Equals the Herfindahl index with respect to subsector employment shares