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Abstract

Over the later 1920s and up to the mid-1930s, German coal-mining saw an exceptional surge in labour productivity led primarily by the Ruhr coalmines' performance. It is a commonly accepted view that the economy-wide 'rationalization boom' between currency stabilization and the depression years explains that pattern. We test the related hypothesis that 'negative rationalization' in the form of a massive wave of mine closures over 1924-29 played a significant role in pushing aggregate labour productivity in the Ruhr coal district up to new levels. Based on an original dataset on the population of Ruhr coalmines, the sources of productivity change over the extended period 1913-38 are identified using the decomposition method of Foster, Haltiwanger and Krizan (2001). Results suggest that labour productivity in Ruhr coal-mining was driven to a large extent by improvements at individual mines attributable to the intensified mechanization of underground operations. Closures regularly raised aggregate productivity in the year after the closure had been conducted; closures also pushed productivity by way of ceding resources to high(er) productivity surviving mines over gradual shut-down. However, on the whole, turnover-effects were marginal compared to the effects stemming from the producer dynamics among surviving mines. Thus, the practical productivity implications of mine closures over the rationalization boom are negligible and still overrated in the relevant literature. These findings call for testing more rigorously the relative importance of 'negative rationalization' in the form of plant closures in other branches of the Weimar economy.

JEL classification: L11, N14, N54, Q35

Keywords: closures, coal-mining, Germany, labour productivity, productivity decomposition, rationalization

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I. What explains the post-inflation surge in labour productivity?

By 1913, Germany had evolved into one of the world's advanced industrial economies.[1] The coal-mining sector, as part of the heavy industries complex, is often credited for having played an important role in backing that development.[2] To serve the economy's growing hunger for coal, the workforce had been constantly extended alongside the number of coal faces.[3] Still, very little of the 190 million tons of coal mined in 1913 had actually been cut with mechanical support; and while labour productivity had nearly doubled over 1850-1888 from 155 to 297 tons per overall worker and year, it had been stagnating since, until the onset of the Great War, at a long-term average of 262 tons. This pattern on the national level primarily follows the development in the Ruhr coal district, with a share of 58 percent in 1913's output the single most important coal district in Germany at the time.[4] It has been argued that capital intensity and total factor productivity, too, had stagnated which would explain that labour productivity had not improved over almost three decades.[5]

Compared to the prewar period, the picture for the interwar period is one of profound ups and downs in output, employment, and productivity. As the share of the Ruhr coal district was further increasing, we decided to concentrate on this largest and exemplary district in the following.[6] Based on aggregate data compiled by Fischer and others, Table 1 provides some stylized facts on the growth performance at the Ruhr over 1861 to 1938 and, in so doing, de-

[1] E.g., Landes (1999), p. 450.

[2] Holtfrerich (1973); Gillingham (1985), p. 5; Parnell (1994), p. 29.

[3] Burghardt (1990), p. 16.

[4] Production taken, and productivity and the Ruhr coal district's share computed, from Fischer (1989), pp. 1, 33. Over 1861-1888 (1889-1913), the average share was about 46 (54) percent. Ziegler (2013), p. 65, quantifies the degree of coal mechanically cut *at the Ruhr* prior to 1914 with around 2.2 percent.

[5] Burhop and Lübbers (2009), p. 510.

[6] The average share over 1914-1938 amounted to 65 percent, and the maximum share to roughly 79 percent in 1922; see Fischer (1995), pp. 1, 35.

fines the empirical phenomenon we want to explore in more detail – namely the exceptional growth of labour productivity over the later 1920s. While labour productivity, regardless of the measure, had further declined over the Great War and the troubled postwar inflationary period, it increased by more than ten percent per p.a. over 1923/24-29. Part of that growth certainly was reconstruction after output had fallen to 42 million tons and productivity to a mere 78 tons in 1923 – the peak year of inflation, and the year of the occupation of the Ruhr. However, the noteworthy gain over the productivity level of 1913 is still pretty obvious.

This surge in productivity has especially been attributed to the deferred mechanization and rationalization of the industry after currency stabilization, when the Weimar economy was in a state of relative calm for the following years.[7] In this respect, contemporary observers regularly distinguished between 'positive' and 'negative' rationalization, the former referring to all technological and organizational changes that would improve the production process directly and thereby raise productivity; and the latter marking improvements in productivity by re-concentrating operating points underground and, in particular, shutting down inefficient, low-productivity mines.[8] However, while historical research has put some focus on the genesis of mining technology and, consequently, the 'rationalization wave'[9], it has to an even greater extent been concerned with the social history of coal-mining and, thus, the struggle between capital and labour.[10] As yet, quantitative studies of German coal-mining productivity

[7] Gillingham (1985); p. 5-28; Shearer (1989); Ziegler (2013), pp. 63-69.

[8] Jüngst (1928), p. 8; Wedekind (1930), pp. 15-19. Recent research has picked up that terminology; see, for example, Shearer (1995), pp. 489, 495.

[9] Burghardt (1990; 1995); Shearer (2003).

[10] E.g., Wisotzky (1983); Tschirbs (1986); Trischler (1988); Feldman and Tenfelde (1989).

and efficiency, of which few exist for the prewar period[11], are still lacking for the interwar period.[12]

Table 1: Output, employment, and productivity in Ruhr coal-mining over 1861-1938

	Coal output (million tons)	Employment (1,000 workers)	Output per worker (tons)	Output per man-shift (tons)
A. Level in				
1861	5.6	31.5	176.5	n/a
1888	33.2	105.4	315.1	1.01
1913	110.8	397.3	278.8	0.89
1924	104.6	401.5	235.9	0.81
1929	124.4	355.8	349.5	1.27
1938	127.3	328.9	387.0	1.55
B. % growth p.a. over				
1861-88	+6.8 %	+4.6 %	+2.2 %	n/a
1888-14	+4.3 %	+5.0 %	–0.6 %	–0.6 %
1914-18	–2.8 %	–2.4 %	–0.4 %	–3.3 %
1918-23	–13.3 %	+7.4 %	–19.3 %	–13.2 %
1923-29	+3.5 %	–5.9 %	+10.1 %	+11.5 %
1929-32	–10.5 %	–16.3 %	+7.0 %	+8.1 %
1932-38	+5.7 %	+5.9 %	–0.2 %	+0.5 %

Sources: Output and employment: Fischer (1989), p. 33; Fischer (1995), p. 35. Output per man-shift: Burghardt (1995), p. 382; Gillingham (1985), p. 57; Wisotzky (1983), p. 74. Author's own computations.

It is the purpose of this paper to examine the relationship between aggregate labour productivity change and mine dynamics at the Ruhr in more detail. To identify the sources of the interwar surge in aggregate labour productivity described above, we analyse mine-level data on production, employment, and productivity covering the full population of Ruhr (hard!) coal mines over 1913-38. Our special interest lies in testing the view that 'negative rationalization' in the form of the exceptional mine closure wave of the later 1920s significantly contributed to improvements in aggregate productivity. To that end, we apply a source decomposition method that enables us to separate the contribution of mine closures from that of newly enter-

[11] Holtfrerich (1973); Burhop and Lübbers (2009).

[12] There are, indeed, a couple of rather qualitative studies on that matter; see Shearer (1989; 1995).

ing and surviving mines; or, put slightly differently, the contribution of a re-allocation of resources between mines in contrast to technological improvements at individual mines. This method has recently been used, for example, to explore the micro-level sources of labour productivity change in Japanese coal-mining during World War II.[13]

This study contributes in several ways: Firstly, it sheds new light on the German coal industry's productivity performance and development over a politically and economically very troubled period. It therefore picks up the claim often made in the industrial economics literature that accurately understanding aggregate productivity trends on the sectoral or national level requires analysing firm- or even establishment-level data. Many empirical studies indeed have highlighted the importance of micro-level heterogeneity in this respect.[14] Secondly, it links up with the strand of the resource economics literature that tests the hypothesis that labour productivity in an extractive industry must fall over time as the quality of deposits coming into production successively diminishes; it is assumed that, under perfect information, the best-quality deposits are necessarily depleted first and, thus, that mineral production is exemplary for an industry operating with diminishing returns. However, this traditional view has been convincingly questioned in many cases – not the least because information in the actual world is imperfect, technological change is present, and exploration activities may add new high-quality deposits to known reserves.[15] With this study, we provide one of the few tests that mobilize economic historical evidence to explore this argument.[16] Thirdly, we gain further insight into the 'mechanics of rationalization' and the practical productivity effects of

[13] Okazaki (2014).

[14] E.g., Dunne, Roberts and Samuels (1988); Bresnahan and Raff (1991); Griliches and Regev (1995); Foster, Haltiwanger and Krizan (2001); Baily, Bartelsman and Haltiwanger (2001), p. 151.

[15] E.g., Tilton (1992), pp. 240-242; Aydin and Tilton (2000); Ellerman, Stoker and Berndt (2001); Garcia, Knights and Tilton (2001).

[16] Okazaki (2014), of course, is another.

closures as one prominent measure, the use of which certainly was not a unique feature of the mining industry.[17] Fourthly, and finally, this study also contributes to the literature on other important coal producers in Europe, and the competition among them. This primarily goes for Great Britain, which has been shown to have fallen behind Germany (and, in fact, other continental European coal producers) in terms of coal-mining productivity growth in the 1920s.[18]

We proceed by briefly describing in Section II which attempts had been made to rationalize the Ruhr coal industry. Section III presents our newly constructed, original data set and provides baseline information on mine dynamics, such as the number of mine exits and entries during the observation period. Section IV outlines the methodological approach and reports the empirical findings. Finally, Section V concludes.

II. The rationalization wave in Weimar Germany

Judged by recent textbooks on German economic history, it is commonplace to view the short period of time between the stabilization of currency at the turn of 1923/24 and the Great Depression in late 1929 as, among other things, shaped by 'euphoric belief in progress and rationalization' and accelerated technological modernization of the industry and the private households' sphere.[19] However, various authors have pointed out that one should separate the broad public discussion on what rationalization meant, and on which advantages and disadvantages it would bring, from the actual extent of measures taken to, for example, introduce Fordian or Tayloristic practices (e.g., assembly-line work and 'scientific management' in the

[17] Knortz (2010), p. 127.

[18] Broadberry and Fremdling (1990), p. 405; Scott (2006), p. 22-24. See, for example, also Greasley (1982, 1990) and Garside (1992) for special accounts on productivity growth and the mechanization in the British coal industry; and Supple (1989) for the general picture.

[19] Kleinschmidt (2007), pp. 33-44; Knortz (2010a), pp. 126-140; Spoerer and Streb (2013), pp. 51-52; citation in inverted commas from Spoerer and Streb.

form of job planning, time studies, and scientific wage calculation) or push forward concentration and cooperation within and across sectors. It is thus still open to debate how much was mere 'talking rationalization', which would not cost much and would also support spreading ideology if intended, and how much was 'advancing rationalization', literally;[20] among the sceptics ranges, for example, Harold James who expresses his doubts about the existence of a 'rationalization boom' at the time.[21] In answering that question, one specific challenge has certainly been to operationalize the concept of 'rationalization' – that is, to measure how it affected indicators of business efficiency and profitability as well as, more generally, indicators of societal well-being and progress.[22] Industry and firm-related studies have provided essential insights in this respect.[23]

But contemporaries already were aware of the definitional and measurement issues. Hinnenthal (1927) provides one prominent passage when he summarizes a number of circulating definitions:

> "The ones say: rationalization is attempts to increase the useful effect […]. Others explain rationalization is picking the right way to simplify the process of production and distribution of goods […]. Or rationalization is defined as combining congenial or related economic forces in cartels, trusts, concerns. Some […] define on the grounds of a value judgement: Rationalization means saving manpower […]; or on the grounds of a demand: Rationalization is identical with price cuts […]. Another view is: Rationalization essentially is improvements in quality. […]. Recently even voices have been raised: Rationalization is nothing new. An entrepreneur has always tried to make the best of his business."[24]

[20] E.g., Freyberg (1989), pp. 23, 308-320; Lippert (1994), p. 168); Shearer (1995); Borscheid (1996); Knortz (2010b), pp. 31-32.

[21] James (1986), pp. 146-161. He actually made two exceptions with the automobile and coal-mining industries.

[22] Stollberg (1981), p. 47; Lippert (1994), p. 176.

[23] E.g., Brady (1933); Freyberg (1989); Zimmermann (1992); Kleinschmidt (1993); Lippert (1994); Spoerer (1994); Peters (1996).

[24] Hinnenthal (1927), pp. 5-6. Author's own translation of the German original.

He then puts forward what appears to be a synthesis; this is the definition of the *Reichskuratorium für Wirtschaftlichkeit in Industrie und Handel* ('Reich Board for Economic Efficiency in Industry and Trade'), founded in 1921:

> "Rationalization is identification and application of all means that technology and methodical organisation offer to raise efficiency. The aim is: Increasing the wealth of a nation by reducing the price of goods, increasing their supply, and improving their quality. This requires collaboration in all relevant circles […]."[25]

Perhaps most important is the latter sentence which emphasizes the need for collaboration (*Gruppenarbeit*) beyond sectoral boundaries and, what is more, between producers, distributors, and consumer of goods. So the purpose of the *Reichskuratorium* apparently was to intermediate an all-party permanent dialogue, to channel concerted action, and to advocate standardization beyond sectoral boundaries where possible.[26]

In his 1930 study on the rationalization in the Ruhr coal-mining industry, Wedekind proposes a definition that takes the somewhat narrower and perhaps more practical entrepreneurial perspective, although he acknowledges, in line with Hinnenthal, that rationalization has a broader societal dimension as well:

> "Rationalization in mining is 'the sum of all measures that aim – based on a scientific approach, and not rules of thumb – at reducing operating costs, facilitating human work and increasing work safety'."[27]

Table 2 assembles some statistics illustrate the extent of rationalization in Ruhr coal-mining in the later 1920s. To begin with, there is the coal-winning method. Winning coal by use of manual work in combination with explosives was the dominating prewar practice. By 1925, almost one-half of coal was won by complementing manual work with cutter-scrapers and especially the pneumatic pick, which, according to Burghardt, was the 'key innovation' of the

[25] Hinnenthal (1927), pp. 11-12. Author's own translation of the German original.

[26] Hinnenthal (1927), p. 11.

[27] Wedekind (1930), p. 9. Author's own translation of the German original.

time to raise productivity.[28] Over the next few years, the share of pure manual work and work with explosives was further reduced to a marginal four percent. Facilitating work by machines was the centrepiece of what contemporaries coined 'positive rationalization'.[29] This was not confined to the coal-winning process. Underground transport, too, saw a more intensive use of machinery, with the conveyor belt (*Schüttelrutsche*) leading the way.[30] Accordingly, the volume of installed horsepower underground increased nine-fold; and this volume varied towards 1932 in line with the general downsizing of the workforce apparent from Table 1. Besides 'rationalization-caused unemployment', which Shearer estimated to about 38 percent over 1926-29,[31] mechanization necessarily came with organisational changes of the workforce underground, in that the traditional small, comradely groups of miners (*Gedingekameradschaften*) performing all necessary tasks on their own were busted and substituted by larger, more efficient single task-oriented groups.[32]

Additional measures not reflecting new technology were put under the header 'negative rationalization'.[33] Besides the strategy to close mines that were assessed as inefficient, which we will come back to in more detail in the following two Sections, these measures included the reduction of work points underground which visibly increased the production per operating point (see Table 2). It might be argued, though, that much in this direction had been apparently achieved after 1929, during the Great Depression.

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[28] Burghardt (1990), p. 38. For an in-depth account of the evolution of mining technology at the Ruhr, see Burghardt's 1995 monograph.

[29] Wedekind (1930), p. 21.

[30] Belt length more than tripled between 1913 (105,000 kilometers) and 1925 (390,000 kilometers); see Wedekind (1930), p. 24.

[31] Shearer (2003), pp. 27-28.

[32] See Zimmermann (1992), pp. 434-436.

[33] See Wedekind (1930), p. 16.

Table 2: Rationalization indicators for interwar Ruhr coal-mining

	Coal-winning methods (% of coal won by)			Operating points		Total horse-power installed underground
	Pneumatic pick	Cutter-scraper	Hand/ Explosives	Number	Production per operating point (tons per day)	
1903	-	-	-	-	-	125,491
...						
1913	0.0	2.2	97.8	-	-	-
...					-	
1925	36.5	11.5	52.0	-		-
1926	56.5	10.9	32.6	22,871 (Dec.)	-	1,127,199
1927	74.4	8.5	17.1	19,907 (Dec.)	26	-
1928	83.9	6.4	9.6	16,181 (Dec.)	-	-
1929	87.4	5.5	7.1	15,700 (Jan.)	30	-
1930	93.8	0.0	6.2	-	-	-
1931	95.9	0.0	4.1	7,438 (Jan.)	47	-
1932	88.8	8.1	3.1	5,111 (Jan.)	59	995,613
1933	88.5	7.5	4.0	4,075 (Jan.)	73	891,071
1934	89.3	7.7	3.0	4,035 (Dez.)	94	896,623
1935	87.9	8.3	3.8	3,172	106	918,450
1936	90.3	6.3	3.4	3,416	110	972,724
1937	89.7	6.8	3.5	3,551	116	1,039,946
1938	89.4	7.2	3.4	-	122	1,075,958

Notes: Installed horsepower refer to horses, steam engines, compressed air engines, and electric engines.

Sources: Coal-winning methods: Gillingham 1985, p. 9. Working points and horsepower: Burghardt (1995), pp. 382, 392, and Gillingham (1985), p. 72.

Even if the stylized facts presented so far may convey the impression of a success story, the mines at the Ruhr still had to cope with the after-effects of the war. Principally since August 1914, the German economy had laboured under coal shortage; and the territorial losses and reparations in coal due to the Treaty of Versailles further increased the pressure on the supply side. This, for example, led to many new, but rather small mines being opened during the inflationary period (see below); many of these mines, however, were closed only some years later as they were not competitive. Besides, the practice of overexploiting the already developed and high-quality deposits – commonly referred to as *Raubbau* in the German literature – and of postponing additional replacement and expansion investments caused severe asset erosion. Towards the mid-1920s, increased domestic competition with brown coal and also tight-

er international competition substituted the problem of coal shortage for the problem of stagnating demand.[34]

One after-effect especially plagued mines during the later 1920s, and that was the labour force having gained bargaining power to a hitherto unprecedented extent.[35] Following Borchardt, the struggle between labour and capital, which emerged once the old political order had been overthrown in 1918/19, led to an overexpansion of the welfare state which set limits to government policies, especially on the peak of the Great Depression, and thus accelerated Weimar's decline.[36] The view that wages and ancillary wage costs all over the economy were too high to be sustainable has certainly been controversially debated since.[37] But evidence on the Ruhr coalmines seems to suggest that rationalization did not bring a significant reduction in operating costs. Labour costs – that is, wages, salaries, and employers' contributions to social insurance together – accounted for well about two-thirds, or more, of all costs (as of 1927/28), the remaining part being material (e.g., timber, explosives, building materials, energy) and miscellaneous costs (e.g., taxes and freight).[38] Based on counterfactual estimations of wage costs per (usable) ton over 1924-28 assuming constant wages, contemporary expert Ernst Jüngst, for example, voiced that labour costs at the Ruhr had actually remained quite stable over the rationalization period (between 8.8 and 9.9 Reichmarks), although more coal had been extracted with less miners.[39] Had wages themselves remained constant on their late 1924-level, so the counterfactual goes, labour costs would have fallen towards 6.5 Reichmarks per ton, as of the end of 1928. So it seems that a large part of rationali-

[34] Burghardt (1990), p. 21. This trend was certainly reinforced by basic improvements in energy and heating efficiency.

[35] E.g, Tschirbs (1986); Shearer (1989); Hartewig (1992); Plumpe (1999).

[36] Borchardt (1979, 1980).

[37] E.g., Holtfrerich (1984); von Kruedener (1985).

[38] Jüngst (1929), p. 84.

[39] Jüngst (1929), p. 118. This, of course, does not mean

zation gains were redistributed to workers. It quite fits that the profitability of mining firms is said to have been rather modest. Spoerer (1995) estimated the average return-on-equity for mining and investment-goods corporations to have been 2.1 percent over 1925-29, which lay markedly below the average for the nazi period (i.e., 1933-41: 12.5 percent), but also below prewar levels.[40] Hence, we may doubt that rationalization in mining brought a significant reduction in operating costs.

III. A primer in Ruhr coal mine survival

Data sources

To explore the mine dynamics at the Ruhr in more detail, we make use of a unique source that has not yet been exploited in a fashion comparable to ours. More specifically, our data come from a compilation named *Die Bergwerke und Salinen im niederrheinisch-westfälischen Bergbaubezirk*, a periodical publication supplementing the *Jahrbuch für den Oberbergamtsbezirk Dortmund* since 1907;[41] both publications were edited by the *Verein für die bergbaulichen Interessen im Oberbergamtsbezirk Dortmund*, one of the important interest groups of mine entrepreneurs. The *Bergwerke und Salinen*, as we will refer to this source in short-hand, offers annualized mine-level information on firm affiliation, coal quality, coal output (in tons), by-product output (e.g., tons of coking coal or ammonia), and employment of, as we believe, every mine at the Ruhr. So we are confident that, in analysing this source, we are dealing with the *population* of Ruhr mines.

For the sake of comparability, we decided not just to zoom into 1924-29, our primary period of interest, but to extend observation back to 1913 and forth to 1938. Entry and espe-

[40] Spoerer (1995), pp. 152-155.

[41] The *Jahrbuch für den Oberbergamtsbezirk Dortmund*, in turn, was first published in 1893; it was renamed in *Jahrbuch für den Ruhrkohlenbezirk* in 1932.

cially exit patterns are recoverable from the reported statistical data in combination with given notes on dates of entry, phases of operation, phases of temporary closure, and dates of terminal closure. Table 3 presents a summary of our original data set. On the whole, we observed 303 different mines over 26 years resulting in an unbalanced panel of 4,650 mine-year-combinations. Of these mines, 117 – or 39 percent – are both left and right censored – i.e., survived the entire observation period; another 30 mines came into operation after 1913 and remained in the data set until 1938; a further 78 mines already existed in 1913 and exited before 1938; and 78 mines both entered and exited the data set some time during 1913-38.

Table 3: Summary of the data set

Type of observational unit	Number of mines
A. Observed over 1913-1938	117
B. Observed over 1913-exit event	78
C. Observed over entry event-1938	30
D. Observed over entry event-exit event	78
Different mines in the data set	303
Number of mine-year-combinations observed	4,650

Sources: Author's own depiction.

What constitutes a mine? A practical, though tautological, definition on the boundaries of a mine follows from the *Bergwerke und Salinen* directly: What is explicitly reported a as production unit in there, has to be taken as representing a self-standing mine. However, mines defined in this fashion still exhibited a lot of heterogeneity. As for technology, on the one extreme, we are dealing with really small mines that extracted coal via near-to-the-surface tunnels; and, on the other extreme, we are dealing with those really large mines that used vertically sunk shafts up to 1,000 metres depth. It is imperative to bear in mind that a mine in this sense could have extracted coal from just one shaft, but also from four or five. This may complicate the comparison of the figures we will present with any source or study that uses even

more disaggregated information on the shaft-level, which the *Bergwerke und Salinen* might not give. We will refer back to this point at times as it has a bearing on the question of what might be the correct number of closures and the correct shut-down capacity in Ruhr coal-mining.

Number of operating mines, entrants, and exits

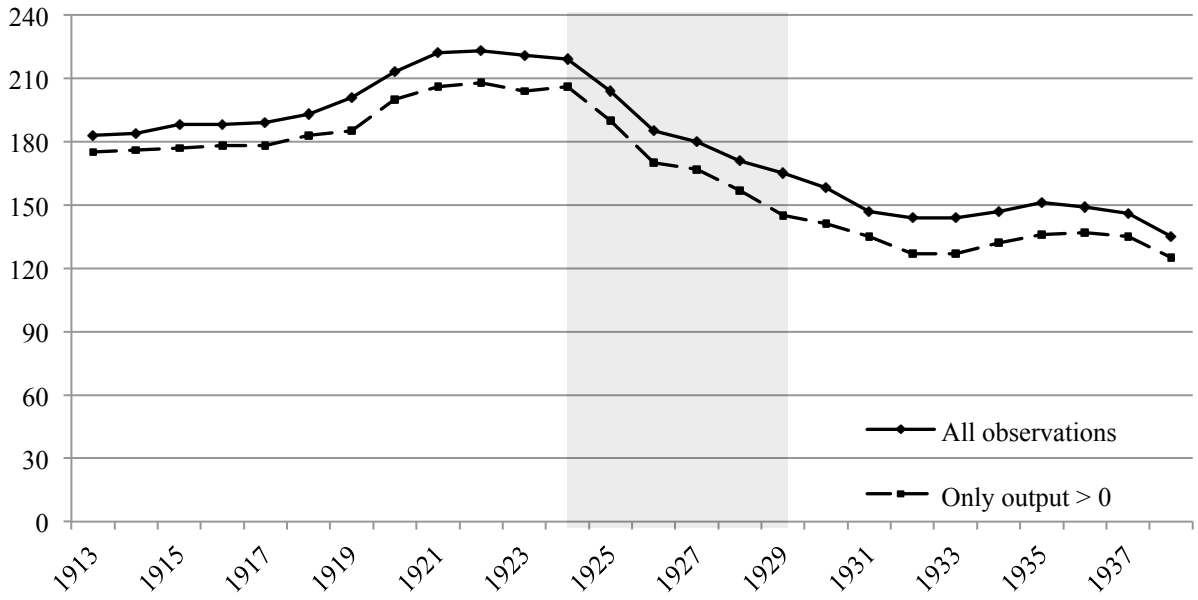
In Figure 1 two graphs of the number of mines at the Ruhr are shown as deduced from our data set. The upper graph is made of all 4,650 mine-year observations regardless of whether or not mines were reported as actually producing a certain amount of coal. The lower graph only counts mines in operation – that is, mines with a non-zero output. Three cases of reported zero output have to be acknowledged: i) following entry, it still took some time to make a mine fully operational; ii) a mine temporarily went out of production; and iii) a mine that had already been terminally closed, was reported further on because it still produced some by-product output, but no coal any more.

In fact, both graphs imply the same time pattern. As can be seen, around 180 mines were reported as operative in 1913. That number remained stable until 1919, but then rose by 30 mines, in net terms, to about 210 in 1922. On the one hand, this might be explained by inflation, which reduced the barriers for founding a business by making credit costs cheaper; on the other hand, besides mere adverse incentives due to the distorted money system, the postwar coal shortage called for additional supply and, thus, might have presented a worthwhile opportunity to start a mine.[42] However, that 'founding fever' came to an end in 1924,

[42] As suggested in the previous subsection, our series deviate from other series in the literature. Figure A.1 in the Appendix shows the series compiled by Fischer (1989, 1995) as a prominent source of aggregate statistical data on German mining. The difference to our series stems from the relatively higher number of mines between 1920 and 1932 in the first place; this is, if we focus on the upper graph in Figure 1. There is one explanation that might solve for this puzzling deviation: From 1920 on, the *Bergwerke und Salinen* among others report on the *Verband*

when the number of mines began to shrink. In 1929, not 150 mines remained in operation which corresponds to a net reduction of roughly one-third over the (grey-shaded) later 1920s, our period of primary interest. The number of mines further shrank during the Great Depression to slightly over 120 in 1931/32 where it also stood in 1938, after a temporary, modest increase over 1933-36.

Figure 1: Number of mines at the Ruhr



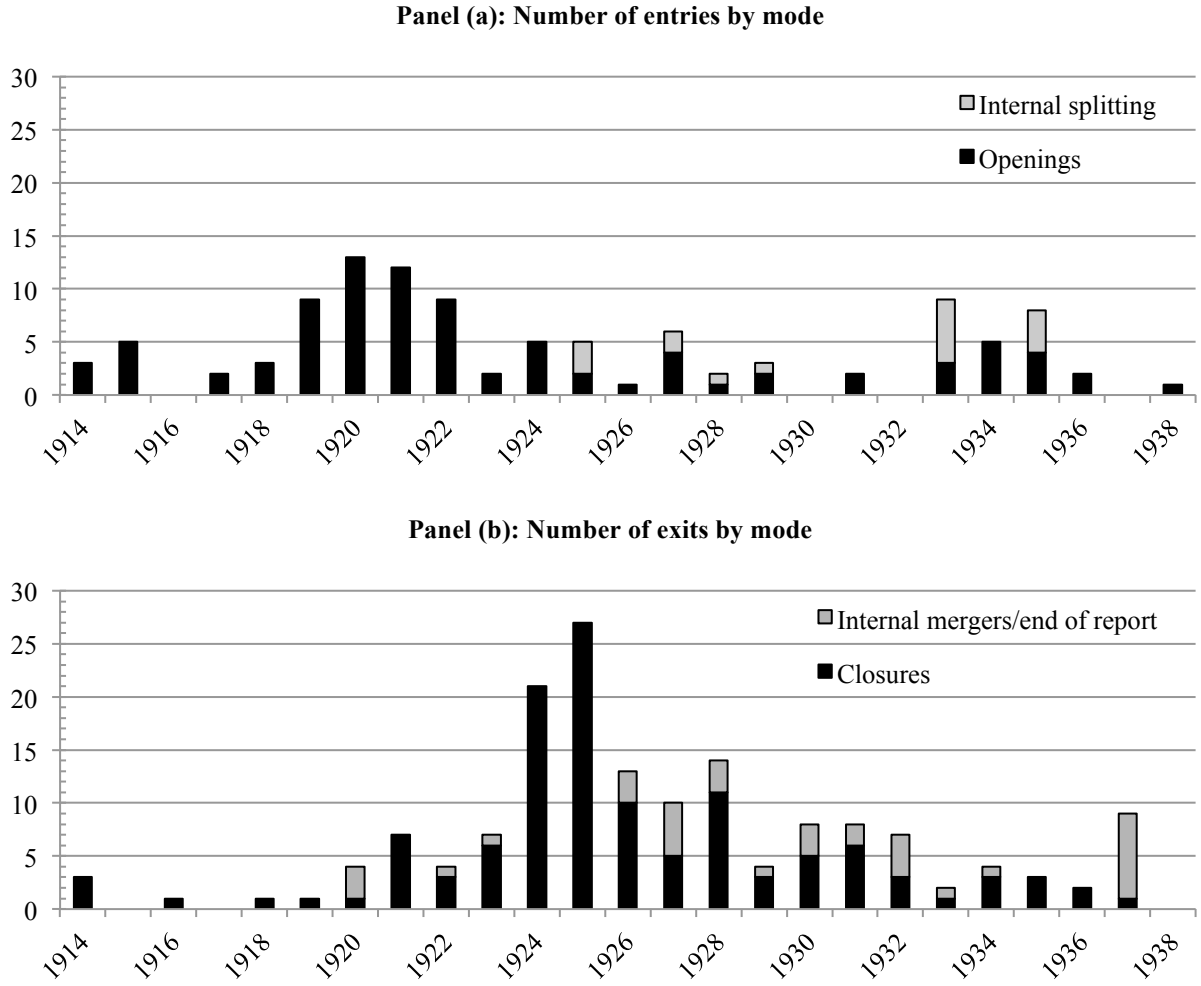
Sources: Verein für die bergbaulichen Interessen (1919-1939). Author's own depiction.

Figure 2 illustrates the survival process in more detail by showing the number of entering and exiting mines by year and mode. In fact, a mine could enter the data set in one of two ways: It was literally newly established, which we refer to as 'new opening'; or it appeared on the scene because an already existent mine had been split into two, or more, mines that would be

Ibbenbürener Bergbauunternehmer ('Union of Ibbenbüren Mining Entrepreneurs'). As the name suggests, this reflects a larger number of mines – 70, as of 1920, for example (Verband für die bergbaulichen Interessen 1921, p. 108). These were all small-scale mines operating in the Ibbenbüren mining district, and due to the fact that they were aggregated in our source, we counted them as one. Over the following years, many of these small mines were closed.

reported separately thereafter ('internal splitting'). In a substantive sense, an internal splitting is, of course, a false entry because these mines have already existed in the data beforehand, in terms of output and employment. However, we must account for this form of entry in decomposing aggregate productivity.

Figure 2: Mine entry and exit over 1913-1938



Sources: See Figure 1. Author's own depiction.

Figure 2, panel (a), shows that new openings regularly occurred over the entire observation period. But, regarding quantity, most new mines were brought into operation over only a short period of time – namely 43 over 1919-22 –, which was nearly as many as over the remaining 22 years. Table 4 provides the corresponding entry rates for new openings by sub-period. We

distinguished between the Great War, postwar inflation, the early and the late 'Golden Twenties', the Great Depression, and initial nazi dictatorship. Note that, in addition to new openings, one and a half dozen internal splittings, of which the earliest occurred in 1925, have been recorded. These are *not* included in the entry rates.

Table 4: Entry and exit rates (1913-1938)

Rate	1914-18	1919-23	1924-26	1927-29	1930-32	1933-38
Mine birth rate	1.5 %	4.6 %	1.3 %	1.4 %	0.5 %	1.9 %
Mine death rate	0.7 %	1.3 %	9.1 %	5.3 %	3.3 %	1.6 %

Notes: Mine birth rate refers to new mine openings; mine death rate to terminal closures. Birth and death rates computed according to Dunne, Roberts and Samuels (1988), p. 502.

Sources: See Figure 1. Author's own computations.

Analogous to entries, we also have to acknowledge that mines could have disappeared in more than just one way from the data set: by terminal closure; by internal merger; and by end of report. Panel (b) in Figure 2 in combination with Table 4 highlights that, indeed, the majority of terminal closures occurred over 1924-29 – 77, or about nine percent over 1924-26 and still slightly over five percent over 1927-29. Among these closures were many of the mines that had been brought into operation shortly before, during the inflated 'founding fever'. Besides, not few internal mergers occurred where, *within a particular firm*, two or more mines were operationally put together which showed up in the way they were reported in the *Bergwerke und Salinen*.[43] Here, we are dealing, of course, with false exits since the data still account for the production capacity post-merger. Entailed in the series on internal mergers are also few exits that are the result of the report on them ending abruptly;[44] among these are the

[43] In the literature this is often referred to as the tendency to form *Verbundbergwerke* ('compound mines'); see, for example, Burghardt (1990), p. 29.

[44] This is probably due to the reform of the mining administration districts' boundaries in 1933.

Verband Ibbenbürener Bergbauunternehmer and the *Ibbenbürener Steinkohlenbergwerk*, one of the state-owned mines, for which the data streams ends in 1932 without a closure being implied as the very reason.[45]

Were the closed mines the most unproductive?

Based on standard economic thinking, it seems plausible to assume that mines subject to terminal closure must have been the most inefficient and most unproductive ones. However, we may add some flesh to the bone and take a closer look at the characteristics of the closed mines. To begin with, Table 5 reports descriptive statistics on mine size in terms of tons of coal and employment by period to convey an impression of the micro-level heterogeneity in Ruhr coal-mining. As is obvious, the range in mine size was quite substantial, regardless of the period, with the largest mine producing beyond 3.5 million tons. If we took minimum mine size conditional on output being not zero, we would find that the annual minimum scores varied between a mere two (1921) and very modest 2,660 (1938) tons. What is more, the average mine in 1913-38 produced about 550,000 tons of coal utilizing a total workforce of nearly 2,100, and average mine size by period fluctuated around these values pretty closely. The ratio of average mine size to maximum mine size in terms of tons of coal ranged between 8.2 (1919-23) and 20.0 (1933-38) percent; and in terms of employment, between 10.5 (1919-

[45] Note that the number of exits we report does slightly deviate from that reported by the *Verein für die bergbaulichen Interessen* in another statistical publication (*Statistisches Heft*, May 1935); see Table A.1 in the Appendix. The difference seems to be a matter of differences in the degree of disaggregation. The list in the *Statistisches Heft* refers to 1920-34 and mentions a number of closures we cannot trace on the basis of our source. This is because these 'excess closures' refer to single shafts – shafts that our source does not separately report on. One example should suffice to make the point: Separately recorded are the closures of shaft *Uhlenberg* in 1924 and of shaft *Beust* in 1925, which together constituted the mine *Deutschland*. Our source only accounts for this mine as a whole, whose terminal closure is recorded for 1925. The same goes for exit by internal merger. The *Statistisches Heft* shows are larger number of such internal mergers than Figure 2.

23) and 18.8 (1933-38) percent. These figures already highlight that there was considerable heterogeneity among Ruhr coalmines.

Table 5: Descriptive statistics on mine size by period

Period	Measure	Mean	Stand. dev.	Minimum	Maximum	*N*
1913	Tons of coal	624,991	602,275	0	4,460,011	*183*
	Total workers	2,221	1,987	0	13,711	
1914-18	Tons of coal	504,044	456,966	0	3,897,002	*942*
	Total workers	1,972	1,734	0	12,294	
1919-23	Tons of coal	363,665	411,179	0	4,432,500	*1,080*
	Total workers	2,359	2,439	0	22,447	
1924-29	Tons of coal	592,765	597,195	0	4,764,970	*1,124*
	Total workers	2,258	2,226	0	16,434	
1930-32	Tons of coal	588,638	545,355	0	4,414,170	*449*
	Total workers	1,833	1,692,9	0	14,367	
1933-38	Tons of coal	717,563	616,014	0	3,588,000	*872*
	Total workers	1,800	1,436	0	9,565	
Overall	Tons of coal	545,854	544,208	0	4,764,970	*4,650*
	Total workers	2,095	2,013	0	22,447	

Sources: See Figure 1. Author's own computations.

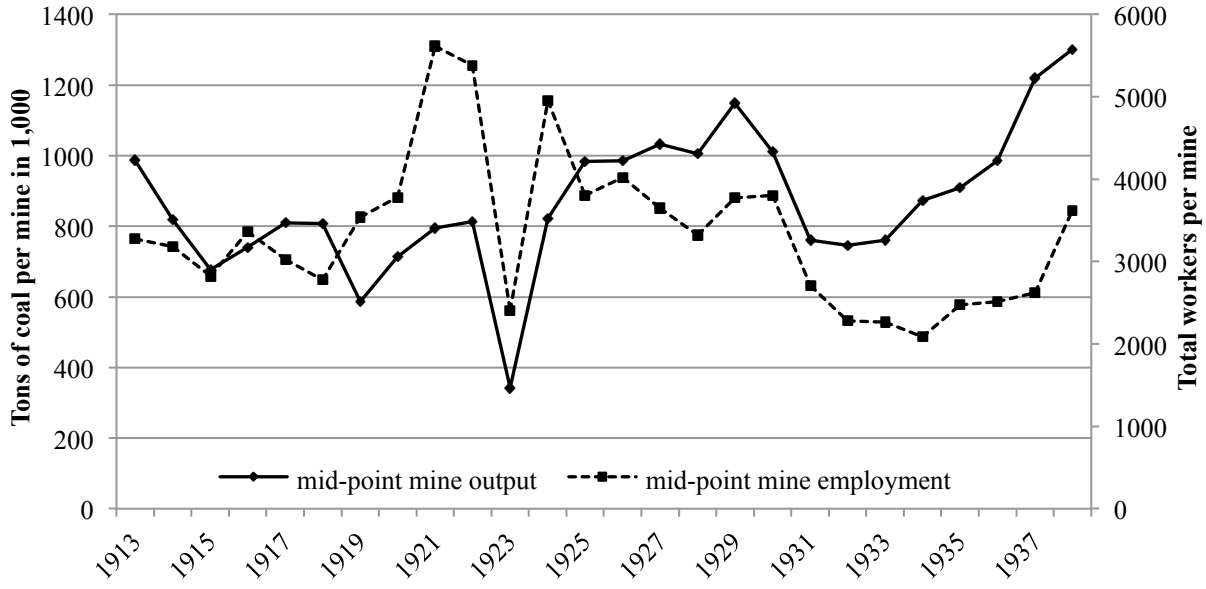
The economic literature has developed a number of ad-hoc measures of minimum efficient size in an industry based exclusively on the size distribution of establishments or firms. Average mine size as depicted in Table 5 would correspond to the approach commonly associated with Pashigian (1969).[46] However, it might be questioned that average mine size is the most appropriate ad-hoc measure in our case for the reason that the standard deviation and distance to maximum size are quite high. It seems as if a large part of output was mined in higher segments of the size distribution.[47] Therefore, Figure 3 reports two other measures corresponding to Weiss's mid-point plant size, which implies that 50 percent of overall output comes from

[46] Other popular measures include Weiss's (1963) mid-point plant size index and Comanor and Wilson's (1967) top-50-percent-index.

[47] In fact, the share in production of mines sized between 250,000 and 750,000 tons varied considerably and, at times, amounted to around 50 percent (i.e., in 1915, 1919, 1924, 1932, and 1933). In 1913 and 1938, the shares were 35 and 13 percent; and over 1925-29 it amounted to 29 percent, on average.

plants larger than mid-point plant size and 50 percent from plants smaller. We computed mid-point mine output accordingly from the size distribution of Ruhr coalmines and determined mid-point mine employment as the employment of the mid-point mine.

Figure 3: Mid-point mine size in Ruhr coal-mining (1913-1938)



Notes: For the concept of mid-point plant size, see Weiss (1963), p. 74.

Sources: See Figure 1. Author's own computations.

Both mid-point mine output and employment show substantial variation over time as, of course, they are not independent of the business-cycle. The long-term average of mid-point mine output (employment) was 871,000 tons (3,350 workers). In particular, it stands out that over 1925-28, mid-point mine output was similar to prewar conditions; only in 1929, and then again in 1937 and 1938, had it risen to a level markedly above one million tons. The picture regarding mid-point mine employment is slightly different. The years 1924-25 were used to downsize employment in mining again, after Ruhr mines had served as a 'labour sponge' over de-mobilization (1919-22).[48] However, it should strike the observer that the mid-point mine

[48] See Shearer (1989), pp. 148-149, 395, for this term.

still used more miners over the rationalization period than in 1913 – and that is, while producing a similar quantity of coal.

Now that we have some basic information on heterogeneity among Ruhr mines at hand, what were the characteristics of closed mines during the rationalization period and before and after? Again by period, Table 6 gives a first answer to this question by reporting average mine size among closures, their average cumulative percent share in total coal output, and the size of the largest mine closed in the respective periods. That information is given for two years – for the year in which the closure occurred and for the year prior to the year of closure. This is intended to allow for the possibility that mines might not have been closed all of a sudden, out of full-scale operation, but in a way that output and employment were gradually run down over maybe a couple of years ('gradual shut-down'). To look only at the closed mines' characteristics in the year of closure (t^c) might then fail to accurately describe them.

Firstly, the average mine closed during 1914-38 was quite small in both t^c and t^c-1 compared to the simple period means and mid-point mine output discussed above. Since this holds for average employment, too, the closed mines must have had, on average, below-average employment shares which will be relevant for the decomposition procedure used in the subsequent section. Secondly, notwithstanding business cycle fluctuations, the fact that average mine size was higher in t^c-1 than in t^c in all periods but one (i.e., the war period) shows that mines were gradually shut down. Thirdly, the closed mines' average cumulative share in total output, as a measure of shut down capacity, was consequently quite low, too. The largest annual shares in t^c (t^c-1) amounted to two (3.2) and 1.9 (3.2) percent in 1925 (1924) and 1928 (1927), respectively. Thus, at this stage, we may already doubt that the productivity effect of closures could have been really significant.[49]

[49] The cumulative shares we derived are notably lower than those implied by the data published elsewhere, in the *Statistisches Heft*. While we measure shut-down capacity in actual production of the year, the alternative shut-down capacity given in Table A.1 in the Appendix was computed, per year, as the sum of each mine's maximum

Table 6: Closed mines' selected characteristics

	t^c (= year of closure)			T^c-1		
	Ø size	Ø cumulative market share	Largest mine closed in t	Ø size	Ø cumulative market share	Largest mine closed in t
1914-18	19,391	0.04 %	80,206	15,515	0.02 %	77,279
1919-23	900	0.005 %	5,874	3,560	0.11 %	111,466
1924-26	47,107	0.89 %	520,950	102,034	1.61 %	514,853
1927-29	26,597	0.68 %	565,828	351,895	1.77 %	936,40
1930-32	142,991	0.81 %	525,910	218,161	1.08 %	802,400
1933-38	753	0.002 %	5,213	3,129	0.005 %	14,301

Notes: Neglected are closed mines that had zero production throughout their life cycle.

Sources: See Figure 1. Author's own computations.

Finally, we turn to the question of whether the closed mines were the worst performers in terms of labour productivity. Therefore Table 7 shows the closed mines' position in the labour productivity distribution. Given are the absolute and relative numbers per quintile and period for again the year of closure and the previous one.[50] In the year of closure itself, and except for the Great War, the majority of closed mines clustered in the bottom quintile. Adding the second quintile, at least about 80 percent of closures visibly lay in the lower half of the distribution. However, it must also be noted that a couple of closed mines lay in the upper half.[51] Regarding the performance in t^c-1, it still holds for three out of five periods (i.e., 1919-23, 1924-29, and 1933-38) that at least 50 percent of closed mines ranged in the bottom quintile and 76 in the bottom and second quintile together.

production occurring in the five years preceding the closure. So those estimates may, literally, convey an impression of the production potential.

[50] In selecting quintiles, we follow Baily, Hulten and Campbell (1992), p. 1992. In their study of the closure wave in postwar UK coal-mining, Glyn and Machin (1997), pp. 204-205, for example, depict percentile ranks.

[51] Glyn and Machin (1997), for example, could show that the same held true the closure wave in the UK in the 1970s and 1980s.

Table 7: The closed mines in the labour productivity distribution

	Number per quintile per period (each exit counted exactly one time)									
	Bottom quintile		Second quintile		Third quintile		Fourth quintile		Top quintile	
	No.	%	No.	%	No.	%	No.	%	No.	%
	A. Labour productivity in t^c (year of closure)									
1914-18: t^c	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0
1919-23: t^c	13	72.2	4	22.2	0	-	1	5.6	0	-
1924-29: t^c	43	55.8	18	23.4	7	9.1	4	5.2	5	6.5
1930-32: t^c	9	64.3	2	14.3	0	-	2	14.3	1	7.1
1933-38: t^c	10	100.0	0	-	0	-	0	-	0	-
	B. Labour productivity in t^c-1									
1914-18: t^c-1	1	20.0	1	20.0	0	-	0	-	3	60.0
1919-23: t^c-1	8	61.5	4	30.8	1	7.7	0	-	0	-
1924-29: t^c-1	35	50.0	18	25.7	8	11.4	5	7.1	4	5.8
1930-32: t^c-1	1	7.7	4	30.8	3	23.0	4	30.8	1	7.7
1933-38: t^c-1	7	77.7	2	22.2	0	-	0	-	0	-

Sources: See Figure 1. Author's own computations.

In all, it seems to be appropriate to think of the majority of closed as mines as having belonged to the group of worse performers; this does not necessarily mean that they were the worst performers being, literally, at the very end of the distribution (some certainly were). These results should, however, be taken with some caution since labour productivity alone does not reflect all variables on the basis of which mining entrepreneurs may have decided to shut down a mine. This especially goes for the closed mines ranging in the upper part of the distribution. Even if they operated with relatively high productivity in their last year, this does not mean they could have maintained that productivity levels in the future.

IV. The productivity implications of closures

Methodology

According to equation (1), our empirical setting is based on the notion that industry-level labour productivity is a weighted average of mine-specific productivity scores where y_i, l_i, Y

and L denote output and employment of mine i and, respectively, of the industry aggregate at time t. Here, a mine's productivity is weighted with its share in total employment:[52]

$$(1) \qquad \frac{Y_t}{L_t} = \frac{\sum_i y_{it}}{\sum_i l_{it}} = \sum_i \frac{l_{it}}{\sum_i l_{it}} \frac{y_{it}}{y_{it}}.$$

In order to examine the sources of industry-level productivity bottom-up, we apply the modified decomposition method of Baily, Hulten and Campbell (1992) as described in Foster, Haltiwanger and Krizan (2001) and applied, for example, in Okazaki's (2014) study on Japanese coal-mining during WWII.[53] This approach is built around the basic distinction of production units into survivors (subset S), entrants (subset E), and exits (subset X). From the perspective of year t, classified as survivors are those units that were in operation in t-τ and t; classified as entrants in year t are those units that did not operate in t-τ, but began producing in t; and classified as exits in t are those units that did not make it from period t-τ into t. Hence, entrants and exits are classified as such only in the period of the closure or opening event, but not in the periods preceding closure or following entry; otherwise they are survivors, too.

Based on these subsets, productivity change may be decomposed into five effects:

[52] See Ellerman, Stoker and Berndt (2001), p. 382, and Aydin and Tilton (2000), p. 289, for this formulation. In their analysis of establishment-level data, Foster et al. (2001) have argued that weighting with employment instead of output shares leads to roughly equal productivity patterns. This holds true in our case, too. So, we decided to concentrate on employment shares.

[53] See Baily, Hulten and Campbell (1992); Foster, Haltiwanger and Krizan (2001), p. 315; Okazaki (2014), p. 44.

$$(2)\quad \Delta\left(\frac{Y_t}{L_t}\right) = \underbrace{\sum_{i\in S}\frac{l_{it-\tau}}{L_{t-\tau}}\Delta\left(\frac{y_{it}}{l_{it}}\right)}_{\text{“within-effect“}} + \underbrace{\sum_{i\in S}\left(\frac{y_{it-\tau}}{l_{it-\tau}}-\frac{Y_{t-\tau}}{L_{t-\tau}}\right)\Delta\left(\frac{l_{it}}{L_t}\right)}_{\text{“between-effect“}} + \underbrace{\sum_{i\in S}\Delta\left(\frac{y_{it}}{l_{it}}\right)\Delta\left(\frac{l_{it}}{L_t}\right)}_{\text{“cross-effect“}}$$

$$+ \underbrace{\sum_{i\in N}\left(\frac{l_{it}}{L_t}\right)\left(\frac{y_{it}}{l_{it}}-\frac{Y_{t-\tau}}{L_{t-\tau}}\right)}_{\text{“entry-effect“}} - \underbrace{\sum_{i\in X}\left(\frac{l_{it-\tau}}{L_{t-\tau}}\right)\left(\frac{y_{it-\tau}}{l_{it-\tau}}-\frac{Y_{t-\tau}}{L_{t-\tau}}\right)}_{\text{“exit-effect“}}.$$

The within-effect measures the contribution of establishment-level changes in productivity to aggregate productivity by holding weights – i.e., employment shares – constant. The between-effect captures contributions resulting from shifting employment shares weighted with the deviation of establishment-level productivity from the industry-average in the previous period. In addition, the cross-, or covariance-, effect combines the two effects which are confined to the subset of survivors. Finally, the entry- and exit-effects, too, are based on deviations of establishment-level productivity from the industry-average.[54]

Due to the data structure outlined in the previous section, some adjustments to this decomposition method seem to be in order. As we are dealing, at least in an accounting sense, with several modes of entry and exit, we intend to split the baseline subsets further. So, regarding the subset of survivors, we will distinguish into i) surviving mines that survived over the entire observation period 1913-1938 (subset S_1), ii) mines newly opened in t from t+τ on until 1938 (subset S_2), iii) mines having entered another way in t from t+τ on until 1938 (subset S_3), iv) mines having survived until t-τ before they were closed in t (subset S_4); and v) mines having survived until t-τ before they exited another way in t (subset S_5). Note that those mines that both entered *and* exited sometime in the observation period are part of subsets S_4 or S_5. Further decomposing the within-, between-, and cross-effects this way enables us to

[54] A related decomposition procedure is that of Griliches and Regev (1995) who, however, do not incorporate the cross-term and specify the weights differently.

check whether the productivity effect of closures might have come into play time before the closure actually occurred, due then to gradual shut-down. In the same manner, we will further decompose the entry- and exit-effects into the entry-by-new-opening-effect (subset E_1), the entry-by-internal-splitting-effect (subset E_2), the exit-by-closure-effect (subset X_1), and the exit-by-internal-merger-effect ,which includes the exits due to end of report (subset X_2).

Regarding our research question, the exit-by-closure-effect is the one of primary interest. It forms part of what a shift in the location of mining contributes to productivity change – that is, a reallocation of resources from low- to high-productivity mines (or vice versa). Hence, in order to link up our results with the approach taken in the resource economics literature (e.g., Aydin and Tilton 2000; Ellerman, Stoker and Berndt 2001; Garcia, Knights and Tilton 2001), the 19 single sources we identify (within-, between- and cross-effects for five subsets of survivors plus two entry- and two exit-effects) may be re-arranged to the 'shift-in-location-effect' and the 'development-at-individual-mines-effect'. To get the former, the between-, entry-, and exit-effects are put together; and to get the latter, we re-aggregate the within-effects over the subsets of survivors; due to its nature, we will report the cross-effect separately. To draw a bow back to the historical case under study, it should be highlighted that what contemporaries called 'positive rationalization' in the context of Ruhr coal-mining is fully contained in the 'development-at-individual-mines-effect', as is the part of 'negative rationalization' that was also confined to individual mines (i.e., the concentration of operating points underground).

Empirical evidence

In the following, we go through the decomposition procedure in several steps. All results are based on the aforementioned 19 single effects, which are reported year-by-year in Table A.2 in the Appendix.

To begin with, Table 8 presents a summary of the source decomposition, which already yields a couple of basic insights into the mine dynamics during the later 1920s and the

comparative periods. In the upper part of the table it is shown the cumulative absolute change in labour productivity and the five main effects as aggregates over the relevant single effects; the corresponding explanatory percentage shares of each sub-aggregate in total productivity change are reported in the lower part.[55]

Table 8: Summary of source decomposition by period

	Overall	Within	Between	Cross	Entry	Exit
A. Absolute change in tons of coal per worker						
1914-18	–19.6	–18.81	–0.73	–0.58	–0.05	+0.58
1919-23	–159.9	–157.24	+1.92	–3.66	–0.64	–0.29
1924-26	+203.2	+193.78	+3.56	+2.49	+1.67	+1.69
1927-29	+38.2	+35.77	+2.24	–1.81	+0.05	+1.97
1930-32	+23.2	+18.9	+2.21	+0.98	–0.10	+1.21
1933-38	+57.5	+54.05	+2.01	–5.20	+4.28	+2.39
B. Relative contribution to overall change						
1914-18		90.6 %	3.5 %	2.8 %	0.2 %	2.8 %
1919-23		96.0 %	1.2 %	2.2 %	0.4 %	0.2 %
1924-26		95.4 %	1.7 %	1.2 %	0.8 %	0.8 %
1927-29		84.5 %	5.3 %	4.3 %	1.3 %	4.6 %
1930-32		79.3 %	9.3 %	4.1 %	0.4 %	6.8 %
1933-38		79.2 %	2.9 %	7.6 %	6.7 %	3.5 %

Notes: Figures may not exactly sum to overall change or 100 percent, respectively, due to rounding. Exit effect as depicted in equation (2) multiplied with (-1.0).

Sources: Author's own computations based on Table A.2 in the Appendix.

Corresponding to Table 1, aggregate labour productivity declined towards 1924, but then climbed up again towards 1938. Arithmetically, the increase in productivity over early rationalization not only compensated, but over-compensated the previous decline. It is apparent from the percentages that productivity dynamics, generally, were by far dominated by within-mine performance. However, it is also apparent that the relative weight of productivity in-

[55] The percentage shares were derived by dividing an effect's absolute value by the sum over all effects' absolute values.

creases within surviving mines declined (from 96 to 79 percent) and, thus, the compositional effects, reflecting between-mine flows of output and inputs, gained importance over time, such that they finally accounted for about one-fifth of aggregate productivity change.[56] Among the compositional effects, the between- and also the cross-effect appear to have been slightly more important than the entry- and exit-effects. Apart from the Great War, the between-effect was straight positive implying that, on average (based on the within-effect), mines with above industry-average productivity increased their employment shares. The cross-effect, however, was negative in four out of six periods which indicates that, to use the terminology of Baily, Bartelsman and Haltiwanger (1996), resource re-allocations among survivors were predominantly triggered by successful downsizing (i.e., $\Delta(l/L) < 0$ and $\Delta(y/l) > 0$) or, respectively, by unsuccessful upsizing (i.e., $\Delta(l/L) > 0$ and $\Delta(y/l) < 0$).[57] In contrast resource flows among continuing mines in the early rationalization period, as well as in the depression years, were dominated by a combination of successful upsizing (i.e., $\Delta(l/L) > 0$ and $\Delta(y/l) > 0$) and unsuccessful downsizing (i.e., $\Delta(l/L) < 0$ and $\Delta(y/l) < 0$).

Furthermore, the exit effect on which our primary focus rests is positive for all periods but the inflationary period implying that mine exits, overall, positively contributed to labour productivity change over those periods; that is, labour productivity change would have been somewhat lower, maybe even negative, ceteris paribus, had exits not occurred. Obvious-

[56] Here, a comparison with Okazaki's (2014), p. 44, figures on Japanese mining is interesting. He found that over 1930-35 the compositional effects accounted for slightly more than the average 20 percent we found for the Ruhr, namely about 26 percent (computed according to Footnote 54). But, regarding the period 1935-39, he established that compositional effects were responsible for even about 60 percent of aggregate productivity change. This is a striking difference to what we find on the Ruhr, even though we do not have the year 1939 in our data set, which may account for part of that difference.

[57] Baily, Bartelsman and Haltiwanger (1996), p. 263. Whether there was large number of successful downsizers and unsuccessful upsizers with each small effects or only few of them with large effects over-compensating successful upsizers and unsuccessful downsizers, is a matter that would have to be explored.

ly, apart from 1919-23, the mines selected for exit were among the prime candidates to select from, in terms of productivity performance. Note that, due to how the exit effect is defined in the decomposition formula, we have to shift the whole series depicted in Table 9, panel (b), by one year forward; that means the exit effect for 1924, for example, refers to closures of 1923. So to be precise, the exit effect based on the closures of the last year of the rationalization period, 1929, is that for 1930, and thus it is entailed in the figures for 1930-32.

It also strikes that the exit-effect is quite modest overall. The combined effect over the 'rationalization boom' is +3.66 tons per worker, and thus the period 1924-29 certainly stands out as the period with the relatively largest positive exit-effect. Although, as Figure 2 has shown, the majority of exits – 55 (i.e., due to how exit is defined in our decomposition, the years 1923-25), in fact – occurred over 1924-26, these exits do not explain one percent of aggregate productivity change over that period. In turn, 37 exits over 1927-29 (i.e., the years 1926-28 in Figure 2) at least explain 4.6 percent. Thus, we can already conclude that, in terms of improving aggregate productivity, the exit wave over 1924-26 really is negligible, and this view is reinforced by the comparison with the other periods.

Table 8 also shows that entering mines had positively contributed to aggregate productivity during rationalization and the early nazi period meaning they had above-average productivity. To be more specific on whether new openings and terminal closures or rather internal splittings and mergers had driven the turnover effects, Table 9 presents the separate effects year-by-year. We confine the discussion here to the period 1924-32 as most exits occurred then. So when internal splittings occurred, they had the larger weight in the total entry-effect, except for 1927. This is not a surprise as the necessary surface and underground structures including machinery had already existed and thus enabled the internally split mine to be fully operational from its start (a 'false' start, actually). To be more precise, in 1928 and 1929, the internal splitting effect even compensated for negative effects from new openings.

Table 9: Decomposition of entry- and exit-effects over 1924-1933

	New opening	Splitting	Closure	Internal merger	Net survivor
A. Absolute change in tons of coal per worker					
1924	–0.001	0.000	+0.026	+0.097	+117.774
1925	+0.225	+1.450	+0.175	0.000	+34.223
1926	+0.000	0.000	+1.400	0.000	+47.833
1927	–0.134	–0.013	+1.444	–0.226	–1.091
1928	–0.105	+0.122	+0.082	+0.226	+9.474
1929	–0.001	+0.186	–0.182	+0.623	+27.812
1930	0.000	0.000	+0.064	–0.019	–11.230
1931	–0.103	0.000	+0.611	–0.217	+16.460
1932	0.000	0.000	+0.744	+0.022	+16.884
1933	–0.018	+4.516	+0.748	+1.162	+12.072
B. Relative contribution to overall change					
1924	0.00 %	-	0.02 %	0.08 %	99.90 %
1925	0.60 %	3.88 %	0.47 %	-	95.05 %
1926	0.00 %	-	2.74 %	-	97.26 %
1927	2.10 %	0.21 %	22.65 %	3.55 %	71.49 %
1928	0.79 %	0.92 %	0.61 %	1.70 %	95.97 %
1929	0.00 %	0.63 %	0.62 %	2.12 %	96.63 %
1930	-	-	0.51 %	0.15 %	99.34 %
1931	0.47 %	-	2.79 %	0.99 %	95.74 %
1932	-	-	3.45 %	0.10 %	96.45 %
1933	0.07 %	18.04 %	2.99 %	4.64 %	74.16 %

Notes: The ‘net survivor’ effect sums over the within-, between- and cross-effects.

Sources: Author’s own computations based on Table A.2 in the Appendix.

Turning to exits, internal mergers – false exits in fact – were relatively more important than closures in 1928 and 1929, thus two out of six years making up the rationalization period in terms of exits (i.e. for technical matters, 1925-30; see above). But, regarding closures, there actually is one year that clearly stands out – namely 1927 (exit-by-closure-effect of mines closed in 1926). That year’s closures – as to our counting, ten – explain almost 23 percent of aggregate productivity change which is, by far, the largest explanatory share that one year’s cumulative exit-effect had in the whole observation period. So this renders the year 1927 truly special, not the least because that year was a saddle point in aggregate labour productivity development. More specifically, that year’s closures had not pushed productivity to a new, higher level, but offset especially temporary stagnation of productivity among continuing

mines. Had closures not occurred, productivity would have fallen in that year below the previous year's score.[58]

If the effect of the closures themselves were rather modest overall, maybe it was the re-allocation of resources over the years preceding the closures that affected aggregate productivity more profoundly? Table 10 provides information that may help to assess the closed mines' pre-closure contributions when they still were classified as survivors. In the upper part of the table, under 'A.', the cumulated employment shares for the closure-cohorts 1923-32 (corresponding to the exit-effects depicted in Table 9) are shown for the year of closure and the previous five years. As can be seen, the closure-cohorts 1926, 1929, and 1932 had the largest aggregate employment shares. If the supposition was right that mines were usually not closed all of a sudden, out of full operation, but gradually, we should find that the closure- cohorts' aggregate employment shares fell towards t^c. Except for the closure-cohort 1923, this is indeed what we can observe. At the earliest, employment shares began to be lowered four years before closure (1928); at the latest, they were visibly lower in the year of closure itself (1925, 1931). According to our decomposition procedure, this reduction in employment shares substantiates the resource re-allocation from the closed mines to the continuing high(er) productivity mines, when they were still operative.[59]

However, falling employment shares are a *necessary* condition for this resource flow. As *sufficient* condition, compositional effects should be positive and preferably big. Part 'C.' in combination with 'D.' yields insights on that. The aggregate within-effects by closure-cohort are added for illustrative purposes. The closure-cohorts 1923, 1928, and 1930-32 show declining labour productivity over gradual shut-down. The cumulative effect of the other co-

[58] For illustrative purposes, Table A.2 in the Appendix lists the fifteen largest exit-by-closure effects.

[59] Aggregate output shares likewise fell; and as discussed in relation to Table 7, the mines that were subject to closures mostly were below-average-productivity mines.

horts is positive, though this does not necessarily mean that the effect in the year of closure itself was positive.

Table 10: The closed mines' pre-closure employment shares

A.	Cumulative employment shares (in percent) for closure-cohorts t^c									
	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932
t^c-5	0.01	0.50	4.26	1.94	0.44	2.92	0.44	1.65	2.46	0.92
t^c-4	0.02	0.44	4.35	1.98	0.47	2.84	0.45	1.65	2.27	0.92
t^c-3	0.02	0.57	4.30	2.05	0.38	2.76	0.62	1.75	2.46	0.96
t^c-2	0.03	0.64	4.52	2.05	0.25	3.02	0.64	1.68	2.56	0.88
t^c-1	0.04	0.66	3.93	1.90	0.10	2.99	0.59	1.69	2.53	0.68
t^c	0.04	0.38	2.61	1.03	0.04	1.87	0.17	1.27	1.54	0.30
B.	Re-allocation of labour due to gradual shut-down begins ... years before closure									
	0	1	2	2	4	2	2	1	2	3
C.	Cumulative within- and compositional effect over B.									
Within-effect	–0.015	+0.471	+3.637	+0.265	+0.127	–0.519	+0.141	–0.664	–1.864	–1.722
Between- + cross-effect	–0.011	–0.128	+0.019	+0.437	+0.414	–0.026	–0.007	+0.235	+0.602	+0.907
D.	Average share of C. in total productivity change (in percent)									
Within-effect	0.02	0.39	1.61	1.37	0.57	2.77	0.82	5.26	5.37	3.70
Between- + cross-effect	0.01	0.22	0.71	0.59	0.59	1.61	0.16	1.87	1.39	1.93

Notes: t^c is the year of closure. Change in aggregate productivity under C. in tons per worker. For 1924, the within- and compositional effects in 1923 are given.

Sources: See Figure 1. Author's own computations.

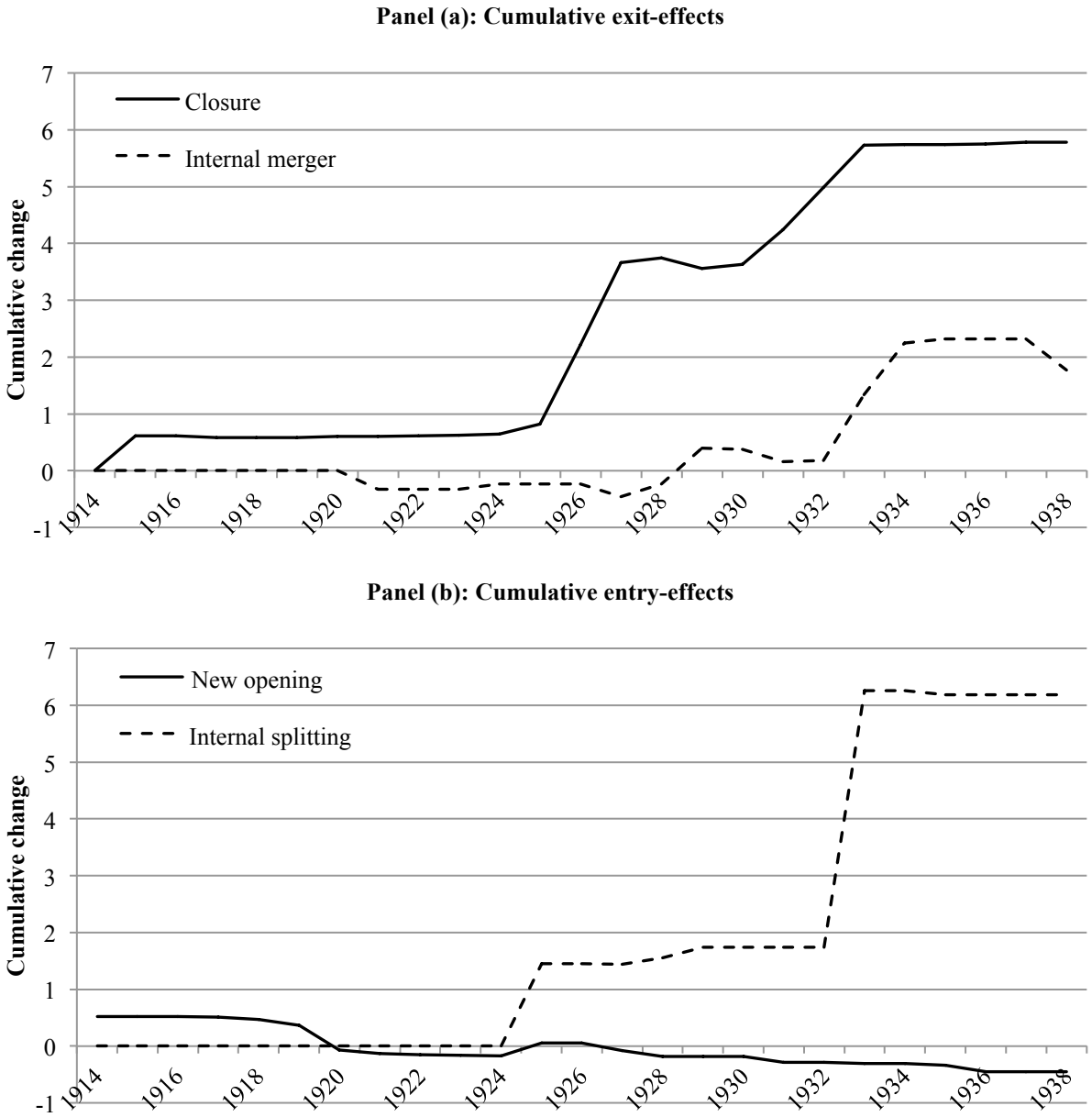
Much more instructive is the evidence on the cumulated compositional effects. Six closure-cohorts, of which three actually fall into the 'rationalization boom' and three into the Great Depression, show a positive cumulated compositional effect over gradual shut-down. For these cohorts it holds that resources were set free to be used more efficiently in continuing mines with high(er)-productivity. In fact, in an accounting sense, mines belonging to the remaining closure-cohorts stripped the remaining mines from resources, which were not brought in effi-

cient use thereafter. In order to get a sense of the magnitude of the compositional effects over the shut-down period, we may compare them with the exit-by-closure-effects in Table 9. Note once again that the appropriate exit-effect of, for example, closure-cohort $t^c = 1923$ is the one of 1924 in that table.

There are only two closure-cohorts for which it holds that the gradual-shut-down effect exceeded the exit-by-closure-effect – namely 1927 (+0.414 vs. +0.082) and 1932 (+0.907 vs. +0.748), or 1928 and 1933 if we stick to the notation used in Table 9. This holds if we focus on the change in tons per worker as reported under 'C.'. Turning to the effects' explanatory share reported under 'D.', we find that the closure-cohort 1928 (1929's exit-by-closure-effect in Table 9) has to be associated with a gradual-shut-down-effect that was larger than its exit-by-closure-effect. But, whatever the angle, evidence generally indicates that the effect of closures on aggregate productivity practically operated, however modest it were, through the closure itself, and only occasionally through resource allocation shortly before closure, over the shut-down period.

Finally, Figure 4 summarizes the evidence by plotting the cumulative turnover-effects over the full observation period. Note once again that these effects confine to the year of the event itself and not to the performance of entrants and exits when they (still) belonged to the subset of survivors. So, according to Panel (a), all closures at the Ruhr together raised aggregate productivity over 1914-38 by not quite six tons per worker; and more than one-half of this net surge certainly is explained by the closures of 1925 and 1926 alone, which had their effect, concretely, in 1926 and 1927. Besides, the closures of the depression years 1930 and 1931 explain the remaining net surge. In comparison, internal mergers somewhat pushed productivity only over 1933-4.

Figure 4: Summary on cumulative turnover-effects (in tons per worker)



Sources: See Figure 1. Author's own computations.

As Panel (b) shows, the cumulative effect of internal splittings was marginally higher than that of closures and due, chiefly, to splittings in 1933. A final striking feature certainly is that entrants' performance, as far as their first year of operation is concerned, depressed aggregate productivity. On the whole, as has been argued above, the turnover-effects still were modest compared to the within- and compositional effects among survivors.

V. Conclusion

Over the later 1920s and up to the mid-1930s, Ruhr coalmines saw an exceptional surge in labour productivity, paralleled only by the 1960s and early 1970s.[60] Owing to the Ruhr coal district's weight in the industry this surge dictated the pattern on the national level. This study set out to examine the micro-level sources of that exceptional growth by analyzing a newly-constructed dataset on the population of Ruhr coalmines over a period spanning the Great War, the Weimar Republic, and the first six years of nazi dictatorship. Based on the commonly accepted view that the later 1920s stand out as reflecting a 'rationalization boom' and a technological catching-up with the latest prewar developments, we tested the hypothesis that mine closures as a measure of 'negative rationalization' played a significant role in pushing aggregate productivity up to new levels. As a somewhat necessary condition in this respect, the frequency with which closures were conducted was definitely much higher over 1924-29 than over the surrounding periods, including the depression years.

So, did closures actually do any good to aggregate labour productivity? Based on the results from the decomposition of productivity change, we can safely say that closures regularly raised aggregate productivity in the year after the closure had been conducted; and we can also say that over half the 'rationalization boom' (1925-27), closures likewise pushed productivity by way of ceding resources to high(er) productivity mines that would, in most cases, continue operation for more than just a few years. However, evidence has been provided that all forms of turnover-effects including exit-by-closure were marginal compared to the effects stemming from the producer dynamics among surviving mines. Thus, we feel confident to conclude that the practical productivity implications of mine closures over the rationalization boom are negligible and still overrated in the relevant literature. These findings call

[60] This follows from Fischer's data; see Fischer (1995), p. 35.

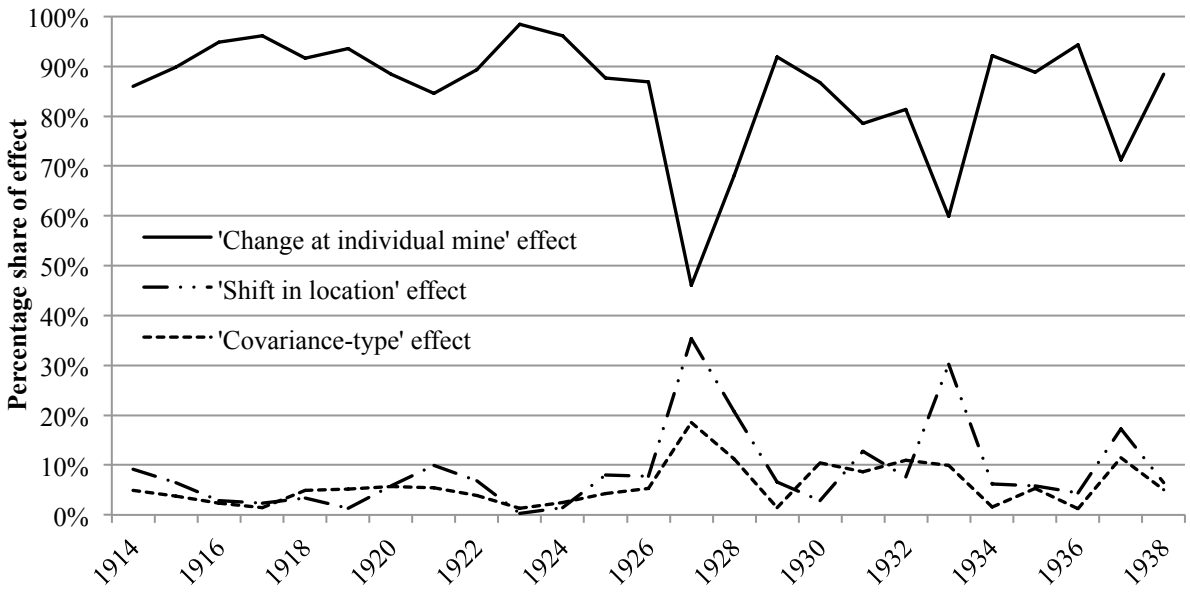
for testing more rigorously the relative importance of 'negative rationalization' in the form of plant closures in other branches of the Weimar economy.

There are two caveats to this interpretation that should be mentioned. Firstly, although low productivity may usually go hand in hand with more unfavourable cost-structures, it has to be borne in mind that this study did not analyze costs explicitly. In the longer-term, the mine closures may well have taken considerable cost pressure off mining firms. Secondly, as Harvie (1996) has us consider, labour productivity of surviving mines might not be independent of closed mines' performance as, possibly, "[...] a high rate of [mine] closures resulted in productivity improvements partly through its likely effect of increasing pressure on mineworkers to accept changes in work practices."[61] Even if closures did not have direct significant productivity effects at the time of closure, they might have had indirect effects of the sort in the future.

Finally, by answering the question of how significant mine turnover-effects practically were for aggregate labour productivity change, we at the same answered the question of how significant technological improvements at individual mines were that continued operation. In line with the resource economics literature, the combination of turnover- and compositional-effects is indicative of how a shift in the location of mining affected industry performance. Figure 5 presents our conclusive argument in this respect. Generally, changes at individual mines played the dominant role in determining productivity, which supports the view in the recent resource economics literature mentioned above. However, it has to be noted that 1927, 1933, and also 1937 stand out as years in which the shift-in-location-effect was relatively more important than usual.

Figure 5: Shifts in the location of mining vs. changes at individual mines

[61] Harvie (1996), p. 422.



Notes: The 'change at individual mine' effect equals the within-effect. The 'shift in location' effect is the sum of the between-, entry-, and exit-effects. The 'covariance-type' effect corresponds to the cross-effect.

Sources: Author's own computations based on Table A.2 in the Appendix.

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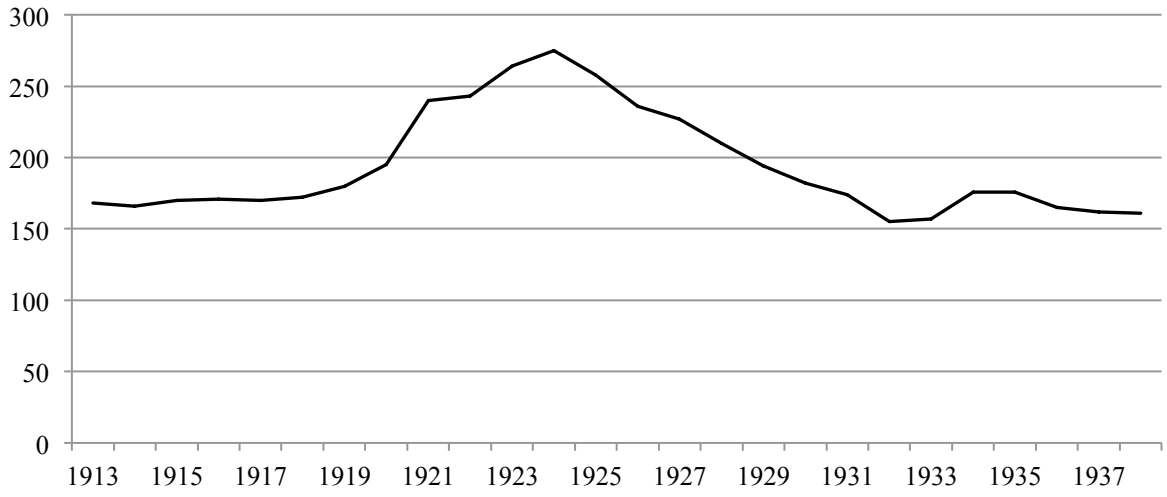
Appendix

Figure A.1: Number of mines at the Ruhr according to Fischer



Sources: Fischer (1989), p. 33; Fischer (1995), p. 35.

Table A.1: Alternative figures on the number of mine closures and on shut-down capacity

Year	Number of closures	Shut-down capacity
1920	1	3,885
1921	3	1,607
1922	2	5,660
1923	16	276,795
1924	16	707,093
1925	32	6,359,723
1926	5	1,343,737
1927	6	107,427
1928	12	3,761,112
1929	2	523,758
1930	5	2,091,719
1931	13	7,479,265
1932	3	1,196,931
1933	1	578
1934	5	6,577

Notes: Shut-down capacity is in tons and is measured per mine as the highest production of coal occurring over the last five years prior to closure.

Sources: Verein für die bergbaulichen Interessen (1935), p. 18.

Table A.2: The fifteen largest exit-by-closure-effects

Mine	Firm affiliation	Closure (t^c)	Closure effect in t^c+1
Massener Tiefbau	Harpener Bergbau	1926	+0.698
Vondern I/II	Gutehoffnungshütte	1933	+0.681
Maximilian	Eisenwerk-Gesellschaft Maximilian-hütte	1915	+0.608
Vereinigte Rheinelbe & Alma	Vereinigte Stahlwerke	1932	+0.588
Borth I/II	Deutsche Solvery-Werke	1927	+0.424
Blankenburg	Gewerkschaft Blankenburg	1927	+0.379
Hermann	Bergwerksgesellschaft Hermann	1927	+0.360
Vereinigte Germania	Vereinigte Stahlwerke	1931	+0.312
Tremonia	Vereinigte Stahlwerke	1932	+0.250
Admiral	Westfälische Bergbau- und Kohlen-verwertungs-AG	1926	+0.177
Glückauf Tiefbau	Deutsch-Luxemburgische Berg-werks- und Hütten-AG	1926	+0.158
Kaiser Friedrich	Vereinigte Stahlwerke	1926	+0.129
Arenberg Fortsetzung	Rheinische Stahlwerke	1931	+0.126
Rhein 1	Vereinigte Stahlwerke	1929	–0.116
Margarethe	Aplerbecker Actien-Verein	1927	+0.114

Notes: Closure effect in tons per worker.

Sources: See Figure 1.

Table A.2: Source decomposition of labour productivity change over 1913-1938 year-by-year

Year	Total	Within_S1	Within_S2	Within_S3	Within_S4	Within_S5	Between_S1	Between_S2	Between_S3	Between_S4
1914	–23.580	–16.464	–3.696	–3.313	0	0	–1.260	–0.566	–0.140	0
1915	+21.248	+13.091	+5.147	+2.778	+0.070	0	–0.271	–0.615	+0.007	–0.019
1916	–16.479	–9.944	–3.990	–2.073	–0.009	0	–0.271	+0.107	+0.098	+0.002
1917	–15.337	–10.691	–1.710	–2.733	–0.020	0	–0.154	+0.094	+0.089	–0.001
1918	–9.031	–7.032	–1.150	–0.481	–0.061	0	+0.232	–0.041	+0.004	+0.005
1919	–56.907	–39.176	–7.396	–7.407	–0.110	0	+0.354	–0.179	+0.103	–0.021
1920	+8.770	+7.633	+0.243	+1.688	+0.044	0	–0.017	+0.129	+0.032	–0.012
1921	–20.829	–13.589	–5.174	–2.488	–0.004	0	+1.268	+0.700	–0.057	–0.074
1922	+3.041	+2.755	+0.393	–0.071	+0.025	0	–0.007	–0.122	+0.074	+0.008
1923	–93.991	–66.135	–15.093	–12.914	–0.463	0	–0.056	–0.139	–0.073	+0.008
1924	+117.895	+83.571	+18.173	+14.402	+0.510	0	+1.114	+0.485	+0.027	–0.010
1925	+36.074	+22.599	+4.545	+5.312	+0.349	0	+0.891	–0.046	+0.196	+0.015
1926	+49.231	+33.858	+4.313	+5.905	+0.238	0	+1.554	–0.812	+0.092	+0.068
1927	–0.020	–1.179	+1.275	–0.370	+0.033	–0.081	+0.261	+0.125	+0.020	–0.015
1928	+9.799	+7.455	+0.011	+0.953	+0.217	+0.413	+0.721	+1.080	–0.036	–0.366
1929	+28.439	+22.143	+0.693	+2.905	+0.282	+1.018	+0.666	+0.038	–0.156	–0.095
1930	–11.185	–6.699	–1.486	–1.831	+0.327	–0.590	–0.091	+0.071	+0.010	–0.069
1931	+16.751	+14.235	–1.060	+1.227	+0.145	+0.524	+1.560	+0.005	+0.171	+0.006
1932	+17.650	+15.296	–1.710	+0.043	+0.024	+0.480	+0.573	+0.045	–0.123	+0.129
1933	+18.482	+13.236	–0.006	+1.471	–0.194	+0.088	–0.579	+0.065	0.157	–0.150
1934	+28.170	+20.364	+0.011	+2.126	+1.038	+3.432	+0.542	–0.028	+0.197	–0.085
1935	+13.801	+13.634	–0.008	–0.736	+0.811	+0.611	+0.311	+0.012	–0.396	–0.056
1936	+25.098	+20.699	–0.010	+0.741	+0.722	+2.367	+0.528	–0.007	+0.028	–0.090
1937	+0.740	–1.170	+0.001	+1.191	+0.529	+1.069	–0.370	+0.006	–0.041	–0.264
1938	–28.753	–24.852	0	–0.228	+0.056	–2.938	+1.405	0	–0.002	–0.007

Table A.2 continued

Year	Between_S5	Cross_S1	Cross_S2	Cross_S3	Cross_S4	Cross_S5	Entry_E1	Entry_E2	Exit_X1	Exit_X2
1914	0	+0.852	+0.396	+0.084	0	0	+0.512	0	–0.007	0
1915	0	–0.212	+0.405	+0.195	+0.065	0	–0.001	0	–0.609	0
1916	0	–0.128	–0.137	–0.132	–0.000	0	0	0	0	0
1917	0	–0.172	+0.030	–0.029	+0.000	0	–0.009	0	+0.031	0
1918	0	–0.350	–0.059	–0.055	–0.004	0	–0.038	0	0	0
1919	0	–1.099	–1.525	–0.332	–0.011	0	–0.105	0	+0.001	0
1920	0	–0.456	–0.129	+0.019	+0.013	0	–0.433	0	–0.016	0
1921	0	–1.198	+0.077	+0.045	+0.058	0	–0.064	0	–0.004	+0.327
1922	0	–0.054	+0.050	–0.019	+0.018	0	–0.024	0	–0.014	0
1923	0	+0.953	–0.104	+0.107	–0.075	0	–0.011	0	–0.003	+0.000
1924	0	+1.205	–1.317	–0.405	+0.016	0	–0.001	0	–0.026	–0.097
1925	0	+0.919	–0.487	–0.139	+0.070	0	+0.225	+1.450	–0.175	0
1926	0	+0.756	+1.844	–0.045	+0.070	0	+0.000	0	–1.398	0
1927	+0.020	–0.054	–1.108	–0.012	–0.000	–0.005	–0.134	–0.013	–1.444	+0.226
1928	–0.012	–0.093	–1.074	–0.052	+0.263	–0.005	–0.105	+0.122	–0.082	–0.226
1929	–0.008	+0.114	+0.052	+0.050	+0.163	–0.054	–0.001	+0.186	+0.182	–0.623
1930	–0.039	–1.041	+0.202	–0.029	+0.021	+0.020	0	0	–0.064	+0.019
1931	–0.084	–1.102	+0.573	+0.083	+0.055	+0.082	–0.103	0	–0.611	+0.217
1932	+0.010	+1.029	+0.948	–0.007	–0.122	+0.267	0	0	–0.744	–0.022
1933	+0.165	–2.327	+0.002	+0.090	+0.034	+0.022	–0.018	+4.516	–0.748	–1.162
1934	+0.043	–0.367	+0.013	–0.036	+0.034	–0.015	–0.006	0	–0.004	–0.902
1935	+0.088	–0.652	+0.012	+0.235	–0.037	–0.013	–0.026	–0.072	–0.006	–0.076
1936	+0.375	–0.223	+0.008	+0.057	–0.014	+0.021	–0.114	0	–0.009	0
1937	+0.247	–0.378	–0.001	–0.065	+0.077	–0.120	0	0	–0.028	0
1938	–0.085	–1.583	0	+0.001	+0.018	+0.011	–0.001	0	–0.002	+0.550

Notes: For the definitions of the subsets, see Section IV. All effects in tons of coal per worker.

Sources: See Figure 1. Author's own computations.

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