The wartime origins of the *Wirtschaftswunder*: The growth of West German industry, 1938-55

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The paper offers a detailed quantitative account of industrial development in West Germany between 1938 and 1955. Our disaggregated analysis focusses on the growth of value added, labour productivity, and TFP. Even though productivity growth was rapid by historical standards in the reconstruction phase following the economic reforms of 1948, the expansion of industrial production between 1938 and 1955 was entirely input-driven. The resulting backlog in productivity growth allowed manufacturing in West Germany to retain remarkably high growth rates until the end of the Golden Age. The post-war productivity gap took a decade to close after 1945 because the West German economy remained dislocated for much longer than previously thought. The main dislocating factors besides labour misallocation resulting from the war-induced urban housing shortage were structural disproportions in industrial production caused by the division of Germany. During the Wirtschaftswunder, industrial recovery could tap into surplus capacity and increased market potential.

I. Introduction

World War II represents a watershed in the history of Germany and has long been considered a momentous episode by economic historians. There is a vast literature on the Nazi war economy: on the growth of armaments production, on the exploitation of occupied lands, and on the financing of Hitler's preposterous quest for world domination (Milward 1965; Zilbert 1981; Tooze 2006).[1] Recent investigations offered novel insight and demonstrated that earlier accounts grossly overestimated output expansion and productivity improvements achieved in the phase of total war (Scherner and Streb 2006).

A consensus of moderation also emerged over the extent of material damage inflicted upon industrial plant and machinery. Contemporary accounts which claimed that almost one half of pre-war capacity had been destroyed and which, on this basis, accentuated fears of 'deindustrialisation' in post-war Germany (Niederschlag 1947; Seume 1947; Eisendraht 1950) proved to be erroneous. Estimates by the German Institute of Economic Research (DIW) showed that West German industry was not only well-endowed with physical capital on the eve of its post-war growth miracle; it was much better endowed than it had been until 1939 (Wagenführ 1954, Krengel 1958). Wartime expansion had substantially outweighed the impact of wartime destruction and post-war dismantling under the Allied reparations regime (Baumgart and Krengel 1970; Scherner 2010). This finding is in sharp contrast to the popular hypothesis of Roskamp (1965), also shared by Hoffmann (1965), that the revival of the German economy was fuelled by investment in modern equipment required to replace the technologically outdated machinery that had been destroyed during the war.

[1] For an extensive bibliography of the earlier German literature, see Volkmann 1984.

Recent historiography has instead argued that economic recovery was hindered by a combination of factors that disrupted the chains of production (Manz 1968; Abelshauser 1975 and 1983; Karlsch and Matschke 1993). Vonyó (2010) expanded on this point by showing that the economy remained dislocated after 1950 due to labour misallocation that resulted from the wartime destruction of urban housing. This revisionist view on Germany's post-war revival has been inspired by the reconstruction thesis of Hungarian economist Ferenc Jánossy (1969). In a nutshell, his theory claims that war-shattered economies automatically recover to their long-run productive potential. War-induced distortions to factor allocation secure high returns on future investment, which leads to accelerated accumulation in the reconstruction phase. Long-run growth potential depends solely upon improvements in labour quality.

The presence of a reconstruction dynamic in post-war growth is an old notion. John Stuart Mill had already talked about a *vix mediatrix naturae* that lifts nations out of their devastation and restores them into their normal conditions (cited in Abelshauser 2004, 282). Jánossy formalised this concept and applied it specifically to explain the growth miracles of post-war Europe. His work was introduced into German historiography by Manz (1968), Abelshauser (1975, 1983) and Borchardt (1991), among others. Eichengreen and Ritschl (2009) put substance behind this revisionist literature by showing that the *Wirtschaftswunder* was primarily a productivity miracle that reversed a sharp war-induced decline in TFP.

International scholarship has also recognised the relevance of the Jánossy model for post-war growth (Carlin 1996; Crafts and Toniolo 1996). Cliometric studies confirmed the presence of a strong reconstruction dynamic in western industrialised nations during the 1950s (Dumke 1990; Wolf 1995; Vonyó 2008). Vonyó has shown that relative growth performance was largely a reflection of the scale of wartime dislocation until the late 1960s. My fixed-effects model produced a particularly close fit for West Germany. This finding reveals a paradox: the German economy retained its war-induced potential for rapid productivity growth even after post-war reconstruction had been completed and bottlenecks to efficient factor allocation resulting from wartime destruction had been eliminated. As shown in Table 1, industrial expansion slowed down considerably after 1955, but productivity within industry continued to grow at an accelerating rate.

Table 1 about here

This paper offers an explanation for this paradox. The war-induced dislocation of the German economy had persisted for much longer than previously thought, and thus pre-war levels of industrial efficiency could not be surpassed until the mid 1950s. Reconstruction growth was largely input-driven; productivity was enhanced only by the improved allocation of existing factors endowments. Industrial output had expanded by more than 60% between 1938 and 1955, but industrial TFP was scarcely above its corresponding pre-war level. To make matters worse, industrial efficiency had already stagnated in the period 1929-38. In turn, this quarter-century backlog in TFP growth embodied the potential for a productivity miracle in West German industry that lasted until the end of the post-war Golden Age, well beyond the actual reconstruction years.

The paper is structured as follows. Section II presents territorially consistent data at the industry level in mining and manufacturing on output and factor inputs for 1938, 1948, 1950 and 1955, including new capital-stock estimates for each year between 1938 and 1949. In Section III, I compute labour-productivity levels and apply decomposition techniques to illustrate the industry origins of aggregate productivity growth. Section IV reports growth accounts for industry as a whole. Section V seeks to explain the paradox of high output and low productivity by pre-war standards during the reconstruction phase. Section VI concludes.

The paper is not only relevant for the debate over Germany's post-war revival. By constructing industry-level growth accounts, it contributes to a broader literature on the structural analysis of economic growth that reaches back to the seminal work of Kuznets (1966). The disaggregated approach has recently been adopted by leading development economists (Lin 2011; McMillan and Rodrik 2011), who argue that aggregate indicators are not sufficient to reveal the dynamics of technological progress and productivity growth, or to design successful development policies. As a result, the economics profession has also been witnessing a renaissance in empirical studies of structural change (Timmer et al. 2010; Jorgenson and Timmer 2011).

II. Output and factor inputs

My investigation opens with a detailed quantitative account of industrial development between 1938 and 1955. I use official data to determine levels of industrial value-added and labour input expressed in actual hours worked in 5 major sectors and 32 branches of mining and manufacturing for the years 1938, 1948, 1950, and 1955. Expanding on previous work on the post-1950 period, I report new estimates for capital stock at the industry level between 1938 and 1950. All figures refer to post-war West German territory excluding the Saar area and West Berlin. German industry statistics exclude construction and the public utilities, which are thus not discussed in this paper.

Table 2 reports index numbers for net industrial production. The most prominent feature of the late 1940s was a historical nadir in output levels unseen since the late 19th century. Between 1938 and 1948, industrial value added in constant prices declined by more than a half. The metallurgical and metal processing industries suffered the sharpest contraction. At the branch level, output also plummeted in the fuel industry, china and earthenware, entertainment instruments, paper products, leather and footwear, and tobacco manufactures. The extraction of crude oil and natural gas, still in its infancy in the 1930s, was the sole industry that increased production. By contrast, the reconstruction period after 1948 saw the fastest growth ever recorded in German history. By 1950, industrial value-added was already close to its pre-war peak, and by 1955 it was more than 60% larger than what it had been in 1938. Early on, the consumer goods industries were leading the race, but further expansion after 1950 was driven by production and investment goods. Between 1938 and 1955, the fastest growing industries were crude oil and natural gas, fuels, transport vehicles, electrical engineering, and plastic products. They were all closely connected to Germany's belated motorization, which was a dominant force of technological progress and productivity growth in the post-war era.

Table 2 about here

To construct a dataset on factor inputs with levels territorially and methodologically consistent over time was a complicated task. Appendix 2 and 3 present a detailed exposition. For the first time, this paper reports capital-stock estimates at the industry level for the pre-1950 period, fully consistent with the existing time-series evidence for the post-war era (see Tables A.1 and A.2). I also present comparable levels of employment drawn from various sources (see Table A.3).

Table 3 reports index numbers for gross capital stock, calculated from the estimates shown in Appendix 2. The data sources do not allow us to separate tobacco manufactures from food and beverages, as we do for industrial production and labour input. Over the period as a whole, the rate of capital accumulation was comparable to that of output growth, but there was marked deviation within sub-periods. As shown in previous research, the industrial capital stock increased across the war and continued to expand rapidly during the reconstruction period. In the 1940s, accumulation was the fastest in mining and production goods. After 1948, the engineering sector and consumer goods were leading the pack. At the branch level, the biggest increases occurred in timber and woodworking, the paper industry, china and earthenware, and the clothing industry. The index numbers reported for value added and for gross capital stock suggest huge fluctuations in the efficiency with which capital was employed. This was a central feature of war-induced dislocation and post-war reconstruction which we shall return to in Section IV.

Table 3 about here

Table 4 reports index numbers for annual labour hours. Adjusting labour input for changes in average working hours was especially important for 1948, when actual hours worked per week in fell about 20% short of the corresponding figures for both 1938 and 1950. Employment data alone would have suggested stagnation between 1938 and 1948, and only a minimal increase in the late 1940s. After the appropriate adjustments, labour expansion moves in line with output growth, although both the contraction until and the recovery after 1948 appear much more modest in working hours than in value added. Since employment was maintained at a higher level than production in the late 1940s, it also recovered more quickly to the pre-war level. Employment in mining increased substantially between 1938 and 1948, but thereafter labour expansion was most robust in engineering and a few consumer industries. Over the whole period, most industries increased their labour input significantly, except for the extraction of metallic ores, the fuel industry, iron and steel, and, most notably, the tobacco industry, which lost a third of its workforce between 1938 and 1955.

Table 4 about here

III. Labour productivity

The figures reported in Tables 2 and 4 in the previous section allow us to compute labour productivity at the industry level. As shown in Table 5, industrial value adder per worker hour fell sharply between 1938 and 1948, but increased rapidly thereafter. This pattern seems to follow the development of industrial production, but there is a major difference. Whereas value-added grew by more than 60% over the period as a whole, labour productivity was scarcely 10% above its pre-war peak in 1955. Considering the factors that constrained industrial efficiency in the Nazi era and both the improvement of domestic market institutions and international trade liberalization in the 1950s, this is an astonishingly poor result.

In mining, rubber and asbestos, the paper industry, steel constructions, machine tools, and several consumer industries, labour productivity had not recovered to the pre-war level even by the end of the reconstruction period, despite massive output growth. The sharp deterioration in steel constructions and entertainment products was partially due to shifts in the product mix after 1945, due to the shutdown of armaments production – which was highly mechanized and adopted mass production methods to meet the demands of military procurement.[2] However, in coal and salt mining, or in the leather and footwear industries, it would be difficult to attribute worsening productivity to changing product composition over time. By contrast, value added per worker hour grew astronomically fast between 1938 and 1955 in crude oil and natural gas, the fuel industry, transport vehicles, the clothing industry, and tobacco manufactures – primarily due to increased mechanization.

Table 5 about here

Such marked differences across industries in productivity performance begs the question to what extent structural shifts over time can explain aggregate labour-productivity growth. Decomposition techniques are frequently used in disaggregated growth accounts to exploit the richness of data in order to gain better understanding of the aggregate growth processes. The exact specification used here is derived from the work of Timmer and associates.[3] In the model, aggregate nominal value added (Y) in any given time (t) is defined as the sum of nominal value added (Z) in all industries *j*.

$$P_t^Y Y_t = \sum_j P_{jt}^Z Z_{jt} \tag{1}$$

The volume growth of output is defined as a Törnqvist weighted industry value-added growth, where weights represent the period-average shares of industry *j* in aggregate value-added.

[2] Before 1945, the production of cannons was reported under steel constructions, the manufacturing of small firearms under entertainment products that included sport and hunting weapons in German industry statistics.
[3] Timmer et al. (2010), pp. 153-154. The authors applied the above model to decompose GDP growth.

$$\Delta \ln Y_t = \sum_j \bar{\upsilon}^Y_{Z,jt} \Delta \ln Z_{jt} \tag{2}$$

Labour-productivity growth in a given industry is computed as the growth of value-added divided by the growth of labour hours (L) in industry *j* over a certain period of time (t).

$$\Delta \ln z_{jt} = \Delta \ln Z_{jt} - \Delta \ln L_{jt} \tag{3}$$

Using this formula, aggregate labour-productivity growth can be decomposed into industry contributions and a residual that measures the effect of labour reallocation across industries.

$$\Delta \ln Y_t / L_t = \sum_j \Delta \ln z_{jt} \bar{\upsilon}^Y_{Z,j} + \left(\sum_j \Delta \ln L_{jt} \bar{\upsilon}^Y_{Z,jt} - \Delta \ln L \right) = \sum_j \Delta \ln z_{jt} \bar{\upsilon}^Y_{Z,j} + R_t \tag{4}$$

The term R_t is positive whenever industries with above-average levels of labour productivity increase their weight in total labour input, or when industries with modest productivity levels show declining employment shares.

The decomposition results are reported in Table 6. Both in the years of contraction and reconstruction, aggregate labour-productivity growth reflected industry contributions. Structural shifts were insignificant and, if anything, moderated the rate of decline in industrial valued added per worker hour until 1948 and the rate of growth thereafter.

Table 6 about here

To demonstrate which industries specifically were driving aggregate labour- productivity growth in the 1940s and the early 1950s, I represent industry-weighted contributions on a horizontal bar chart. Figure 1 demonstrates clearly that the sharp fall in aggregate labour productivity between 1938 and 1948 came primarily from the most important war industries: coal mining, iron and steel, chemicals (explosives), steel constructions (artillery), machine tools (tanks), and transport vehicles. Productivity in coal mining deteriorated both during and immediately after the war because production was maintained through the increased application of unskilled, often forced, and often poorly integrated foreign labour. The metal making and metal processing industries suffered disproportionately after the war from the dismantling of machinery, de-Nazification in management boards, and output ceilings imposed by the occupation authorities. Productivity growth after 1948 was more spread out, but again, metallurgy, chemicals, and the engineering industries made very substantial contributions. The other drivers were textiles, food and beverages, and tobacco manufactures, which all carved out large shares from industrial production in post-war West Germany.

Figure 1 about here

IV. Total Factor Productivity

In this section, we compute growth rates of industrial Total Factor Productivity (TFP), applying the standard growth-accounting framework that models the economy by a Cobb-Douglas production function.

$$Y_t = A_t(K_t)^{\alpha}(L_t)^{1-\alpha} \tag{5}$$

Output (Y) at a given time (t) is the function of the available stock (K_t), the size of the labour input (L_t) and TFP (A_t). The coefficients α and $1-\alpha$ represent the elasticities of output with respect to capital and labour. In a dynamic framework, output growth can arise either from the expansion of factor inputs or from TFP growth.

$$\Delta \ln Y = \alpha \Delta \ln K + (1-\alpha)\Delta \ln L + \Delta \ln A \tag{6}$$

The terms α and $1-\alpha$ stand for the respective shares of capital and labour in gross value-added, while TFP growth represents the growth-accounting residual. Equation (6) can be rewritten to express this residual as the proportion of labour-productivity growth that is unexplained by capital deepening, i.e. the increase of the capital-labour ratio.

$$\Delta \ln A = \Delta \ln(Y/L) - \alpha[\Delta \ln(K/L)] \tag{7}$$

The standard growth-accounting framework most commonly assumes the value of 1/3 for α, which is a reasonable approximation of the share of capital in national income. Constant returns to scale constitute another important feature of the model. These assumptions do not hold for industries that are highly capital intensive and cluster in order to increase productive efficiency. Since we lack reliable data required to determine factor shares and returns to scale at the industry level, I only compute rates of TFP growth for industry as a whole.

As noted in the previous section, the period under investigation saw large swings in the rate of capital utilization. In the presence of large spare capacities, capital-stock levels do not accurately measure capital input. Using DIW estimates for the rate of utilization, Table 7 reports index numbers for nominal and effective capital intensity, measured as gross capital stock per worker hour. The adjusted figures show that the growth of labour productivity after 1948, and particularly in the early 1950s, was fuelled by capital deepening. Unfortunately, we have no reliable data on capacity utilization for the period prior to 1948. Assuming identical rates for 1938 and 1955 would imply that the effective capital-labour ratio in West German industry declined by about 20% between 1938 and 1948, which would explain a nontrivial part of the productivity meltdown documented above.

Table 7 about here

The growth accounts are summarized in Table 8, reporting logarithmic growth rates. As explained in the previous section, industrial value added grew between 1938 and 1955 largely because of labour expansion. Since capital intensity had increased over time, TFP grew even less than labour productivity. Within each of the two sub-periods, TFP played a more prominent role. Even after adjusting for capacity utilization, neither the sharp decline of labour productivity before 1948 nor the rapid recovery thereafter can be explained mainly by capital deepening. This finding confirms the results of Eichengreen and Ritschl (2009) for the total economy. However, it must be emphasized that reconstruction growth in West German industry was primarily not a productivity miracle. More than half of the output expansion between 1948 and 1955 came from increased labour input, and close to one-third of labour-productivity growth was due to higher capital intensity. In other words, factor accumulation explained two-thirds of output growth.

Table 8 about here

The level of industrial TFP increased hardly at all between 1938 and 1955, with an average annual rate of 0.34%. If we extend the growth accounts back to 1929, the last year before the Great Depression, the annual rate of TFP growth appears even more modest: 0.28%. However, even these rates are too high as the model assumptions yield lower-bound estimates for factor accumulation and, therefore, overstate TFP growth. First, it is unlikely that capacity utilization in 1929 and 1938 was as high as during the 1955 export boom. This means that effective capital intensity must have increased at a higher rate than reported in Table 8. Second, there is ample evidence to suggest that industrial production exhibits increasing returns to scale (Krugman 1991; Basu and Fernald 1997; Fingleton and McCombie 1998). Inklaar et al. (2011) used panel regressions to estimate approximately 20% returns to scale for US manufacturing during the interwar period. If the sum of factor shares in equation (6) are greater than one, factor accumulation explains a larger proportion of value-added growth and thus reduces the residual (TFP). Third, the elasticity of output with respect to capital may be higher in industry than in the whole economy. A higher capital share, in turn, implies larger contribution from increased capital intensity to labour-productivity growth.

Appendix 4 reports sensitivity tests against these assumptions. As shown in Table A.4, relaxing each of them substantially reduces the rate of TFP growth for both 1938-55 and 1929-55. The results are especially sensitive to the scale factor, much more than to the utilization rate or to factor-share specifications. If German industry exhibited significant increasing returns to scale, or some increasing returns in combination with slightly lower utilization rates for 1929 and 1938 compared to 1955, then we would obtain close to zero TFP growth for both periods. This demonstrates that West Germany achieved no improvement in industrial efficiency over a quarter century between the start of the Great Depression and the end of post-war reconstruction. Reconstruction growth merely restored levels of industrial TFP that had already been achieved in the interwar period.

V. The limits of post-war growth

This revelation raises the fundamental question why industrial productivity performed so poorly, despite a remarkable growth spurt between 1948 and 1955, which was supported by ambitious institutional reforms and the liberalisation of international trade (Eichengreen 2007). This would seem paradoxical in light of previous accounts, which argued that the most critical war-induced impediments to recovery were eliminated in the late 1940s. The restoration of the railway network brought coal shortages to an end by the summer of 1947 (Abelshauser 1983). Food scarcity, equally severe early on, was gradually eased by rising imports and Allied aid (Carlin 1989). Marshall Aid alleviated raw-material shortages in bottleneck industries (Borchardt and Buchheim 1987). Finally, the currency reform and market liberalisation in June 1948 together with the lifting of import restrictions in 1949 restored business confidence and rationalised inventories. By eliminating supply-side bottlenecks and market restrictions, the West Germany was propelled back onto a path of sustained growth (Ritschl 1985; Klemm and Trimmel 1987; Carlin 1989; Buchheim 1990).

I challenged this view by showing that the German economy remained dislocated after 1950 due to labour misallocation that resulted from the wartime destruction of residential housing (Vonyó 2012). Until the urban housing stock had not been rebuilt, the rural unemployed could not resettle into the industrial heartlands of the country. This was critical as the West German population, and thus the labour force, increased substantially between 1939 and 1950, mostly due to the influx of minority Germans expelled from East and Central Europe after the war. Hence, urban labour scarcity coexisted with rural capital shortage, and a significant share of industrial capacities remained idle: the overall utilisation rate averaged 55.6% in the second half of 1948, 66.8% in 1949, and 79% in 1950 (Krengel 1960, p. 81). While the recovery of urban industry was sluggish, rural industry and handcrafts substituted labour for capital to meet the demand for manufactures in the face of insufficient urban production. Thus, the war-induced redistribution of industrial employment made a devastating impact on labour productivity in the West German economy (Vonyó 2012, 111).

Factor markets could not clear automatically as the housing deficit was far too great to surmount without extensive state intervention, which only materialised after the creation of the sovereign West German state. The *Wirtschaftswunder* was driven primarily by factor accumulation, rather than productivity growth, as shown in Table 8. To the extent that growth occurred within the limits of existing capacities it could rely on labour expansion and did not require productivity-boosting technical advances. Improvements in productivity could be achieved simply by a better allocation of existing factor endowments. The rural unemployed were gradually absorbed by the urban economy with the help of a gigantic national housing program, under which half a million dwellings were restored or newly built annually until 1957 (Statistisches Bundesamt 2000, 49) and over half of all building activity in the country was in residential construction (Sachverständigenrat 1965, 200). In parallel, rural industry, endowed with surplus labour, built up capital rapidly in an era characterised by high investment and moderate wages. Rural investment was not crowded out by the requirements of the urban economy, which was able to recover, to a large extent, by utilising initially idle capacities.

Table 9 about here

That the growth of industrial output throughout the period 1938-55 was driven by labour expansion is confirmed by the disaggregated data presented in the previous sections. The coefficients reported in Table 9 indicate strongly positive correlations between the growth of industrial value-added and worker hours on the one-hand, but no statistically significant relationship between the former and capital accumulation on the other, where the coefficients even pick up the wrong sign. However, once we adjust the rate of growth in gross fixed capital between 1948 and 1955 for capacity utilisation, the correlation between the growth of output and capital input becomes positive and highly significant. This result confirms that German industry derived a large part of its growth potential during the *Wirtschaftswunder* from spare capacities, as demonstrated in Figure 2.

Figure 2 about here

German historiography provides ample material to explain the paradox between high growth rates and sluggish technological progress during the early 1950s. First, as long as efficiency gains could be achieved by factor reallocation, the abolition of market restrictions and the state-sponsored monopolies of the Nazi era, industrial firms had no incentive to increase their production costs by boosting R&D expenditure. Second, the war-torn society had an insatiable thirst for traditional manufacturing goods, especially consumer durables (Wildt 1993). In 1950, three out of four households had coal heating and only 7% of them were equipped with an electrical stove. Even by 1958, only every fifth family owned a refrigerator, and there was substantial pent-up demand for simple household appliances as well as furniture and textiles (Weimer 1998, 116).

Urban reconstruction at home and the restocking of industrial plants in countries plundered under German occupation meant that the capital goods industries could thrive in both domestic and foreign markets by effectively producing with the technologies of the 1930s. In steel constructions, firms were still selling old coal furnaces and steam-powered locomotives, while the darling of the automobile industry remained the Volkswagen 'Beetle'. In some key industries, plant size was also insufficient for standardised mass production (Radkau, 1993). Particularly in engineering, Germany had long specialised in skilled-labour intensive, high value-added differentiated quality products, and thus firms continued to focus on product rather than process innovation. Since quality engineering goods with the lucrative 'Made in Germany' label faced highly income elastic demand, their producers could maintain high profits without making significant real efficiency gains (Ambrosius, 1993).

Finally, restoring pre-existing levels of industrial productivity in the early post-war period was made difficult by the deterioration of labour qualifications. Tremendous wartime casualties depressed the share of men aged between 20 and 35 in the total population from 12.1% to 7.4% between 1939 and 1946 (Kramer 1991, 11). Increased female participation in subsequent years could not sufficiently substitute for male employment, as manual work in industry was physically demanding and female employees had significantly lower levels of qualification than their male colleagues. In September 1950, the skilled-labour ratio in the manual workforce was 50% for men but only 16.2% for women.[4]

Abelshauser (1999) suggested that the introduction of compulsory apprenticeships in 1938 for male school leavers induced considerable improvements in industrial working skills, potentially acting to increase productivity in later years. As compelling as this proposition may seem, it does not find support in the historical evidence. World War II administered a massive blow to human-capital accumulation in German industry. Vocational school teachers were conscripted into the armed forces, except in the most directly war-related occupations. The government preferred on-the-job training to formal apprenticeships given the urgency of war production, and shut down most of the training workshops established shortly before the war (Pätzold 1989). Enrolment in polytechnics diminished rapidly after most students were either called into military service, or were forced to graduate prior to completing the standard training period, if they had specialised in fields critical for armaments production. Towards the end of the war, several polytechnics were completely closed down (Grüner 1989). Finally, the most direct impact of wartime destruction was the demolition of schools and training facilities, as the overwhelming majority of these establishments were located in industrial cities, which were the prime targets of aerial bombardment.

One additional factor behind the persistence of war-induced dislocation, namely the division of Germany, has been largely overlooked in the literature. Scholars have recognised its crippling impact on the East German economy, which was greatly dependent on imported raw materials and intermediate inputs from the West, particularly coal and primary metals (Zank 1987; Maatschke 1988; Sleifer 2006). However, due to a high degree of regional concentration, structural disproportions were also substantial in West German industry. Surplus capacity in coal mining, iron and steel and heavy equipment stood in contrast with excess demand for engineering and consumer products. To the extent that inter-zone trade in post-war Germany fell short of East-West transactions within the former Reich before 1945 and as long as external trade had not made up for this deficiency, post-war growth reflected the need to eliminate these structural disproportions.

In a comparative study on industrial TFP in East and West Germany, Ritschl and Vonyó (2013) test this hypothesis econometrically for the late 1940s. We investigate to what extent industrial recovery after 1948 depended upon inherited structural disproportions, once we control for the reconstruction effect, i.e. the rebounding from the war-induced contraction of output. The logarithmic growth rate of net industrial production between 1948 and 1950 is regressed on output growth between 1938 and 1948 and on the West German share in the value-added of the respective industry within the former Reich in 1936. These shares were calculated using data from Sleifer (2006), who studied the rich archival records of the 1936 German industry census to determine levels of output, intermediate inputs and employment at a highly disaggregated level in East and West Germany, as well as the eastern provinces

[4] *StBRD*, vol. 45.2 (1952), p. 81.

ceded to Poland and the USSR after 1945.[5] Our model is effectively an extension of the Jánossy thesis of post-war reconstruction. It implies that the potential for reconstruction growth in the German economy was complemented, or conditioned, by the impact of structural disproportions.

I replicate the above regression on the dataset reported in the present paper. The model is estimated with robust standard errors to account for heteroskedasticity. The coefficients reported in Table 10 show that structural disproportions had, indeed, a highly significant impact on output growth after 1948, even after we control for the strong reconstruction effect. On average, an industry with a one percentage point smaller western share in German value-added in 1936 achieved 0.6% higher growth in output between 1948 and 1950.

Table 10 about here

The explanatory power of the model is confirmed in Figure 3. The scatter plot demonstrates a very strong negative relationship between the growth rates of output in the periods prior to and after 1948 for all but a few industries. Most outlying observations exhibit a growth dynamic different from what the reconstruction thesis would predict precisely because of the other explanatory variable in the model. Steel constructions and entertainment instruments suffered a large output shock between 1938 and 1948, but their growth potential thereafter was limited by their high level of concentration in West Germany. In the case of shipbuilding this was complemented by output restrictions that remained in place until 1951. By contrast, electrical engineering, plastic products, the clothing and the glass industries all achieved strong growth after 1948 despite a relatively modest decline of output during the 1940s. The western share in German industrial output in 1936 was the smallest in clothing, glass and plastic products, which thus enjoyed extended market potential after the division of Germany. The expansion of electrical engineering reflected the mass relocation of firms in the late 1940s from the Soviet occupation zone and West Berlin – prompted both by fear of expropriation and severe shortages of intermediate inputs (see Hefele 1988).

Figure 3 about here

The only odd outlier is the extraction of crude oil and natural gas, which recorded fast growth throughout the entire period, even though it was concentrated exclusively in the western part of Germany in 1936. As noted earlier, this industry was still in its infancy before the war, and in a country almost completely reliant on fuel imports, its expansion in the post-war era was a strategic necessity. Regression diagnostics are commonly used in cross-sectional analysis to determine the impact of outliers. Perhaps the most eye-catching approach

[5] The author has kindly granted us access to his complete electronic database which has not fully appeared in published work. Sleifer computed industrial value-added based on data on sales revenue from BArch R 3102/3309 and data on the use of raw materials, fuels and intermediary products from BArch R 3102/5922. These archival records constitute a much more detailed source than previous work (Gelitze 1956) based on the published data (Reichsamt 1939). Moreover, official figures were manipulated for military-strategic purposes, but these distortions are not present in the archival material (Fremdling 2005).

is to run a leverage-versus-squared residual plot after estimating the model. The diagram plots leverage against the square of normalised residuals. The dots closest to the origin on the vertical axis represent the best behaving observations. The two additional axes plotted into the graph region mark the average of squared residuals and levels of leverage respectively. The only observations likely to weaken the estimation results are located far from both these axes in the positive spectrum. As shown in Figure 4, the only such observation is precisely crude oil and natural gas.

Figure 4 about here

If we re-estimate the model after excluding this gross outlier, we obtain significantly larger coefficients on both explanatory variables and a higher R^2. More importantly, as shown in Table 10, the model remains robust, if the period of analysis is extended to 1955, although the results remain highly significant only after the exclusion of two further outliers. As noted above, electrical engineering after 1948 expanded partly thanks to resettled firms that had operated in the East before the war. Salt mining, by contrast, experienced sluggish growth in the post-war period, even though it had not concentrated excessively in the West in 1936. Germany was a major power in salt mining, which thus constituted the most export-oriented industry after 1950 with little room for domestic market expansion. Overall, on average, an industry with a one percentage point smaller western share in German value added in 1936 achieved 1.6% higher growth in output between 1948 and 1955.

Figure 5 about here

This result confirms that industrial expansion during the *Wirtschaftswunder* reflected, to a large extent, the necessity of rebalancing the disproportionate industrial structure that had resulted from the division of Germany. As shown in Figure 5, the growth of gross fixed capital between 1948 and 1955 was strongly conditioned by how well each industry was represented in the western part of the country before the war. Industries with increased market potential after 1945 had to extend their productive base to realise their growth potential.

VI. Conclusions

World War II dislocated the German economy in more ways than one. As long as these effects lingered on, pre-war levels of industrial efficiency could not be surpassed. Millions of displaced workers had to be reintegrated into the urban-industrial production process, and new capacities had to be built up both in overpopulated rural areas and in industries which faced excess demand after the division of Germany. Consequently, the *Wirtschaftswunder* was driven primarily by factor accumulation, rather than productivity growth. In fact, the opportunity to expand on the basis of existing endowments and the need to meet the pent-up demand of a war-torn population for manufactures that had already been marketed before

1939 thwarted technological progress and product innovation. The resulting backlog in productivity growth had moved German industry far away from the efficient frontier by the mid 1950s, and thus created further scope for catch-up in subsequent years through the adoption of new technologies when labour-supply constraints had become tighter. As a result, growth rates of industrial labour productivity and TFP remained remarkably high by international standards until the end of the post-war Golden Age.

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Table 1: Annualised growth accounts for West German industry (log %)

	1951-55	1956-60	1961-65	1966-70
Value-added	11.66	7.42	5.47	5.66
Labour hours	6.20	1.42	-1.14	-0.64
Labour productivity	5.14	5.92	6.69	6.34
Capital input	6.97	8.12	7.32	5.07
Effective capital input	11.22	8.44	6.55	5.77
Effective capital intensity	4.72	6.92	7.78	6.45
TFP	3.57	3.61	4.10	4.19

Note: For the method used to calculate TFP growth, see text in Section IV.

Sources: Value-added and labour hours from *Lange Reihen zur Wirtschaftsentwicklung*, pp. 48-53; gross capital stock from Baumgart and Krengel (1970), pp. 82-83; rates of capacity utilisation from Krengel (1960), p. 81, and Baumgart (1972), p. 74.

Table 2: Index of net industrial production (1950 = 100)

	1938	1948	1950	1955
Mining	***117.4***	***76.0***	***100***	***136.3***
Coal Mining	120.8	78.0	100	127.8
Metallic Ores	104.5	65.2	100	143.8
Salt Mining	98.2	61.0	100	174.6
Crude Oil and Gas	49.4	58.7	100	289.6
Production Goods	***112.9***	***53.0***	***100***	***174.6***
Fuel Industry	84.1	22.9	100	263.5
Iron and Steel	142.3	48.6	100	177.5
Non-Ferrous Metals	119.3	47.1	100	184.0
Construction Materials	108.5	53.4	100	167.4
Chemical Industry	97.6	53.7	100	179.4
Rubber and Asbestos	114.3	68.7	100	196.5
Timber Industry	105.4	69.6	100	114.6
Paper and Pulp	107.3	47.4	100	153.5
Investment Goods	***117.3***	***50.2***	***100***	***222.6***
Steel Constructions	224.5	56.5	100	163.7
Machine Tools	127.3	45.5	100	209.9
Transport Vehicles	92.1	33.5	100	275.8
Shipbuilding	237.3	50.7	100	362.9
Electrical Engineering	65.7	54.5	100	246.3
Optical and Precision Eng.	103.0	44.8	100	222.4
Fabricated Metal Products	121.9	66.3	100	189.2
Consumer Goods	***99.6***	***46.1***	***100***	***162.1***
China and Earthenware	132.8	56.3	100	188.3
Glass Industry	68.0	55.0	100	168.9
Entertainment Instruments	207.5	63.4	100	251.3
Woodworking	103.9	57.1	100	151.2
Paper and Board	112.1	39.7	100	158
Printing and Publishing	95.9	42.2	100	155.4
Plastic Products	67.0	46.0	100	324.9
Leather Industry	148.6	57.7	100	149.3
Footwear Industry	138.0	54.3	100	137.5
Textile Industry	93.6	41.9	100	150.5
Clothing Industry	64.7	45.0	100	197.4
Food and Tobacco	***104.0***	***56.8***	***100***	***164.9***
Food and Beverages	90.0	65.8	100	166.2
Tobacco Manufactures	134.2	37.6	100	162.1
Total Industry	**109.7**	**53.4**	**100**	**178.5**

Source: IndBRD, Series 4, No. 8 (1956), p. 17. Sub-industries aggregated by 1950 value-added weights from Ibid, p. 9.

Table 3: Index of gross capital stock (1950 = 100)

	1938	1948	1950	1955
Mining	**81.4**	**97.4**	**100**	**131.0**
Coal Mining	80.6	97.9	100	129.7
Metallic Ores	74.2	91.0	100	146.4
Salt Mining	99.4	97.2	100	122.0
Crude Oil and Gas	75.2	93.4	100	153.9
Production Goods	***77.5***	***99.3***	***100***	***130.1***
Fuel Industry	73.9	99.6	100	119.7
Iron and Steel	82.1	101.0	100	148.8
Non-Ferrous Metals	81.1	102.3	100	112.6
Construction Materials	86.6	93.9	100	154.3
Chemical Industry	72.9	101.7	100	115.0
Rubber and Asbestos	69.2	91.6	100	131.4
Timber Industry	71.3	64.1	100	176.4
Paper and Pulp	95.5	91.0	100	172.5
Investment Goods	***79.3***	***94.9***	***100***	***153.5***
Steel Constructions	72.7	92.7	100	165.0
Machine Tools	84.4	95.4	100	150.1
Transport Vehicles	76.3	97.7	100	151.8
Shipbuilding	68.0	101.2	100	122.2
Electrical Engineering	73.1	90.1	100	164.7
Optical and Precision Eng.	80.5	98.3	100	141.4
Fabricated Metal Products	88.6	93.1	100	165.5
Consumer Goods	***99.1***	***86.2***	***100***	***151.0***
China and Earthenware	90.8	84.3	100	181.5
Glass Industry	93.2	87.9	100	155.3
Entertainment Instruments	133.3	98.5	100	117.2
Woodworking	78.9	70.5	100	165.0
Paper and Board	86.2	79.8	100	191.8
Printing and Publishing	118.0	90.2	100	159.5
Plastic Products	68.9	85.9	100	198.0
Leather Industry	94.8	87.0	100	118.6
Footwear Industry	89.2	88.9	100	152.3
Textile Industry	101.3	88.4	100	136.8
Clothing Industry	95.0	78.4	100	229.2
Food and Tobacco	***97.5***	***87.0***	***100***	***139.9***
Total Industry	**83.4**	**95.1**	**100**	**138.9**

Sources and methods: see text.

Table 4: Index of annual labour hours (1950 = 100)

	1938	1948	1950	1955
Mining	***74.7***	***89.01***	***100***	***105.2***
Coal Mining	73.0	90.05	100	101.2
Metallic Ores	103.9	76.94	100	105.0
Salt Mining	64.6	88.74	100	137.7
Crude Oil and Gas	42.0	77.37	100	133.7
Production Goods	***100.2***	***68.52***	***100***	***127.6***
Fuel Industry	113.9	77.72	100	108.0
Iron and Steel	138.7	66.33	100	135.9
Non-Ferrous Metals	99.8	60.72	100	136.2
Construction Materials	99.6	68.82	100	129.9
Chemical Industry	70.1	69.99	100	118.2
Rubber and Asbestos	78.4	74.71	100	154.0
Timber Industry	80.0	85.25	100	100.1
Paper and Pulp	78.3	51.63	100	122.4
Investment Goods	***87.6***	***68.91***	***100***	***158.6***
Steel Constructions	64.8	80.48	100	128.8
Machine Tools	76.0	67.76	100	158.9
Transport Vehicles	68.1	62.71	100	144.1
Shipbuilding	169.9	64.91	100	208.0
Electrical Engineering	58.8	74.75	100	178.8
Optical and Precision Eng.	96.2	74.30	100	167.3
Fabricated Metal Products	134.1	64.11	100	152.7
Consumer Goods	***85.9***	***60.75***	***100***	***132.5***
China and Earthenware	86.9	70.75	100	161.7
Glass Industry	58.4	61.76	100	165.6
Entertainment Instruments	74.5	75.29	100	207.5
Woodworking	81.5	77.86	100	128.3
Paper and Board	107.1	46.72	100	153.5
Printing and Publishing	70.1	50.48	100	136.2
Plastic Products	48.8	62.38	100	199.4
Leather Industry	104.7	84.24	100	127.9
Footwear Industry	97.6	75.93	100	125.1
Textile Industry	86.5	49.94	100	113.4
Clothing Industry	95.1	67.96	100	153.7
Food and Tobacco	***98.3***	***68.22***	***100***	***124.6***
Food and Beverages	82.4	73.24	100	130.1
Tobacco Manufactures	167.7	48.35	100	102.1
Total Industry	**91.8**	**70.03**	**100**	**135.1**

Sources and methods: see text.

Table 5: Index of industrial labour productivity (1950 = 100)

	1938	1948	1950	1955
Mining	***157.2***	***85.4***	***100***	***129.5***
Coal Mining	165.5	86.6	100	126.3
Metallic Ores	100.6	84.7	100	136.9
Salt Mining	152.1	68.7	100	126.8
Crude Oil and Gas	117.7	75.9	100	216.7
Production Goods	***112.6***	***77.4***	***100***	***136.8***
Fuel Industry	73.8	29.5	100	244.0
Iron and Steel	102.6	73.2	100	130.6
Non-Ferrous Metals	119.5	77.6	100	135.1
Construction Materials	108.9	77.6	100	128.9
Chemical Industry	139.2	76.7	100	151.8
Rubber and Asbestos	145.8	92.0	100	127.6
Timber Industry	131.7	81.6	100	114.5
Paper and Pulp	137.0	91.8	100	125.4
Investment Goods	***133.9***	***72.9***	***100***	***140.4***
Steel Constructions	346.6	70.2	100	127.1
Machine Tools	167.5	67.2	100	132.1
Transport Vehicles	135.3	53.4	100	191.4
Shipbuilding	139.7	78.1	100	174.4
Electrical Engineering	111.7	72.9	100	137.7
Optical and Precision Eng.	107.1	60.3	100	132.9
Fabricated Metal Products	90.9	103.5	100	123.9
Consumer Goods	***116.0***	***75.9***	***100***	***122.4***
China and Earthenware	152.8	79.6	100	116.4
Glass Industry	116.5	89.0	100	102.0
Entertainment Instruments	278.5	84.2	100	121.1
Woodworking	127.5	73.3	100	117.8
Paper and Board	104.7	85.0	100	103.0
Printing and Publishing	136.8	83.6	100	114.1
Plastic Products	137.2	73.7	100	162.9
Leather Industry	141.9	68.5	100	116.7
Footwear Industry	141.4	71.5	100	109.9
Textile Industry	108.2	83.9	100	132.7
Clothing Industry	68.0	66.2	100	128.4
Food and Tobacco	***105.8***	***83.3***	***100***	***132.4***
Food and Beverages	109.2	89.8	100	127.8
Tobacco Manufactures	80.0	77.8	100	158.7
Total Industry	**119.5**	**76.3**	**100**	**132.1**

Sources: Industrial value-added from Table 2; labour hours from Table 3.

Table 6: Decomposing labour-productivity growth in West German industry (log %)

	1938-1948	1948-1955
Aggregate labour productivity	-44.9	55.0
Industry contributions	-46.6	56.3
Residual	1.7	-1.3

Methods: See text.

Table 7: Index of industrial capital intensity (1950 = 100)

	Nominal				Effective	
	1938	1948	1950	1955	1948	1955
Mining	***109.0***	***109.4***	***100***	***124.5***	***93.5***	***122.3***
Coal Mining	110.4	108.7	100	128.1	94.2	121.1
Metallic Ores	71.5	118.2	100	139.4	89.8	166.4
Salt Mining	154.0	109.5	100	88.6	79.2	97.3
Crude Oil and Gas	179.1	120.7	100	115.1	97.4	140.2
Production Goods	***77.3***	***145.0***	***100***	***102.0***	***94.4***	***126.9***
Fuel Industry	64.9	128.1	100	110.9	43.4	136.5
Iron and Steel	59.2	152.3	100	109.4	93.7	139.6
Non-Ferrous Metals	81.3	168.5	100	82.6	107.4	104.5
Construction Materials	86.9	136.4	100	118.8	102.4	128.7
Chemical Industry	104.0	145.2	100	97.3	94.1	128.9
Rubber and Asbestos	88.2	122.6	100	85.3	115.0	117.2
Timber Industry	89.1	75.2	100	176.2	68.3	163.9
Paper and Pulp	122.0	176.2	100	141.0	107.5	157.2
Investment Goods	***90.6***	***137.8***	***100***	***96.8***	***94.1***	***144.9***
Steel Constructions	112.3	115.2	100	128.1	82.6	162.0
Machine Tools	111.1	140.8	100	94.5	87.6	121.8
Transport Vehicles	112.2	155.8	100	105.3	84.6	171.3
Shipbuilding	40.0	156.0	100	58.8	88.4	160.1
Electrical Engineering	124.3	120.6	100	92.1	90.6	146.0
Optical and Precision Eng.	83.7	132.2	100	84.5	86.6	123.6
Fabricated Metal Products	66.1	145.3	100	108.4	121.0	173.2
Consumer Goods	***115.3***	***141.9***	***100***	***114.0***	***87.3***	***131.6***
China and Earthenware	104.5	119.2	100	112.2	92.0	145.4
Glass Industry	159.6	142.4	100	93.7	93.4	128.7
Entertainment Instruments	179.0	130.9	100	56.5	94.8	94.4
Woodworking	96.8	90.6	100	128.6	71.8	139.7
Paper and Board	80.5	170.8	100	125.0	91.0	135.6
Printing and Publishing	168.3	178.6	100	117.1	94.5	127.6
Plastic Products	141.2	137.6	100	99.3	104.7	150.5
Leather Industry	90.5	103.3	100	92.7	78.9	104.9
Footwear Industry	91.4	117.1	100	121.8	89.4	137.8
Textile Industry	117.0	177.1	100	120.6	99.1	139.0
Clothing Industry	99.9	115.4	100	149.1	77.8	153.7
Food and Tobacco	***99.1***	***127.5***	***100***	***112.3***	***102.5***	***138.1***
Total Industry	**90.8**	**135.8**	**100**	**102.8**	**95.6**	**126.0**

Note: Capital intensity is measured as gross capital stock per worker hour. The effective index is adjusted for changes in capacity utilisation.

Sources: Capital stock from Table 5; labour hours from Table 3; rates of capacity utilisation for 1948, 1950, and 1955 from Krengel (1960), p. 81.

Table 8: Growth accounts for West German Industry 1929 –1955 (log %)

	1938-48	1948-55	1938-55	1929-38	1929-55
Value-added	-72.0	120.7	48.7	11.3	60
Labour hours	-27.1	65.7	38.6	12.8	51.4
Value-added per hour	-44.9	55.0	10.1	-1.5	8.6
Capital input (gross)	-42.3	93.3	51.0	3.5	54.5
Capital intensity	-15.2	27.6	12.4	-9.3	3.1
TFP	-39.8	45.8	6.0	1.6	7.6

Note: Capital input is measured as gross capital stock adjusted for capacity utilisation. We assume the 1955 utilisation rate for 1929 and 1938. For the method used to compute TFP growth, see text.

Sources: Data for 1929-38 from Krengel (1958) and *Statistisches Jahrbuch des Deutschen Reichs 1939*.

Table 9: Correlations between factor accumulation and output growth

	1938-48		1948-55	
	Coefficient	Sig. Level	Coefficient	Sig. Level
Output – Capital	-0.097	.602	-0.179	.335
Output – Labour	0.569	.001	0.503	.004

Table 10: Regressions explaining the rate of growth in industrial value-added after 1948

	1948-50	1948-50	1948-55
Growth 1938-48	-0.3221 (-3.39)	-0.4684 (-4.57)	-0.7402 (-3.42)
West share 1936	-0.6282 (-2.25)	-1.0712 (-3.53)	-1.5825 (-2.54)
(constant)	85.0173 (4.30)	101.9561 (5.34)	171.2398 (4.34)
N	32	31	29
F	7.56	12.40	7.07
R^2	0.3428	0.4697	0.3521

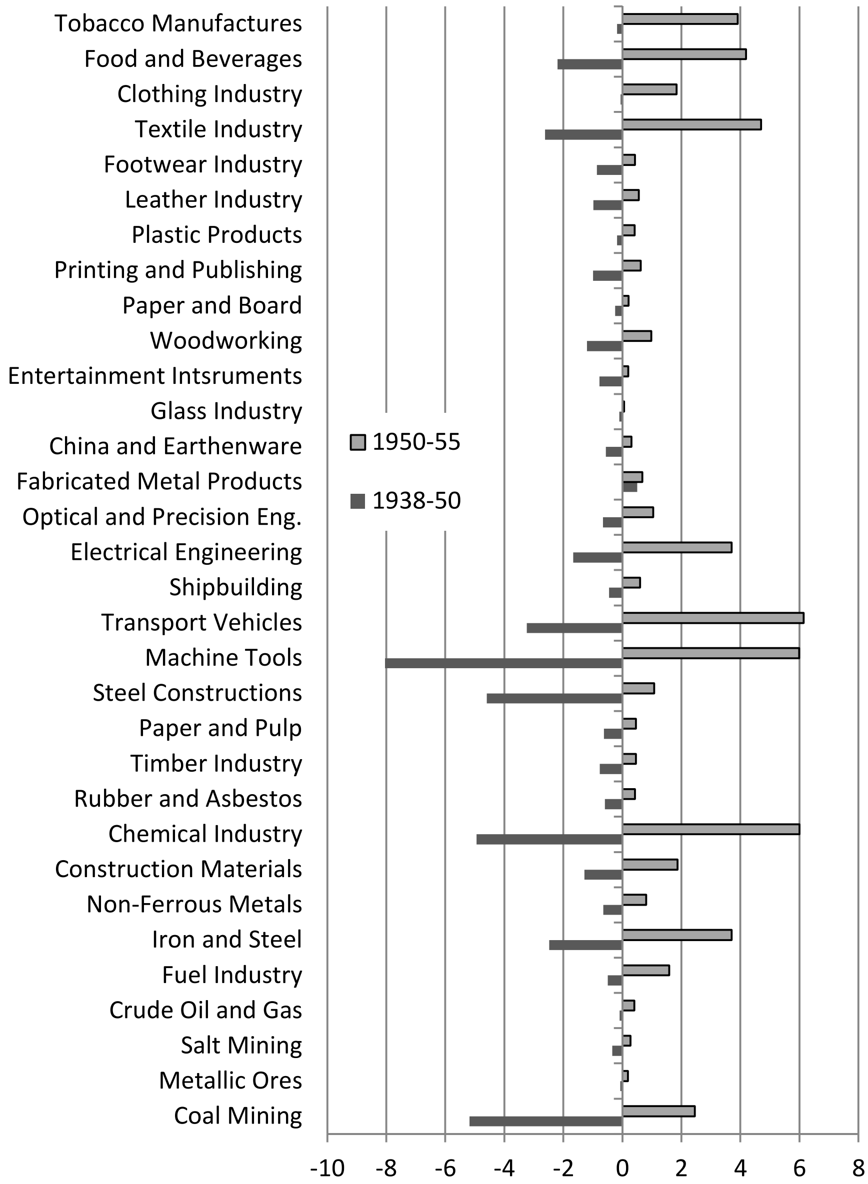

Figure 1: The industry origins of labour-productivity growth

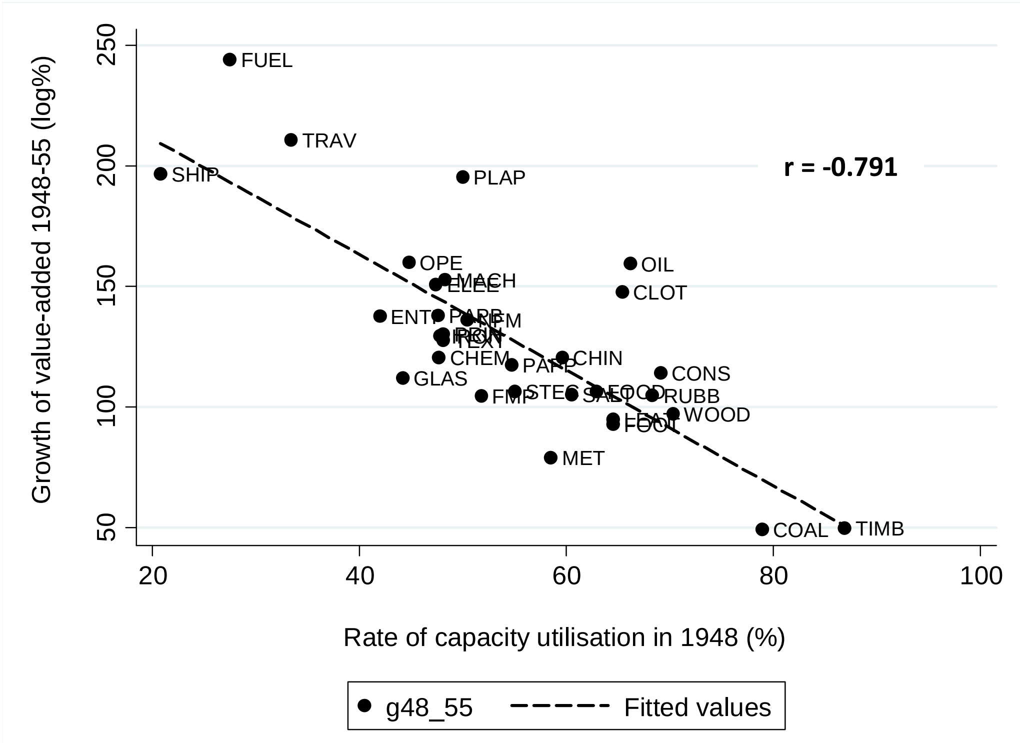

Figure 2: Growth potential derived from spare capacities during the *Wirtschaftswunder*

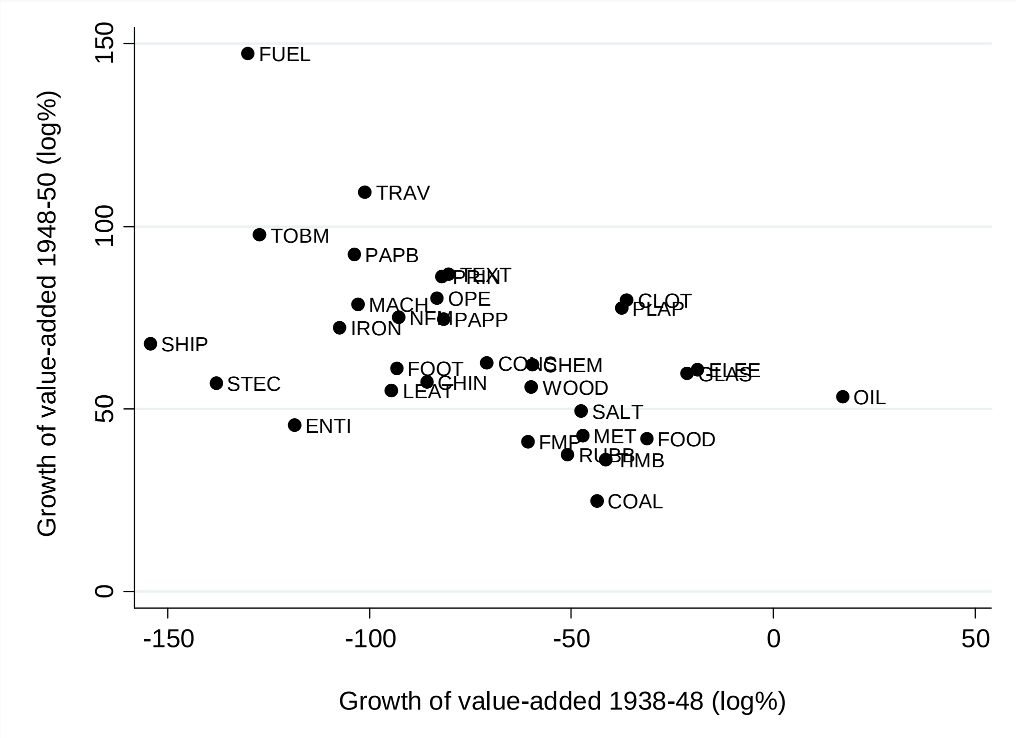

Figure 3: Reconstruction growth 1948-1950

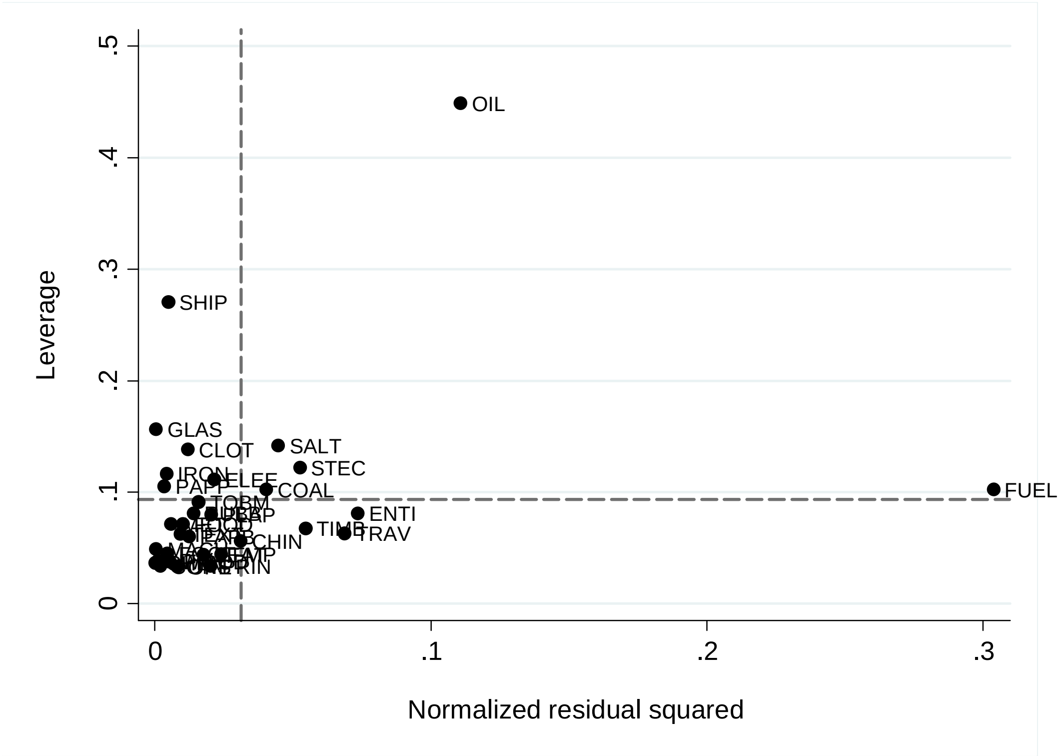

Figure 4: Leverage-versus-squared residual plot

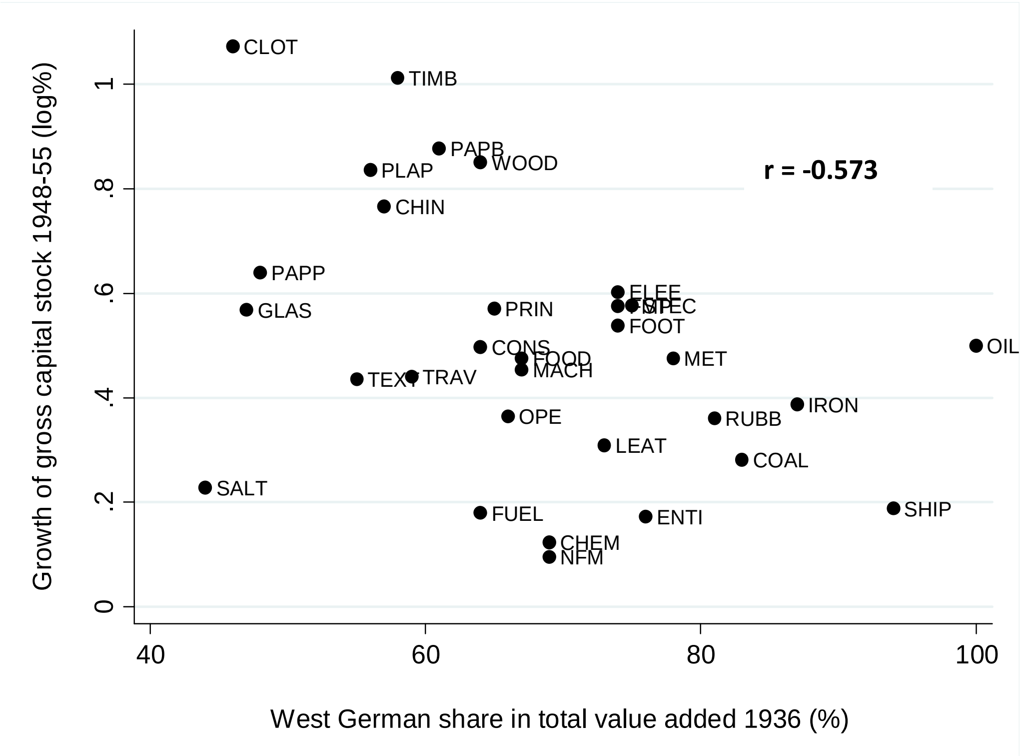

Figure 5: Rebalancing industrial structures during the *Wirtschaftswunde*r

Note: The correlation coefficient is computed after excluding crude oil and natural gas and salt mining.

Appendix 1: Sources for official statistics

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—— *Die Industrie der Bundesrepublik Deutschland*, Series 4: Sonderveröffentlichungen, No. 9, Beschäftigung und Umsatz, Brennstoff- und Energieversorgung in den Jahren 1950 bis 1954: Jahreszahlen der Industrieberichterstattung (1955).

—— *Die Industrie der Bundesrepublik Deutschland*, Series 4: Sonderveröffentlichungen, No. 14, Beschäftigung und Umsatz, Brennstoff- und Energieversorgung in den Jahren 1952 bis 1956: Jahreszahlen der Industrieberichterstattung (1957).

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—— *Statistisches Jahrbuch 1952*.

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—— *Statistisches Jahrbuch für das Deutschen Reich 1939/40*.

USSBS (1945): United States Strategic Bombing Survey, *Overall Report: European War*. Washington: Secretary of War.

Appendix 2: Estimating the capital stock of West German industry, 1938-50

The DIW has published estimates of gross capital stock for 41 industries, separately for buildings and machinery, for the years between 1950 and 1968 and of the corresponding levels of gross investment in 1962 prices going back to 1924 (Baumgart and Krengel 1970, 48-82).[6] The investment series were adjusted for wartime damage, post-war dismantlement and territorial changes. Capital-stock figures

[6] For DIW estimates on other sectors of the economy, see Kirner (1968), and Görzig and Kirner (1976).

were computed only for the period after 1950. The perpetual-inventory method used in the estimation requires investment series to be sufficiently long to cover the average working life of fixed assets in a given industry under the assumption of non-linearity for capital retirement.

A non-linear retirement function cannot be used to derive capital-stock estimates for earlier years by backward projection, since this would require comparable investment data from prior to 1924, which are not available. Therefore, I assumed the rate of capital retirement to be constant over time, meaning that at zero gross investment the capital stock would shrink at a constant rate. The retirement rate is computed as the reciprocal of the average working life of fixed assets in a given industry. This procedure, even if not precisely correct, enables us to determine the gross value of the capital stock for any given year based on existing investment data and the capital-stock of subsequent years. Baumgart and Krengel (1970, 49) also provide industry-specific estimates for the length of the period machine tools were used for. With this data, we can compute industry-specific rates of capital retirement. The approach to estimate gross capital stock is summarised in the following formula, where t denotes the year for which the capital stock of a given industry (K_i) is estimated.

$$K_i^t = K_i^{t+1} - I_i^t + A_i^t \tag{1}$$

I_i stands for investment in fixed capital and A_i for capital retirement in the same industry. A_i is, in turn, the product of the industry-specific retirement rate (a_i) and the capital stock of the same industry in a given year.

$$K_i^t = K_i^{t+1} - I_i^t + a_i K_i^t \tag{2}$$

Equation (2) can be rewritten in a way to express the capital stock available at the start of a given year with variables which have already been calculated in a sequential procedure starting from 1950 and projecting backwards to 1938.

$$K_i^t = \frac{K_i^{t+1} - I_i^t}{1 - a_i} \tag{3}$$

While adjusting their investment series for the impact of wartime destruction and post-war dismantlement, Baumgart and Krengel distributed the estimated losses evenly over all potentially affected investment years. Therefore, their data do not precisely account for the timing of the damage that occurred to fixed capital in West German industry during the mid-1940s. Albeit perfectly suitable for the purpose of determining capital-stock levels for the post-1950 period, these estimates are inappropriate for the objectives of this paper. First, I readjust investment levels to exclude the evenly distributed effects of war damage and post-war dismantlement. Second, based on estimates published in an earlier study (Krengel, 1958, 95 and 104), I determined (i) the size of these effects as a proportion of the 1950 capital stock and (ii) the timing of the losses. Third, I assumed lower retirement rates for the period 1945-9, since at very modest capacity utilisation industrial machinery was not run down as fast as in normal periods, and with little market incentive to increase production firms employed a large share of their workforce to carry out essential repairs.

$$K_i^t = \frac{K_i^{t+1} - I_i^t}{1 - a_i} + DAM_i^t \tag{4}$$

Following these adjustments, I used the extended formula (4), where DAM_i^t is the amount of capital lost in a particular branch in a given year due to either war damage or post-war dismantlement and *I* denotes actual gross investment that is not adjusted for these effects. Aircraft manufacturing is excluded from the dataset for the reason explained in the text. The estimates are reported in Tables A1 and A2 separately for machinery and structures. For structures, an identical rate of capital retirement of 2% p.a. is assumed for all industries and all periods, since the number of years buildings are expected to last without major renovation is unlikely to be substantially affected by the type and intensity of industrial activity carried out in them.

Appendix 3: Computing labour hours for West German industry, 1938-50

Between 1950 and 1955, labour input can be measured directly using data from the annual industry statistics which report total hours worked by manual labour.[7] For earlier years, comparisons can be made based on official employment data adjusted for changes in average hours worked per week, using a number of different sources. Employment data can be obtained from the non-agricultural workplace censuses of 17 May 1939 and of 13 September 1950.[8] The provincial records of the 1939 census allow us to construct aggregate levels for West Germany at a level of disaggregation that corresponds to the post-war industry classification.

The Federal Ministry for Labour published territorially adjusted employment estimates for 1938 (Bundesministerium für Arbeit 1952, 12-23) based annual data from the work-book statistics (*Arbeitsbucherhebun*g).[9] In theory, this classified document would allow us to create a 1938 benchmark. However, the level of disaggregation is insufficient to match the post-war industry classification, especially in metallurgy and the metal working industries. Furthermore, the provincial labour bureau districts (*Landesamtbezirke*) did not correspond to actual provincial or state boundaries in the Reich. In particular, the territories of Nordmark and Mitteldeutschland contained vast areas falling under both West and East German jurisdiction after the war. Both had a fairly large weight in industrial employment: including the port cities of Hamburg, Kiel and Lübeck in the former, and the emerging industrial cluster around Braunschweig, Salzgitter and Wolfsburg in the latter. Without data for local labour bureau districts, we cannot precisely adjust the figures for post-war territory. It is also not entirely clear how industrial employment is defined in the workbook statistics, and whether it corresponds to the definitions used in industry statistics.

The alternative approach followed here is to estimate employment in 1938 based on 1939 census data adjusted for the growth of employment at the industry level in Germany as a whole between 1938 (annual average) and May 1939, calculated using index numbers reported in the 1939 statistical yearbook.[10] The post-war annual industry statistics report employment both for the end of September and averaged over the year.[11] The ratio of these levels for each industry is used to adjust the census data in order to estimate annual average levels of employment for 1950. We cannot use the annual figures from industry statistics directly because they are not perfectly consistent with census data. This is due to differences (i) in the mechanism of reporting by industrial establishments and (ii)

[7] *IndBRD*, Series 4, No. 9 (1955), p. 9; Ibid, No. 14 (1957), p. 9.
[8] *StDR*, vol. 568.8-14. (1942-44); *StBRD*, vol. 45.2. (1952), pp. 4-18.
[9] Reichsministerium für Arbeit , Nr. 2993, pp. 19-21.
[10] *Statistisches Jahrbuch 1939/40*, pp. 382-383.
[11] *IndBRD*, Series 4, No. 9 (1955), pp. 5-6.

in the way the two sources distinguish between industrial plants and handcraft workshops. Thus, to be methodologically consistent, census data can only be compared with census data.

Industrial employment for West Germany in 1948 is determined by aggregating the average of monthly employment levels in the Bizone and that in the French occupation zone.[12] Methodologically, these figures are consistent with the annual industry statistics published from 1950 onward. Table A3 reports levels of employment by industry. To account for the growth of labour input between 1938, 1948, and 1950, the rate of employment expansion is adjusted for changes in average working hours. Several sources are used in combination that report average weekly hours for manual labour at the industry level.[13] The only critical assumption we make is that there were no differences in the length of the work week within individual industries between different parts of Germany in 1938.

Appendix 4: Sensitivity tests for the industrial growth accounts

This appendix reports three sensitivity tests for the aggregate industrial growth accounts presented in Section IV. Each test relaxes one critical assumption of the growth-accounting model while holding all else constant. All three assumptions were made to minimise the contribution of capital deepening and thereby provide an upper-bound estimate for TFP growth.

First, we test the effect of assuming a significantly smaller rate of capacity utilisation for both 1929 and 1938 than the corresponding rate for 1955 reported by Krengel (1960). Instead of 96.8%, we assume 87.7%, the average utilisation rate in 1958. Economic conditions in 1958 show some similarity to 1929 and – to a lesser extent – to 1938. In all these years, the growth of German industry was slowed down by weak external demand due to international crises. This assumption increases the rate of effective capital input, which reduces TFP growth by about a half.

Second, we relax the assumption of constant returns to scale, and assume 20% increasing returns to weighted average input growth (as in Inklaar et al. 2011), using the standard weights 1/3 for capital and 2/3 for labour. This test completely eliminates TFP growth for both periods, turning it into the negative.

Third, we assume constant returns to scale, but increase the elasticity of output with respect to capital from 1/3 to 1/2. Thus, we reduce TFP growth by about a third between 1938 and 1955. Given the very modest rate of capital deepening in the period 1929-55, the results are not sensitive to factor-share specifications.

[12] Control Commission for Germany (UK), *Monthly Statistical Bulletins*, different volumes (1948-49); Commandement en Chef Francais en Allemagne, Division de L'Économie Generale et des Finances, *Bulletin Statistique*, No. 7 (Oct, 1948), No. 9 (April, 1949).

[13] For 1939, see Hachtmann (1989), p. 51, Länderrat des Amerikanischen Besatzungsgebiets (1949), pp. 469-471, and *Statistisches Jahrbuch 1939/40*, pp. 384-385. For 1948 and 1950, see Schudlich (1987), pp. 158-167, and *Statistisches Jahrbuch 1952*, pp. 412-418.

Table A.1: Estimates of gross capital stock in West German industry at the start of each year: machinery and equipment (million 1962 DM)

	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938
Hard coal	7,450	7,316	7,376	7,531	7,702	8,182	8,504	8,287	7,720	7,134	6,551	6,057	5,709
Brown coal and lignite	1,121	1,047	1,022	1,027	1,036	1,104	1,179	1,164	1,103	1,042	982	933	903
Iron ore	172	161	158	159	161	171	173	165	154	143	133	125	121
Rock and potassium salt	659	642	634	641	648	692	739	741	717	688	660	630	600
Crude oil and natural gas	614	583	573	583	590	631	656	638	600	556	511	473	451
Other mining	79	70	63	61	59	62	66	66	63	61	59	57	56
Construction materials	1,728	1,671	1,663	1,695	1,744	1,876	1,979	1,973	1,883	1,767	1,634	1,518	1,467
Iron making	4,194	4,222	4,365	4,607	5,030	5,624	5,692	5,364	4,879	4,410	3,977	3,625	3,373
Iron and steel foundries	1,123	1,119	1,143	1,179	1,229	1,323	1,358	1,293	1,192	1,095	1,004	927	874
Rolling mills	544	543	559	586	643	714	723	683	623	565	512	468	437
Non-ferrous metals	1,970	1,993	2,040	2,115	2,234	2,415	2,467	2,360	2,197	2,035	1,881	1,741	1,576
Chemical industry	10,405	10,492	10,734	11,120	11,700	12,652	12,828	12,091	11,026	9,965	8,965	8,084	7,472
Fuel industry	1,670	1,674	1,694	1,729	1,767	1,870	1,904	1,801	1,652	1,504	1,377	1,273	1,205
Rubber and asbestos	732	698	685	683	686	721	742	704	655	607	563	528	502
Timber industry	473	366	305	278	259	263	296	308	312	315	315	316	319
Paper and pulp	981	933	918	928	942	1,002	1,067	1,075	1,061	1,042	1,015	984	940
Steel constructions	479	456	453	464	482	519	530	503	465	433	403	378	355
Machine tools	3,760	3,613	3,606	3,761	4,092	4,537	4,531	4,248	3,894	3,619	3,383	3,191	3,049
Motor vehicles	2,123	2,077	2,105	2,190	2,324	2,534	2,540	2,367	2,145	1,973	1,824	1,703	1,600
Shipbuilding	617	613	623	651	707	783	773	714	641	581	527	480	445
Electrical engineering	2,252	2,097	2,045	2,098	2,281	2,559	2,570	2,411	2,205	2,041	1,895	1,782	1,717
Optical and precision engineering	353	345	353	374	414	465	467	435	394	374	341	312	286
Fabricated metal products	1,201	1,143	1,134	1,172	1,245	1,371	1,413	1,359	1,278	1,207	1,142	1,089	1,039
Pottery industry	197	177	163	161	162	176	195	195	189	184	179	170	162
Glass industry	237	213	203	201	202	218	233	233	225	221	214	206	201
Woodworking	491	397	328	301	295	326	362	369	368	369	366	360	354
Entertainment products	54	52	52	52	51	52	59	62	63	64	65	66	67
Paper and board	202	179	164	158	157	169	184	189	191	189	185	180	180
Printing and publishing	593	539	519	525	541	592	648	670	682	688	688	682	678
Plastic products	117	107	103	102	105	111	114	107	99	93	87	83	80
Leather making	203	189	179	179	178	192	209	210	204	202	198	191	181
Leather processing	67	60	57	57	57	61	68	69	67	66	64	62	59
Footwear industry	269	254	247	253	257	278	297	290	277	267	257	250	244
Textile industry	3,476	3,237	3,146	3,188	3,272	3,529	3,748	3,776	3,748	3,691	3,617	3,525	3,446
Clothing industry	220	176	155	149	146	159	172	172	170	170	172	176	184
Flouring mills	802	756	735	730	735	779	819	811	795	783	771	762	761
Oil pressing and margarine	480	473	467	474	483	514	534	517	501	482	468	457	448
Sugar industry	465	431	411	413	420	447	465	450	435	421	412	407	398
Brewing and malting	1,334	1,281	1,262	1,282	1,319	1,423	1,531	1,561	1,557	1,542	1,517	1,477	1,454
Other food and tobacco	3,386	2,921	2,624	2,546	2,530	2,711	2,915	2,932	2,902	2,885	2,876	2,878	2,886
Total Industry	**57,293**	**55,316**	**55,069**	**56,402**	**58,886**	**63,804**	**65,750**	**63,360**	**59,333**	**55,473**	**51,792**	**48,610**	**46,280**

Table A.2: Estimates of gross capital stock in West German industry at the start of each year: structures (million 1962 DM)

	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938
Hard coal	3,711	3,662	3,654	3,678	3,706	4,015	4,365	4,320	4,110	3,875	3,633	3,420	3,258
Brown coal and lignite	485	460	446	442	441	481	534	531	508	483	456	433	417
Iron ore	153	151	150	151	151	165	175	170	159	147	136	128	122
Rock and potassium salt	421	417	416	417	420	458	507	516	510	502	493	483	473
Crude oil and natural gas	245	236	229	227	226	245	268	264	251	235	219	205	195
Other mining	27	23	20	20	21	23	26	25	25	24	23	22	21
Construction materials	941	886	843	840	843	924	1,023	1,029	998	956	909	867	844
Iron making	1,812	1,755	1,728	1,758	1,795	1,980	2,130	2,080	1,970	1,854	1,742	1,649	1,577
Iron and steel foundries	644	627	619	624	633	689	745	729	691	651	612	578	551
Rolling mills	363	356	354	358	366	400	430	418	395	371	347	327	312
Non-ferrous metals	825	820	819	837	857	936	1,004	979	925	866	808	754	692
Chemical industry	6,018	5,970	5,960	6,055	6,167	6,716	7,151	6,875	6,381	5,848	5,321	4,850	4,497
Fuel industry	668	651	634	635	640	694	748	724	679	631	587	550	524
Rubber and asbestos	354	331	310	305	304	327	356	346	325	303	281	263	248
Timber industry	304	242	193	179	170	185	222	232	233	234	234	235	235
Paper and pulp	399	362	338	336	337	370	416	423	419	412	402	392	378
Steel constructions	342	321	308	307	306	332	358	346	323	301	279	260	242
Machine tools	3,203	3,097	3,037	3,089	3,159	3,462	3,697	3,589	3,393	3,222	3,066	2,934	2,829
Motor vehicles	1,708	1,658	1,638	1,663	1,691	1,843	1,953	1,868	1,733	1,614	1,503	1,408	1,324
Shipbuilding	732	735	742	761	779	852	885	825	741	664	590	524	472
Electrical engineering	1,732	1,623	1,546	1,552	1,578	1,742	1,852	1,763	1,619	1,490	1,367	1,266	1,195
Optical and precision engineering	328	318	316	324	332	365	389	374	350	325	301	280	262
Fabricated metal products	992	940	909	913	922	1,010	1,102	1,089	1,049	1,010	971	937	904
Pottery industry	198	184	170	166	167	185	210	213	211	208	205	201	197
Glass industry	248	232	223	224	225	245	273	276	272	269	263	257	252
Woodworking	486	418	361	344	341	381	438	448	446	442	435	427	418
Entertainment products	150	149	149	150	153	166	187	194	196	199	201	203	205
Paper and board	127	111	98	93	90	98	112	115	114	112	109	106	104
Printing and publishing	732	695	676	681	687	754	848	873	882	885	888	886	885
Plastic products	82	72	68	67	66	73	81	77	72	67	63	60	57
Leather making	157	144	134	132	130	141	161	165	164	163	162	160	156
Leather processing	90	85	80	80	82	90	101	102	101	101	99	96	94
Footwear industry	165	149	139	140	137	149	168	167	162	156	151	147	143
Textile industry	2,199	1,993	1,871	1,865	1,884	2,082	2,336	2,387	2,384	2,371	2,350	2,323	2,300
Clothing industry	318	287	267	264	261	290	324	328	325	323	322	323	327
Flouring mills	380	362	352	352	354	390	431	433	427	420	413	407	405
Oil pressing and margarine	360	358	354	357	362	392	429	428	422	412	404	396	390
Sugar industry	236	222	213	213	215	236	260	256	249	242	235	230	224
Brewing and malting	1,019	997	986	995	1,010	1,106	1,228	1,251	1,244	1,230	1,211	1,182	1,161
Other food and tobacco	2,066	1,888	1,751	1,729	1,728	1,905	2,140	2,178	2,166	2,156	2,145	2,139	2,135
Total Industry	**35,420**	**33,989**	**33,100**	**33,322**	**33,736**	**36,899**	**40,061**	**39,406**	**37,623**	**35,775**	**33,939**	**32,311**	**31,026**

Table A.3: Levels of employment in West German industry between 1938 and 1950 ('000s)

	Census Data		Estimate		Industry Statistics	
	May 1939	Sept. 1950	1938	1950	1948	1950
Mining	***443.8***	***557.4***	***438.1***	***557.5***	***534.3***	***572.8***
Coal Mining	392.4	503.2	388.5	504.4	486.2	517.4
Metallic Ores	37.1	30.1	34.2	29.4	25.3	29.6
Salt Mining	9.8	15.1	9.8	14.7	15.5	16.7
Crude Oil and Gas	4.5	9.0	3.9	9.0	7.3	9.0
Production Goods	***1,203.5***	***1,189.3***	***1,132.0***	***1,133.9***	***859.0***	***1,099.8***
Fuel Industry	19.1	16.2	17.9	16.0	17.9	20.3
Iron and Steel	474.4	335.5	436.3	320.9	248.2	332.6
Non-Ferrous Metals	77.2	73.7	71.0	69.3	49.7	69.6
Construction Materials	256.0	260.2	247.3	238.9	155.4	194.5
Chemical Industry	192.9	272.2	180.9	262.8	223.1	281.3
Rubber and Asbestos	43.8	58.7	41.5	55.6	45.7	58.4
Timber Industry	90.8	111.0	87.7	109.0	85.0	87.7
Paper and Pulp	49.3	61.8	49.4	59.9	34.0	55.3
Investment Goods	***1,404.0***	***1,558.9***	***1,279.0***	***1,490.4***	***1201.3***	***1,432.6***
Steel Constructions	97.4	131.1	84.7	125.9	118.9	118.1
Machine Tools	382.8	485.3	339.9	469.6	380.7	450.4
Transport Vehicles	144.8	190.3	130.4	181.8	146.3	190.7
Shipbuilding	91.5	47.6	79.5	44.9	35.8	44.0
Electrical Engineering	165.9	276.9	150.8	263.8	214.5	252.6
Optical and Precision Eng.	78.9	85.3	74.8	82.0	70.6	77.7
Fabricated Metal Products	442.8	342.3	419.0	322.3	234.5	299.0
Consumer Goods	***1,288.0***	***1,505.9***	***1,240.9***	***1,447.9***	***935.1***	***1,326.3***
China and Earthenware	48.3	59.4	49.0	57.3	42.9	56.2
Glass Industry	28.3	49.8	28.3	47.7	30.5	43.5
Entertainment Instruments	26.4	38.9	25.4	35.6	26.8	30.1
Woodworking	144.9	183.3	139.4	174.2	160.5	167.2
Paper and Board	67.9	63.3	64.7	59.8	32.8	56.3
Printing and Publishing	93.6	125.8	89.8	122.4	62.8	104.7
Plastic Products	16.2	31.4	14.6	29.6	15.5	21.3
Leather Industry	68.4	65.2	65.7	63.0	49.3	54.2
Footwear Industry	89.8	90.1	81.7	86.5	72.1	81.7
Textile Industry	508.4	582.6	500.4	566.6	299.8	527.7
Clothing Industry	195.8	216.0	182.0	205.0	142.0	183.5
Food and Tobacco	***431.8***	***457.0***	***431.8***	***416.2***	***253.4***	***336.9***
Food and Beverages	294.8	368.4	294.8	339.1	217.4	269.2
Tobacco Manufactures	137.0	88.6	137.0	77.4	36.1	67.7
Total Industry	**4,766.4**	**5,178.8**	**4,521.9**	**4,964.8**	**3796.2**	**4,768.4**

Table A.4: Sensitivity of the growth accounts to model assumptions (log %)

	u K 87.7%		***γ = 1.2***		***α = 0.5***	
	1938-55	1929-55	1938-55	1929-55	1938-55	1929-55
Value-added	48.7	60.0	48.7	60.0	48.7	60.0
Labour input	38.6	51.4	38.6	51.4	38.6	51.4
Capital input	60.9	65.1	51.0	54.5	51.0	54.5
TFI	46.0	56.0	51.3	62.9	44.8	53.0
TFP	2.7	4.0	-2.6	-2.9	3.9	7.0

Notes: 'u K' stands for capacity utilisation, γ for the scale factor in the production function, and α for the elasticity of output with respect to capital.