Bombs, Brains, and Science

The Role of Human and Physical Capital for the Creation of Scientific Knowledge

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Abstract

This paper examines the relative roles of human and physical capital for the creation of scientific knowledge. To address the endogeneity of inputs, I analyze a shock to human capital, the dismissal of scientists in Nazi Germany, and a shock to physical capital, WWII bombings of universities. In the short-run, a 10% decline in human capital reduced output by .2 sd whereas a 10% decline in physical capital reduced output by .05sd. The human capital shock persisted in the long-run, while the physical capital shock did not. To explore mechanisms for the persistence of the human capital shock I show that the dismissal of 'star scientists' was particularly detrimental as they are key for attracting other successful researchers and for the training of PhD students.

Keywords: Human Capital, Physical Capital, Productivity of Universities, Star Scientists, Long-Run Persistence, Nazi Germany, Bombings.

1 Introduction

Which inputs create successful research universities? Anecdotal observation suggests that human and physical capital, i.e. scientists and their laboratories, are important inputs in the production of scientific knowledge (Machlup, 1961). Understanding the causal effect of these inputs and their relative role for the creation of scientific output in universities is important for policy makers, university administrators, and researchers alike. At the moment, many countries such as Brazil, South Korea, and especially China, are making large investments in higher education (Kugler, 2011, Rhee, 2011, Wang et al. 2011). Should they hire outstanding scholars or construct new laboratories to achieve the highest returns on their investments?

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Despite the significance of these issues we know little about the effects of different inputs for the production of scientific knowledge. As highlighted for firms by a large literature in industrial economics, the estimation of production functions is difficult because inputs are often chosen on the basis of unobservable productivity shocks (e.g. Ackerberg, et al. 2007). Estimating 'knowledge production functions' is similarly challenging. 'Star scientists' may be attracted by more productive departments and at the same time enhance the departments' productivity. Similarly, high quality departments attract more funding for physical capital, which further increases productivity. Finally, star scientists may attract funding for additional physical capital.

To overcome these difficulties I use two extensive, but temporary, shocks affecting German and Austrian science departments. As human capital shock I use the dismissal of mostly Jewish scientists in Nazi Germany and Austria between 1933 and 1940. As physical capital shock I use the destruction of science facilities during the Allied bombing campaign in the Second World War. The two shocks create ample variation because they affected departments to varying extents. In some departments, up to 60 percent of the faculty were dismissed while other departments did not lose anyone. Similarly, Allied bombings completely destroyed the facilities of some departments while other departments were not destroyed.

To investigate how the two shocks impacted department output in the short-run and whether they persisted in the long-run I construct a new data set of all scientists in German and Austrian physics, chemistry, and mathematics departments at seven points in time between 1926 and 1980. The micro data contain more than 10,000 scientist-year observations with detailed measures of their publication records in top journals. These data allow me to construct output measures for all science departments between 1926 and 1980. I add information on the two shocks from detailed historical records of dismissals in Nazi Germany and from archival material on bombing destruction during WWII.

Results show that both human and physical capital shocks had a negative effect on scientific output in the short-run. A 10 percent shock to human capital lowered department output by 0.2 standard deviations. A 10 percent shock to physical capital lowered output by 0.05 standard deviations in the short-run. As it took time to rehire after the dismissals and to reconstruct buildings after the bombings these short-run results inform us about the importance of human and physical capital inputs in the 'knowledge production function'. I also investigate the long-run persistence of the two shocks to understand how quickly departments adjusted to the human and physical capital shocks. The human capital shock persisted in the long-run and continued to have a negative impact on scientific output until 1980, almost 50 years after the dismissals. The physical capital shock, however, did not persist. Scientific output of departments that had been bombed during WWII recovered by 1961. By 1970, bombed departments even had slightly higher output than other departments. This suggests that bombed departments benefitted from upgrading during post-war reconstruction; the latter results are only significant in some specifications.

I show that the results are not driven by other changes that affected the German and

Austrian university system which may have been correlated with the two shocks. In particular, the results are robust to controlling for post-war occupation zones (U.S., U.K., French, or Soviet zones) and dropping East German and Austrian universities from the sample. The results are also robust to controlling for the creation of federal states after WWII. Similarly, controlling for changes at the university level, such as changes in university age and changes in competition from newly founded universities, does not affect the results. I also show evidence that changes at the city level are not driving my findings; the results are robust to controlling for bombing destruction at the city level, changes in the fraction of Jews in a city, investment in armament related industries by the Nazi government, and distance to the 'iron curtain' after the division of Germany. Furthermore, I show that the results are robust to controlling for mean reversion and university wide changes after 1945.

Recent work has highlighted the importance of 'star scientists' for the creation of scientific knowledge (Azoulay, Zivin, and Wang, 2010). Many of the dismissed scholars were among the leaders of their profession; my data include eleven dismissed Nobel Laureates such as the physicists Albert Einstein and Max Born and the chemists Fritz Haber and Otto Meyerhof. I can therefore investigate whether losing high quality scientists had particularly large effects on department output. The results indicate that losing high quality scientists and especially 'star' scientists caused particularly large reductions in output. The loss of a scientist in the top 5th percentile of the quality distribution, for example, lowered output by between 0.7 and 1.6 standard deviations, compared to an effect of 0.2 standard deviations for losing any scientist.

I then evaluate potential mechanisms that could explain the persistence of the human capital shock. A reduction in department size after the dismissals only explains some of the decline in output. I show that a key mechanism for the persistence of the human capital shock was a permanent fall in the quality of hires, in particular after losing high quality scientists. Recent work on the short-run effects of the dismissal of scientists in Nazi Germany has documented that the quality of PhD students declined in affected departments while the productivity of established scientists who were directly exposed to the dismissal of their colleagues was unaffected (Waldinger, 2010, 2012).[1] While this earlier research indicates that the productivity of faculty peers was *not* affected by the dismissal of high quality colleagues the results in the current paper show that departments with dismissals declined in the long-run. These results show that despite the absence of localized productivity spillovers the loss of human capital can have persistent negative effects on output because of a permanent decline in the quality of hires.

To my knowledge, no previous paper has analyzed the role of human and physical capital for the creation of scientific knowledge using exogenous variation in both inputs. Existing empirical evidence has shown that scientific output of university departments is correlated with department size and research expenditure (Johnes, Taylor, and Francis, 1993). At the country level, patenting is significantly related to R&D manpower and spending (Furman, Porter, and

[1]Similarly, Borjas and Doran (2012) document that the migration of highly qualified Soviet mathematicians to the United States did not lead to a productivity increase of incumbent U.S. mathematicians but rather to a decrease in publication output.

Stern, 2002).[2] In a recent paper, Agrawal, McHale, and Oettl (2013) show that hiring stars increases output of evolutionary biology departments through improved hiring but not through positive spillovers on existing members of the department.

My findings also relate to several papers investigating the persistence of large economic shocks. Physical capital shocks, such as extensive bombings, usually dissipate relatively quickly (Davis and Weinstein, 2002, Brackman, Garretsen, Schramm, 2004, Miguel and Roland, 2011). Most human capital shocks, however, seem to persist in the long-run. The extinction of the Jewish population in the Soviet Union by the German Army during WWII still affects city growth, per capita income, wages, and political outcomes today (Acemoglu, Hassan, Robinson, 2011) and reduces entrepreneurship and support for markets and democracy (Grosfeld, Rodnyansky, and Zhuravskaya, 2013). In Germany, the decline of the Jewish population during the Nazi era had persistent negative effects on education levels (Akbulut-Yuksel and Yuksel, 2011).[3] In the present paper I analyze the persistence of human and physical capital shocks within the same framework for the first time. My results corroborate the findings of earlier papers that have separately analyzed human and physical capital shocks.

This paper also improves our understanding of Germany's decline as scientific superpower after WWII. At the beginning of the 20th century, German scientists were at the pinnacle of their profession. The leading German universities, especially Göttingen and Berlin, attracted large numbers of foreign scholars. Physicists like Arthur Compton (Nobel Prize, 1927) and Robert Oppenheimer from the United States, Leo Szilard and Eugene Wigner (Nobel Prize, 1961) from Hungary, Enrico Fermi (Nobel Prize, 1938) from Italy, and many Germans such as Werner Heisenberg (Nobel Prize, 1932), Max Born (Nobel Prize, 1954), and James Frank (Nobel Prize, 1925) had permanent or visiting positions in Göttingen during the 1920s (Dardo, 2004, p. 171). Many of these illustrious scientists were later dismissed by the Nazi regime. Born and Franck were dismissed from their professorships in Göttingen; Szilard and Wigner, who had moved in the meantime, were dismissed from their positions in Berlin. After WWII, the importance of German science declined massively and the United States became the dominant force in science. This development is reflected in data on Nobel Prizes as shown in appendix Figure A1. Germany's decline may have been caused by a number of factors. The dismissal of some of the most prominent scientists (among them eleven Nobel laureates) and bombing destruction during WWII are obvious factors that I consider in this paper.

[2] A number of papers investigate other drivers of university output. University governance significantly affects how changes in funding affect research performance (Aghion et al., 2010). An increase of university level funding increases the number of published papers but not their quality (Payne and Siow, 2003, Whalley and Hicks, 2012). At the level of individual scientists, National Institutes of Health funding only has a limited impact on the research of marginal grant recipients (Jacob and Lefgren, 2011). Howard Hughes Medical Institute grants, however, which tolerate early failure and reward long-run success, increase the probability of publishing high-impact papers (Azoulay, Graff Zivin, and Manso, 2011).

[3] Economic historians have also argued that the forced emigration of approximately 200,000 Huguenots in 1685 had long-lasting effects on some parts of the French economy (Scoville, 1953, 1960). Similarly, the expulsion of 130,000 converted Muslims from the Kingdom of Valencia in 1609 had long-lasting negative effects on population and total output but positive effects on output per capita (Chaney and Hornbeck, 2013). Some historians also argue that the expulsion of 40,000 to 50,000 Jews from Spanish lands in 1492 caused long-lasting effects on the Spanish economy. More recent historical accounts, however, suggest that the expulsion may have had large effects in affected communities but that places with few Jews were not affected (Kamen, 1988).

My estimates indicate that the dismissals of scientists reduced total output in affected German and Austrian science departments by 9,576 top journal publications between 1933 and 1980; a reduction of about 33.5 percent. Total output as measured by citation weighted publications declined by 191,920 (34.6 percent) citations as a result of the dismissals. In the same time period dismissed scientists produced 1,181 top journal publications receiving 32,369 citations. These results indicate that German science lost much more than the publications of the dismissed scientists because the reduction in output in departments with dismissals persisted at least until 1980. WWII bombings of German and Austrian science departments reduced total output of affected departments by 1,028 top journal publications between 1944 and 1980; a fall of about 5.7 percent. Citation weighted publications declined by 22,194 (6.4 percent).[4] These calculations suggest that the dismissal of scientists in Nazi Germany contributed about nine times more to the decline of German science than physical destruction during WWII.[5]

2 Human and Physical Capital Shocks

The production of scientific knowledge uses human and physical capital as main inputs (Machlup, 1961). University governance determines how the inputs are combined to produce scientific knowledge. Recent research has shown that more autonomous universities and those operating in a more competitive environment are better at converting funding increases into research output (Aghion et al., 2009).

Estimating 'knowledge production functions' is challenging because departments adjust inputs on the basis of unobservable productivity shocks (Ackerberg et. al., 2007). More productive departments attract 'star scientists' who then make these departments even more successful. Similarly, more productive departments invest more in physical capital. Finally, good scientists prefer universities with well equipped laboratories and attract funding for additional physical capital. It is therefore difficult to establish causality in this context.

Even without these endogeneity concerns it is challenging to directly estimate the production function of universities because it is difficult to measure physical capital of science departments over reasonably long time periods. I therefore use an indirect way to identify the importance of human and physical capital by investigating the effect of large and, I argue, exogenous shocks to the human and physical capital of German and Austrian science departments. I estimate how the shocks affected department output in the short and long-run as follows:

$$\begin{aligned}\text{Output}_{dt} = \beta_1 &+ \sum_{t\neq 1931}^{t} \beta_{2t}\ \text{HCShock(1933-40)}_d * \text{Year}_t + \sum_{t\neq 1940}^{t} \beta_{3t}\ \text{PCShock(1942-45)}_d * \text{Year}_t \\ &+ \beta_4\ \text{DepartmentFE}_d + \beta_5 \text{YearFE}_t + \beta_5 \text{X}_{ct} + \varepsilon_{dt}\end{aligned} \quad (1)$$

$Output_{dt}$ is a measure of department d's research output in year t, i.e. total publications or citation weighted publications. $HCShock(1933\text{-}40)_d$ measures the shock to human capital during the dismissal of mainly Jewish scientists between 1933 and 1940. *PCShock(1942-45)*

[4] The time periods for these calculations differ for dismissals and bombings because dismissals started in 1933 and bombings intensified in 1943.

[5] For subject level results and details on these calculations see appendix section 9.3.

measures the shock to physical capital during Allied bombings that occurred between 1942 and 1945. I describe both shocks in more detail below. The interactions of the shocks with year dummies (one for each of the seven years between 1926 and 1980 for which I observe department output; one of those 7 interactions will be excluded as the omitted category for each shock) allow me to investigate the short and long-run effects of the two shocks.[6] As it took time to rehire after the dismissals and to rebuild destroyed departments after WWII the short-run effects inform us about the importance of human and physical capital inputs in the 'knowledge production function'. The long-run persistence of the two shocks indicates how quickly departments recovered from losses to human and physical capital.

2.1 Human Capital Shock: The Dismissal of Scientists in Nazi Germany

As human capital shock I use the dismissal of Jewish and 'politically unreliable' scientists by the Nazi government. Just over two months after the National Socialist Party seized power at the end of January 1933, the new government passed the "Law for the Restoration of the Professional Civil Service" on April 7, 1933. Jewish and 'politically unreliable' persons were dismissed from civil service positions in Germany. As anybody with at least one Jewish grandparent was to be dismissed, all civil servants had to document their ancestry until 1800 and those with Jewish grandparents were dismissed from service.

Scientists of Jewish origin who had been civil servants since 1914 or who had fought or lost a close family member in WWI were initially exempted. In 1935, however, the Reich Citizenship Law (Reichsbürgergesetz) revoked the exemption and remaining scientists of Jewish origin were ultimately dismissed. The 1933 law also served to dismiss civil servants with opposing political views such as members of the Communist Party. The law was immediately implemented and resulted in a wave of dismissals and early retirements from German universities. After the annexation of Austria on March 12, 1938, the law was extended to Austrian universities.[7]

Overall, more than 1,000 academics were dismissed from German universities. This included 15.0 percent of physicists, 14.1 percent of chemists, and 18.7 percent of mathematicians (Table 1). Most dismissals occurred in 1933, immediately after the law had been passed. The small

[6] One may be concerned that scientists died during the bombings and that bombings therefore affect human capital, as well. There is no evidence that the number of scientists who disappear from the sample between 1940 and 1950 is correlated with bombing destruction at the department level. In a regression of the number of scientists who disappear from the sample in each department (for non-retirement reasons) on bombing destruction, the coefficient on destruction interacted with the 1950 dummy is -0.006 with a p-value of 0.43. These results indicate that bombings are not related to sample attrition in affected departments. This evidence is consistent with historical accounts that show that the total number of bombing casualties in Germany was relatively low. Historians debate about the exact number of casualties but estimates range from 305,000 (United States Strategic Bombing Survey, 1945, p. 95) to between 750,000 and 1 million (Frankland, 2005, p. 833). Allied bombings therefore killed between 0.4 and 1.4 per cent of the 69.3 million people living in Germany at the beginning of WWII.

[7] For more details on the dismissal of professors and the consequences for Ph.D. students and contemporaneous effects on faculty peers see Waldinger (2010, 2012).

spike in dismissals in 1938 is driven by dismissals from Austrian universities.[8]

Many dismissed scientists were outstanding members of their profession. They published more papers in top journals and received more citations than average scientists. While 15.0 percent of physicists were dismissed, they published 23.8 percent of papers in top journals before 1933 and received 64 percent of the citations to papers published before 1933. In chemistry, 14.1 percent were dismissed but they wrote 22.0 percent of top journal articles, and received 23.4 percent of the citations. In mathematics, 18.7 percent were dismissed, but contributed 31.0 percent of top journal publications, and received 61.3 percent of the citations (Table 1).

My data do not allow me to identify whether researchers were dismissed because of their Jewish origin or because of their political orientation. Historical studies, however, have shown that about 87 percent of the dismissed in chemistry (Deichmann, 2001), and 79 percent of the dismissed in mathematics (Siegmund-Schultze, 1998) were either Jewish or of Jewish decent.

Most of the dismissed scientists emigrated and the majority of them obtained positions in foreign universities (Moser, Voena, and Waldinger, 2012). The main emigration destinations were the United States, the United Kingdom, Turkey, the British Mandate of Palestine (later Israel), and Switzerland.

The dismissals affected departments to a varying degree. There was a lot of variation across departments even within universities. Some departments lost more than 60 percent of their faculty while others did not lose anyone (Table 2).

2.2 Physical Capital Shock: Allied Bombings of Universities in World War II

I use destruction caused by allied bombings during WWII as a shock to physical capital. At the beginning of the war in 1939, the Royal Air Force (RAF) concentrated bombings on military targets, such as the German fleet. After the German invasion of the Low Countries and the bombing of Rotterdam by the Luftwaffe in May, 1940, the RAF started bombing other targets such as oil reservoirs, railway lines in the Ruhr area, aircraft factories, aerodromes, U-boat shipyards, and ports. To avoid the German antiaircraft defence the majority of raids were flown under the cover of darkness which made targeting extremely difficult.

At the end of 1940, the RAF flew the first "area attacks" on German cities to "affect the morale of the German people" (Webster and Frankland, 1961 p. 156) and to "concentrate the maximum amount of damage in the centre of town" (Peirse, 1940). The first "area attack" was flown by 134 RAF bombers on December 16, 1940, and targeted the inner city of Mannheim in the south of Germany as a response to the devastation of Coventry by the German Luftwaffe.

In 1941 the RAF increased the number of small scale area attacks on German cities. Most of these attacks, however, did not cause large destruction as only about 20 percent of bombers managed to navigate within five miles of their destination, even less managed to hit the target.

[8] Dismissals that occurred in German universities after 1933 affected researchers who had been exempted under the clause for war veterans or for who had taken up their position before 1914. Furthermore, some political dismissals occurred after 1933.

As a result, the smallest potential targets were whole towns (Frankland, 2005, Webster and Frankland, 1961, vol. 1, p.156, p.257). Even these were often missed. A bombing raid of Karlsruhe and Stuttgart on October 1st, 1941, for example, hit not only the two target cities but also 25 other cities, some of them several hundred kilometers away (Webster and Frankland, 1961, vol. 1, p. 185).

The appointment of Sir Arthur Harris as head of "Bomber Command" on February 23, 1942, and the "Area Bombing Directive" that was issued a week earlier caused an intensification of the bombing campaign as more planes were deployed in each raid. On May 30, 1942 the RAF flew the first 1,000 bomber attack against Cologne, a city that had been bombed with at most 40 planes in each of the 107 preceding attacks. The raid damaged about a third of Cologne's surface area (Hohn, 1991 p.12, Webster and Frankland, 1961, vol. 1, p. 340, pp. 402-410). To maximize destruction of inner cities the RAF used incendiary bombs that started fires in bombed cities. The introduction of heavy bombers (in particular the Lancaster bomber that was gradually introduced after March, 1942), the use of radar and radar-like devices (introduced in March, 1942), and the deployment of Pathfinder target marking planes (first used in January, 1943) increased the precision and efficiency of bombings.

In January, 1943 the United States Army Air Force (USAAF) entered the bombing campaign against Germany. While the British continued to fly night time raids and in particular area attacks against inner cities, the USAAF mostly attacked during the day and bombed strategically important targets such as the German aircraft and ball bearing industries.

The bombing of targets in Germany intensified in 1944 with the introduction of the "double blow" tactic. Two, or later three, bombing attacks over short time periods increased the efficacy of incendiary bombs. The increased air supremacy of the Allied forces further facilitated the bombings. Towards the end of the war the bombardments were extended to smaller cities that had been spared in previous attacks.

Overall, about 1.35 million tons of bombs were dropped over German territory. Data on monthly bomb loads show an almost continuous increase between 1940 and 1945, with particularly large increases in the last years of the war (Figure 1).

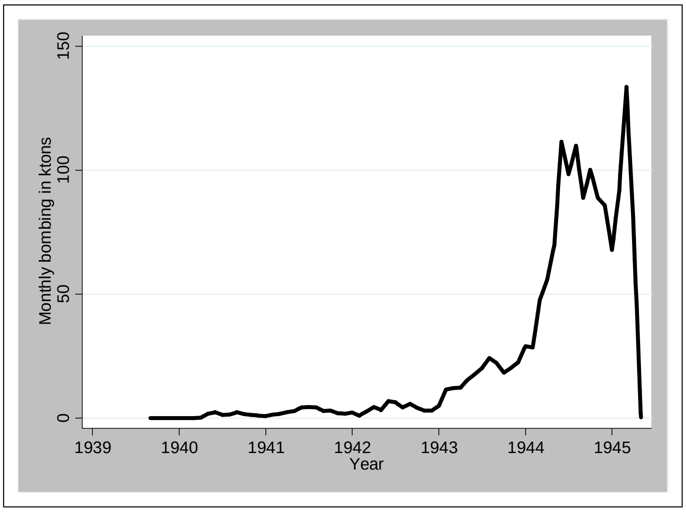

Figure 1: Allied bombings

Allied bombings completely destroyed about 18.5 percent of homes in what later became the Federal Republic of Germany (Hohn, 1991, p. 59). As area bombings targeted the inner cities of all larger cities they were most heavily affected.

Universities were never listed as targets in any of the Allied bombing directives and similar documents. Nonetheless, many university facilities were destroyed because bombs could not be precisely aimed until the end of the war. Because of targeting problems bombs fell relatively randomly within cities and there was large variation in destruction across different university departments (Table 2). Targeting buildings of particular departments would have been impossible. Because many bombing raids involved the use of incendiary bombs, fires in affected buildings destroyed most of the scientific equipment and important manuscripts that had not been relocated to safer locations.[9] At the relatively unimportant University of Cologne, for example, bombing raids of the chemical institute destroyed scientific materials such as chemicals, glass storage bottles, and other valuable equipment with a total value of about 50,000 RM (about 300,000 in today's US dollars). At the institute of applied physics bombings destroyed X-ray valve tubes, capacitors, electrical instruments and other apparatuses with a total value of about 127,000 RM (about 813,000 in today's US dollars) (Table A1).[10] The fires also destroyed many of the valuable private libraries that professors had assembled during their careers.

As bombings intensified in 1944 most science departments were hit in 1944 or 1945. For some universities I obtain exact dates for the first and last bombing raid that destroyed university buildings. According to these data, the first raid occurred in June, 1941, and destroyed buildings at the Technical University of Aachen. Bombing raids that hit other universities continued and intensified until the end of WWII.

After the end of the war on May 8, 1945, reconstruction of university buildings was initially hampered by a lack of funds and skilled craftsmen, missing supplies, and the devastation of

[9]Many departments relocated material to safer towns but many of them were bombed during the later stages of the war.

[10]At the time, Cologne had small science departments that were not particularly productive. At larger departments the loss of valuable scientific material was probably much larger.

many German cities. Most universities enlisted students to clear away rubble and to help with reconstruction. The universities of Bonn, Karlsruhe, and Hannover, for example, required up to 1,000 reconstruction service hours from its students until 1949 (van Rey, 1995 p. 42, Hoepke, 2007 p. 137, Wolters, 1950 pp. 123-129). Most universities had completed reconstruction by the end of the 1950s but some was not completed until the 1960s (Hoepke, 2007 p. 139, Technische Universität Dresden 1996, pp. 18-36).

3 Panel Data Set of Science Departments

3.1 Scientists in German and Austrian Universities from 1926 to 1980

To evaluate the effect of the two shocks I construct a new panel data set covering physicists, chemists, and mathematicians at German and Austrian universities. The data come from "Kürschners Deutscher Gelehrtenkalender" that has been published since the 1920s in 5 to 10 year intervals. Volumes published in 1926, 1931, 1940/41, 1950, 1961, 1970, and 1980 allow me to construct complete faculty rosters for science departments at these seven points in time spanning 54 years. From each volume I extract all scientists who were chaired professors, extraordinary professors, or 'Privatdozenten' (the first position in the German university system with the right to give lectures).[11] I include scientists from all 35 German or Austrian universities that existed in 1926 and remained on German (both FRG and GDR) or Austrian territory after 1945; see Table 2 for a listing of the universities in my sample.[12] For each university I obtain data on physics, chemistry, and mathematics departments; 105 science departments, overall.[13] The data appendix provides additional details and references on the data construction.

The micro data include 5,716 scientists (2,456 chemists, 2,000 physicists, and 1,260 mathematicians) with 10,387 person-year observations (4,605 in chemistry, 3,594 in physics, and 2,188 in mathematics). The number of scientists in German and Austrian universities increased massively after 1926. The exception is 1941 (and 1950 in chemistry), the first data point after the dismissal of scientists (Figure 2).

[11] Privatdozenten are comparable to junior faculty at U.S. universities. Extraordinary professors are comparable to associate professors and chaired professors are comparable to full professors in the U.S. system.

[12] This excludes three universities that were based in eastern territories that Germany lost after WWII. The University and Technical University of Breslau, now Wroclaw in Poland, and the University of Königsberg, now Kaliningrad in Russia. As the "Gelehrtenkalender" no longer listed researchers from these three universities after 1945 they cannot be included in the long-term analysis. Most scientists from these universities relocated to universities that continued to be in Germany after 1945.

[13] Scientists in universities located in the GDR were not listed in the "Gelehrtenkalender" in 1980.

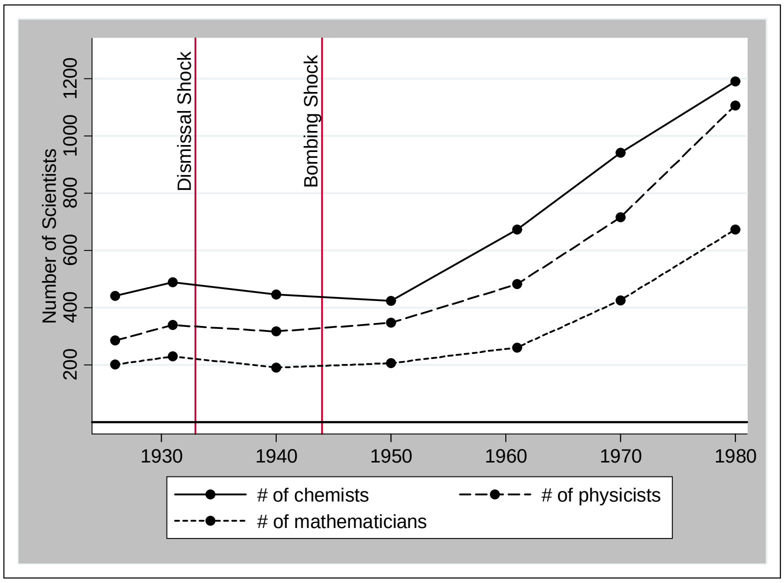

Figure 2: Number of scientists 1926-1980

3.2 Output of German and Austrian Science Departments

To measure department level output I obtain publications and citation weighted publications for each scientist in the sample. The publication data are downloaded from the "ISI Web of Science" and include all top journals for German and Austrian scientists. As journal rankings changed over time, I download both historical and current top journals.

The list of historical top journals includes all science journals published in Germany that the Web of Science covers for the period 1920 to 1944.[14] I add a number of general science journals (e.g. Nature and Science) and historically relevant international field journals (e.g. Acta Mathematica) that were outlets for German scientists in the 1920s and 30s. I augment this list of historical top journals with a set of current top journals that I obtain from commonly used journal rankings. Table A2 lists all journals used in the analysis and appendix 9.4 provides additional information on the journal data.

I then download all articles published between 1920 and 1985 in any of the journals in my list.[15] I can therefore calculate the number of top journal publications and citation weighted publications for each scientist and year. The Web of Science data only include the last name and the initial of the first name (or two initials if the author uses two first names) for each author. Most German scientists have distinct last names that are also different from most foreign names. In the rare cases that the last name and first initial do not uniquely identify a scientist in my

[14] Historical journals with coverage in the Web of Science were the top journals at their time because Thomson Scientific digitized only the most cited journals for the period 1900 to 1944. See http://wokinfo.com/products_tools/backfiles/cos/ for further information on the digitization of historical top journals.

[15] A few top journals, such as Physical Review Letters, were founded after 1920. For these journals I download all articles after their creation. The changing pool of journals does not affect my findings as all regressions include year fixed effects.

data I split (citation weighted) publications according to the number of scientists with the same last name and first initial. Table A3 shows the most cited scientists in my data. Most of them are very well known in the scientific community. This indicates that the output measures carry meaningful information. Interestingly, Johann von Neumann who later emigrated to the United States is the most cited mathematician.

To measure department output for each of the seven points in time I add individual output measures within departments. Individual output is measured using a five year window around the relevant year. Albert Einstein's individual output measure for 1926, for example, is the sum of his publications between 1923 and 1927.[16] I then sum the individual output measures within departments. Say a department had three scientists with individual output equal to 1, 2, and 3; total department output would be 1+2+3=6. The Web of Science data also include information on the number of times each article was subsequently cited in any journal covered by the Web of Science. This allows me to construct an analogous output measure based on citation weighted publications.[17]

Publication and citation patterns are different across the three subjects. To ensure comparability across subjects I normalize total department output to have zero mean and unit variance in each subject. This also allows for easy interpretation of the estimated regression coefficients.

3.3 Data on Dismissals

I obtain data on dismissed scientists from a number of sources. The main source is the "List of Displaced German Scholars". It was compiled by the relief organization "Emergency Alliance of German Scholars Abroad" that had been founded by some dismissed scientists with the purpose of supporting other dismissed scholars to find positions in foreign universities. The list was published in 1937 and contained about 1,650 names of dismissed researchers. I extract all dismissed physicists, chemists, and mathematicians from the "List".

As the "List" was published before 1938 it did not include dismissals from Austrian universities. I consult the "Biographisches Handbuch der deutschsprachigen Emigration nach 1933 - Vol. II : The arts, sciences, and literature (1983)" to obtain dismissals from Austria. This source also contains a few additional dismissals from German universities, for example, because dismissed scientists passed away before the "List of Displaced German Scholars" was compiled. The two sources together cover about 90 percent of all dismissals. I augment this information with data on a few additional dismissals from three secondary sources compiled by historians who have studied the dismissal of scientists in Nazi Germany.[18]

[16] Publications are measured using an asymmetric window around the relevant year of the "Gelehrtenkalender"; i.e. output for the faculty in 1926 is measured with publications between 1923 and 1927 (instead of publications between 1924 and 1928). This asymmetry accounts for the delay in the publication of the "Gelehrtenkalender" as questionnaires for a certain volume had to be sent out and returned before publication. Using a symmetric window to compute average output does not affect the results.

[17] The citation weighted productivity measure is constructed as above by adding all citations to publications published in a five year window around the relevant year. Citations are counted until today.

[18] Dismissed chemists are contained in Deichmann (2001), dismissed physicists in Beyerchen (1977) and dismissed mathematicians in Siegmund-Schultze (1998).

3.4 Data on Bombings of Science Departments

No existing data set covers bombing destruction of German and Austrian science departments. To measure department level bombing destruction, I therefore assemble new data based on information from university archives. After bombing raids university institutes often provided detailed destruction reports to obtain funds and materials for reconstruction. These reports and other sources allow me to construct a measure of destruction at the department level.

To obtain this information I first contacted university archivists and asked them for information on destruction levels for all buildings used by physicists, chemists, and mathematicians. In most universities bombing destruction was reported as percentage of buildings that were destroyed by the bombings. I therefore use percentage destruction to measure the physical capital shock. Some universities provided very accurate descriptions or even maps of bombing destruction (see Figure A2 for a map provided by the Technical University of Berlin). Other departments did not report destruction in percentages but gave verbal descriptions of bombing damages instead. I convert this information into percentage destruction using a rule outlined in appendix 9.4. If university archivists could not provide adequate information, my research assistant or I personally consulted the relevant archive to obtain a department level measure of bombing destruction.[19]

While percentage destruction measures the destruction of buildings the measure also proxies for destruction to scientific equipment and materials. As highlighted above for the case of Cologne, the bombing raids often destroyed scientific equipment and other physical inputs. Unfortunately, detailed data on the destruction of scientific equipment is not available for most universities.

To analyze the importance of measurement error I also construct a measure of bombing destruction at the university level. The data for this alternative measure come from information on university websites and a number of additional sources (Tietze, 1995, Phillips, 1983, Samuel and Thomas, 1949, Schneider, 1990, and Cheval, 1991). Appendix 9.4 provides additional details on the destruction data.

3.5 Data on Control Variables

To investigate the robustness of my findings to the inclusion of additional controls I obtain data on university age, the creation of nearby universities, the share of firms in armament related industries in 1933, the fraction of Jews at the city level in 1933, and the distance to the 'iron curtain'. Further information on the control variables can be found in appendix 9.4.

The final data set contains panel data for German and Austrian science departments covering seven points in time (1926, 1931, 1940, 1950, 1961, 1970, and 1980). The data include different

[19] As we could not obtain a measure for destruction at the department level for the University of Darmstadt I use university level destruction in this case.

measures of department output, information on dismissal and bombing shocks, and time-varying control variables.

4 The Effect of Human and Physical Capital Shocks on Department Output

4.1 Main Results

I investigate how the human and physical capital shocks affected output in the short-run (before departments fully adjusted to the shocks) and in the long-run by estimating equation (1). I start by analyzing the dismissal shock. As dismissals occurred between 1933 and 1940, with most dismissals happening in 1933, the first post-dismissal observation is 1940. The short-run results indicate that between 1931 (the last data point before the dismissals) and 1940 output in departments with one more dismissal fell by .17 standard deviations compared to departments without dismissals (Table 3, column 1). Coefficients on the interactions with subsequent years indicate that this effect persisted in the long-run until 1980. Controlling for subject times year fixed effects to allow for differential output trends in the three subjects does not affect the results (column 2). Further controlling for occupation zone (U.S. zone, U.K. zone, French zone, Soviet zone) times post-1945 dummies has a negligible effect on estimated coefficients but lowers standard errors (column 3). Estimates imply that the dismissal of one scientist lowered department output, even in the long-run, by between 0.17 and 0.28 standard deviations (column 3).

I next analyze the bombing shock. As bombings intensified towards the end of the war, the first post-bombing observation is 1950. The short-run results indicate that output of departments with 10 percent bombing destruction declined by .05 standard deviations between 1941 and 1950 compared to departments without destruction. This effect is only significant at the 5 percent level if I control for subject times year fixed effects and occupation zone times post-1945 dummies (Table 3, columns 4 to 6). Output recovered quickly after WWII. Already in 1961, there was no significant difference between departments that were bombed during WWII and other departments. By 1970, departments that were bombed even performed slightly better than other departments. While the 1970 results are only significant at the 10 percent level in two of the three specifications they suggest that upgrading during reconstruction may have had a small positive effect on output in the long-run.

Jointly estimating effects of the bombing and dismissal shocks leads to similar conclusions (Table 3, columns 7 to 9). To investigate whether the bombing results are driven by the destruction of department buildings or by more general destruction at the city level, I add interactions of year dummies with city level destruction to the regression. The results do not change substantially (Table 3, column 10). This indicates that output is primarily driven by department facilities and not by more general city level destruction.

To investigate the relative magnitude of the two shocks I plot the effect of 10 percent shocks to the human and physical capital of a hypothetical science department. For this exercise I scale the coefficients and standard errors reported in column (10) of Table 3 to reflect a 10 percent shock to both human and physical capital.[20]

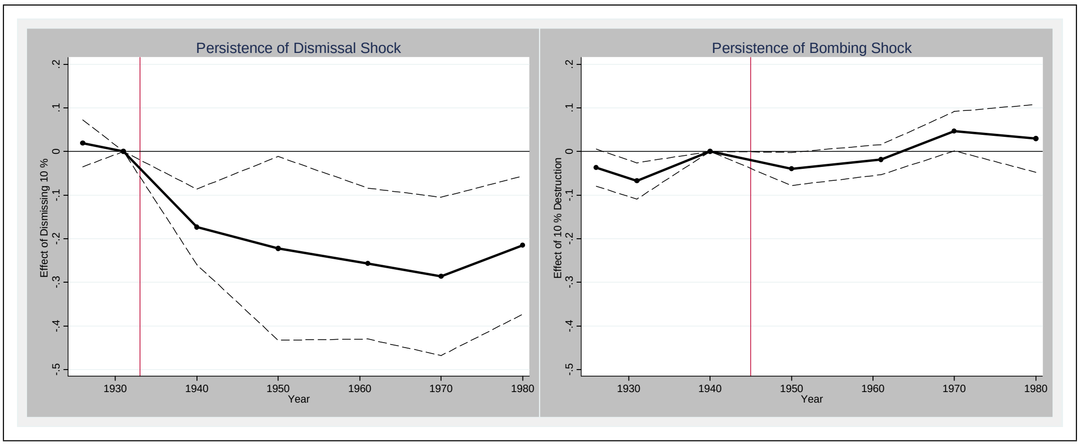

Figure 3: Persistence of 10% shocks - publications

Note: The figure plots scaled regression coefficients and 95 percent confidence intervals obtained from the estimation of equation (1) as reported in column (10) of Table 3. Point estimates and confidence intervals are scaled to reflect a 10 percent shock to both human and physical capital.

In the short-run, before departments could re-hire and reconstruct, a 10 percent shock to human capital reduced output about four times more than a 10 percent shock to physical capital (Figure 3).[21] While the human capital shock persisted for almost 50 years until 1980, the physical capital shock dissipated quickly and even had a small positive effect on output in 1970. The figure also shows that pre-trends are unlikely to drive the human capital results. For the bombing shock the coefficient on the interaction of the 1931 dummy with WWII destruction is negative and significant. This indicates that output of departments that were bombed during WWII improved before the bombings occurred. This pre-trend suggests that the effect of bombing destruction may be underestimated in 1950. I show below, that including additional controls reduces the magnitude and significance of the pre-war bombing coefficients while leaving the post-war coefficients unchanged.

For the previous results output was measured as the sum of publications in top journals (normalized to have a mean of zero and a standard deviation of one). An alternative output measure uses citation weighted publications. This measure multiplies publications by the number of subsequent citations in any journal covered by the Web of Science (again normalized

[20] Average department size in 1931 was 10.15. A 10 percent shock to human capital therefore corresponds to losing 1.015 scientists. I therefore multiply the dismissal coefficients and standard errors reported in column (10) of Table 3 by 1.015. As departmental destruction is already measured in percentages, I multiply the bombing coefficients and standard errors reported in column (10) of Table 3 by 10.

[21] In 1950, the p-value of a test of the Null hypothesis (1.015*coefficient # dismissed*1950) = (10*coefficient % destruction*1950) has a p-value of 0.097. For all later years, the effect of a 10 percent human capital shock is significantly larger (at the 5 percent level) than a 10 percent physical capital shock (p-values between 0.001 and 0.012).

to have a mean of zero and a standard deviation of one). The citations quantify the quality of each published paper using valuations of the entire scientific community. The alternative output measure yields similar results (Table 4). The dismissal of one scientist reduced output, even in the long-run, by between 0.16 and 0.22 standard deviations (column 10). Bombings had a small negative, but insignificant, effect in 1950. By 1970, bombed departments even performed slightly better (significant at the 10 percent level). Figure 4 plots the effects of 10 percent shocks to human and physical capital corresponding to the estimates reported in column (10) of Table 4. The dismissal shock had a larger effect than the bombing shock and was much more persistent.[22]

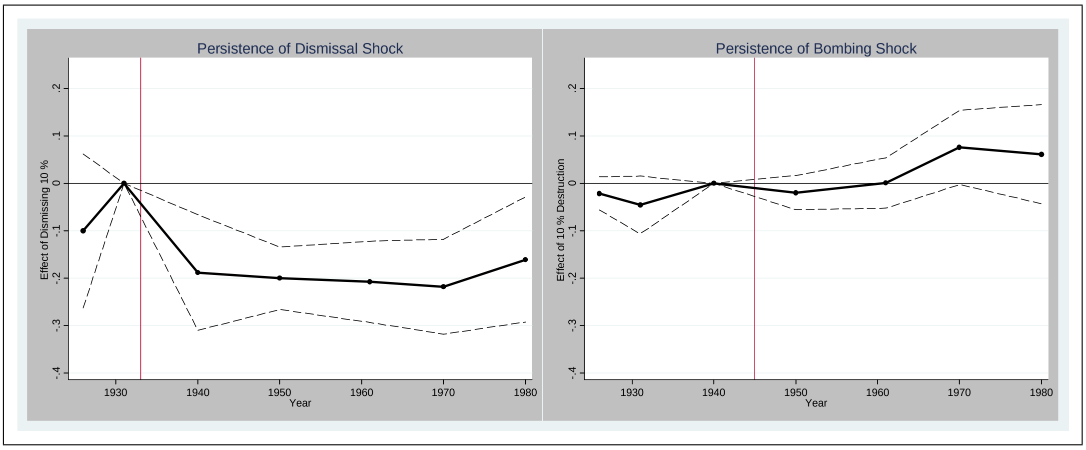

Figure 4: Persistence of 10% shocks - citation weighted publications

Note: The figure plots scaled regression coefficients and 95 percent confidence intervals obtained from the estimation of equation (1) as reported in column (10) of Table 4. Point estimates and confidence intervals are scaled to reflect a 10 percent shock to both human and physical capital.

4.2 Robustness of Main Results

In the following, I show that the results are robust to the inclusion of additional control variables and to the adjustment of output for changes in a department's age-structure. I also investigate whether the use of different samples, different definitions of the two shocks variables, measurement error in destruction, university wide changes after 1945, and controlling for mean reversion affect the results.

Additional Controls and Changes in Departments' Age Structure

After WWII, federal states (Länder) became responsible for universities in West Germany. To investigate whether these changes were correlated with the shocks and therefore affect my findings, I add interactions of federal state indicators with a post-1945 dummy to the regression.[23] Reassuringly, the results remain almost unchanged (Tables 5 and 6, column 1).

[22] The test of the Null hypotheses (1.015*coefficient # dismissed*year dummy) = (10*coefficient % destruction*year dummy) has p-values between 0.000 and 0.011.

[23] The GDR was a centralized state and did not re-introduce federal states after WWII. I therefore include a

I also add university age and its square as additional controls. This specification allows me to investigate whether the two shocks disproportionately affected older (or younger) universities that may have been on different output trends. The results are almost unaffected (Tables 5 and 6, column 2).

During the post-war period, in particular during the 1960s and 1970s, a number of new universities were founded in Germany and Austria. Increased competition from these universities may have influenced the output of established departments. To investigate whether the results are affected by these changes I include a time-varying control that measures the number of departments within 50 kilometers of each science department. The results remain unchanged (Tables 5 and 6, column 3).

After the Nazi government seized power in 1933, it invested heavily in rearmament (Tooze, 2006). This investment was concentrated in a few industries and may therefore have impacted department output in cities with firms that benefitted from rearmament spending, either through spillovers from industry to universities or because the Allies may have targeted these cities during the bombing campaign. To investigate whether investments in the armaments industry affects the results I include the interaction of the share of firms in three armament related industries with year dummies as additional controls.[24] The results change only very slightly (Tables 5 and 6, column 4).

Departments with more Jewish scientists may have been located in cities with a higher fraction of Jewish residents. The disappearance of the Jewish population may have had long-lasting effects on these cities (Acemoglu, Hassan, Robinson, 2011, and Grosfeld, Rodnyansky, and Zhuravskaya, 2013, and Akbulut-Yuksel and Yuksel, 2011) that could have affected science departments in the long-run. To investigate the effect of these changes on my results, I add the interaction of a post-1945 dummy with the fraction of Jews at the city level in 1933 to the regression.[25] If anything, the dismissal coefficients become slightly more negative (Tables 5 and 6, column 5). This indicates that the extinction of Jews from German and Austrian cities is not driving the results.

Finally, I investigate whether the two shocks were correlated with the geographic location of universities. Universities in cities that were closer to the 'iron curtain' may have suffered after 1945 because these cities experienced a decline in population growth after the division of Germany (Redding and Sturm, 2008). To investigate this issue I add the interaction of a post-1945 dummy with distance to the iron curtain to the regression. The results remain unchanged (Tables 5 and 6, column 6).

joint indicator for all universities in East Germany, including the Technical University of Berlin that was located in West Berlin. The federal states of Hamburg and Schleswig-Holstein had only one university and I therefore combine them with the adjacent state of Niedersachsen. The five Austrian universities are also covered by a joint indicator.

[24]The three armament relevant industries are iron and steel production, mechanical engineering and vehicle construction, and chemicals. The shares of firms in these industries are measured in 1933 (1930 for Austrian cities). They are therefore determined before the Nazi government seized power and are not endogenously affected by the two shocks.

[25]For Austrian cities the fraction of Jews at the city level is measured in 1934 (Vienna) and 1938 (Graz and Innsbruck) and thus before the annexation of Austria by Nazi Germany in 1938.

Figure 5 shows the effect of 10 percent shocks including all controls. The figure looks similar to the previous figure with the limited set of controls (Figure 3) but the coefficients on the human capital shock are slightly larger than the baseline results. This suggests that the results are not driven by other factors that may have affected scientific output. The figure also indicates that the addition of controls reduces the magnitude and significance of pre-trends for the bombing results while leaving the effect in 1950 unchanged. The equivalent figure for citation-weighted publications can be found in the appendix (Figure A3).

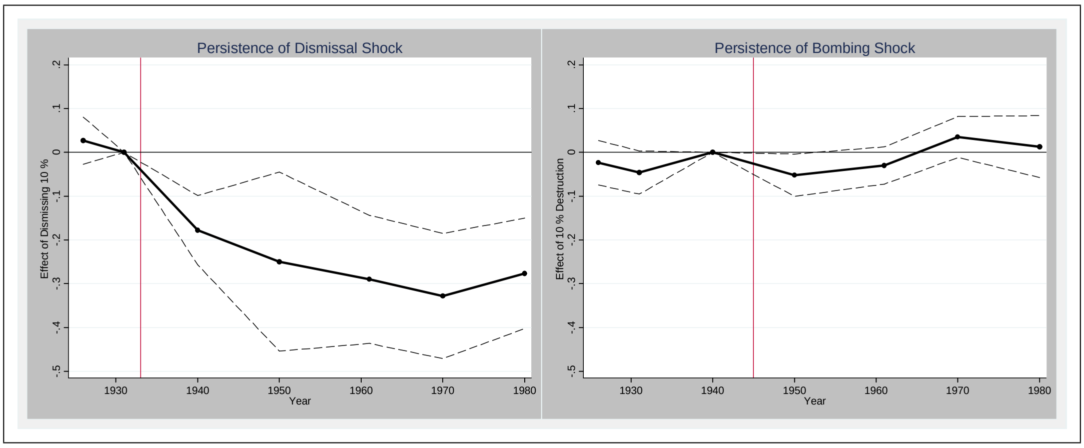

Figure 5: Persistence of 10% shocks - publications with all controls

Note: The figure plots scaled regression coefficients and 95 percent confidence intervals obtained from the estimation of equation (1) as reported in column (6) of Table 5. Point estimates and confidence intervals are scaled to reflect a 10 percent shock to both human and physical capital.

Output of scientists follows a concave pattern over their lifetime (Levin and Stephan, 1991). Some changes in the age structure of departments are endogenous to the dismissals because departments with dismissals may have had to hire younger researchers, for example. If this were the case one should not control for endogenous changes in the age structure of departments. Nevertheless, I investigate whether the results are driven by these changes. I adjust output by regressing individual output on a full set of age dummies (in 5 year bins). The residuals from this regression are then used to construct department output that I normalize to have a zero mean and a standard deviation of one. Using age-adjusted output as the dependent variable yields similar results (Tables 5 and 6, column 7).

Different Samples

The main sample includes all German and Austrian universities that existed before 1926. Dropping Austrian science departments from the sample does not affect the results (Tables 7 and 8, column 1). German universities include universities in West Germany (FRG) and East Germany (GDR). Reconstruction and re-hiring may have been different in the GDR compared to the market economy of the FRG. Dropping East German departments from the sample only slightly reduces the absolute magnitude of the coefficients suggesting that the results are not primarily driven by a different development in the GDR (Tables 7 and 8, column 2). These results also demonstrate that the special situation of the University of Berlin that was located in the Soviet sector does not drive the results.[26] In specifications not reported in the table I also show that the results are robust to dropping both Austria and the GDR.

In an additional test I use Swiss universities as an alternative control group. As Jewish scientists were of above average quality they worked in above average quality departments. As a result, German and Austrian departments without dismissals may not be an approriate control group for the high quality departments that experienced dismissals. To investigate this concern, I use four German speaking Swiss universities as an alternative control group.[27] Some of the Swiss universities are among the top universities in the German speaking world. I estimate results in a sample that only includes German and Austrian departments who lost people during the dismissals and the Swiss departments as control departments. Results are highly significant with point estimates that are mostly larger than the main results (Tables 7 and 8, column 3).

Different Shock Measures

In the main specification the human capital shock measure counts the number of dismissals in each department. This will allow me to disentangle dismissals into different quality groups in the following section of the paper. An alternative measure of the human capital shock uses percentage dismissals in each department. Results that use this alternative measure are less significant, in particular for publications. The magnitude of the coefficient of a 10 percent decline in department size, however, is very similar to the baseline specification (Tables 7 and 8, column 4).

As outlined above, most dismissals took place during the first years of the Nazi regime. When I measure the human capital shock using only early dismissals between 1933 and 1934 estimates remain similar to the baseline results (Tables 7 and 8, column 5).

The dismissal shock was confined to particular departments because most scientists specialize in only one subject. As a result, universities could not reallocate physicists to chemistry departments if a university had few dismissals in physics but many in chemistry. Following a bombing shock, however, universities could reallocate buildings across departments. This could have mitigated any negative effect of bombing destruction at the department level. To investigate whether universities reallocated buildings after the bombings, I use an alternative destruction measure that captures average destruction across all science departments. Using this alternative measure yields a more negative coefficient for the interaction of bombing destruction with the 1950 dummy. The destruction of an additional 10 percent of science buildings lowered output by 0.11 instead of 0.05 standard deviations (Table 7, column 6). In regressions that use citation weighted publications as the dependent variable, the coefficient changes from

[26] The University of Berlin was located in the Soviet sector of Berlin. It reopened in January 1946 (and was renamed Humboldt University in 1949). In 1948, the Free University of Berlin was founded in the U.S. sector of Berlin.

[27] Swiss universities are not part of the main sample because they hired a small number of dismissed scientists. The University of Basel hired one dismissed chemist, but no physicists or mathematicians, the Technical University in Zurich hired one mathematician, but no physicists or chemists, the University of Zurich hired one physicist, one chemist, but no mathematician, and the University of Bern did not hire any dismissed scientists.

-0.04 to -0.08 (Table 8, column 6). These results suggest that universities could mitigate some of the bombing effects by reallocating buildings across departments.[28] Using this alternative destruction measure I also find a slightly more persistent decline in output after the bombings. When I use publications as the dependent variable the negative effect persists until 1961 (significant at the 10 percent level) (Table 7, column 6) but not if I use citation-weighted publications (Table 8, column 6). By 1970, bombed departments had completely recovered independently of the destruction and output measures. In fact, citation-weighted publications were significantly higher in bombed departments in 1970. This further suggests that bombed departments may have benefitted from upgrading during reconstruction.

Measurement Error in Bombing Destruction

The destruction measure of some departments may contain measurement error. To investigate whether this attenuates the bombing results I instrument for department level destruction with destruction at the university level.[29] The measure of university destruction is based on data from different sources than the measure of department destruction (see appendix 9.4). As a result, the two measurement errors should be uncorrelated. The instrumental variable strategy should therefore minimize attenuation bias. First-stage regressions are reported in Table A4 and indicate that university destruction is a strong predictor of department destruction.[30] The instrumental variable results indicate that publications in departments with 10 percent more destruction fell by 0.13 standard deviations in 1950. In 1961, departments with 10 percent more bombing destruction still had 0.11 standard deviations lower output. By 1970, however, output had recovered in bombed departments (Table 7, column 7). Equivalent results for citation-weighted publications indicate that output in departments with 10 percent more destruction fell by 0.08 standard deviations in 1950, and 0.05 standard deviations (significant at the 10 percent level) in 1961. By 1970, output had completely recovered (Table 8, column 7). These results suggest that measurement error attenuates the bombing results for 1950 and 1961. The finding that bombed departments had completely recovered by 1970, however, is not distorted by measurement error.

University Wide Changes after 1945

It may be the case that dismissals or bombings were related to university wide changes that occurred after 1945, such as a reorientation of the university's focus away from sciences towards

[28] An alternative explanation for the larger coefficient (in absolute magnitude) could be lower measurement error for science wide destruction compared to destruction in each individual science department.

[29] As the university level destruction measure captures destruction of all university buildings it is different from the average destruction in science departments that has been used above.

[30] As I instrument for all interactions of year dummies with department level destruction, I estimate six first stage regressions: one for the interaction of % subject destruction with the 1926 dummy, one for the interaction of % subject destruction with the 1931 dummy, and so on. As a result, the usual F-test on the excluded instruments is not appropriate in this context. Stock and Yogo (2005) propose a test for weak instruments based on the Cragg-Donald (1993) Eigenvalue Statistic. Stock and Yogo (2005) only provide critical values for up to two endogenous regressors. With two endogenous regressors and two instruments the critical value is 7.03. Here, I use six instruments for six endogenous regressors. Appropriate critical values should be lower than 7.03. The Cragg-Donald EV statistic reported in Table A3 is 19.6. Weak instruments should therefore not bias the results.

other fields. To investigate whether such changes are driving the results I include the interaction of a full set of 35 university fixed effects with a post-1945 dummy in the regression. Results indicate that publication output fell by 0.16 to 0.23 standard deviations after the dismissal of one scientist with the majority of results remaining significant at the 1 percent level (Table 7, column 8). The coefficient on bombing destruction interacted with the 1950 dummy indicates that output fell by 0.04 standard deviations in 1950 but this result is no longer significant. Equivalent results for citation-weighted publications indicate that output fell by 0.12 to 0.18 standard deviations after the dismissal of one scientist but only the 1940 coefficient remains significant at the 5 percent level (Table 8, column 8). The coefficient on bombing destruction interacted with the 1950 dummy indicates that output fell by 0.03 standard deviations in 1950, but as for publications the result is no longer significant.[31]

Controlling for Mean Reversion

Some of the dismissals affected the best universities such as Göttingen or Berlin. It is possible that the relative quality of these departments would have declined even without dismissals because of mean reversion. To investigate this hypothesis I include the interaction of department quality in 1926 with the number of years that have passed since 1926 as additional control.[32] Results that control for mean reversion yield smaller coefficients for the dismissals and indicate that the dismissal of one scientist lowered output by between 0.10 and 0.15 standard deviations. Most coefficients remain significant at the 1 percent level (Table 7, column 9). The bombing results remain relatively similar. Equivalent results for citation-weighted publications indicate that the dismissal of one scientists lowered output by between 0.11 and 0.17 standard deviations with most coefficients significant at the 5 percent level (Table 8, column 9). Bombing results indicate a small but significantly negative effect on output in 1950 that was not persistent.

Complementarities of Human and Physical Capital Shocks

The empirical model estimated above does not allow for complementarities of human and physical capital. To investigate whether complementarities are important I add triple interactions of number dismissed, percentage destruction, and year dummies to the regression, i.e. I estimate

$$\begin{aligned}\text{Output}_{dt} = \beta_1 &+ \textstyle\sum_{t\neq 1931}^{t} \beta_{2t}\text{HCShock(1933-40)}_d * \text{Year}_t + \textstyle\sum_{t\neq 1940}^{t} \beta_{3t}\ \text{PCShock(1942-45)}_d * \text{Year}_t \\ &+ \textstyle\sum_{t\geq 1950}^{t} \beta_{4t}\ \text{HCShock(1933-40)}_d * \text{PCShock(1942-45)}_d * \text{Year}_t \\ &+ \beta_5\ \text{DepartmentFE}_d + \beta_6\text{YearFE}_t + \varepsilon_{dt} \qquad (2)\end{aligned}$$

The first data point that could have been affected by both shocks is 1950. I therefore include the triple interactions for the years 1950, 1961, 1970, and 1980. The publication results show that departments with dismissals that were subsequently bombed did significantly worse than other departments in 1950. The estimated coefficient indicates a reduction in publications by

[31] Alternatively, one could include the interaction of university fixed effects with a dummy for each year (i.e. adding 35*6=210 interactions). As the degrees of freedom become small (714 observations - 210 university FE*year - 105 department fixed effects - 18 subject*year FE - 30 time varying controls - 1 constant) and dismissals and bombings within universities are positively correlated the results are no longer significant.

[32] Department quality in 1926 is measured as the sum of (citation-weighted) publications for the specification with (citation-weighted) publications as the dependent variable.

0.03 standard deviations in departments that lost one scientist and 10 percent of department buildings. As departments recovered quickly from the physical capital shock triple interactions with later years are no longer significant. (Table A5, column 2). For the citation weighted output measure all triple interactions are insignificant (Table A5, column 4). The dismissal results are remarkably robust to the inclusion of the triple interactions. The findings suggest that there are some complementarities between human and physical capital but that these are relatively minor. Furthermore, human capital effects are not driven by important complementarities with physical capital.

4.3 Subject Specific Results

Data on the three subjects allow me to investigate whether the human and physical capital shocks had different effects across disciplines. While physical capital may be more important in chemistry and some fields of physics it is presumably less important in mathematics. The estimation results, however, indicate that the decline in output after the physical capital shock hardly differed across fields (Table 9).

Despite the fact that most results are less precisely estimated because of smaller sample sizes, the dismissal results reveal interesting differences across subjects. If one considers citation weighted publications as the output measure, the results are largest and most persistent in mathematics, followed by physics (even though most coefficients in physics are not significant), and then chemistry (Table 9, columns 2, 4, and 6). As dismissals in mathematics and physics were of higher quality than in chemistry (Table 1) the results suggest that high quality scientists may be particularly important for science departments.

4.4 The Effect of High Quality Scientists

To further investigate this hypothesis I assign scientists to quality percentiles based on their pre-dismissal citation weighted publications. I then investigate how the dismissal of high quality scientists affected department output. The dismissal of any scientist lowered department output by 0.18 to 0.32 standard deviations (Table 10, columns 1 and 2). The dismissal of a scientist whose pre-dismissal citation-weighted publications put him above median quality lowered output by between 0.24 and 0.50 standard deviations (columns 3 and 4). The dismissal of higher quality scientists caused even larger reductions in output that persisted in the long-run. The dismissal of a scientist in the top 5th percentile lowered output by 0.7 to 1.6 standard deviations (columns 9 and 10). Figure 6 summarizes these findings graphically.[33]

[33] To improve clarity I do not report confidence intervals. The majority of estimated coefficients are significantly different from 0 (Table 10).

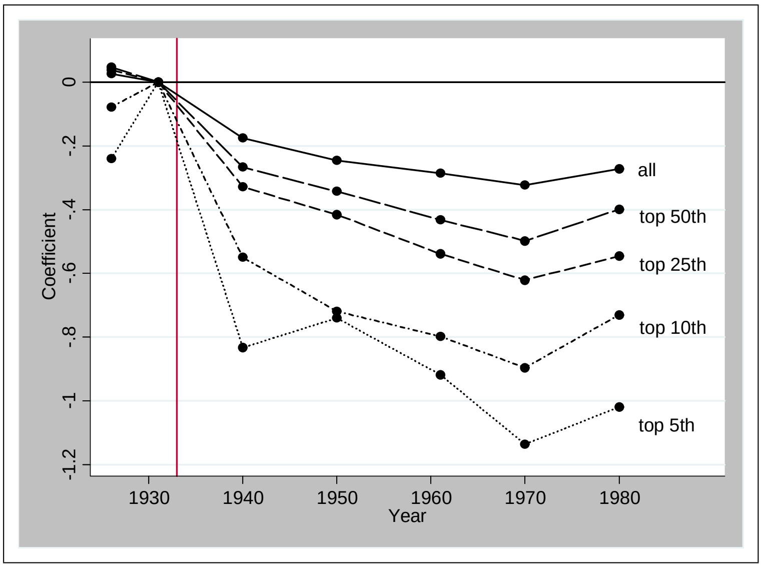

Figure 6: Persistence of high quality dismissals

Note: The figure plots regression coefficients reported in Table 10. The dependent variable is the total number of publications in department d and year t. The top line reports coefficients on the interaction of the number of dismissals (between 1933 and 1940) with year dummies as in column (1). The second line from the top reports coefficients on the interaction of the number of dismissals of above median quality with year dummies as in column (3), and so on.

The figure shows declines in output after the dismissal of a scientist of the relevant quality group: the higher the quality of dismissals the larger the decline in output.[34]

5 Mechanisms for the Persistence of the Human Capital Shock

The main results indicate that human capital is particularly important for the output of science departments. In the short-run a 10 percent shock to human capital lowered output about four times more than a 10 percent shock to physical capital. Furthermore, I find strong persistence of the human capital shock, with especially large declines after the dismissal of high quality scientists. In the following, I investigate possible mechanisms for the long-run persistence of the temporary dismissal shock.

The Effect of Dismissals on Department Size

One possible explanation for the decline in output could be a relative fall in department size from which departments never recovered. I investigate this hypothesis by regressing department

[34]The coefficients reported in the figure are estimated in separate regressions for each quality group. As dismissals in different quality groups are correlated within departments it is difficult to jointly estimate results for five quality groups. To investigate how results are affected when I jointly investigate the effect of losing scientists of different quality I split dismissals into three quality groups (bottom 50 percentiles, between the top 50th and the top 10th percentile, and top 10th percentile and above). Results are reported in Figure A4 and Table A6 and confirm that high quality dismissals are particularly detrimental. I also investigate whether the dismissal results are entirely driven by very high quality scientists. For this test I exclude dismissed scientists whose citation-weighted publications place them in the top 5th percentile. The dismissal effect remains significant when I use this alternative dismissal measure (results available upon request).

size on the dismissal and destruction variables. Departments with dismissals were significantly smaller until 1970 but their size had completely recovered by 1980 (Table 11). These results indicate that a fall in department size can only explain some of the persistence of the human capital shock.[35]

The Effect of Dismissals on the Quality of Hires

An alternative mechanism for the persistence of the human capital shock may be a permanent fall in the quality of hires. 'Star scientists' are often instrumental in attracting other high quality faculty. Before 1933, for example, the great mathematician David Hilbert was instrumental in attracting theoretical physicist Max Born (Nobel Prize, 1954) to the University of Göttingen. Max Born then used his influence to hire experimental physicist James Franck (Nobel Prize, 1925) (Jungk, 1963 pp. 22-23). Born and Franck were dismissed from the University of Göttingen in 1933. It is likely that these and other dismissals permanently affected the quality of subsequent hires.

I therefore investigate whether hiring quality declined in departments with dismissals, especially after departments lost high-quality scientists. I identify hires from changes in the composition of departments. As a result, I can measure hiring quality from 1931 onwards. For 1931 for example, I classify all scientists who joined a department between 1926 and 1931 as a hire. I obtain equivalent measures for subsequent years. I then construct two measures of the quality of each hire. Arguably the best measure for a scientist's quality are average citation weighted publications over the whole career span. As this measure may be endogenous to a scientist's moving decision I also compute an alternative measure that quantifies quality by pre-hiring citation weighted publications. While this alternative measure is less likely to be endogenous to the moving decision it is a noisier measure of quality, in particular for young scientists. I normalize both of these measures to have a zero mean and a standard deviation of one within subjects. I then construct hiring quality for each department and year by calculating the average quality of all hires.

I regress this measure for hiring quality on the number of dismissals interacted with year indicators. I also control for bombing destruction as above. Using lifetime citation weighted publications to measure quality I find that the dismissal of one scientist lowered hiring quality by between 0.05 and 0.06 standard deviations. Estimated effects are significant for all years and persist until 1980 (Table 12, panel A, column 1). Additional results show that hiring quality dropped more after losing high quality scientists, in particular after losing scientists of exceptional quality (columns 2 to 5). Figure 7 shows the reduction in hiring quality after the dismissal of scientists with different qualities.

[35] It is important to note that the results for department size do not imply that departments with dismissals remained smaller in absolute terms until 1980. They only remained smaller in relative terms.

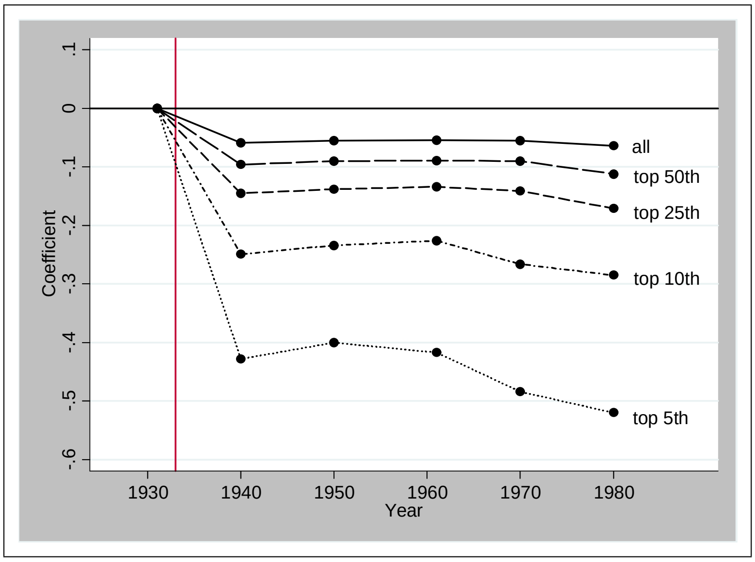

Figure 7: Dismissals and the quality of hires

Note: The figure plots regression coefficients as reported in Table 12, panel A. The dependent variable is quality of new hires in department d and year t. The top line reports coefficients on the interaction of the number of dismissals (between 1933 and 1940) with year dummies as in column (1). The second line from the top reports coefficients on the interaction of the number of dismissals of above median quality with year dummies as in column (2), and so on. To improve clarity, 95 percent confidence intervals are omitted from the graph. All post-dismissal regression coefficients are significantly different from 0 (Table 12).

Using pre-hiring citation weighted publications to measure the quality of hires I obtain similar results that are less precisely estimated (Table 12, panel B).

The fall in the quality of hires could have been caused by two different channels. First, the loss of high quality scientists may have reduced a department's ability to identify promising scholars. Second, the loss of high quality scientists may have reduced the quality of applications for open positions. My data does not allow me to distinguish these two channels as I do not observe the pool of applicants. I do, however, investigate whether the dismissal of older or younger scientists is driving the hiring results. I find that the loss of younger scientists (below median age) is particularly detrimental for the quality of new hires (Table A7).[36] The scientists in my data are most productive at the beginning of their career (Figure A5). This suggests that hiring quality is driven by particularly research active scientists.

Some of the fall in hiring quality was likely driven by a decline in the quality of PhD students that were produced in departments with dismissals after 1933 (Waldinger, 2010). As some departments hired their former PhD students the decline in faculty quality may have been perpetuated because these departments hired former students who were of inferior quality.[37]

Localized Productivity Spillovers

[36] Median age is 49 years for physics and chemistry and 46 years for mathematics.

[37] While German universities usually do not appoint full professors from their own staff many researchers return to their former university in later years. Almost 20 percent of mathematics PhD students who graduated between 1912 and 1940 and obtained a university position in Germany returned to the university that had granted their PhD. The Pearson chi-squared test statistic to test the hypothesis of independence of the PhD university and the university of employment is 1,300. The hypothesis is rejected with a p-value smaller than 0.001.

Another potential mechanism for the persistence of the human shock could be localized productivity spillovers. The output of scientists who remained in departments with dismissals after 1933 could have declined because of a reduction in the number and quality of local peers. The declining output of scientists who were directly exposed to the dismissals could have affected later generations of scientists in departments with dismissals. Previous research, however, has found that individual output of contemporary scientists did not decline after the dismissal of local peers in Nazi Germany (Waldinger, 2012). As a result, localized spillovers are unlikely to drive persistence in this context.

6 Conclusion

I use the dismissal of scientists in Nazi Germany and Allied bombings during WWII as exogenous and temporary shocks to the human and physical capital of science departments. In the short-run, before departments could fully respond, the human capital shock lowered output by about four times more than the physical capital shock. The human capital shock persisted in the long-run, until 1980. The dismissal of high quality scientists caused particularly large declines in output.

The negative effect of the physical capital shock, however, disappeared during the next few decades. By 1970, departments with buildings that were destroyed during WWII even did slightly better than departments without bombing destruction. These findings suggest that human capital is more important than physical capital for the output of science departments.

My findings, of course, do not indicate that physical capital is irrelevant for output because post-war reconstruction targeted destroyed departments. It seems, however, that negative shocks to physical capital can be overcome much more easily than human capital shocks. In recent years, some fields of science have become more dependent on large capital expenditures such as particle accelerators. Today, negative physical shocks in these fields may lead to more persistent effects than in the past.

The persistence of the human capital shock is particularly remarkable if one considers that most scientists of the former German universities (Breslau now Wroclaw, TU Breslau, and Königsberg now Kaliningrad) that became part of Poland and the Soviet Union had to relocate to universities that remained on German territory after 1945. Departments that had lost people during the dismissals could have hired the best people from these universities. I show, however, that an important mechanism for the persistence of the human capital shock was a permanent fall in the quality of new hires, in particular after the dismissal of high quality scientists. 'Star scientists' seem to be especially valuable as they attract other high quality researchers. This suggests that appointing high quality scholars may be a good strategy if a university or country wanted to raise its research profile.

An important question is whether evidence from historical events in Germany help our understanding of science departments today, and in other countries. Recent evidence on evolutionary biology departments suggests that the human capital part of my findings is likely to be similar today and in other countries. Agrawal, McHale, and Oettl (2013) show that the arrival of a star scientist increases output of the hiring department through attracting other good researchers but not by increasing the productivity of incumbent scientists. While Agrawal, McHale, and Oettl cannot use exogenous variation in the arrival of a star scientist, their findings provide a useful confirmation of the human capital result in this paper in a setting of current science departments. While this is no definite proof of external validity it increases my trust in the generalizability of the findings in this paper.

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8 Tables

Table 1: Number and Quality of Dismissed Scientists

	Physics				Chemistry				Mathematics			
Year of Dismissal	# of Dismissals	% of all scientists in 1931	% of pubs. published by dismissed	% of citation weighted pubs. published by dismissed	# of Dismissals	% of all scientists in 1931	% of pubs. published by dismissed	% of citation weighted pubs. published by dismissed	# of Dismissals	% of all scientists in 1931	% of pubs. published by dismissed	% of citation weighted pubs. published by dismissed
1933	32	9.4	13.6	59.3	38	7.8	11.2	11.2	27	11.7	23.6	51.3
1934	6	1.8	6.8	1.4	8	1.6	1.0	1.3	4	1.7	0.8	0.0
1935	6	1.8	1.6	1.5	6	1.2	2.7	1.5	5	2.2	3.5	0.8
1936	0	0.0	0.0	0.0	1	0.2	0.4	0.8	0	0.0	0	0.0
1937	1	0.3	0.3	0.0	3	0.6	0.3	0.5	2	0.9	1.7	5.7
1938	3	0.9	0.6	0.1	9	1.8	5.5	7.3	3	1.3	0.9	3.3
1939	2	0.6	0.6	0.0	3	0.6	0.8	0.7	1	0.4	0.3	0.0
1940	1	0.3	0.2	1.6	1	0.2	0.1	0.1	1	0.4	0.3	0.2
1933-40	51	15.0	23.8	64.0	69	14.1	22.0	23.4	43	18.7	31.0	61.3

# of Dismissals is the total number of dismissals in a subject (physics, chemistry, or mathematics) in a given year. *% of all Scientists in 1931* reports dismissals as percentage of total faculty in 1931. *% of pubs. published by dismissed* reports the percentage of publications that were published by the dismissed between 1928 and 1932. *% of citation weighted pubs. published by dismissed* reports the percentage of citation weighted publications that were published by the dismissed between 1928 and 1932.

Table 2: Dismissal and Bombing Shocks Across Science Departments

University	Physics: Dismissal Shock: # of scientists (1931)	Physics: Dismissed 33-40 #	Physics: Dismissed 33-40 in %	Physics: Bombing Shock: Destruct. 40-45 in %	Chemistry: Dismissal Shock: # of scientists (1931)	Chemistry: Dismissed 33-40 #	Chemistry: Dismissed 33-40 in %	Chemistry: Bombing Shock: Destruct. 40-45 in %	Mathematics: Dismissal Shock: # of scientists (1931)	Mathematics: Dismissed 33-40 #	Mathematics: Dismissed 33-40 in %	Mathematics: Bombing Shock: Destruction 40-45 in %	Total Destruction: University Destruct. in %	Total Destruction: City Destruct. in %
Aachen TU	5	1	*20.0*	20.4	11	1	*9.1*	52.4	6	2	*33.3*	25.0	70	49
Berlin	41	10	*24.4*	10.0	47	16	*34.0*	65.0	14	5	*35.7*	10.0	45.8	37
Berlin TU	30	9	*30.0*	25.0	41	11	*26.8*	11.1	17	5	*29.4*	48.0	48	37
Bonn	10	1	*10.0*	50.0	14	2	*14.3*	20.6	8	1	*12.5*	20.6	40	24
Braunschweig TU	5	0	*0*	90.0	11	0	*0*	47.0	2	0	*0*	25	70	26
Darmstadt TU	10	3	*30.0*	m	12	4	*33.3*	m	5	1	*20.0*	m	75	46
Dresden TU	11	1	*9.1*	100.0	17	1	*5.9*	5.0	8	0	*0*	100.0	65	39
Erlangen	5	0	*0*	0	9	1	*11.1*	0	3	0	*0*	0	0	4.8
Frankfurt	13	2	*15.4*	37.0	18	5	*27.8*	57.0	8	4	*50.0*	27.0	60	32
Freiburg	5	1	*20.0*	100.0	11	2	*18.2*	60.0	5	1	*20.0*	85.0	72.5	28
Giessen	6	1	*16.7*	50.0	9	0	*0*	100.0	4	0	*0*	50.0	67.5	53
Göttingen	20	8	*40.0*	0	17	3	*17.6*	0	16	10	*62.5*	0	1.7	2.1
Graz	7	1	*14.3*	10.0	8	0	*0*	0	6	0	*0*	0	5	33
Graz TU	1	0	*0*	0	7	0	*0*	0	5	0	*0*	50.0	20	33
Greifswald	7	0	*0*	0	4	0	*0*	0	4	0	*0*	0	0	0
Halle	4	0	*0*	0	7	1	*14.3*	0	5	1	*20.0*	0	5	5
Hamburg	15	2	*13.3*	30.0	12	2	*16.7*	30.0	8	1	*12.5*	15.0	50	54
Hannover TU	4	0	*0*	22.2	10	0	*0*	37.5	4	0	*0*	22.2	41.3	47
Heidelberg	6	0	*0*	0	19	2	*10.5*	0	5	3	*60.0*	0	0	1
Innsbruck	6	0	*0*	0	8	0	*0*	50.0	5	0	*0*	0	m	60
Jena	14	1	*7.1*	0	10	0	*0*	62.5	5	0	*0*	50.0	87.3	20
Karlsruhe TU	5	1	*20.0*	75.0	16	5	*31.3*	100.0	5	1	*20.0*	75.0	70	26
Kiel	7	1	*14.3*	62.5	8	0	*0*	50.0	5	2	*40.0*	75.0	60	41
Köln	6	1	*16.7*	66.7	6	0	*0*	50.0	5	1	*20.0*	0	20	44
Leipzig	12	2	*16.7*	41.0	21	2	*9.5*	100.0	8	2	*25.0*	0	70	19
Marburg	5	0	*0*	0	8	0	*0*	50.0	6	0	*0*	0	16.3	4
München	11	2	*18.2*	42.0	19	3	*15.8*	95.0	8	1	*12.5*	70.0	70	32
München TU	15	1	*6.7*	36.7	17	1	*5.9*	30.0	5	0	*0*	50.0	80	32
Münster	4	0	*0*	100.0	7	0	*0.0*	100.0	6	0	*0*	75.0	75.3	49
Rostock	4	0	*0*	0	6	0	*0.0*	0	1	0	*0*	0	0	40
Stuttgart TU	7	1	*14.3*	76.7	10	1	*10.0*	66.7	9	0	*0*	40	80	35
Tübingen	3	0	*0*	0	9	0	*0.0*	0	4	0	*0*	0	0	5
Wien	4	0	*0*	25.0	30	5	*16.7*	37.5	9	2	*22.2*	25.0	30	28
Wien TU	8	0	*0*	0	19	1	*5.3*	40.0	13	0	*0*	0	13.3	28
Würzburg	29	3	*10.3*	90.0	12	1	*8.3*	90.0	3	0	*0*	90.0	82.5	75

# of scientists (1931) reports the number of scientists in a department in 1931 (before the dismissal shock). *Dismissed 33-40* reports the number of dismissals in a department between 1933 and 1940. The total number of dismissal is slightly higher than in Table 1 because professors with appointments in two universities are reported twice in this table. *Destruct. 40-45* reports percentage destruction of department facilities due to Allied bombings between 1940 and 1945. *University Destruct.* reports the percentage of university facilities that were destroyed by Allied bombings between 1940 and 1945. *City Destruct.* reports city level percentages of buildings that were destroyed by Allied bombings. Data on dismissals, department level destruction, and city level destruction were compiled by the author. City level destruction data come from Hohn (1994) and other sources. See appendix 9.4 for details.

Table 3: Persistence of Dismissal and Bombing Shocks - Publications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variable:	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations
Number of Dismissals * 1926	0.023	0.017	0.017				0.024	0.018	0.018	0.018
	(0.025)	(0.025)	(0.025)				(0.025)	(0.026)	(0.026)	(0.026)
Number of Dismissals * 1940	-0.173***	-0.173***	-0.173***				-0.172***	-0.171***	-0.171***	-0.170***
	(0.037)	(0.039)	(0.039)				(0.039)	(0.041)	(0.041)	(0.042)
Number of Dismissals * 1950	-0.210*	-0.222*	-0.219**				-0.210	-0.221*	-0.218**	-0.219**
	(0.121)	(0.125)	(0.099)				(0.124)	(0.128)	(0.102)	(0.102)
Number of Dismissals * 1961	-0.245**	-0.257**	-0.254***				-0.244**	-0.255**	-0.253***	-0.253***
	(0.102)	(0.105)	(0.080)				(0.105)	(0.107)	(0.083)	(0.084)
Number of Dismissals * 1970	-0.291***	-0.286**	-0.283***				-0.290**	-0.283**	-0.281***	-0.282***
	(0.104)	(0.108)	(0.084)				(0.108)	(0.111)	(0.087)	(0.088)
Number of Dismissals * 1980	-0.202**	-0.202**	-0.207***				-0.199**	-0.198**	-0.202***	-0.212***
	(0.077)	(0.079)	(0.071)				(0.077)	(0.078)	(0.070)	(0.077)
% Destruction * 1926				-0.004	-0.005*	-0.005*	-0.004*	-0.004**	-0.004**	-0.004*
				(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% Destruction * 1931				-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.007***
				(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
% Destruction * 1950				-0.002	-0.003*	-0.005**	-0.003	-0.003*	-0.005**	-0.004**
				(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% Destruction * 1961				0.000	-0.001	-0.003	0.000	-0.001	-0.003	-0.002
				(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% Destruction * 1970				0.003*	0.004*	0.002	0.003	0.004*	0.002	0.005**
				(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% Destruction * 1980				0.001	0.001	-0.000	0.001	0.001	-0.000	0.003
				(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)
Department FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes			yes			yes			
Subject*Year FE		yes	yes		yes	yes		yes	yes	yes
Occupation Zones * Post1945			yes			yes			yes	yes
% City Destruction * Year FE										yes
Observations	714	714	714	714	714	714	714	714	714	714
R-squared	0.590	0.650	0.678	0.513	0.576	0.603	0.603	0.664	0.689	0.693

***significant at 1% level **significant at 5% level *significant at 10% level (All standard errors clustered at university level)

The dependent variable *Publications* is the sum of publications published by all scientists in department d in a five-year window around year t. The variable is normalized to have zero mean and a standard deviation of one within subjects. *Number of Dismissals * 1926* is equal to the number of dismissals between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. *Department FE* is a full set of 105 department fixed effects. *Year FE* is a set of year dummies for each year 1931, 1940, 1950, 1961, 1970, and 1980 (1926 is the excluded year). *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, and mathematics) with year dummies. *Occupation Zones * Post1945* is the interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post-1945 dummy. *% City Destruction * Year FE* is the interaction of city level destruction with the full set of year fixed effects.

Table 4: Persistence of Dismissal and Bombing Shocks - Citation Weighted Publications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variable:	Citation weighted Pubs.	Citation weighted Pubs.	Citation weighted Pubs.	Citation weighted Pubs.	Citation weighted Pubs.	Citation weighted Pubs.	Citation weighted Pubs.	Citation weighted Pubs.	Citation weighted Pubs.	Citation weighted Pubs.
Number of Dismissals * 1926	-0.093	-0.100	-0.100				-0.092	-0.099	-0.099	-0.099
	(0.076)	(0.078)	(0.078)				(0.076)	(0.078)	(0.078)	(0.079)
Number of Dismissals * 1940	-0.181***	-0.188***	-0.188***				-0.181***	-0.186***	-0.186***	-0.185***
	(0.063)	(0.062)	(0.062)				(0.060)	(0.059)	(0.059)	(0.059)
Number of Dismissals * 1950	-0.195***	-0.201***	-0.196***				-0.195***	-0.200***	-0.196***	-0.197***
	(0.030)	(0.036)	(0.031)				(0.031)	(0.036)	(0.032)	(0.032)
Number of Dismissals * 1961	-0.190***	-0.207***	-0.202***				-0.189***	-0.206***	-0.202***	-0.205***
	(0.036)	(0.041)	(0.042)				(0.034)	(0.040)	(0.042)	(0.042)
Number of Dismissals * 1970	-0.210***	-0.220***	-0.215***				-0.209***	-0.217***	-0.212***	-0.215***
	(0.047)	(0.049)	(0.053)				(0.038)	(0.042)	(0.046)	(0.049)
Number of Dismissals * 1980	-0.129*	-0.142**	-0.141**				-0.126**	-0.139**	-0.138**	-0.158**
	(0.065)	(0.059)	(0.061)				(0.059)	(0.055)	(0.057)	(0.064)
% Destruction * 1926				-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.002
				(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% Destruction * 1931				-0.006**	-0.006*	-0.006*	-0.006**	-0.005**	-0.005**	-0.005
				(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)
% Destruction * 1950				-0.002	-0.002	-0.004*	-0.002	-0.002	-0.004*	-0.002
				(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
% Destruction * 1961				-0.001	-0.001	-0.003	-0.001	-0.001	-0.003	0.000
				(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
% Destruction * 1970				0.006*	0.006*	0.005	0.006*	0.006*	0.005	0.008*
				(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
% Destruction * 1980				0.001	0.001	-0.000	0.001	0.001	-0.000	0.006
				(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Department FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes			yes			yes			
Subject*Year FE		yes	yes		yes	yes		yes	yes	yes
Occupation Zones * Post1945			yes			yes			yes	yes
% City Destruction * Year FE										yes
Observations	714	714	714	714	714	714	714	714	714	714
R-squared	0.460	0.484	0.496	0.440	0.460	0.471	0.475	0.497	0.507	0.518

***significant at 1% level **significant at 5% level *significant at 10% level (All standard errors clustered at university level)

The dependent variable *Citation weighted Pubs.* is the sum of citation weighted publications published by all scientists in department d in a five-year window around year t. The variable is normalized to have zero mean and a standard deviation of one within subjects. *Number of Dismissals * 1926* is equal to the number of dismissals between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. *Department FE* is a full set of 105 department fixed effects. *Year FE* is a set of year dummies for each year 1931, 1940, 1950, 1961, 1970, and 1980 (1926 is the excluded year). *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, and mathematics) with year dummies. *Occupation Zones * Post1945* is the interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post-1945 dummy. *% City Destruction * Year FE* is the interaction of city level destruction with the full set of year fixed effects.

Table 5: Robustness Checks - Publications
Adding Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable:	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Age-adj. Pubs.
Sample:	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample
# of Dismissals * 1926	0.018	0.020	0.020	0.026	0.026	0.026	0.086**
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.036)
# of Dismissals * 1940	-0.170***	-0.173***	-0.173***	-0.165***	-0.175***	-0.175***	-0.160***
	(0.042)	(0.042)	(0.042)	(0.037)	(0.038)	(0.038)	(0.053)
# of Dismissals * 1950	-0.236**	-0.244**	-0.252**	-0.236**	-0.248**	-0.246**	-0.178
	(0.102)	(0.103)	(0.108)	(0.102)	(0.103)	(0.099)	(0.122)
# of Dismissals * 1961	-0.271***	-0.282***	-0.289***	-0.276***	-0.288***	-0.286***	-0.233**
	(0.078)	(0.077)	(0.081)	(0.075)	(0.075)	(0.071)	(0.090)
# of Dismissals * 1970	-0.300***	-0.314***	-0.322***	-0.314***	-0.326***	-0.323***	-0.285***
	(0.079)	(0.078)	(0.079)	(0.074)	(0.073)	(0.069)	(0.074)
# of Dismissals * 1980	-0.234***	-0.251***	-0.261***	-0.259***	-0.272***	-0.272***	-0.287***
	(0.067)	(0.065)	(0.066)	(0.063)	(0.062)	(0.061)	(0.087)
% Destruction * 1926	-0.004*	-0.004*	-0.004*	-0.003	-0.002	-0.002	-0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
% Destruction * 1931	-0.007***	-0.007***	-0.007***	-0.005**	-0.005*	-0.005*	-0.006*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
% Destruction * 1950	-0.006***	-0.005***	-0.005***	-0.005**	-0.005**	-0.005**	-0.005
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
% Destruction * 1961	-0.004**	-0.003*	-0.003*	-0.003	-0.003	-0.003	-0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
% Destruction * 1970	0.003	0.003	0.003	0.004	0.004	0.003	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
% Destruction * 1980	0.001	0.002	0.002	0.001	0.001	0.001	-0.000
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Standard Controls	yes	yes	yes	yes	yes	yes	yes
Länder Dummies * P45	yes	yes	yes	yes	yes	yes	yes
Quadratic in Uni. Age		yes	yes	yes	yes	yes	yes
# of Deps. within 50km			yes	yes	yes	yes	yes
Industries (1933) * Year				yes	yes	yes	yes
Fract. Jews (1933) * P45					yes	yes	yes
Dist. to Iron Curtain * P45						yes	yes
Observations	714	714	714	714	714	714	714
R-squared	0.703	0.706	0.707	0.716	0.717	0.718	0.603

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Publications* is the sum of publications published by all scientists in department d in a five-year window around year t. The variable is normalized to have zero mean and a standard deviation of one within subjects. In column (7) the dependent variable is age adjusted publications, also normalized to have zero mean and a standard deviation of one within subjects. *# of Dismissals * 1926* is equal to the number of dismissals between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. *Standard Controls* are all controls as reported in column (10) of Table 3, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, and % City Destruction * Year FE. *Länder Dummies * Post1945* is a set of dummy variables for each post-war German federal state (Land) interacted with a post-1945 dummy. *Quadratic in Uni. Age* is equal to the age of the university in each year and its square. *# of Deps. Within 50km* measures the number of departments in the same subject within 50 kilometers of each department in each year. *Armament Industries (1933) * Year FE* is the fraction of firms in a city belonging to each of 3 armament related universities in 1933 (1930 for Austria) interacted with a full set of year fixed effects. The 3 industries are: iron and steel production, mechanical engineering and vehicle construction, and chemical industry. *Fract. Jews (1933) * Post1933* is the fraction of Jews in each city in 1933 interacted with a post 1933 dummy. *Dist. to Iron Curtain * Post1945* is the distance to the iron curtain from each city interacted with a post-1945 dummy.

Table 6: Robustness Checks - Citation weighted Publications Adding Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable:	Cit. weig. Pubs.	Cit. weig. Pubs.	Cit. weig. Pubs.	Cit. weig. Pubs.	Cit. weig. Pubs.	Cit. weig. Pubs.	Age-adj. Cit. weig. Pubs.
Sample:	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample
# of Dismissals * 1926	-0.099	-0.098	-0.099	-0.087	-0.087	-0.087	-0.076
	(0.079)	(0.079)	(0.079)	(0.077)	(0.077)	(0.077)	(0.098)
# of Dismissals * 1940	-0.185***	-0.186***	-0.185***	-0.180***	-0.180***	-0.181***	-0.188**
	(0.059)	(0.060)	(0.060)	(0.062)	(0.064)	(0.064)	(0.076)
# of Dismissals * 1950	-0.188***	-0.190***	-0.204***	-0.191***	-0.191***	-0.187***	-0.150***
	(0.031)	(0.031)	(0.044)	(0.031)	(0.027)	(0.028)	(0.030)
# of Dismissals * 1961	-0.196***	-0.198***	-0.211***	-0.196***	-0.196***	-0.191***	-0.157***
	(0.038)	(0.039)	(0.046)	(0.038)	(0.037)	(0.039)	(0.047)
# of Dismissals * 1970	-0.206***	-0.209***	-0.223***	-0.220***	-0.220***	-0.215***	-0.194***
	(0.046)	(0.046)	(0.048)	(0.046)	(0.048)	(0.050)	(0.060)
# of Dismissals * 1980	-0.146**	-0.150**	-0.169**	-0.181***	-0.181***	-0.181***	-0.191***
	(0.066)	(0.066)	(0.070)	(0.061)	(0.064)	(0.064)	(0.067)
% Destruction * 1926	-0.002	-0.002	-0.002	-0.003	-0.003	-0.003	-0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
% Destruction * 1931	-0.005	-0.005	-0.005	-0.003	-0.003	-0.003	-0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
% Destruction * 1950	-0.003	-0.003	-0.003	-0.004*	-0.004*	-0.004*	-0.005
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
% Destruction * 1961	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	-0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
% Destruction * 1970	0.006	0.006	0.007	0.007	0.007	0.007	0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
% Destruction * 1980	0.005	0.005	0.005	0.009	0.009	0.009	0.010
	(0.005)	(0.005)	(0.005)	(0.007)	(0.007)	(0.007)	(0.008)
Standard Controls	yes	yes	yes	yes	yes	yes	yes
Länder Dummies * P45	yes	yes	yes	yes	yes	yes	yes
Quadratic in Uni. Age		yes	yes	yes	yes	yes	yes
# of Deps. within 50km			yes	yes	yes	yes	yes
Industries (1933) * Year				yes	yes	yes	yes
Fract. Jews (1933) * P45					yes	yes	yes
Dist. to Iron Curtain * P45						yes	yes
Observations	714	714	714	714	714	714	714
R-squared	0.525	0.525	0.526	0.550	0.550	0.552	0.367

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Cit. weig. Pubs.* is the sum of citation weighted publications published by all scientists in department d in a five-year window around year t. The variable is normalized to have a zero mean and a standard deviation of one within subjects. In column (7) the dependent variable is age adjusted citation weighted publications, also normalized to have zero mean and a standard deviation of one. *# of Dismissals * 1926* is equal to the number of dismissals between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. *Standard Controls* are all controls as reported in column (10) of Table 3, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, and % City Destruction * Year FE. *Länder Dummies * Post45* is a set of dummy variables for each post-war German federal state (Land) interacted with a post-1945 dummy. *Quadratic in Uni. Age* is equal to the age of the university in each year and its square. *# of Deps. Within 50km* measures the number of departments with the same subject within 50 kilometers of each department in each year. *Armament Industries (1933) * Year* FE is the fraction of firms in a city belonging to each of 3 armament related universities in 1933 (1930 for Austria) interacted with a full set of year fixed effects. The 3 industries are: iron and steel production, mechanical engineering and vehicle construction, and chemical industry. *Fract. Jews (1933) * Post1933* is the fraction of Jews in each city in 1933 interacted with a post 1933 dummy. *Dist. to Iron Curtain * Post1945* is the distance to the iron curtain from each city interacted with a post-1945 dummy.

Table 7: Further Robustness Checks - Publications
Different Samples, Different Shock Measures, Controlling for University*Post1945 and Mean Reversion

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Depend. Variable:	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations
Sample:	Droping Austria	Dropping East Ger.	Swiss unis. as control	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample
				% dism.	33-34 dism. only	Science Dest.	Instrument w/ uni dest.	UniFE* Post45	Control for m revers.
Dismissals * 1926	0.024	0.027	0.030	-0.022	0.048	0.028	0.030	0.026	0.004
	(0.029)	(0.043)	(0.032)	(0.064)	(0.041)	(0.026)	(0.028)	(0.027)	(0.021)
Dismissals * 1940	-0.138***	-0.116***	-0.161***	-0.229*	-0.153***	-0.175***	-0.182***	-0.163***	-0.129***
	(0.041)	(0.033)	(0.029)	(0.135)	(0.040)	(0.036)	(0.037)	(0.039)	(0.027)
Dismissals * 1950	-0.221***	-0.080	-0.249***	-0.260	-0.209*	-0.242**	-0.228**	-0.148*	-0.152*
	(0.079)	(0.047)	(0.080)	(0.172)	(0.114)	(0.098)	(0.096)	(0.080)	(0.081)
Dismissals * 1961	-0.259***	-0.151***	-0.293***	-0.292	-0.275***	-0.283***	-0.268***	-0.187***	-0.143***
	(0.051)	(0.048)	(0.049)	(0.174)	(0.081)	(0.069)	(0.066)	(0.066)	(0.044)
Dismissals * 1970	-0.298***	-0.203***	-0.324***	-0.334*	-0.314***	-0.322***	-0.309***	-0.225***	-0.143***
	(0.050)	(0.069)	(0.047)	(0.177)	(0.081)	(0.066)	(0.068)	(0.071)	(0.038)
Dismissals * 1980	-0.271***	-0.184***	-0.321***	-0.207	-0.238***	-0.271***	-0.256***	-0.220***	-0.104**
	(0.053)	(0.065)	(0.076)	(0.145)	(0.059)	(0.061)	(0.065)	(0.079)	(0.049)
Destruction * 1926	-0.004	-0.003	-0.006**	-0.003	-0.002	-0.003	-0.007	-0.003	-0.003
	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.006)	(0.002)	(0.002)
Destruction * 1931	-0.006***	-0.005*	-0.010***	-0.005**	-0.004	-0.003	-0.005	-0.005**	-0.005**
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.006)	(0.002)	(0.002)
Destruction * 1950	-0.008**	-0.007*	-0.002	-0.007**	-0.006**	-0.011**	-0.019***	-0.004	-0.006**
	(0.003)	(0.004)	(0.003)	(0.003)	(0.002)	(0.004)	(0.007)	(0.003)	(0.002)
Destruction * 1961	-0.005***	-0.002	-0.001	-0.005**	-0.004*	-0.006*	-0.015***	-0.002	-0.003*
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)	(0.005)	(0.003)	(0.002)
Destruction * 1970	0.001	0.004	0.005	0.002	0.002	0.004	-0.003	0.005	0.003
	(0.002)	(0.004)	(0.003)	(0.002)	(0.002)	(0.004)	(0.006)	(0.003)	(0.002)
Destruction * 1980	-0.003	0.001	0.001	-0.001	0.001	0.001	-0.025	0.002	0.001
	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.018)	(0.004)	(0.004)
Extended Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
UniFE*Post45								yes	
Quality1926*Years									yes
Observations	609	588	486	714	714	714	714	714	714
R-squared	0.724	0.698	0.733	0.668	0.704	0.719	0.703	0.755	0.743

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Publications* is the sum of publications published by all scientists in department d in a five-year window around year t. The variable is normalized to have zero mean and a standard deviation of one within subjects. In columns (1)-(3) and (6)-(9) *Dismissals * 1926* is equal to the number of dismissals between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. In column (4) *Dismissals* is equal to the percentage of dismissals between 1933 and 1940 (divided by 10 so that the coefficient is equivalent to a 10 percent change in the size of the faculty). In column (5) *Dismissals* is equal to the number of dismissals between 1933 and 1934. In columns (1)-(5) and (7)-(9) *Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. In column (6) *destruction* is equal to the average destruction in the three science departments in each university. In column (7) I instrument for *Destruction* at the department level with percentage destruction measured at the university level. *Extended Controls* are all controls as reported in column (6) of Table 5, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, % City Destruction * Year FE, Länder Dummies * Post1945, # of Deps. Within 50km, Armament Industries (1933) * Year FE, Fract. Jews (1933) * Post1933, and Dist. to Iron Curtain * Post1945. In column (3) *Extended controls* do not include Armament Industries (1933) * Year FE because the data for armament industries is missing for Swiss cities. *UniFE*Post1945* is a full set of 35 university fixed effects interacted with a post-1945 dummy. *Quality1926*Years* is the interaction of department quality in 1926 interacted with the number of years that have passed since 1926.

Table 8: Further Robustness Checks - Citation Weighted Publications Different Samples, Different Shock Measures, Controlling for University*Post1945 and Mean Reversion

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Depend. Variable:	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations
Sample:	Dropping Austria	Dropping East Ger.	Swiss unis. as control	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample
				% dism.	only 33-34 dism.	Science Dest.	Instrument w/ uni. dest.	UniFE* Post45	Control for m revers.
Dismissals * 1926	-0.080	-0.154*	-0.093	-0.176	-0.080	-0.084	-0.084	-0.086	-0.094
	(0.078)	(0.090)	(0.090)	(0.121)	(0.089)	(0.078)	(0.080)	(0.078)	(0.075)
Dismissals * 1940	-0.150*	-0.248***	-0.173**	-0.310**	-0.177**	-0.181**	-0.186***	-0.180**	-0.165**
	(0.087)	(0.057)	(0.076)	(0.150)	(0.074)	(0.067)	(0.066)	(0.067)	(0.064)
Dismissals * 1950	-0.156***	-0.177***	-0.184***	-0.300**	-0.173***	-0.182***	-0.171***	-0.117	-0.151***
	(0.040)	(0.048)	(0.051)	(0.142)	(0.031)	(0.029)	(0.033)	(0.087)	(0.040)
Dismissals * 1961	-0.163***	-0.196***	-0.200***	-0.268*	-0.192***	-0.188***	-0.177***	-0.122	-0.138**
	(0.054)	(0.062)	(0.060)	(0.143)	(0.048)	(0.041)	(0.044)	(0.103)	(0.056)
Dismissals * 1970	-0.186***	-0.221**	-0.232***	-0.286	-0.229***	-0.212***	-0.207***	-0.147	-0.149**
	(0.065)	(0.083)	(0.080)	(0.174)	(0.063)	(0.055)	(0.050)	(0.124)	(0.058)
Dismissals * 1980	-0.168**	-0.197**	-0.258**	-0.242*	-0.161*	-0.178**	-0.168**	-0.134	-0.111*
	(0.076)	(0.086)	(0.116)	(0.137)	(0.088)	(0.066)	(0.077)	(0.133)	(0.060)
Destruction * 1926	-0.004	-0.001	-0.002	-0.003	-0.003	-0.004	-0.007	-0.003	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)	(0.002)
Destruction * 1931	-0.003	0.003	-0.003	-0.003	-0.002	-0.001	-0.003	-0.003	-0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.006)	(0.004)	(0.004)
Destruction * 1950	-0.005*	-0.002	0.002	-0.005*	-0.004*	-0.008**	-0.015***	-0.003	-0.005**
	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.005)	(0.004)	(0.002)
Destruction * 1961	-0.003	0.001	0.002	-0.003	-0.002	-0.004	-0.010*	-0.001	-0.003
	(0.003)	(0.005)	(0.004)	(0.003)	(0.003)	(0.003)	(0.006)	(0.005)	(0.003)
Destruction * 1970	0.007	0.013**	0.010	0.006	0.007	0.009**	0.008	0.008	0.006
	(0.005)	(0.006)	(0.007)	(0.004)	(0.004)	(0.004)	(0.007)	(0.006)	(0.004)
Destruction * 1980	0.009	0.012*	0.002	0.008	0.009	0.004	-0.020	0.010	0.008
	(0.009)	(0.007)	(0.008)	(0.007)	(0.007)	(0.005)	(0.019)	(0.009)	(0.007)
Extended Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
UniFE*Post45								yes	
Quality1926*Years									yes
Observations	609	588	486	714	714	714	714	714	714
R-squared	0.558	0.571	0.507	0.543	0.548	0.548	0.509	0.563	0.557

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Cit. weig. Pubs.* is the sum of citation weighted publications published by all scientists in department d in a five-year window around year t. The variable is normalized to have zero mean and a standard deviation of one within subjects. In columns (1)-(3) and (6)-(9) *Dismissals * 1926* is equal to the number of dismissals between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. In column (4) *Dismissals* is equal to the percentage of dismissals between 1933 and 1940 (divided by 10 so that the coefficient is equivalent to a 10 percent change in the size of the faculty). In column (5) *Dismissals* is equal to the number of dismissals between 1933 and 1934. In columns (1)-(5) and (7)-(9) *Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. In column (6) *Destruction* is equal to the average destruction in the three science departments in each university. In column (7) I instrument for *Destruction* at the department level with percentage destruction measured at the university level. *Extended Controls* are all controls as reported in column (6) of Table 5, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, % City Destruction * Year FE, Länder Dummies * Post1945, # of Deps. Within 50km, Armament Industries (1933) * Year FE, Fract. Jews (1933) * Post1933, and Dist. to Iron Curtain * Post1945. In column (3) *Extended controls* do not include Armament Industries (1933) * Year FE because the data for armament industries is missing for Swiss cities. *UniFE*Post1945* is a full set of 35 university fixed effects interacted with a post-1945 dummy. *Quality (1926) * Years* is the interaction of department quality in 1926 interacted with the number of years that have passed since 1926.

Table 9: Individual Subjects

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable:	Publications	Citation weighted Publications	Publications	Citation weighted Publications	Publications	Citation weighted Publications
	Physics		Chemistry		Mathematics	
# of Dismissals * 1926	0.164	-0.033	0.026	0.012	-0.180	-0.469**
	(0.140)	(0.286)	(0.016)	(0.038)	(0.181)	(0.187)
# of Dismissals * 1940	-0.112**	-0.181	-0.178***	-0.053**	-0.295*	-0.553***
	(0.044)	(0.227)	(0.060)	(0.020)	(0.162)	(0.192)
# of Dismissals * 1950	-0.059	-0.122	-0.317***	-0.101*	-0.445**	-0.606***
	(0.190)	(0.248)	(0.110)	(0.054)	(0.182)	(0.182)
# of Dismissals * 1961	-0.215**	-0.277	-0.309***	-0.060	-0.440**	-0.472**
	(0.089)	(0.189)	(0.089)	(0.084)	(0.178)	(0.202)
# of Dismissals * 1970	-0.271***	-0.314	-0.346***	-0.101	-0.454**	-0.500**
	(0.080)	(0.204)	(0.096)	(0.061)	(0.177)	(0.200)
# of Dismissals * 1980	-0.291**	-0.436**	-0.247***	0.078	-0.404**	-0.475**
	(0.119)	(0.186)	(0.089)	(0.082)	(0.165)	(0.175)
% Destruction * 1926	-0.002	-0.001	0.005	0.003	-0.007	-0.007
	(0.005)	(0.002)	(0.005)	(0.003)	(0.005)	(0.006)
% Destruction * 1931	-0.002	-0.000	0.001	-0.001	-0.013**	-0.005
	(0.003)	(0.002)	(0.007)	(0.004)	(0.006)	(0.009)
% Destruction * 1950	0.000	-0.001	0.000	0.002	-0.007	-0.004
	(0.005)	(0.004)	(0.007)	(0.006)	(0.005)	(0.006)
% Destruction * 1961	0.001	-0.002	0.003	0.005	-0.007	-0.005
	(0.003)	(0.003)	(0.008)	(0.010)	(0.006)	(0.006)
% Destruction * 1970	0.003	0.001	0.008	0.018	0.008	0.006
	(0.004)	(0.003)	(0.007)	(0.012)	(0.005)	(0.007)
% Destruction * 1980	-0.002	0.002	0.017*	0.023**	-0.003	0.002
	(0.007)	(0.008)	(0.009)	(0.011)	(0.007)	(0.008)
Extended controls	yes	yes	yes	yes	yes	yes
Observations	238	238	238	238	238	238
R-squared	0.761	0.645	0.868	0.761	0.750	0.666

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Publications* reported in odd columns is the sum of publications published by all scientists in department d in a five-year window around year t. The dependent variable *Citation weighted Publications* reported in even columns is the sum of citation weighted publications published by all scientists in department d in a five-year window around year t. Dependent variables are normalized to have zero mean and a standard deviation of one within subjects. *# of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. *Extended Controls* are all controls as reported in column (6) of Table 5, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, % City Destruction * Year FE, Länder Dummies * Post1945, # of Deps. Within 50km, Armament Industries (1933) * Year FE, Fract. Jews (1933) * Post1933, and Dist. to Iron Curtain * Post1945.

Table 10: Dismissal of Top Scientists

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variable:	Publi-cations	Citation weighted Pubs.	Publi-cations	Citation weighted Pubs.	Publi-cations	Citation weighted Pubs.	Publi-cations	Citation weighted Pubs.	Publi-cations	Citation weighted Pubs.
	All Dismissals		Above Median Quality		Top 25th percentile		Top 10th percentile		Top 5th percentile	
Number of Dismissals * 1926	0.026	-0.087	0.047*	-0.098	0.039	-0.161	-0.079	-0.471**	-0.241	-0.784*
	(0.026)	(0.077)	(0.028)	(0.071)	(0.057)	(0.127)	(0.067)	(0.202)	(0.237)	(0.444)
Number of Dismissals * 1940	-0.175***	-0.181***	-0.267***	-0.243***	-0.329***	-0.349***	-0.550***	-0.712***	-0.833***	-1.198***
	(0.038)	(0.064)	(0.039)	(0.085)	(0.059)	(0.111)	(0.157)	(0.153)	(0.262)	(0.298)
Number of Dismissals * 1950	-0.246**	-0.187***	-0.343**	-0.254***	-0.416*	-0.354***	-0.719**	-0.739***	-0.740	-1.078***
	(0.099)	(0.028)	(0.157)	(0.056)	(0.221)	(0.099)	(0.321)	(0.122)	(0.467)	(0.309)
Number of Dismissals * 1961	-0.286***	-0.191***	-0.433***	-0.237***	-0.539***	-0.345***	-0.798***	-0.662***	-0.918***	-1.189***
	(0.071)	(0.039)	(0.102)	(0.061)	(0.149)	(0.094)	(0.258)	(0.148)	(0.291)	(0.280)
Number of Dismissals * 1970	-0.323***	-0.215***	-0.498***	-0.278***	-0.621***	-0.428***	-0.896***	-0.845***	-1.136***	-1.441***
	(0.069)	(0.050)	(0.088)	(0.097)	(0.130)	(0.113)	(0.265)	(0.145)	(0.295)	(0.296)
Number of Dismissals * 1980	-0.272***	-0.181***	-0.399***	-0.237	-0.546***	-0.417**	-0.730***	-0.764***	-1.019***	-1.583***
	(0.061)	(0.064)	(0.104)	(0.160)	(0.125)	(0.155)	(0.259)	(0.184)	(0.270)	(0.381)
% Destruction * Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Extended controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	714	714	714	714	714	714	714	714	714	714
R-squared	0.718	0.552	0.726	0.548	0.720	0.555	0.708	0.572	0.683	0.584

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Publications* reported in odd columns is the sum of publications published by all scientists in department d in a five-year window around year t. The dependent variable *Citation weighted Pubs.* reported in even columns is the sum of citation weighted publications published by all scientists in department d in a five-year window around year t. Dependent variables are normalized to have zero mean and a standard deviation of one within subjects. In columns (1)-(2) *Number of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. In columns (3)-(4) *Number of Dismissals * 1926* is equal to the number of dismissals of above median quality interacted with an indicator that is equal to 1 for observations from 1926. In columns (5)-(6) *Number of Dismissals * 1926* is equal to the number of dismissals in the top 25 percentile interacted with an indicator that is equal to 1 for observations from 1926, and so on. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * Year FE* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with a set of year indicators as in the main specification. *Extended Controls* are all controls as reported in column (6) of Table 5, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, % City Destruction * Year FE, Länder Dummies * Post1945, # of Deps. Within 50km, Armament Industries (1933) * Year FE, Fract. Jews (1933) * Post1933, and Dist. to Iron Curtain * Post1945.

Table 11: Persistence of Dismissal and Bombing Shocks - Department Size

	(1)	(2)	(3)
Dependent Variable:	Department Size	Department Size	Department Size
Number of Dismissals * 1926	-0.217***		-0.218***
	(0.060)		(0.056)
Number of Dismissals * 1940	-0.612***		-0.604***
	(0.078)		(0.083)
Number of Dismissals * 1950	-1.129***		-1.124***
	(0.353)		(0.336)
Number of Dismissals * 1961	-1.045***		-1.064***
	(0.267)		(0.257)
Number of Dismissals * 1970	-0.935**		-1.009**
	(0.381)		(0.374)
Number of Dismissals * 1980	0.063		0.024
	(0.665)		(0.656)
% Destruction * 1926		0.005	0.006
		(0.013)	(0.013)
% Destruction * 1931		0.005	0.004
		(0.011)	(0.010)
% Destruction * 1950		-0.034	-0.029
		(0.025)	(0.024)
% Destruction * 1961		-0.008	-0.003
		(0.029)	(0.029)
% Destruction * 1970		0.050*	0.056**
		(0.025)	(0.027)
% Destruction * 1980		0.034	0.041
		(0.055)	(0.056)
Extended controls	yes	yes	yes
Observations	714	714	714
R-squared	0.882	0.878	0.884

***significant at 1% level **significant at 5% level *significant at 10% level
(All standard errors clustered at university level)
The dependent variable *Department Size* measures department size in department *d* and year *t*. *Number of Dismissals * 1926* is equal to the number of dismissals between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. *Extended Controls* are all controls as reported in column (6) of Table 5, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, % City Destruction * Year FE, Länder Dummies * Post1945, # of Deps. Within 50km, Armament Industries (1933) * Year FE, Fract. Jews (1933) * Post1933, and Dist. to Iron Curtain * Post1945.

Table 12: Quality of New Hires

	(1)	(2)	(3)	(4)	(5)
Dependent Variable:	Quality of Hires	Quality of Hires	Quality of Hires	Quality of Hires	Quality of Hires
	All Dismissals	Above median Quality	Top 25th percentile	Top 10th percentile	Top 5th percentile
Panel A: Quality measured by lifetime citation weighted publications					
Number of Dismissals * 1940	-0.059***	-0.096***	-0.145***	-0.249***	-0.428***
	(0.014)	(0.018)	(0.040)	(0.051)	(0.133)
Number of Dismissals * 1950	-0.055**	-0.090***	-0.138***	-0.234***	-0.400***
	(0.020)	(0.027)	(0.046)	(0.061)	(0.139)
Number of Dismissals * 1961	-0.054***	-0.089***	-0.134***	-0.226***	-0.417***
	(0.013)	(0.018)	(0.037)	(0.049)	(0.120)
Number of Dismissals * 1970	-0.055***	-0.090***	-0.141***	-0.266***	-0.484***
	(0.020)	(0.028)	(0.041)	(0.054)	(0.130)
Number of Dismissals * 1980	-0.064***	-0.112***	-0.171***	-0.285***	-0.520***
	(0.017)	(0.031)	(0.054)	(0.069)	(0.160)
Panel B: Quality measured by pre-hiring citation weighted publications					
Number of Dismissals * 1940	-0.010	-0.046*	-0.060	-0.166*	-0.174
	(0.013)	(0.024)	(0.044)	(0.094)	(0.214)
Number of Dismissals * 1950	-0.051***	-0.111***	-0.162***	-0.220***	-0.287*
	(0.010)	(0.023)	(0.046)	(0.068)	(0.156)
Number of Dismissals * 1961	-0.030**	-0.075**	-0.123*	-0.142	-0.199
	(0.014)	(0.035)	(0.061)	(0.087)	(0.181)
Number of Dismissals * 1970	-0.051***	-0.103***	-0.146***	-0.223***	-0.300*
	(0.011)	(0.024)	(0.043)	(0.072)	(0.169)
Number of Dismissals * 1980	-0.053***	-0.120***	-0.192***	-0.281***	-0.380**
	(0.016)	(0.032)	(0.049)	(0.076)	(0.172)
% Destruction * Year FE	yes	yes	yes	yes	yes
Extended controls	yes	yes	yes	yes	yes
Observations	602	602	602	602	602

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Quality of Hires* measures the average quality of new hires in department d between year t and year *t-1*. In panel A, quality of hires is measured by the career average of citation-weighted publications averaged across all hires in a department. In panel B, quality of hires is measured by average citation-weighted publications before year t averaged across all hires in a department. The average is calculated for 5 years at the midpoint between year t and year *t-1* adjusted for the age of the scientist. The dependent variables are normalized to have zero mean and a standard deviation of one within subjects. In column (1) *Number of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. In column (2) *Number of Dismissals * 1926* is equal to the number of dismissals of above median quality interacted with an indicator that is equal to 1 for observations from 1926. In column (3) *Number of Dismissals * 1926* is equal to the number of dismissals in the top 25 percentile interacted with an indicator that is equal to 1 for observations from 1926, and so on. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * Year FE* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with a set of year indicators as in the main specification. *Extended Controls* are all controls as reported in column (6) of Table 5, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, % City Destruction * Year FE, Länder Dummies * Post1945, # of Deps. Within 50km, Armament Industries (1933) * Year FE, Fract. Jews (1933) * Post1933, and Dist. to Iron Curtain * Post1945.

9 Appendix

9.1 Appendix Figures

Figure A1: Nobel Prizes

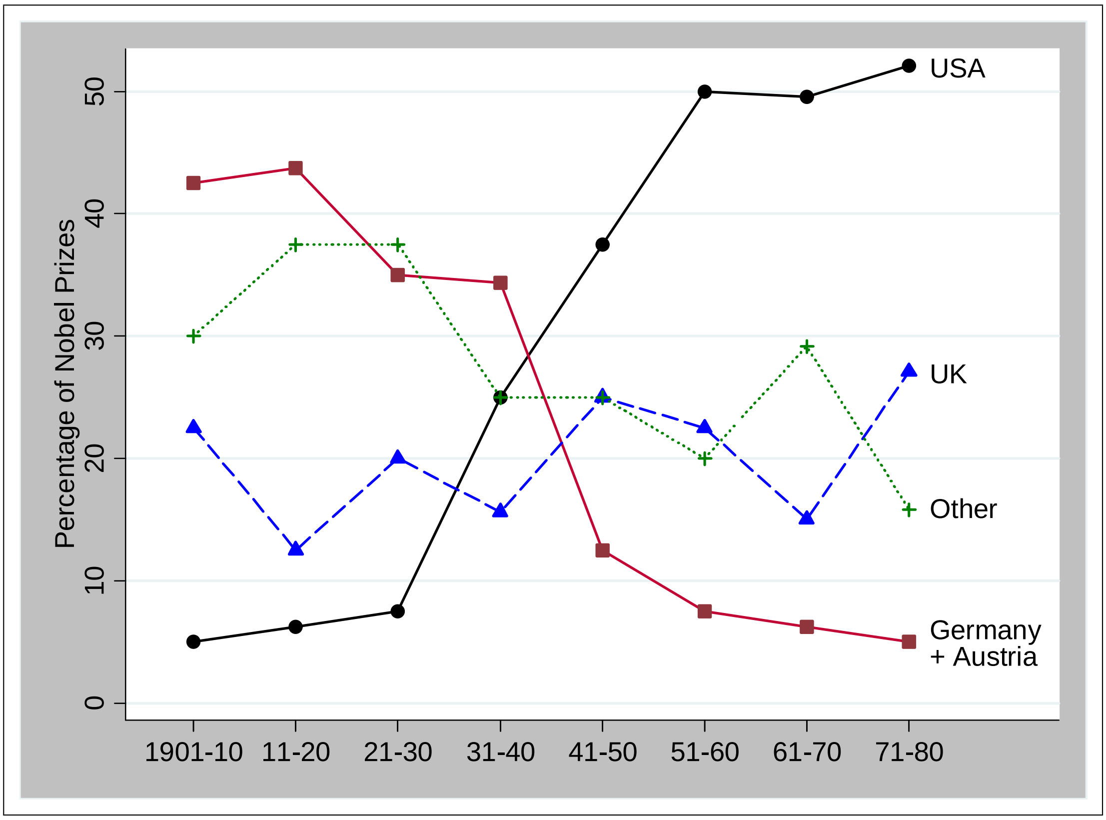

Figure A1: Nobel Prizes in physics and chemistry

Note: The figure reports the percentage of Nobel Prizes awarded in physics and chemistry to scientists affiliated with a university in the respective country for each decade from 1901 to 1980. Prizes are weighted according to the fractions awarded by the Nobel committee (i.e. if the prize was awarded to 3 scientists in one year with one scientist getting 0.5 of the prize, and the other two scientists receiving 0.25 of the prize their countries would be assigned 0.5 and 0.25 respectively). Over the time period 1901 to 1980 scientists based in Austrian universities contribute 2 prizes to the combined total of 33.75 prizes awarded to scientists in German and Austrian universities. Data on Nobel Prizes and university affiliations come from http://www.nobelprize.org/nobel_prizes/.

Figure A2: Bombing Destruction at the Technical University of Berlin

Figure A2: Bombing destruction at the Technical University of Berlin

Note: The map shows bombing destruction at the Technical University of Berlin. The large building in the middle of the map is the main building. Circles indicate individual bombing impacts. Small triangles indicate destruction from artillery fire. Completely burned out buildings are shaded dark grey. Partially burned out buildings are shaded light grey. Destroyed roof structures are shaded with little dots. Crashed planes are marked by a plane symbol.

Figure A3: Including Controls - Citation-weighted Publications

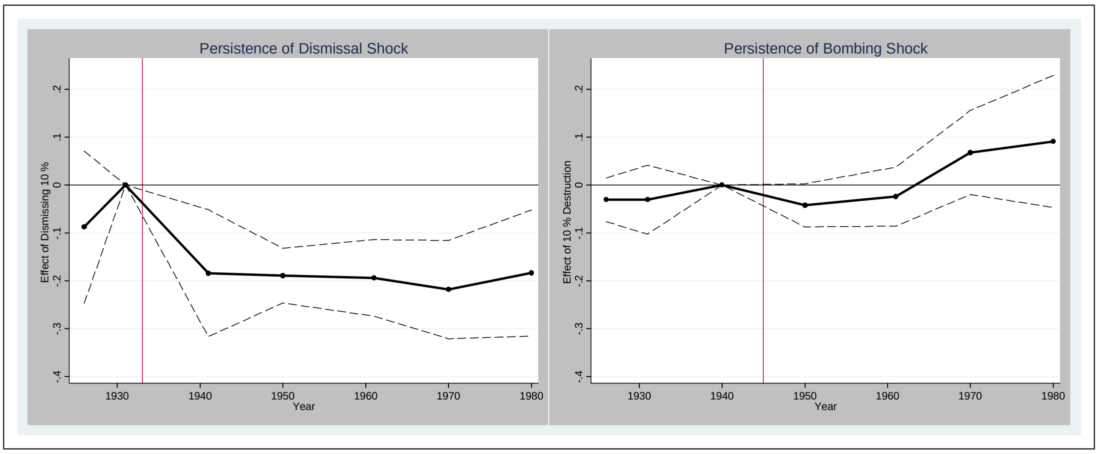

Figure A3: Persistence of 10% shocks - Citation weighted publications with all controls

Note: The figure plots scaled regression coefficients and 95 percent confidence intervals obtained from the estimation of equation (1) as reported in column (6) of Table 6. Point estimates and confidence intervals are scaled to reflect a 10 percent shock to both human and physical capital.

Figure A4: Persistance of Different Quality Dismissals

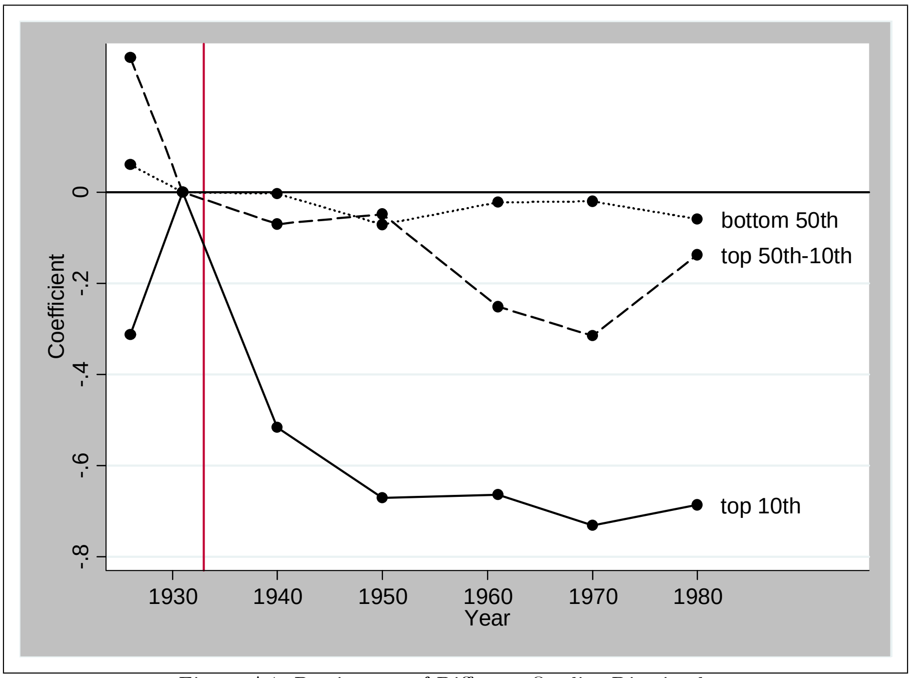

Figure A4: Persistence of Different Quality Dismissals

Note: The figure plots regression coefficients reported in column (1) of Table A6. The dependent variable is the total number of publications in department d and year t. All coefficients are estimated in one regression. The top line shows coefficients on the interation of the number of dismissals of below median quality (between 1933 and 1940) with year dummies. The middle line shows coefficients on the interation of the number of dismissals between the top 50th and 10th quality percentiles with year dummies. The bottom line shows coefficients on the interation of the number of dismissals in the top 10th percentile with year dummies.

Figure A5: Age-Output Profile

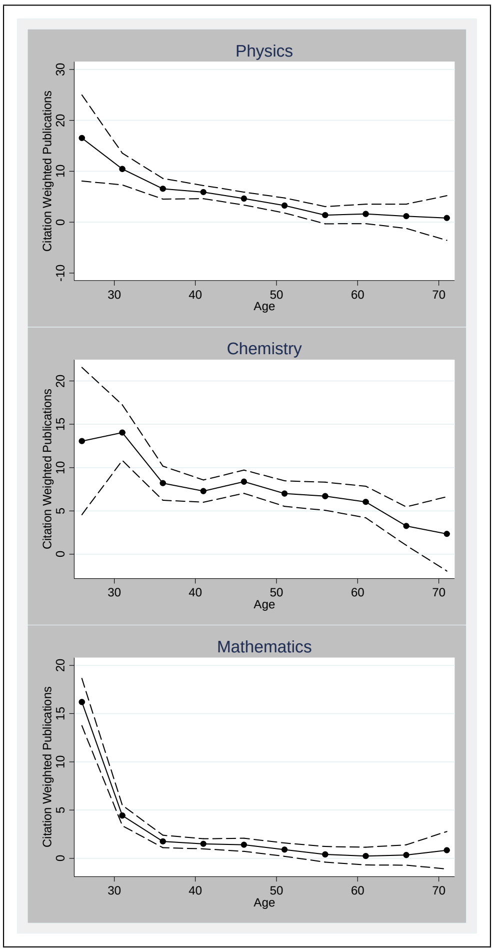

Figure A5: Output over the life-cycle

Note: The figure reports regression coefficients and 95 percent confidence intervals from a regression of citation weighted publications on 5-year age dummies. The regression is estimated separately for each subject.

9.2 Appendix Tables

Table A1: Destruction of Equipment University of Cologne

Date of Bombing	Destroyed Equipment	Value in RM	In 1940 US $	In 2011 US $
Chemical Institute				
April 6th, 1942	Storage bottles in chemical storage	75.00	30.01	480.19
April 23rd, 1942	Damage to apparatuses, storage bottles	40.00	16.01	256.10
July 10th, 1942	Destruction to various apparatuses	15000.00	6002.40	96038.42
February 14th, 1943	technologic collection	20000.00	8003.20	128051.22
	glass and chemicals collection	8000.00-12000.00	3201.28-4801.92	51220.48-76830.72
	valuable apparatuses	3000.00-5000.00	1200.48-2000.80	19207.68-32012.80
June 16th, 1943	no destruction to equipment			
June 29th, 1943	no destruction to equipment			
July 9th, 1943	no destruction to equipment			
March 17th 1944	no destruction to equipment			
Total		46115.00-52115.00	18453.38-20854.34	295254.10-333669.50
Institute for Applied Physics				
April 25th, 1942	high voltage transformer	285.00	114.05	1824.73
	capacitors of stable voltage system	468.00	187.27	2996.40
	X-ray valve tube	645.00	258.10	4129.65
	electrical instruments	8209.00	3284.91	52558.62
	other instruments	12089.00	4837.54	77400.56
	furniture (shelves, laborary tables, chairs)	7696.20	3079.71	49275.39
May 31st, 1942	electrical instruments	8209.00	3284.91	52558.62
	other instruments	3880.20	1552.70	24843.22
	electrical equipment (switchboards...)	4565.00	1826.73	29227.69
	personal equipment of Professor Malsch	3655.00	1462.59	23401.36
	instruments destroyed by water damage	2214.00	885.95	14175.27
June/July 1943	damage to equipment	75000.00	30012.00	480192.08
Total		126915.40	50786.47	812583.59

Note: Table based on post-bombing reports from institute directors to the university administration. Material comes from the archive of the University of Cologne and was compiled by the author. Currency conversion rates for 1940 Reichsmark to 1940 U.S. Dollar come from Lawrence H. Officer (2011) "Exchange Rates Between the United States Dollar and Forty-one Currencies", MeasuringWorth, accessed online at www.measuringworth.com/exchangeglobal/. Prices in 2011 U.S. Dollars were obtained by converting 1940 U.S. Dollars into 2011 using percentage increases in the CPI. Data come from www.measuringworth.com.

Table A2: Top Journals

Journal Name	Published in	Historical Top Journal	Current Top Journal
General Journals			
Nature	UK	yes	yes
Naturwissenschaften	Germany	yes	
Proceedings of the National Academy of Sciences	USA		yes
Proceedings of the Royal Society of London A (Mathematics and Physics)	UK	yes	
Science	USA	yes	yes
Sitzungsberichte der Pressischen Akademie der Wissenschaften	Germany	yes	
Physics			
Annalen der Physik	Germany	yes	
Applied Physics Letters	USA		yes
Astrophysical Journal	UK		yes
Journal of Applied Physics	USA		yes
Journal of Chemical Physics	USA		yes
Journal of Geophysical Research B: Solid Earth	USA		yes
Physical Review	USA	yes	yes
Physical Review A	USA		yes
Physical Review B	USA		yes
Physical Review C	USA		yes
Physical Review D	USA		yes
Physical Review Letters	USA		yes
Physikalische Zeitschrift	Germany	yes	
Zeitschrift für Physik	Germany	yes	
Chemistry			
Analytical Chemistry	USA		yes
Angewandte Chemie - International Edition in English	UK		yes
Berichte der Deutschen Chemischen Gesellschaft	Germany	yes	
Biochemische Zeitschrift	Germany	yes	
Chemical Communications	USA		yes
Inorganic Chemistry	USA		yes
Journal für Praktische Chemie	Germany	yes	
Journal of Biological Chemistry	USA		yes
Journal of Organic Chemistry	USA		yes
Journal of Physical Chemistry	USA	yes	yes
Journal of the American Chemical Society	USA		yes
Journal of the Chemical Society	UK	yes	
Justus Liebigs Annalen Chemie	Germany	yes	
Kolloid Zeitschrift	Germany		
Tetrahedron Letters	Netherlands		yes
Zeitschrift für Anorganische Chemie und Allgemeine Chemie	Germany	yes	
Zeitschrift für Elektrochemie und Angewandte Physikalische Chemie	Germany	yes	
Zeitschrift für Physikalische Chemie	Germany	yes	
Mathematics			
Acta Mathematica	Sweden	yes	yes
Advances in Mathematics	USA		yes
Annals of Mathematics	USA	yes	yes
Bulletin of the American Mathematical Society	USA		yes
Inventiones Mathematicae			yes
Jounal für die reine und angewandte Mathematik	Germany	yes	
Journal of Functional Analysis	USA		yes
Journal of the London Mathematical Society	Germany		
Mathematische Annalen	Germany	yes	
Mathematische Zeitschrift	Germany	yes	
Philosophical Transactions of the Royal Society A	UK		yes
Proceedings of the London Mathematical Society	UK	yes	
Zeitschrift für angewandte Mathematik und Mechanik	Germany	yes	

Table A3: Top Scientists

Name	University 1	University 2	Yearly Career Cit. weighted Publications	Nobel Prize	Dis-missed 1933-40	First year in data	Last year in data
Physics							
Wigner, Eugen	Berlin TU		619.8	yes	1933	1931	1931
Binder, Kurt	Köln		468.3			1980	1980
Cardona, Manuel	Stuttgart TU		284.3			1980	1980
Ewald, Peter Paul	Stuttgart TU		161.8		1937	1926	1931
Wegner, Franz	Heidelberg		148.3			1980	1980
Born, Max	Göttingen		144.2	yes	1933	1926	1931
Greiner, Walter	Frankfurt		135.6			1970	1980
Schrödinger, Erwin	Berlin		129.6	yes	1933	1926	1931
Schmidt, Michael	Heidelberg		112.5			1980	1980
Bergmann, Gerd	Köln		97.3			1980	1980
Haken, Hermann	Stuttgart TU		96.5			1961	1980
Hess, Karl	Wien		91.5			1980	1980
Schmid, Albert	Karlsruhe TU		88.2			1970	1980
Hohenberg, Pierre	München TU		87.9			1980	1980
Einstein, Albert	Berlin		82.2	yes	1933	1926	1931
Schatz, Gerd	Heidelberg		73.5			1980	1980
Müller, Bernd	Frankfurt		70.1			1980	1980
Fulde, Peter	Frankfurt	Darmstadt TU	68.4			1970	1980
Schlögl, Friedrich	Aachen TU		67.2			1961	1980
Gross, Ferdinand	Graz		66.2			1970	1980
Chemistry							
Meyerhof, Otto	Heidelberg		277.4	yes	1938	1931	1931
Sies, Helmut	München		172.6			1980	1980
Neuberg, Carl	Berlin		163.5		1938	1926	1931
Lynen, Feodor	München		160.2	yes		1961	1970
Eckstein, Fritz	Göttingen		159.2			1980	1980
Giese, Bernd	Darmstadt TU		153.0			1980	1980
Reetz Manfred T.	Marburg		151.0			1980	1980
Pette, Dirk	München		141.1			1970	1970
Lohmann, Karl	Heidelberg	Berlin	136.1			1931	1961
Neupert, Walter	München		135.8			1980	1980
Bergmann, Max	Dresden TU		129.6		1933	1926	1931
Vorbrüggen, Helmut	Berlin TU		125.2			1980	1980
von Raque Schleyer, Paul	Erlangen		110.8			1980	1980
Paulsen, Hans	Hamburg		110.0			1970	1980
Witkop, Bernhard	München		108.9			1950	1950
Hoppe, Rudolf	Gießen		106.3			1961	1980
Vögtlke, Fritz	Würzburg		104.7			1980	1980
Kessler, Horst	Frankfurt		103.8			1980	1980
Wieghardt, Karl	Hannover TU		95.0			1980	1980
Westphal, Otto	Freiburg		94.2			1961	1980
Mathematics							
von Neumann, Johann	Berlin		150.6		1933	1931	1931
Keller, Wilfried	Hamburg		75.6			1980	1980
Bott, Raoul	Bonn		51.8			1961	1970
Kaup, Wilhelm	Tübingen		43.2			1980	1980
Lorentz, George G.	Tübingen		39.7			1950	1950
von Mises, Richard	Berlin TU		38.2		1933	1926	1931
Friedrichs, Kurt	Göttingen		37.4		1937	1931	1931
Jensen, Ronald	Bonn		35.6			1980	1980
Krieger, Wolfgang	Heidelberg		35.3			1980	1980
Barth, Wolf	Erlangen		29.1			1980	1980
Szegö, Gabriel	Berlin		27.6		1933	1926	1931
Löh, Hans-Günter	Hamburg		26.2			1980	1980
Weyl, Hermann	Göttingen		26.0		1933	1926	1931
Schaeffer, Helmut	Hamburg		24.1			1980	1980
Lewy, Hans	Göttingen		23.4		1933	1931	1931
Dold, Albrecht	Heidelberg		22.3			1961	1980
Grauert, Hans	Göttingen		18.7			1961	1980
Becker, Jochen	Berlin TU		18.3			1980	1980
Hausdorff, Felix	Bonn		16.7			1926	1931
Menger, Karl	Wien		16.7		1938	1931	1931

Table A4: First Stages - Instrumenting with University Destruction for Subject Destruction

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable:	% Dep. Destruction * 1926	% Dep. Destruction * 1931	% Dep. Destruction * 1950	% Dep. Destruction * 1961	% Dep. Destruction * 1970	% Dep. Destruction * 1980
% Uni. Destruction * 1926	0.602***	-0.011	0.003	0.003	0.003	0.005
	(0.166)	(0.014)	(0.004)	(0.004)	(0.006)	(0.011)
% Uni. Destruction * 1931	-0.011	0.602***	0.003	0.003	0.003	0.004
	(0.013)	(0.167)	(0.004)	(0.004)	(0.005)	(0.008)
% Uni. Destruction * 1950	-0.001	0.001	0.608***	-0.002	0.001	0.015
	(0.026)	(0.026)	(0.148)	(0.024)	(0.023)	(0.017)
% Uni. Destruction * 1961	-0.000	0.001	-0.005	0.611***	0.001	0.014
	(0.026)	(0.026)	(0.025)	(0.148)	(0.023)	(0.020)
% Uni. Destruction * 1970	0.001	0.004	-0.013	-0.008	0.611***	0.026
	(0.027)	(0.027)	(0.027)	(0.025)	(0.148)	(0.031)
% Uni. Destruction * 1980	0.002	0.005	-0.041	-0.034	-0.021	0.715***
	(0.040)	(0.039)	(0.060)	(0.061)	(0.070)	(0.250)
# of Dismissals * Year FE	yes	yes	yes	yes	yes	yes
Extended controls	yes	yes	yes	yes	yes	yes
Observations	714	714	714	714	714	714
R-squared	0.814	0.813	0.810	0.810	0.811	0.865
Cragg-Donald EV Statistic			19.6			

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *% Dep. Destruction * 1926* reported in column (1) is equal to percentage destruction at the department level caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. Dependent variables in columns (2) to (6) are defined accordingly. The instrumental variable *% Uni. Destruction * 1926* is equal to percentage destruction at the university level caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other instrumental variables are defined accordingly. The control variables *# of Dismissals * Year FE* are equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with a full set of year dummies as in the main specification. *Extended Controls* are all controls as reported in column (6) of Table 5, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, % City Destruction * Year FE, Länder Dummies * Post1945, # of Deps. Within 50km, Armament Industries (1933) * Year FE, Fract. Jews (1933) * Post1933, and Dist. to Iron Curtain * Post1945.

Table A5: Interaction of Human and Physical Capital

	(1)	(2)	(3)	(4)
Dependent Variable:	Publications	Publications	Citation weighted Publications	Citation weighted Publications
Number of Dismissals * 1926	0.026	0.026	-0.087	-0.087
	(0.026)	(0.026)	(0.077)	(0.077)
Number of Dismissals * 1940	-0.175***	-0.174***	-0.181***	-0.181***
	(0.038)	(0.039)	(0.064)	(0.064)
Number of Dismissals * 1950	-0.246**	-0.159	-0.187***	-0.162***
	(0.099)	(0.096)	(0.028)	(0.035)
Number of Dismissals * 1961	-0.286***	-0.271***	-0.191***	-0.174***
	(0.071)	(0.091)	(0.039)	(0.041)
Number of Dismissals * 1970	-0.323***	-0.316***	-0.215***	-0.244***
	(0.069)	(0.084)	(0.050)	(0.080)
Number of Dismissals * 1980	-0.272***	-0.284***	-0.181***	-0.222**
	(0.061)	(0.072)	(0.064)	(0.106)
% Destruction * 1926	-0.002	-0.002	-0.003	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)
% Destruction * 1931	-0.005*	-0.005*	-0.003	-0.003
	(0.002)	(0.002)	(0.004)	(0.004)
% Destruction * 1950	-0.005**	-0.002	-0.004*	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)
% Destruction * 1961	-0.003	-0.002	-0.002	-0.002
	(0.002)	(0.002)	(0.003)	(0.003)
% Destruction * 1970	0.003	0.004	0.007	0.006
	(0.002)	(0.003)	(0.004)	(0.004)
% Destruction * 1980	0.001	0.000	0.009	0.007
	(0.003)	(0.004)	(0.007)	(0.006)
Number of Dismissals * % Destruction * 1950		-0.003**		-0.001
		(0.001)		(0.001)
Number of Dismissals * % Destruction * 1961		-0.000		-0.001
		(0.001)		(0.001)
Number of Dismissals * % Destruction * 1970		-0.000		0.001
		(0.001)		(0.002)
Number of Dismissals * % Destruction * 1980		0.001		0.002
		(0.002)		(0.003)
Extended controls	yes	yes	yes	yes
Observations	714	714	714	714
R-squared	0.718	0.723	0.552	0.555

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Publications* is the sum of publications published by all scientists in department d in a five-year window around year t. The dependent variable *Citation weighted Pubs.* is the sum of citation weighted publications published by all scientists in department d in a five-year window around year t. Dependent variables are normalized to have zero mean and a standard deviation of one within subjects. *Number of Dismissals * 1926* is equal to the number of dismissals between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * 1926* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with an indicator that is equal to 1 for observations from 1926. The other interactions are defined accordingly. The excluded interaction is % destruction with 1940, the last observation before the bombings. *Number of Dismissals * % Destruction * 1950* is the triple interaction of the number of dismissals, percentage destruction, and an indicator for 1950. The other triple interactions are defined accordingly. *Extended Controls* are all controls as reported in column (6) of Table 5, i.e. Department FE, Subject*Year FE, Occupation Zones * Post1945, % City Destruction * Year FE, Länder Dummies * Post1945, # of Deps. Within 50km, Armament Industries (1933) * Year FE, Fract. Jews (1933) * Post1933, and Dist. to Iron Curtain * Post1945.

Table A6: Dismissals in Different Quality Groups

	(1)	(2)
	Publications	Citation-weighted Publications
# of Dismissals (below median quality) * 1926	0.060	-0.039
	(0.084)	(0.176)
# of Dismissals (below median quality) * 1940	-0.003	-0.065
	(0.087)	(0.136)
# of Dismissals (below median quality) * 1950	-0.071	-0.039
	(0.163)	(0.137)
# of Dismissals (below median quality) * 1961	-0.022	-0.149
	(0.132)	(0.139)
# of Dismissals (below median quality) * 1970	-0.020	-0.099
	(0.120)	(0.157)
# of Dismissals (below median quality) * 1980	-0.059	-0.056
	(0.156)	(0.208)
# of Dismissals (top 50th - 10th perc.) * 1926	0.295***	0.418***
	(0.094)	(0.151)
# of Dismissals (top 50th - 10th perc.) * 1940	-0.070	0.272***
	(0.057)	(0.094)
# of Dismissals (top 50th - 10th perc.) * 1950	-0.048	0.227
	(0.199)	(0.189)
# of Dismissals (top 50th - 10th perc.) * 1961	-0.251**	0.173
	(0.123)	(0.112)
# of Dismissals (top 50th - 10th perc.) * 1970	-0.315***	0.316*
	(0.107)	(0.184)
# of Dismissals (top 50th - 10th perc.) * 1980	-0.137	0.315
	(0.201)	(0.297)
# of Dismissals (top 10th perc.) * 1926	-0.313**	-0.703***
	(0.153)	(0.122)
# of Dismissals (top 10th perc.) * 1940	-0.516**	-0.834***
	(0.207)	(0.109)
# of Dismissals (top 10th perc.) * 1950	-0.671***	-0.860***
	(0.241)	(0.169)
# of Dismissals (top 10th perc.) * 1961	-0.664***	-0.660***
	(0.220)	(0.180)
# of Dismissals (top 10th perc.) * 1970	-0.732***	-0.974***
	(0.229)	(0.202)
# of Dismissals (top 10th perc.) * 1980	-0.686**	-0.908***
	(0.295)	(0.258)
% Destruction * Year Dummies	yes	yes
Department FE	yes	yes
Subject*Year FE	yes	yes
Occupation Zones * Post45	yes	yes
% City Destruction * Year Dummies	yes	yes
All additional controls	yes	yes
Observations	714	714
R-squared	0.735	0.586

***significant at 1% **significant at 5% *significant at 10% (s.e. clustered at university level)

The dependent variable *Publications* reported in column (1) is the sum of publications published by all scientists in department d in a five-year window around year t. The dependent variable *Citation weighted Publications* reported in column (2) is the sum of citation weighted publications published by all scientists in department d in a five-year window around year t. Dependent variables are normalized to have zero mean and a standard deviation of one within subjects. The top part of the table reports coefficients on the interation of the number of dismissals of below median quality (between 1933 and 1940) with year dummies. The middle part of the table reports coefficients on the interation of the number of dismissals between the top 50th and 10th quality percentiles with year dummies. The bottom part of the table reports coefficients on the interation of the number of dismissals in the top 10th percentile with year dummies. The excluded interaction is the number of dismissals with 1931, the last observation before the dismissals. *% Destruction * Year FE* is equal to percentage destruction caused by Allied bombings between 1940 and 1945 interacted with a set of year indicators as in the main specification. All other controls are defined as in previous regressions.

Table A7: Quality of Hires and Age of Dismissed Scientists

	(1)	(2)	(3)	(4)	(5)
Dependent Variable:	Quality of Hires	Quality of Hires	Quality of Hires	Quality of Hires	Quality of Hires
	All Dismissals	Above median Quality	Top 25th percentile	Top 10th percentile	Top 5th percentile
Panel A: Quality measured by lifetime citation weighted publications					
Number of Young Dismissals * 1940	-0.246**	-0.346**	-0.444**	-0.579**	-0.545**
	(0.106)	(0.133)	(0.193)	(0.275)	(0.242)
Number of Young Dismissals * 1950	-0.211**	-0.279**	-0.417**	-0.511**	-0.500**
	(0.091)	(0.120)	(0.174)	(0.240)	(0.186)
Number of Young Dismissals * 1961	-0.202**	-0.259**	-0.422**	-0.556**	-0.514**
	(0.090)	(0.117)	(0.176)	(0.248)	(0.215)
Number of Young Dismissals * 1970	-0.203**	-0.265**	-0.430**	-0.578**	-0.595***
	(0.093)	(0.124)	(0.180)	(0.247)	(0.189)
Number of Young Dismissals * 1980	-0.178**	-0.257**	-0.412**	-0.515**	-0.574***
	(0.078)	(0.107)	(0.161)	(0.217)	(0.193)
Number of Old Dismissals * 1940	0.089	0.155**	0.166*	0.154	-0.075
	(0.057)	(0.074)	(0.088)	(0.302)	(0.487)
Number of Old Dismissals * 1950	0.068	0.097	0.139	0.083	-0.096
	(0.067)	(0.091)	(0.109)	(0.303)	(0.528)
Number of Old Dismissals * 1961	0.062	0.078	0.151*	0.154	-0.123
	(0.057)	(0.079)	(0.088)	(0.247)	(0.458)
Number of Old Dismissals * 1970	0.061	0.081	0.145	0.091	-0.143
	(0.064)	(0.093)	(0.120)	(0.310)	(0.529)
Number of Old Dismissals * 1980	0.022	0.019	0.054	-0.042	-0.474
	(0.060)	(0.087)	(0.141)	(0.283)	(0.601)
Panel B: Quality measured by pre-hiring citation weighted publications					
Number of Young Dismissals * 1940	-0.165	-0.174	-0.126	-0.277	-0.254
	(0.116)	(0.149)	(0.184)	(0.293)	(0.196)
Number of Young Dismissals * 1950	-0.150*	-0.209**	-0.258**	-0.358*	-0.317**
	(0.080)	(0.094)	(0.122)	(0.176)	(0.140)
Number of Young Dismissals * 1961	-0.154*	-0.188	-0.250*	-0.367*	-0.186
	(0.082)	(0.114)	(0.141)	(0.211)	(0.187)
Number of Young Dismissals * 1970	-0.147*	-0.172*	-0.230*	-0.381**	-0.308*
	(0.080)	(0.096)	(0.116)	(0.178)	(0.163)
Number of Young Dismissals * 1980	-0.146*	-0.199**	-0.225*	-0.373**	-0.379***
	(0.073)	(0.088)	(0.114)	(0.166)	(0.137)
Number of Old Dismissals * 1940	0.113*	0.083	0.007	-0.032	0.067
	(0.065)	(0.110)	(0.153)	(0.412)	(0.749)
Number of Old Dismissals * 1950	0.027	-0.015	-0.070	-0.069	-0.195
	(0.046)	(0.074)	(0.087)	(0.215)	(0.529)
Number of Old Dismissals * 1961	0.067**	0.038	0.001	0.114	-0.235
	(0.030)	(0.064)	(0.066)	(0.197)	(0.560)
Number of Old Dismissals * 1970	0.024	-0.036	-0.070	-0.050	-0.274
	(0.047)	(0.079)	(0.089)	(0.218)	(0.553)
Number of Old Dismissals * 1980	0.020	-0.045	-0.214*	-0.204	-0.459
	(0.052)	(0.088)	(0.114)	(0.225)	(0.574)
% Destruction * Year FE	yes	yes	yes	yes	yes
Extended Controls	yes	yes	yes	yes	yes
Observations	602	602	602	602	602

The dependent variable *Quality of Hires* measures average quality of hires in department *d* between year *t* and year *t-1*. In panel A, quality of hires is measured as the career average of citation-weighted publications averaged across all hires in a department. In panel B, quality of hires is measured as average citation-weighted publications before year *t* averaged across all hires in a department. The average is calculated for 5 years at the midpoint between year *t* and year *t-1* and is adjusted for the age of the scientist. The dependent variables are normalized to have zero mean and a standard deviation of one within subjects. *Number of Young Dismissals * 1926* is equal to the number of dismissals of below median age between 1933 and 1940 interacted with an indicator that is equal to 1 for observations from 1926. *Number of Old Dismissals * 1926* is equal to the number of dismissals of equal or above median age interacted with an indicator that is equal to 1 for observations from 1926. Median age is 49 in physics, 46 in mathematics, and 49 in chemistry. The other interactions are defined accordingly. In column (1) number of dismissals are all dismissals, in column (2) number of dismissals measure dismissals of above median quality, and so on. Excluded interactions are the number of dismissals with 1931. *% Destruction * Year FE* measures percentage destruction caused by bombings between 1940 and 1945 interacted with a set of year fixed effects. *Extended Controls* are all controls as reported in column (6) of Table 5.

9.3 Contribution of Human and Physical Capital Shocks to the Decline of German Science

Dismissal Shock

The effect of the dismissals on German science is calculated using the regression results including all controls as in column (6) of Tables 5 and 6. Using the number of dismissals in each department I calculate the reduction in (citation weighted) publications in each department for 1940, 1950, 1961, 1970, and 1980 in terms of standard deviations. For each department and year I therefore calculate:

$\Delta y_{1940} = \widehat{\beta}_{1940}^{dismissals} * (\# \text{ of Dismissals 33-40}),\ldots, \Delta y_{1980} = \widehat{\beta}_{1980}^{dismissals} * (\# \text{ of Dismissals 33-40})$

Multiplying the Δy's with the subject level standard deviations of (citation weighted) publications I calculate the fall in output in each department in terms of (citation weighted) publications (call them ΔY_{year}). The ΔY_{year}'s compute the reduction in (citation weighted) publications for the years 1940, 1950, 1961, 1970, and 1980. To obtain the total reduction in (citations weighted) publications for all years since 1933, I assume that the decline in output between April 1933 and December 1945 was ΔY_{1940} in each year. Similarly, between January 1946 and December 1955 the annual loss in output was ΔY_{1950}, and so on. Total reduction in output between 1933 and 1980 was therefore:

$$\Delta Y_{1933-1980} = 12.75 * \Delta Y_{1940} + 10 * \Delta Y_{1950} + 10 * \Delta Y_{1961} + 10 * \Delta Y_{1970} + 5 * \Delta Y_{1990}$$

Adding $\Delta Y_{1933-1980}$'s for all departments in a subject, I obtain the total loss in (citation weighted) publications in each subject from 1933 to 1980 ($\Delta Y_{1933-1980}^{all}$).

To calculate percentage losses I obtain the total number of (citation weighted) publications that were published in a subject in 1940, 1950, 1961, 1970, and 1980:

$Y_{1940}^{tot}, Y_{1950}^{tot},\ldots, Y_{1980}^{tot}$

Average yearly (citation weighted) publications are obtained as follows:

$Y_{yearly}^{tot} = \frac{1}{5}(Y_{1940}^{tot} + Y_{1950}^{tot} + Y_{1961}^{tot} + Y_{1970}^{tot} + Y_{1980}^{tot})$

Total publications between April 1933 and December 1980 are calculated as:

$Y_{1933-1980}^{tot} = 47.75 * Y_{yearly}^{tot}$

Finally, percentage loss between 1933 and 1980 is calculated as:[38]

$\%\Delta Y_{1933-1980}^{all} = \frac{\Delta Y_{1933-1980}^{all}}{(Y_{1933-1980}^{tot} - \Delta Y_{1933-1980}^{all})} * 100$

The top panel of Table A8 summarizes the total loss of (citation weighted) publications between 1933 and 1980 that was caused by the dismissal of scientists in Nazi Germany.

Bombing Shock

I calculate the effect of Allied bombings on German science in a similar way. The calculations also rely on the regression results including all controls as in column (6) of Tables 5 and

[38] Note: $\Delta Y_{1933-1980}^{all} < 0$.

6. Using percentage destruction in each department I calculate the reduction in (citation weighted) publications in each department for 1950, 1961, 1970, and 1980 in terms of standard deviations. For each department and year I therefore calculate:[39]

$\Delta y_{1950} = \widehat{\beta}_{1950}^{bombings} * (\%$ Destruction 42-45),..., $\Delta y_{1980} = \widehat{\beta}_{1980}^{bombings} * (\%$ Destruction 42-45)

Multiplying the Δy's with the subject level standard deviations of (citation weighted) publications I calculate the fall in output in each department in terms of (citation weighted) publications (call them ΔY_{year}). The ΔY_{year}'s compute the reduction in (citation weighted) publications for the years 1950, 1961, 1970, and 1980. To obtain the total reduction in (citations weighted) publications for all years since 1944, I assume that the loss in output between January 1944 and December 1955 was ΔY_{1950} in each year. Similarly, between January 1956 and December 1965 the annual loss in output was ΔY_{1961}, and so on. Total reduction in output between 1944 and 1980 is therefore:

$$\Delta Y_{1944-1980} = 11 * \Delta Y_{1950} + 10 * \Delta Y_{1961} + 10 * \Delta Y_{1970} + 5 * \Delta Y_{1990}$$

Adding the $\Delta Y_{1944-1980}$'s for all departments in a subject, I obtain the total loss in (citation weighted) publications that was caused by Allied bombings in each subject from 1944 to 1980 ($\Delta Y_{1944-1980}^{all}$).

To calculate percentage losses I obtain the total number of (citation weighted) publications that were published in a subject in 1950, 1961, 1970, and 1980:

Y_{1950}^{tot}, Y_{1961}^{tot},..., Y_{1980}^{tot}

Average yearly (citation weighted) publications are obtained as follows:

$$Y_{yearly}^{tot} = \frac{1}{4}(Y_{1950}^{tot} + Y_{1961}^{tot} + Y_{1970}^{tot} + Y_{1980}^{tot})$$

Total publications between January 1944 and December 1980 are calculated as:

$$Y_{1944-1980}^{tot} = 36 * Y_{yearly}^{tot}$$

Finally, percentage loss between 1944 and 1980 is calculated as:[40]

$$\%\Delta Y_{1944-1980}^{all} = \frac{\Delta Y_{1944-1980}^{all}}{(Y_{1944-1980}^{tot} - \Delta Y_{1944-1980}^{all})} * 100$$

The bottom panel of Table A7 summarizes the total loss of (citation weighted) publications between 1944 and 1980 that was caused by Allied bombings.

[39] I only consider $\widehat{\beta}_{x}^{bombings}$ if the coefficient is at least significant at the 10 percent level for year X. For all other years I set $\Delta y = 0$. As a result, Δy_{1961},Δy_{1970}, Δy_{1980} are set to 0. See column (6) of Tables 5 and 6.

[40] Note: $\Delta Y_{1933-1980}^{all}$ <0.

Table A8: Total Productivity Loss of Dismissals and Bombings

	Physics	Chemistry	Mathematics	Total
Dismissal Loss				
Number of publications lost 1933-1980	2029	6848	699	9576
Number of citation weighted publication lost 1933-1980	60703	122248	8969	191920
Percentage of publications lost 1933-1980	30.5	36.5	33.5	33.5
Percentage of citation weighted publications lost 1933-1980	34.0	33.2	36.6	34.6
Publications by dismissed scientists	362	594	225	1181
Citation weighted publications by dismissed	14826	12708	4835	32369
Bombing Loss				
Number of publications lost 1944-1980	231	710	87	1028
Number of citation weighted publication lost 1944-1980	7410	13589	1195	22194
Percentage of publications lost 1944-1980	5.0	5.9	6.2	5.7
Percentage of citation weighted publications lost 1944-1980	6.2	5.5	7.6	6.4

9.4 Data Appendix

9.4.1 Panel Data Set of Scientists in German and Austrian Universities from 1926 to 1980

As described in the main text I use "Kürschners Deutscher Gelehrtenkalender" (KDG) to construct a panel data set of scientists in German and Austrian universities at 7 points in time between 1926 and 1980. The KDG covers all researchers in German speaking universities. To compile the KDG the editors contacted all German speaking universities to obtain faculty rosters and then sent out questionnaires to all faculty members. The response rate to these questionnaires was very high. If a scholar did not answer the questionnaire the editors of the KDG tried to find as much information as possible on the scholar.

Sometimes a slight delay occurred until a young researcher was included in the KDG or until a university change was recorded. A privatdozent, for example, may have been appointed in 1926 but may not appear in the 1926 volume because she was not a privatdozent at the time the questionnaires were sent out. The same scientist, however, would appear in the 1931 volume with her complete appointment history. If that history indicates that she had already been a privatdozent in 1926 I also include her in the 1926 roster. This gives a more accurate picture of each department's faculty in the relevant year.

The KDGs list researchers who occupied different university positions. I focus on all researchers who had the right to teach ('venia legendi') at a German university, i.e. all researchers who were at least privatdozent. The data therefore include ordinary professors, extraordinary professors, honorary professors, and 'privatdozenten'. The Nazi government renamed the 'privatdozent' position into 'dozent' which affects the data in 1940. To have a comparable set of researchers across different years I also add all dozenten to the data.

9.4.2 Output Measures for German and Austrian Science Departments

The publications and citations data cover historical and current top science journals and were downloaded from the ISI Web of Science. The set of journals is based on historical accounts of relevant top journals and on current journal rankings.

Historical top journals

The list of top journals in the 1920s and 1930s includes mostly German journals but also the major international journals. As German science was leading at the time, many of the German journals were among the best journals worldwide which is underlined by an article published in Science in 1941: "Before the advent of the Nazis the German physics journals (Zeitschrift für Physik, Annalen der Physik, Physikalische Zeitschrift) had always served as the central organs of world science in this domain [...] In 1930 approximately 700 scientific papers were printed in its [the Zeitschrift für Physik´s] seven volumes of which 280 were by foreign scientists" (American Association for the Advancement of Science, 1941).

I obtain the list of historical journals using a three step process. First, I obtain all German science journals published in the 1920s to 1940s that are included in the Web of Science. Second, I include three general science journals that were relevant outlets for German scientists publishing in the 1920s and 1930s: Nature, Science, and the Proceedings of the Royal Society. Finally, the list of historical top journals is augmented by four international field journals that have been recommended by historians of science as important outlets for German scientists. Relevant chemistry journals were suggested by Ute Deichmann and John Andraos who work on chemistry in the early 20th century. Historical mathematics journals were suggested by Reinhard Siegmund-Schultze and David Wilkins who are specialists in the history of mathematics.

Current top journals

The definition of top journals for German (and international) scientists changed substantially since the 1920s and 30s. To reflect this change in my output measure I also compile a second list of top journals based on current international journal rankings. I use rankings provided by SCImago Journal & Country Rank to obtain the ten most cited journals in general science, physics, and chemistry. SCImago does not rank mathematics journals.[41] I therefore obtain the current most cited mathematics journals from a commonly used ranking provided by the University of Texas.[42]

Universe of Articles in Top Science Journals Published Between 1920 and 1985

The overall list of top science journals includes 51 journals. I download all articles published in these journals between 1920 and 1985. I.e. even if a journal only became a top journal in later years I download all articles published in the journal since 1920. A small number of journals were only founded after 1920. For these journals I download all articles since the creation of the journal. The publication of a few journals was interrupted towards the end of WWII. As

[41] See http://www.scimagojr.com, accessed 13th of May 2010.

[42] See http://www.ma.utexas.edu/users/lsilvest/rankings/mranking.html, accessed 13th of May, 2010.

a result these journals have missing data during those years. Furthermore, some journals have missing data in the Web of Science for some years even though the journal was published in that year.[43] The inclusion of year fixed effects in all regressions addresses this limitation.

9.4.3 Data on Bombings of German Universities and Science Departments

Data on university level bombing destruction come from university websites and from Tietze (1995), Phillips (1983), Samuel and Thomas (1949), Schneider (1990), and Cheval (1991).

As outlined in the main text, data on department level bombing destruction is obtained by contacting university archivists and asking them to provide destruction information for buildings used by physicists, chemists, and mathematicians.[44] Detailed data sources for department level destruction are listed in Table A8.

If a department occupied more than one building (e.g. one building for the institute of experimental physics and a different building accommodating the institute for theoretical physics) I average percentage destruction across all buildings that were used by the department.

In some cases the historical sources only provide verbal descriptions of bombing destruction. I convert these descriptions into percentage destruction according to the following rule:

Verbal description	Percentage destruction
"completely destroyed"	100%
"heaviest destruction" or "destroyed to a large extent"	75%
"heavy destruction"	50%
"part destruction" or "burnt out"	25%
"light destruction"	10%

9.4.4 Data Sources of Control Variables

I obtain data on control variables from a number of sources.

Number of Departments Within 50km

For each university I calculate the number of departments in the same subject within 50km. The measure also includes universities that were founded after 1945. The full list of universities in Germany as of 2010 was obtained from "Personal and Hochschulen - Fachserie 11, Reihe 4.4, 2010" accessed online at http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/

[43] I have highlighted this problem to Thomson Scientific. It is caused by error prone scanning of historical journals.

[44] The following university archivists put in a lot of time and effort to gather information on department level bombing destruction or to provide access to the relevant sources: Klaus Graf (Aachen TU), Claudia Schülzky (Berlin TU), Thomas Becker (Bonn), Klaus Oberdieck (Braunschweig TU), Matthias Lienert (Dresden TU), Michael Maaser (Frankfurt), Dieter Speck (Freiburg), Eva-Maria Felschow (Gießen), Ulrich Hunger (Göttingen), Alois Kernbauer (Graz), Marieluise Vesulak (Graz TU), Ralf-Torsten Speler (Halle), Eckart Krause (Hamburg), Lars Nebelung (Hannover TU), Peter Goller (Innsbruck), Joachim Bauer (Jena), Klaus Nippert (Karlsruhe TU), Dagmar Bickelmann (Kiel), Andreas Freitäger (Köln), Jens Blecher and Roy Lämmel (Leipzig), Katharina Schaal (Marburg), Hans-Michael Körner (München), Margot Fuchs (München TU), Sabine Happ (Münster), Norbert Becker (Stuttgart), Thomas Maisel (Wien), Juliane Mikoletzky (Wien TU), Marcus Holtz (Würzburg).

DE/Content/Publikationen/Fachveroeffentlichungen/BildungForschungKultur/Hochschulen/PersonalHochschulen2110440107004,property=file.pdf, a publication of the German statistical agency (Statistisches Bundesamt). A list of Austrian universities in 2011 was obtained from the Austrian statistical agency (Statistik Austria) accessed online at: http://www.statistik.at/web_de/statistiken/bildung_und_kultur/formales_bildungswesen/universitaeten_studium/index.html. Using university websites I check for their founding year and whether they have a physics, chemistry, or mathematics department. This allows me to calculate the number of departments within 50km for each department and year in my sample.

Armament Related Industries in 1933

Data on the share of firms in three armament related industries (iron and steel production, mechanical engineering and vehicle construction, chemical industry) come from the establishment census of 1933 that was published in "Statistik des Deutschen Reichs – Band 463: Gewerbliche Betriebszählung, 1935". Data on industry shares in Austria come from the establishment census of 1930 that was published by the Bundesamt für Statistik in "Gewerbliche Betriebszählung in der Republik Österreich, 1932". The data measure the share of firms that belong to a certain industry (among all firms) at the city level.

Fraction of Jews in 1933

The fraction of Jews in 1933 is based on German census data from 1933. The data were obtained from "Statistik des Deutschen Reiches: Die Bevölkerung des Deutschen Reichs nach den Ergebnissen der Volkszählung 1933, Band 451, Heft 3 (1936)". As the German census of 1933 did not cover Austrian cities data on the Jewish population in the three Austrians cities in my sample were obtained from a number of different sources. Data for Vienna are for the year 1934 and come from "Statistisches Jahrbuch der Stadt Wien 1930-1935 Neue Folge, 3. Band". Data for Graz are from 1938 and come from „Israelitische Kultusgemeinde für Steiermark, Kärnten und die politischen Bezirke des Burgenlandes Oberwart, Güssing und Jennersdorf“ and were accessed online at http://www.ikg-graz.at/. Data on Innsbruck are from 1938 and come from Salinger (2007).

Distance to the Iron Curtain

Distance to the Iron Curtain for German cities come from Redding and Sturm (2008). Distance to the Iron Curtain for Austrian cities is measured equivalently using the original Redding and Sturm method.[45]

[45] I thank Daniel Sturm for kindly offering to use his material to measure distances to the iron curtain for Austrian cities.

Table A8: Detailed Data Sources for Department Level Destruction Data

University	Source for Department Level Destruction
Aachen TU	Kriegsschäden Akten 438, 1189, 1234a
Berlin	Humboldt Universität Berlin, Universitätsarchiv, Bestand des Universitätskurators, Aktennr. 655
Berlin TU	Universitätsarchiv der Technischen Universität Berlin in der Universitätsbibliothek, 602-44
Bonn	van Rey (1995)
Braunschweig TU	Kuhlenkamp (1976)
Darmstadt TU	missing
Dresden TU	Technische Universität Dresden (1996)
Erlangen	no bombing destruction
Frankfurt	Universitätsarchiv Frankfurt (1947), Abteilung 50, Nr. 3046 BII, 241-244
Freiburg	Rösiger (1957)
Gießen	Universitätsarchiv Gießen, PrA. Nr. 2208
Göttingen	Brinkmann (1985)
Graz	e-mail communication with university archivist Prof. Dr. Alois Kernbauer
Graz TU	Weingand (1995), p. 58, p. 103
Greifswald	no bombing destruction
Halle	Eberle (2002)
Hamburg	e-mail communication with university archivist Eckart Krause, Kröplin (1951), pp.422-428, Senat Hamburg (1955), Giles (1985), p. 297
Hannover TU	Wolters (1950)
Heidelberg	no bombing destruction
Innsbruck	Klebelsberg (1953), pp. 193-196
Jena	Schmidt, Elm, Steiger, Böhlaus (1983), pp. 301-302
Karlsruhe TU	Hoepke (2007)
Kiel	Jaeger (1965), pp. 117-202
Köln	Universitätsarchiv documents
Leipzig	Füssler (1961)
Marburg	Fritzsche, Hardt, and Schade (2003), p. 30
München	Mager (1958), p. 255
München TU	Technische Hochschule München (1968)
Münster	Niemer (2010)
Rostock	no bombing destruction
Stuttgart TU	Technische Hochschule Stuttgart (1947)
Tübingen	no bombing destruction
Wien	Adamovich (1947)
Wien TU	e-mail communication with university archivist Dr. Juliane Mikoletzky
Würzburg	e-mail communication with university archivist Dr. Marcus Holtz

The table shows detailed data sources for department level destruction. Detailed citations can be found below.

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