

Bombs, Brains, and Science

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

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Abstract

This paper analyzes how human and physical capital affect the productivity of science departments. As inputs are often chosen on the basis of unobservable productivity factors and high quality scientists attract more funding for physical capital, I use two extensive shocks to identify the relative importance of human and physical capital. As a shock to physical capital I use department level destruction by Allied bombings during WWII. As human capital shock I use the dismissal of mostly Jewish scientists in Nazi Germany. Using data on German and Austrian science departments from 1926 to 1980, I find that a 10 percent shock to physical capital lowered productivity by about 0.05 of a standard deviation in 1950. A 10 percent shock to human capital lowered productivity by about 0.2 of a standard deviation. Departments that experienced a large shock to physical capital recovered very quickly (by 1961). The human capital shock, however, persisted until the end of my sample period (1980). Additional results show that the loss of ‘star scientists’ had particularly large adverse effects on the long-run productivity of science departments.

1 Introduction

What are the inputs which lead to successful scientific research? Similarly to the production of goods, the basic inputs in the creation of scientific knowledge are human and physical capital, i.e. scientists and their laboratories.¹ Having a better understanding of their relative contributions to the productivity of universities is important for researchers, university administrators, and policy makers alike. This is particularly true in a world where ideas are seen as important drivers of technological progress and economic growth as proposed by models of endogenous growth (eg. Romer, 1990). A better understanding of the respective roles of human and physical

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¹In the economics literature the notion of physical and human capital as key inputs for the production of scientific knowledge goes back at least until Machlup (1961).

capital would inform us on the question of whether it is better to hire outstanding scholars or invest in new laboratories if a university or country wanted to raise its research output.

Despite the importance of these issues we know little about the relative importance of different inputs for producing scientific output. As highlighted for firms by a large literature in industrial economics the estimation of production functions is complicated because inputs are often chosen on the basis of unobservable productivity factors (see for example Akerberg et. al., 2007). The estimation of ‘knowledge production functions’ is similarly challenging. ‘Star scientists’ may be attracted by highly productive departments and at the same time enhance the department’s productivity. Similarly, high quality departments attract more funding for physical capital which further increases productivity. Obtaining undistorted estimates of the contribution of human and physical capital is further complicated because the best scientists tend to attract funding for additional physical capital.

In this paper I use two extensive shocks to overcome these difficulties. As a shock to the human capital of science departments I use the dismissal of mostly Jewish scientists in Nazi Germany and Austria. As a shock to physical capital I use the destruction of German and Austrian university facilities by allied bombings in WWII.² The shocks affected departments very differently and therefore create ample variation. The dismissal of scientists reduced department size by up to 60 percent whereas other departments remained unaffected. Similarly, allied bombings completely destroyed facilities of some departments while others were left completely intact.

To investigate the persistence of these human and physical capital shocks I construct a new dataset covering 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 productivity measures in top journals for each scientist. This allows me to construct departmental productivity measures for science departments between 1926 and 1980. I complement this data with historical data on dismissals from German and Austrian science departments. Furthermore, I construct a new dataset from material contained in university archives measuring the destruction of science departments during allied bombings.

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 departmental productivity by about 0.2 standard deviations. A 10 percent shock to physical capital lowered productivity by

²Some science professors may have been killed by Allied bombings and thus bombings may have had an impact on human capital as well. In regressions not reported here I therefore test whether the number of scientists who disappear from the sample between 1940 and 1950 is correlated with the bombing destruction in the department. This is not the case. The p-value in a regression of disappearance from the sample (for non-retirement reasons) on destruction interacted with 1950 is 0.81. This is not very surprising as the total number of casualties in Germany from Allied bombings was relatively low. Historians are still debating about the exact number of casualties in Germany due to Allied bombings but estimates range from 305,000 (United States Strategic Bombing Survey, 1945, p. 95) which is probably an underestimate to between 750,000 and one million (Frankland, 2005, p. 833) which may be too high. Official figures from the German statistical agency mention 410,000 death due to allied bombings (see Hohn, 1991, p. 51). The German population at the beginning of WWII was about 80 million. Therefore, between 0.38 and 1.25 percent of the German population was killed by Allied bombings.

about 0.05 of a standard deviation. Departments that experienced a shock to physical capital, however, recovered very quickly (by 1961 at the latest). In some specifications, departmental productivity in departments that had been bombed during WWII even seem to have benefited from upgrading during post-war reconstruction in the longer run (by 1970). The negative human capital shock, however, persisted in the long run and continued to have a negative impact on scientific output more than 40 years after the dismissals (in 1980).

Recent research has highlighted the importance of ‘star scientists’ for scientific research (Azoulay, Zivin, and Wang, 2010). Many of the dismissed scholars in my data were among the leaders of their profession. Among the dismissed were 14 Nobel Laureates such as the physicists Albert Einstein, Max Born, and Erwin Schrödinger or the chemists Fritz Haber and Otto Meyerhof. This allows me to investigate whether losing high quality scientists has a larger impact on departmental productivity. I indeed find that the dismissal of higher quality scientists was associated with larger drops in departmental productivity. Losing ‘star’ scientists was particularly detrimental. The loss of a scientist in the top 5th percentile of the quality distribution lowered long-run department productivity by between 0.9 and 1.5 standard deviations. I also document that the negative human capital shock had a permanent adverse effect on the quality of new hires and that the quality of hires dropped more after the dismissal of high quality scientists. The fall in the quality of new hires may be an important mechanism for the persistence of the human capital shock.

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 inputs. Existing empirical evidence on the role of human and physical capital for the production of scientific knowledge has mostly shown correlations. Scientific productivity of university departments in the United Kingdom has been shown to be 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 Stern, 2002).³

My findings also relate to several papers investigating the persistence of large economic shocks. Physical capital shocks, such as extensive bombings usually disappear relatively quickly (Davis and Weinstein, 2002, Brackman, Garretsen, Schramm, 2004, Miguel and Roland, 2011). 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, 2011). In Germany, individuals living in cities with a larger loss of Jewish population during the Nazi era still had less education in 1985 (Akbulut-Yuksel and Yuksel, 2011). In this paper I can analyze the persistence of human and physical capital shocks within the same framework for the first time. My results confirm the findings of earlier papers that have separately analyzed physical and human shocks.

In the remainder of this paper I first describe the two shocks that I will use to identify

³Recently, Aghion et al. (2010) have used variation in funding of universities to identify the role of university governance on research performance but they do not investigate the role of human and physical capital.

the importance of human and physical capital for the creation of scientific knowledge. I then provide a more detailed description of the data in section 3. Section 4 presents the main results on the persistence of human and physical capital shocks. Section 5 provides evidence on some of the mechanisms of how the human capital shock could persist for such a long time. Section 6 concludes.

2 Human and Physical Capital Shocks

The production of scientific knowledge uses human and physical capital as main inputs.

$$Y = f(L,K)$$

Where Y measures output such as publications or citations in top science journals, L measures human capital and K measures physical capital. How efficiently human and physical capital are combined is determined by university governance. Recent research has shown that more autonomous universities and those operating in a more competitive environment are better in converting increases in funding into research output (Aghion et al., 2009).

Estimating the production function outlined above is challenging because inputs are often chosen on the basis of unobservable productivity factors (Akerberg et. al., 2007). ‘Star scientists’ may be attracted by highly productive departments and at the same time enhance the department’s productivity. Establishing causality is therefore very challenging. An additional challenge is the separation of the effects of human and physical capital because good scientists try to work in universities with well equipped laboratories and organisational structures, and successful scientists tend to attract the funding for additional physical capital.

Even without these endogeneity concerns it would be very difficult to directly estimate the production function of universities because it is almost impossible to obtain information on capital stocks and flows of individual science departments over reasonably long time periods.⁴

In this paper, I therefore use an indirect way of identifying the importance of human and physical capital by investigating the persistence of large and exogenous shocks to the human and physical capital of German and Austrian universities. In particular, I estimate the following regression equation:

$$\text{Output}_{dt} = \beta_1 + \sum_t \beta_{2t} \text{HCSHock}(1933-40)_d * \text{Year}_t + \sum_t \beta_{3t} \text{PCSHock}(1942-45)_d * \text{Year}_t + \beta_4 \text{DepartmentFE}_d + \beta_5 \text{YearFE}_t + \varepsilon_{dt}$$

Output is a measure of a department’s research output (such as total publications or total citation weighted publications). HCSHock(1933-40) measures the shock to human capital due to the dismissal of mostly Jewish scientists between 1933 to 1940 which is described below. PCSHock(1942-45) measures the shock to physical capital due to allied bombings (most of them

⁴In fact, I have unsuccessfully tried to obtain consistent measures of physical capital for German and Austrian science departments for this paper.

occurred between 1942 and 1945) and is also described in more detail below. The interactions with year dummies (for each of the 7 years between 1926 and 1980) allow me to investigate the persistence of the two shocks over time.

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

As a shock to human capital I use dismissal of Jewish and ‘politically unreliable’ scientists by the Nazi government. Just over two months after the National Socialist Party seized power in 1933 the Nazi government passed the “Law for the Restoration of the Professional Civil Service” on the 7th of April of 1933. The law served as the legal basis to expel all Jewish and ‘politically unreliable’ persons from civil service in Germany.

Anybody with at least one Jewish grandparent was to be dismissed. Scientists of Jewish origin who had been civil servants since 1914 or who had lost a close family member in the First World War were initially exempted from being dismissed. In 1935, however, the Reich citizenship laws (Reichsbürgergesetz) revoked the exception clause and the remaining scientists of Jewish origin were ultimately dismissed. The 1933 law was also used to dismiss civil servants with opposing political views. All members of the Communist Party, for example, were classified as ‘politically unreliable’ persons and were therefore dismissed.

The law was immediately implemented and resulted in a wave of dismissals and early retirement from the German universities.⁵ More than 1,000 academics were dismissed over a short period of time. A careful early study documented that about 14.3 percent of all university teachers were dismissed from the German universities until 1937 (Harthorne, 1937, p. 93). Shortly after the annexation of Austria on the 12th of March 1938 the law was also implemented in all Austrian universities.

My calculations indicate that 15 percent of physicists, 14.1 percent of chemists, and 18.7 percent of mathematicians were dismissed between 1933 and 1940 (Table 1). Most dismissals from German universities occurred in 1933 immediately after the law was implemented. The small spike in 1938 is driven by dismissals from Austrian universities which occurred after the German occupation of Austria in 1938.⁶ Many of the dismissed scientists were outstanding members of their profession. They published more papers in top science journals and received more citations on average. Compared to the scientists who remained in Germany the dismissed were especially prolific in physics and mathematics (Table 1). Moreover, there were 14 Nobel laureates among the dismissed.⁷

The data do not allow me to identify whether researchers were dismissed because they were Jewish or because of their political orientation. Historical studies, however, have shown

⁵For more details on the dismissal of professors and the consequences for Ph.D. students and immediate effects on faculty peers see Waldinger (2010, 2011).

⁶The few dismissals occurring after 1933 in Germany affected researchers who had been exempted under the clause for war veterans or for having obtained their position before 1914. In addition to that, some political dismissals occurred during the later years.

⁷They received the Nobel Prize either before or after 1933.

that about 87 percent of the dismissed in chemistry (Deichmann, 2001), and 79 percent of the dismissed in mathematics (Siegmond-Schultze, 1998) were either Jewish or of Jewish decent. The remaining dismissals occurred for political reasons.

Most of the dismissed scientists emigrated and the majority of them obtained positions in foreign universities in particular in the United States, the United Kingdom, Turkey, the British Mandate of Palestine (later Israel), and in Switzerland (Moser, Voena, and Waldinger, 2011). A very small minority of the dismissed did not leave Germany and most of them died in concentration camps or committed suicide. Extremely few, managed to stay in Germany and survive the Nazi regime. Even these scientists who stayed in Germany were no longer allowed to use university laboratories and other resources. They did thus no longer contribute to the scientific output of their former departments.

The aggregate number of dismissals hides the fact that German and Austrian universities were affected very differently by the dismissals. Even within a university there was a lot of variation across different departments. Some departments lost more than 60 percent of their personnel while others remained completely unaffected (Table 2). An example for the large variation in dismissals is the University of Heidelberg. The university lost 60 percent of its researchers in mathematics and almost 10 percent in chemistry. In physics, however, not a single scholar was dismissed.

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

As a shock to physical capital I use the destruction caused by allied bombings during World War II.

At the beginning of the war in 1939, bombings by the Royal Air Force (RAF) were mostly confined to military targets such as the German fleet. Bombing of targets on German territory only started after the German invasion of the Low Countries and the bombing of Rotterdam by the Luftwaffe in May 1940. To avoid German anti-aircraft measures the vast majority of bombing raids were carried out during the night which made targeting extremely difficult. In this period, the main targets were oil reservoirs, railway lines in the Ruhr area, aircraft factories, aerodromes, U-boat shipyards, and ports.

In the autumn of 1940 the RAF augmented its strategy to include 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” for the first time (Peirse, 1940). The first larger “area attack” carried out by 134 RAF bombers on December 16th, 1940 targeted the inner city of Mannheim in the south of Germany and was a response to the massive German bombing of Coventry four days earlier.⁸ During 1941, the

⁸The German Luftwaffe used 449 planes for the attack of Coventry on December 12th, 1940; the first large scale attack that destroyed large parts of a whole city during WWII (Müller, 2004, p. 78-90). The German Luftwaffe started area bombing of German cities during the summer of 1940. On September 7th, 1940 about 300 German planes started the area bombing of London. During September 1940 the German Luftwaffe dumped

RAF flew an increasing number of relatively small attacks against cities to reduce the moral of the German population. Nonetheless, the bombings between 1939 and 1941 did not cause great destruction or casualties as only about 20 percent of bombers managed to navigate within five miles of their intended targets and even less hit the target. As a result, the smallest targets which could potentially be hit were whole towns (Frankland, 2005, Webster and Frankland, 1961, vol. 1, p.156, p.257).⁹

The appointment of Air Marshal Sir Arthur Harris on February 23rd, 1942 and the passing of the “Area Bombing Directive” a week earlier led to a large intensification of “area bombings” with larger numbers of planes bombing targets for short but intensive time periods to maximize destruction. An example is the first 1,000 bomber attack that was flown against Cologne on May 30, 1942. It inflicted heavy damage on about a third of the total area of Cologne (Hohn, 1991 p.12, Webster and Frankland, 1961, vol. 1, p. 340, pp. 402-410).¹⁰ To maximize destruction of inner cities, the RAF used a large number of incendiary bombs which caused great fires in the targeted 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)¹¹, 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) joined the RAF in bombing German targets.¹² While the British continued their night time raids in particular area attacks on inner cities, the USAAF mostly attacked during the day and focused on strategically important targets such as the German aircraft and ball bearings 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 very short time periods increased the efficacy of incendiary bombs. Increasing air supremacy of the allied forces further facilitated the bombing of German cities. Towards the end of the war the bombardments were extended to hit many smaller cities that had been spared in previous attacks. Furthermore, larger cities were continued to be bombed to lower the moral of the German population.

Overall, about 1.35 million tons of bombs were dropped over German territory. There was

about 20 times as many bombs on London as the RAF did on Berlin during some retaliatory attacks (Müller, 2004 p. 72-75).

⁹An example for the inaccuracy of bombings at the beginning of the war is the intended night time raid of Karlsruhe and Stuttgart on October 1st, 1941. Instead of just hitting these two cities in the southwest of Germany bombs fell on 27 cities, as far apart as Aachen, Chemnitz, or Würzburg. Many of these cities are several hundred kilometres away from the two target cities (Webster and Frankland, 1961, vol. 1, p. 185)

¹⁰The previous 107 smaller attacks on Cologne had involved at most 40 planes each.

¹¹In March, 1942 the RAF introduced a navigation aid called Gee that allowed planes to verify their position with the aid of pulses sent from three stations based in Britain. It was technically not a radar device but improved navigation in the northern and eastern parts of Germany. In December, 1942 the radar system Oboe was introduced which also depended on transmitters and receivers based in Britain and had a higher degree of accuracy than Gee. Furthermore, in January, 1943 the RAF introduced H2S another radar device which was installed in the aircraft and provided information on the ground condition (e.g. land or water) flown over by the aircraft. (see Webster and Frankland, 1961, vol. 1, pp.316-317 for details).

¹²While the first months of the US air offensive against Germany were only moderately successful the effectiveness of the USAAF operations greatly improved towards the end of 1943. These changes were achieved by an increase in the production of bombers, by the introduction of the long-range Mustang fighters which gave bomber formations added protection, and by the establishment of U.S. air bases in Italy.

almost continuous increase between 1940 and 1945 with particularly large increases in the last years of the war. (Figure 1)

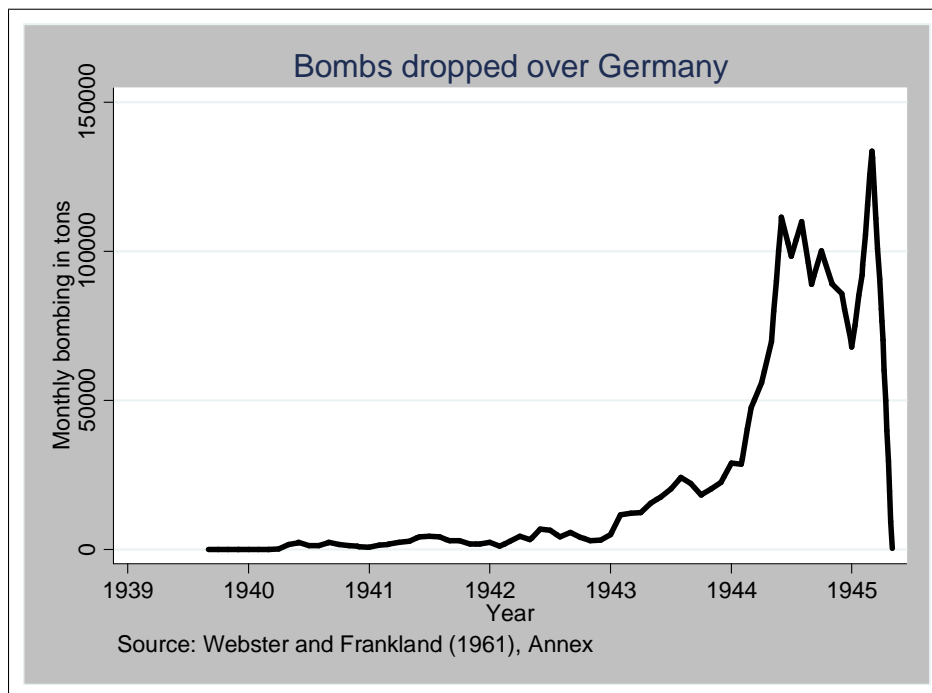


Figure 1: Allied Bombings

Allied bombings, in particular during the last two years of WWII and to a much lesser extent artillery fire during the last months of the war, 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 universities facilities were destroyed by bombings which could never be precisely aimed until the end of WWII. Because of these targeting problems bombs often fell relatively randomly within cities and there was thus large variation in destruction across different university buildings. As a result, departments were affected very differently by the bombings (Table 2). Because most bombing raids involved the use of incendiary bombs, fires in the affected buildings usually destroyed most of the scientific equipment that had not been relocated to safer locations.¹³

As bombing intensified massively in 1944 most bombing destruction affected science departments in 1944 and 1945. For some universities I obtained exact dates for the first and last bombing raids that caused destruction of university buildings. The first recorded raid which caused destruction of university facilities occurred in June 1941 and affected the Technical University of Aachen. Bombing raids that hit other universities and buildings continued and intensified until the end of the war.

¹³Many departments tried to relocate material to safer locations but even those were often not safe enough. The theoretical physics section of the University of Bonn, for example, moved equipment to Hildburghausen in Thuringia but that site was bombed towards the end of the war (van Rey, 1995).

After the end of the war on May 8, 1945 reconstruction of destroyed university buildings was initially hampered by the lack of funds, missing supplies, the lack of skilled craftsmen, and the large devastation of most German cities. Most universities enlisted students to help with reconstruction. The technical universities of Karlsruhe and Hannover, for example, required up to 1,000 reconstruction service hours from its students until 1949 (Hoepke, 2007, Wolters, 1950 pp. 123-129). Most universities completed reconstruction by the end of the 1950s but some reconstruction work lasted until the 1960s (Hoepke, 2007 p. 139, Technische Universität Dresden 1996, pp. 18-36).

3 Panel Data Set of German Science Departments

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

To evaluate the impact and persistence of the two shocks to the human and physical capital of the German and Austrian science departments I construct a new panel dataset covering physicists, chemists, and mathematicians at German and Austrian universities. The data come from “Kürschners Deutscher Gelehrtenkalender” (KDG) that has been published since the 1920s in 5 to 10 year intervals. I use data from volumes published in 1926, 1931, 1940/41, 1950, 1961, 1970, and 1980 and obtain complete faculty lists for science departments at these seven points in time spanning 54 years. From each volume I extract all scientists who were at least ‘Privatdozent’.¹⁴ To obtain a sample that is comparable over time, I focus on scientists in all 35 German or Austrian universities that existed in 1926 and remained on German (both FDR and GDR) or Austrian territory after 1945 (see Table 2 for a listing of the universities in my sample).¹⁵ As I obtain data on scientists in physics, chemistry, and mathematics departments, the final dataset contains information on 105 German speaking science departments.¹⁶ The micro data contain 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). Across all German and Austrian universities, there is a large increase in the number of scientists after 1926. The exception is 1941 (and 1950 in chemistry), the first data points after the dismissal of scientists (Figure 2). The data appendix gives for more details on the KDG data.

¹⁴Researchers at German universities hold a number of different positions. Ordinary Professors are appointed to a chair in a certain subfield. Extraordinary Professors do not hold a chair. At the entry level of academic university staff are Privatdozenten, the first position that allows a researcher to give lectures at a German university.

¹⁵This excludes three universities (the University of Breslau, the Technical University of Breslau, now Wrocław, and the University of Königsberg, now Kaliningrad) that were on German territory in 1926 but became part of Poland and the Soviet Union after 1945. As the KDG no longer listed researchers from these three universities after 1945 they cannot be included in my long-term analysis. Most scientists from these universities relocated to universities which continued to be located on German territory after 1945.

¹⁶Scientists in universities located in the GDR were not listed in the KDG in 1980.

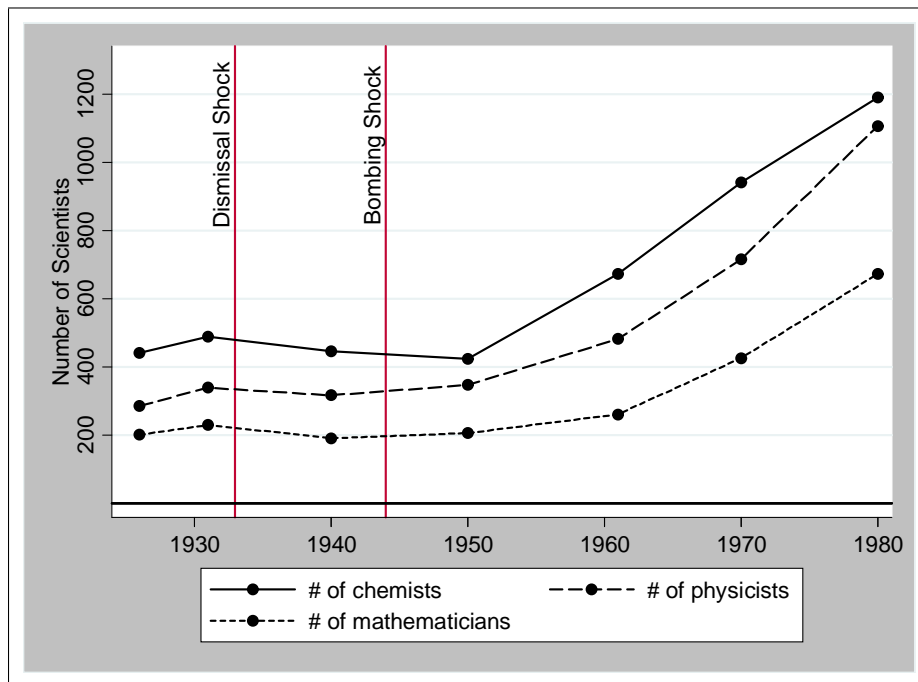


Figure 2: Number of Scientists 1926-1980

3.2 Productivity Measures for German and Austrian Science Departments

To obtain productivity measures for all science departments I first obtain publications and citation weighted publications for each individual scientist. The publication data are downloaded from the ISI Web of Science and include all top journals for German and Austrian scientists. As the set of top journals changed over the time period studied in this paper I use both historical and current journals to define the complete set of top journals.

Historical top journals are all science journals published in Germany and covered by the Web of Science between 1920 and 1945. I furthermore add a number of general science journals (e.g. Nature, Science) that were outlets for German scientists in the 1920s and 30s and historically relevant international field journals recommended by historians of science. I then add current top journals which I obtain from commonly used journal rankings for today’s science journals. The full list of top journals that I use for my analysis therefore encompasses both historical and current top journals (see Table A1 for the list of top journals used in the analysis) The data appendix provides additional information on the journal data.

I download all articles published between 1920 and 1985 in any of these top journals included in the Web of Science.¹⁷ I then merge top journal articles to all German and Austrian scientists.¹⁸ The Web of Science data only include the last name of each author and the first

¹⁷A few top journals, such as Physical Review Letters, were founded after 1920. In those cases I download all articles after the creation of the journal. The changing pool of journals does not affect my findings as all regressions reported below include year fixed effects.

¹⁸To reduce measurement error I merge only publications which correspond to the scientist’s subject. I.e.

letter (or the two first letters if the author uses two first names) of the scientist’s first name. Most German scientists have very distinct names (which are also distinct from foreign scientists publishing in the same journals). In the rare cases that the last name - first letter combination does not uniquely identify a scientist in my data I split publications and citation weighted publications according to the number of scientists with the same last name - first letter combination. Table A2 shows the most cited scientists in my data. Most of these scientists are very well known in the scientific community. This indicates that the productivity measures carry meaningful information. Interestingly, Johann von Neumann who later emigrated to the United States is the most cited mathematician in the data set.

To obtain department level productivity for each of the seven points in time I add individual productivity measures within departments. Productivities are measured by adding all top publications published a five year window around the relevant year. Albert Einstein’s individual productivity measure for 1926, for example, is the sum of his publications between 1923 and 1927.¹⁹ I then sum the individual productivity measures within departments. Say a department had three scientists with individual productivities equal to 1, 2, and 3; total department productivity would then be $1+2+3=6$. The Web of Science data not only include publications but also the number of times each article was subsequently cited in any journal covered by the Web of Science. I can therefore construct an additional productivity measure based on citation weighted publications.²⁰

Publication and citation patterns are very different across the three subjects studied in this paper. To ensure comparability across subjects I normalize total department productivity measure to have zero mean and unit variance. This also allows for easy interpretation of the estimated regression coefficients.

3.3 Data on Dismissals

To measure how different departments were affected by the dismissal shock I obtain data on dismissed scientists from a number of sources. The main source is the “List of Displaced German Scholars” that was compiled by the relief organization “Emergency Alliance of German Scholars Abroad”. The relief organization was founded by some of the dismissed researchers to support

physicists get merged with publications in top physics journals and general science journals that are outlets for physicists but not with publications in chemistry journals. While this may underestimate the publications of some scientists it is preferable to merging a large number of irrelevant publications to each scientist because the last name - first letter combination (which is the only information available in the Web of Science) does not perfectly identify specific scientists, especially across fields.

¹⁹To reduce measurement error I use 1923 to 1927 as the publication of a KDG volume reports faculty lists with a certain time lag. To publish a KDG volume in a certain year, questionnaires asking for faculty affiliations were sent out some time before publication. To capture this lag between sending out questionnaires and the publication of the KDG I use 1923-1927 data to obtain productivity measures for faculty observed in 1926. I could of course also compute average productivity with a symmetric window around the KDG publication date. For 1926, for example, I could measure average productivity using the years 1924-1928. This alternative way of computing average productivities hardly affects my findings.

²⁰The citation weighted productivity measure is constructed as above by adding all citations to publications published in a five year window around the relevant year. For 1926, for example, I add all citations to articles published between 1923 and 1927. Citations are counted until today.

other dismissed scholars to find positions in foreign universities. The list was published in 1937 and contains about 1,650 names of researchers from all university subjects. I extract all dismissed physicists, chemists, and mathematicians from the list.

As the “List of Displaced German Scholars” was published before 1938 it does not include dismissals from Austrian universities. To obtain dismissals from Austrian universities I consult the “Biographisches Handbuch der deutschsprachigen Emigration nach 1933 - Vol. II : The arts, sciences, and literature” which was compiled by the “Institut für Zeitgeschichte München” and the “Research Foundation for Jewish Immigration New York”.²¹ This source also includes a few additional dismissals from German universities, for example because the dismissed passed away before the “List of Displaced German Scholars” was compiled. These two sources cover about 90 percent of all dismissals. I augment this information with data on a few additional dismissals from three secondary sources which have been compiled by historians of science.²²

3.4 Data on Bombings of Science Departments

While data on destruction of German cities during WWII is readily available there is no comprehensive data set covering bombing damages to German and Austrian science departments. The few sources that report destruction of universities only include aggregate information for some universities.

I therefore compile a new dataset measuring bombing destruction of German and Austrian science departments based on information contained in university archives. University institutes that had been bombed during WWII often provided detailed reports of destruction levels after a bombing raid to obtain funds and materials to aid with reconstruction. These post bombing reports allow me to construct department level destruction measures.

I first contacted all university archivists and asked them to provide percentage destruction levels for all buildings used by physicists, chemists, and mathematicians.²³ For the cases where archivists could not provide information on destruction of individual science departments, I or my research assistant personally consulted the historical reports contained in the respective university archive to obtain the missing information.

In the very few cases that this two step method did not yield information on department level destruction I use university level information instead.²⁴

Combining the data from all sources I obtain a panel of German and Austrian science

²¹Kröner (1983) extracted all dismissed university researchers from the handbook. I use Kröner’s list to append my list of all dismissed scientists.

²²Some additional chemists come from Deichmann’s (2001) book on chemistry in Nazi Germany, additional physicists from Beyerchen’s (1977) study on physics in Nazi Germany, and additional mathematicians from Siegmund-Schultze’s (1998) book on mathematics in the Third Reich.

²³In some cases departments did not report destruction in percentage terms but gave verbal descriptions of how much certain buildings were damaged by Allied bombing raids. I convert this information into percentage destruction using a fixed rule outlined in the data appendix.

²⁴I construct comparable university level destruction from information on university websites and a number of sources (Tietze, 1995, Phillips, 1983, Samuel and Thomas, 1949, Schneider, 1990, and Cheval, 1991).

departments from 1926 to 1980, including department productivity at seven points in time (1926, 1931, 1940, 1950, 1961, 1970, and 1980) and information on dismissal and bombing shocks.

4 Persistence of Human and Physical Capital Shocks

4.1 Main Results

I use this data to investigate the persistence of the human and physical capital shocks by estimating equation (1). First, I analyze how the dismissal shock affected the long-run productivity of German and Austrian science departments. The first year that could have been affected by the dismissals is 1940 as the dismissals occurred between 1933 and 1940 with the bulk of the dismissals happening in the early years. The regression results indicate that between 1931 (the last year without dismissals) and 1940 productivity in departments with dismissals fell significantly more than productivity in departments without dismissals (Table 3, column (1)). The interactions with subsequent years indicate that this negative effect persisted until 1980. Controlling for subject times year fixed effects to allow for different productivity trends in the three subjects (physics, chemistry, and mathematics) hardly changes 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 and thus increases the significance of some coefficients (column (3)). The coefficients imply that losing one scientist due to the dismissals in Nazi Germany lowers department productivity even the long run by between 0.17 and 0.28 standard deviations (column (3)).

I then analyze how the bombing shock affected the long-run productivity of science departments. As Allied bombings heavily intensified towards the end of the war the first data point where department productivity could have been affected by the bombings is 1950. Productivity of departments that suffered from bombing destruction indeed fell slightly between 1941 and 1950 compared to the productivity of departments that were not bombed. This effect, however, is only significant if I control for subject times year fixed effects and occupation zone times post-1945 dummies (Table 3, columns (4) to (6)). In that specification the estimated coefficient indicates that ten percent more bombing destruction lowered department productivity by about 0.05 of a standard deviation. Department productivity recovered very quickly after the bombing shock. As early as 1961 there was no significant difference between departments that were bombed in the Second World War and those that did not suffer any physical destruction. By 1970, departments that were bombed even performed slightly better than unaffected departments. This effect, however, is only significant in two of the three reported specifications. This suggests that upgrading during reconstruction may actually have had a positive effect on department productivity.

Jointly estimating the long run effects of the bombing and dismissal shocks leads to very similar conclusions (Table 3, columns (7) to (9)). To investigate the relative magnitudes of how

the two shocks affected department productivity I plot rescaled coefficients and standard errors corresponding to the estimates reported in column (9) of Table 3. I scaled the coefficients to measure the impact of a 10 percent shock to human capital and a 10 percent shock to physical capital.²⁵



Figure 3: Persistence of 10 percent shocks - Publications

This exercise reveals that the effect of a 10 percent shock to human capital had a larger effect on department productivity than a 10 percent shock to physical capital even in 1950 (Figure 3).²⁶ While the human capital shock persisted for more than 40 years until 1980 the physical capital shock dissipated relatively quickly and even seemed to have a slightly positive but not significant effect in 1970. These figures furthermore show that pre-trends are unlikely to drive these findings.

In the results discussed above I measure department productivity as the sum of publications in top journals (normalized to have a mean of zero and a standard deviation of one). An alternative way to measure productivity uses citation weighted publications instead. This measure adjusts publications by the number of subsequent citations they received from any journal covered by the Web of Science. It therefore includes citations from the entire scientific community. Results using this alternative way to measure productivity are very similar (Table 4). The dismissal of one scientist reduced department productivity even in the long run by between 0.14 and 0.21 standard deviations (column (9)). Bombing destruction had a small negative effect on productivity in 1950 (significant at the 10 percent level) but productivity recovered quickly in bombed departments. By 1970 bombed departments even performed slightly better (significant at the 10 percent level). Figure 4 plots the long-run effects of a 10 percent shock to

²⁵ 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 (9) 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 (9) of Table 3 by 10.

²⁶In 1950, the p-value of a test of the Null hypothesis $(1.015 * \text{coefficient} \neq \text{dismissed} * 1950) = (10 * \text{coefficient} \% \text{ destruction} * 1950)$ has a p-value of 0.16. For all later years the effect of a 10 percent human capital shock is significantly larger than a 10 percent physical capital shock (p-values between 0.008 and 0.038).

human and physical capital corresponding to the estimates reported in column (9) of Table 4. The dismissal shock has a larger effect than the bombing shock and is much more persistent.²⁷



Figure 4: Persistence of 10 percent shocks - Citation weighted publications

4.2 Robustness of Main Results

In the following, I show that these results are robust to using different samples, age-adjusted productivity measures, and an alternative definition of the physical capital shock. The main results were estimated with a sample including all German and Austrian universities that existed before 1926. Dropping Austrian science departments from the sample does not affect the results (Table 5, columns (1) and (2)). As outlined in the data section, the main sample includes all German universities that were based within the German borders of 1990 both in the FRG and the 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, however, only has a small effect on the coefficients suggesting that the results are not driven by a different development in the GDR. (columns (3) and (4)). These results also demonstrate that the special situation of the University of Berlin which was located in the Soviet zone does not drive the results.²⁸ Dropping both Austria and the GDR from the sample lowers the significance of some coefficients, also because the sample size becomes fairly small, but the main conclusions remain unchanged (columns (5) and (6)).

As outlined above, most dismissals took place during the first years of the Nazi regime. Restricting the dismissals to those early dismissals the results are again very similar (columns (7) and (8)).

²⁷In 1950, the p-value of a test of the Null hypothesis $(1.015 \cdot \text{coefficient}_{\# \text{ dismissed}} \cdot 1950) = (10 \cdot \text{coefficient}_{\% \text{ destruction}} \cdot 1950)$ has a p-value of 0.11. In 1961, the p-value is 0.059. For 1970 and 1980 the effect of a 10 percent human capital shock is always significantly larger than a 10 percent physical capital shock (p-values between 0.0003 and 0.03).

²⁸The 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 American sector of Berlin.

The productivity of scientists usually follows a concave pattern over the lifetime (Levin and Stephan, 1991). While some of the changes in the age structure of departments is endogenous to the dismissals (e.g. because departments with dismissals can only hire younger or older researchers) and should therefore not be controlled for, it is nonetheless interesting to investigate whether the results are driven by the changing age structure of affected departments. I therefore adjust output by regressing individual productivity measures on a full set of 5-year age dummies. The residuals from this regression are then used to construct department level productivity which is again normalized to zero with a standard deviation of one. Using this age-adjusted productivity measures yields very similar results (columns (9) and (10)).

The dismissal shock was confined to specific departments as universities could not reallocate physicists to become chemists if there were many dismissals in chemistry but few or none in physics. Universities could, however, reallocate buildings across departments following the bombing shock. This may have counteracted negative effects from bombing destruction. To investigate whether the reallocation of buildings is driving my results I re-estimate the model using university level destruction instead of department level destruction as the relevant bombing shock. The results are very similar to the department level results (columns (11) and (12)). Between 1941 and 1950, productivity dropped more in universities that were bombed compared to universities without bombing destruction. This negative effect persisted until 1961 for the publications based department productivity measure but is not significant for the citation weighted publications productivity measure. By 1970 departments had completely recovered for both measures.

4.3 Subject Specific Results

Data on the three subjects allow me to investigate whether the human and physical capital shocks had a differential impact across disciplines. While physical capital may be more important in chemistry and some fields of physics (experimental physics, technical physics, or astrophysics) it is presumably less important in mathematics. The estimation results, however, indicate that the effect of the physical capital shock did not differ across fields (Table 6).

While of course most estimates are less precisely estimated due to the much smaller sample sizes, the results for the human capital shock reveal interesting differences across subjects. If one considers the citation weighted publications productivity 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 (columns (2), (4), and (6)). This is interesting as the dismissals in mathematics and physics were of much higher quality than in chemistry (see Table 1). These results suggest that high quality scientists may be particularly important for scientific productivity.

4.4 The Effect of High Quality Scientists

To further investigate whether high quality scientists indeed had a particularly large effect on department productivity I assign individual scientists to quality percentiles based on their pre-dismissal citation weighted publications. I then investigate how the dismissal of high quality scientists affected department productivity in the long run. Corresponding to the main specification already reported above, the dismissal of one scientist lowered department productivity by between 0.14 and 0.28 standard deviations (Table 7, columns (1) and (2)). The dismissal of one scientist of above median quality lowered long-run department productivity by between 0.19 and 0.45 standard deviations (columns (3) and (4)). Further increasing the quality of dismissed scientists led to larger long-run reductions (in absolute value) of departmental productivity. The dismissal of a scientist in the top 5th percentile led to a reduction in departmental productivity of between 0.9 and 1.5 standard deviations that persisted until 1980 (columns (9) and (10)). Figure 5 summarizes these findings graphically.²⁹ The figure shows the relative drop in department productivity after the dismissal of a scientist of the relevant quality group. The higher the quality of the dismissed scientists the larger the long-run drop in department productivity.

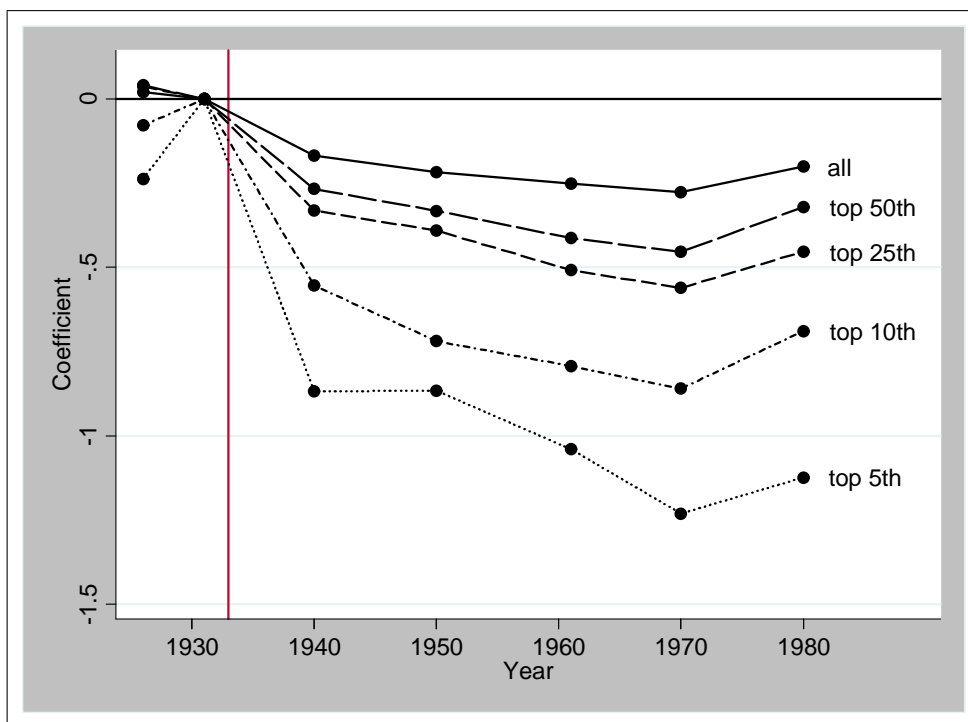


Figure 5: Persistence of high quality dismissals

²⁹To improve the clarity of the figure I do not report confidence intervals. As can be seen from Table 7 the vast majority of the estimated coefficients are significantly different from 0.

5 Understanding the Persistence of the Human Capital Shock

The previous findings indicate that human capital is particularly important for the productivity of science departments and that the negative human capital shock persisted in the long-run. Furthermore, high quality scientists are especially important. In the following I investigate how a short-term shock to human capital that occurred between 1933 and 1940 could still affect department productivity in 1980. A possible explanation could be that department size dropped permanently and never recovered. I investigate this hypothesis by regressing department size on the dismissal and destruction variables. Department size in departments with dismissals was significantly smaller until 1970 but by 1980 it had completely recovered (Table 8). This suggests that a permanent fall in department size is not the main explanation of the persistence of the human capital shock.

Another potential explanation could be localized peer effects that affected the generation of scientists present in 1933. If their productivity fell due to the dismissal of high quality peers they in turn may have lowered the productivity of subsequent generations of scientists due to negative peer effects. In this case, however, it is unlikely that peer effects were driving persistence. Even scientists that were directly affected by dismissals in their own department did not suffer from a disproportionate drop in their productivity. Not even the loss of very high quality colleagues had a negative effect on productivity (see Waldinger, 2011). That rules out peer effects as a potential explanation for the persistence of the human capital shock.

A potential explanation for the persistence of the human capital shock is the effect of lower faculty quality on PhD student outcomes. As German universities often hire their former PhD students the decline in faculty quality can potentially persist for a long time. Previous research has shown that PhD students who obtained their PhD in departments with dismissals in Nazi Germany had a lower probability of publishing their dissertation in a top journal and had fewer lifetime citations (Waldinger, 2010). If the lower quality PhD students are hired by their former universities the decline in faculty quality can persist.³⁰

Another potential mechanism that can explain persistence may be that scientists, and in particular high quality scientists, attract other good colleagues. In the following, I therefore investigate whether the quality of hires fell in departments with dismissals. I also analyze whether the dismissal of high quality scientists led to particularly large reductions in the quality of hires. As I need to observe changes in department composition to identify new hires, the first year for which I can observe hires is 1931. I then classify all faculty that joined a department between 1926 and 1931 as a hire. This allows me to calculate the average quality of new hires in each department between 1931 and 1980.³¹ Regressing the average quality of new hires

³⁰In fact almost 20 percent of PhD students who graduated between 1912 and 1940 and who obtained a university position in Germany returned to work in the same university where they obtained 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 thus rejected with a p-value smaller than 0.001.

³¹The quality of hires is measured by career citation weighted publications which I then normalize to have a zero mean and a standard deviation of one within subjects.

on the number of dismissals interacted with year indicators, I find that losing one scientist because of the dismissals lowers the quality of new hires by between 0.055 and 0.071 standard deviations. The estimated effects are always significant at the 1 percent level and persist until 1980 (Table 8). Furthermore, the quality of hires drops by a larger amount after losing high quality scientists. Figure 6 shows the reduction in hiring quality after the loss of a scientist of different qualities.

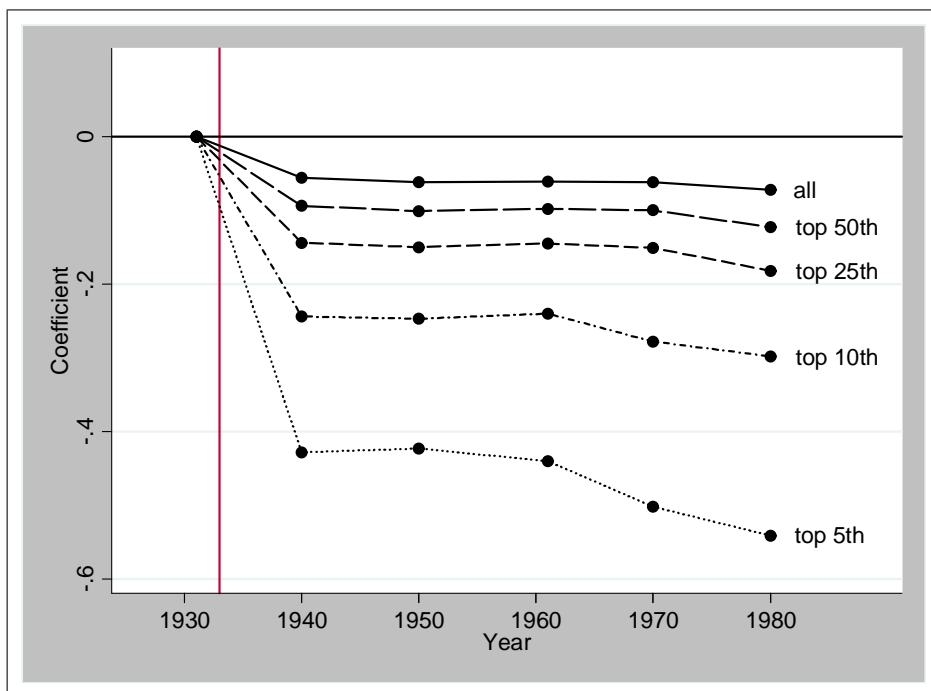


Figure 6: Quality of hires

Clearly the dismissal of high quality scientists has a particularly large effect on the quality of subsequent hires that persisted in the long-run.

6 Conclusion

I use the dismissal of scientists in Nazi Germany and Allied bombings of university facilities as exogenous shocks to the human and physical capital of science departments. While I find evidence that both shocks had a negative effect on productivity in 1950, departments that suffered from physical destruction completely recovered by 1961. By 1970 departments that were heavily bombed even seemed to do slightly better than departments that were not destroyed. The human capital shock, however, had a larger negative effect on productivity and was much more persistent. I also show that the dismissal of high quality scientists had particularly large effects on the productivity of science departments.

The persistence of the human capital shock is particularly interesting if one considers that most scientists who had been employed by the former German universities (Breslau now Wrocław, TU Breslau, and Königsberg now Kaliningrad) that became part of Poland and the Soviet

Union after the war, had to relocate to universities that remained on German territory after 1945. It is surprising that the universities that had lost scientists because of the dismissals could not attract the best scholars from these universities. The findings of this paper suggest that departments that had suffered from the dismissal of scientists also experienced a permanent decline in the quality of new hires.

These findings indicate that human capital is potentially much more important than physical capital for the productivity of science departments. ‘Star scientists’ seem to be particularly valuable as they attract other high quality scientists to the department. This suggests that attracting these very high quality scholars may be a good strategy if a university of country wanted to raise its research profile.

The findings, of course, do not indicate that physical capital is irrelevant as reconstruction after the war targeted destroyed departments. It seems, however, that physical capital shocks can be overcome much more quickly than human capital shocks. In recent years some fields of science have become more and more dependent on large capital expenditures such as particle colliders. A negative shock to physical capital of those fields may lead to more persistent effects on productivity than shocks that have occurred in the past.

The findings of this paper also give suggestive evidence of how the dismissal of scientists may have contributed to the decline of German science after WWII. Losing a large number of outstanding scholars made it much more difficult to attract other promising scholars to work at the German universities.

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7 Tables

Table 1: Number and Quality of Dismissed Scientists

Year of Dismissal	Physics				Chemistry				Mathematics			
	# 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 present at a German or Austrian university. % of pubs. published by dismissed reports the percentage of publications that were published by the dismissed in the 5 year period around 1931. % of citation weighted pubs. published by dismissed reports the percentage of citation weighted publications that were published by the dismissed in the 5 year period around 1931.

Table 2: Dismissal and Bombing Shocks Across Science Departments

University	Physics			Chemistry			Mathematics			Bombing Shock			Total Destruction		
	Dismissal Shock			Dismissal Shock			Dismissal Shock			Shock			University		
	# of scientists (1931)	Dismissed 33-40 #	in %	# of scientists (1931)	Dismissed 33-40 #	in %	# of scientists (1931)	Dismissed 33-40 #	in %	Destruction 40-45 in %	Shock 40-45 in %	Destruct. in %	City Destruct. in %		
Aachen TU	5	1	20.0	11	1	9.1	6	2	33.3	m	70.0	49.0			
Berlin	41	10	24.4	47	16	34.0	14	5	35.7	5.0	45.8	37.0			
Berlin TU	30	9	30.0	41	11	26.8	17	5	29.4	m	48.0	37.0			
Bonn	10	1	10.0	14	2	14.3	8	1	12.5	13.2	40.0	24.0			
Braunschweig TU	5	0	0	11	0	0	2	0	0	27.5	70.0	26.0			
Darmstadt TU	10	3	30.0	12	4	33.3	5	1	20.0	m	75.0	46.0			
Dresden TU	11	1	9.1	17	1	5.9	8	0	0	100.0	65.0	39.0			
Erlangen	5	0	0	9	1	11.1	3	0	0	0	0	4.8			
Frankfurt	13	2	15.4	18	5	27.8	8	4	50.0	27.0	60.0	32.0			
Freiburg	5	1	20.0	11	2	18.2	5	1	20.0	85.0	72.5	28.0			
Giessen	6	1	16.7	9	0	0	4	0	0	50.0	67.5	53.0			
Göttingen	20	8	40.0	17	3	17.6	16	10	62.5	0	1.7	2.1			
Graz	7	1	14.3	8	0	0	6	0	0	0	5.0	33.0			
Graz TU	1	0	0	7	0	0	5	0	0	50.0	20.0	33.0			
Greifswald	7	0	0	4	0	0	4	0	0	0	0	0			
Halle	4	0	0	7	1	14.3	5	1	20.0	0	5.0	5.0			
Hamburg	15	2	13.3	12	2	16.7	8	1	12.5	15.0	50.0	54.0			
Hannover TU	4	0	0	10	0	0	4	0	0	22.2	41.3	47.0			
Heidelberg	6	0	0	19	2	10.5	5	3	60.0	0	0	1.0			
Innsbruck	6	0	0	8	0	0	5	0	0	0	m	60.0			
Jena	14	1	7.1	10	0	0	5	0	0	50.0	87.3	20.0			
Karlsruhe TU	5	1	20.0	16	5	31.3	5	1	20.0	75.0	70.0	26.0			
Kiel	7	1	14.3	8	0	0	5	2	40.0	50.0	60.0	41.0			
Köln	6	1	16.7	6	0	0	5	1	20.0	0	20.0	44.0			
Leipzig	12	2	16.7	21	2	9.5	8	2	25.0	0	70.0	19.0			
Marburg	5	0	0	8	0	0	6	0	0	0	16.3	4.0			
München	11	2	18.2	19	3	15.8	8	1	12.5	70.0	70.0	32.0			
München TU	15	1	6.7	17	1	5.9	5	0	0	50.0	80.0	32.0			
Münster	4	0	0	7	0	0	6	0	0	75.0	75.3	49.0			
Rostock	4	0	0	6	0	0	1	0	0	0	0	40.0			
Stuttgart TU	7	1	14.3	10	1	10.0	9	0	0	40	80.0	35.0			
Tübingen	3	0	0	9	0	0	4	0	0	0	0	5.0			
Wien	4	0	0	30	5	16.7	9	2	22.2	25.0	30.0	28.0			
Wien TU	8	0	0	19	1	5.3	13	0	0	0	13.3	28.0			
Würzburg	29	3	10.3	12	1	8.3	3	0	0	90.0	82.5	75.0			

of *scientists (1931)* reports the number of scientists in a department in 1931 (before the dismissal shock). *Dismissal 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 joint appointments 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 data appendix for details.

Table 3: Persistence of Dismissal and Bombing Shocks - Publications

Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Publications	Publications	Publications	Publications	Publications	Publications	Publications	Publications	Publications
Number of Dismissals * 1926	0.023 (0.025)	0.017 (0.025)	0.017 (0.025)	0.017 (0.025)	0.025 (0.027)	0.025 (0.027)	0.025 (0.027)	0.020 (0.027)	0.020 (0.027)
Number of Dismissals * 1940	-0.173*** (0.037)	-0.173*** (0.039)	-0.173*** (0.039)	-0.173*** (0.039)	-0.169*** (0.035)	-0.169*** (0.035)	-0.169*** (0.035)	-0.168*** (0.036)	-0.168*** (0.036)
Number of Dismissals * 1950	-0.210* (0.121)	-0.222* (0.125)	-0.219** (0.099)	-0.219** (0.099)	-0.207** (0.121)	-0.207** (0.121)	-0.207** (0.121)	-0.218* (0.125)	-0.217** (0.100)
Number of Dismissals * 1961	-0.245** (0.102)	-0.257** (0.105)	-0.254** (0.080)	-0.254** (0.080)	-0.241** (0.100)	-0.241** (0.100)	-0.241** (0.100)	-0.252** (0.103)	-0.251*** (0.080)
Number of Dismissals * 1970	-0.291*** (0.104)	-0.286** (0.108)	-0.283*** (0.084)	-0.283*** (0.084)	-0.286*** (0.101)	-0.286*** (0.101)	-0.286*** (0.101)	-0.278** (0.104)	-0.276*** (0.082)
Number of Dismissals * 1980	-0.202** (0.077)	-0.202** (0.079)	-0.207*** (0.071)	-0.207*** (0.071)	-0.197** (0.074)	-0.197** (0.074)	-0.197** (0.074)	-0.195** (0.074)	-0.200*** (0.067)
% Destruction * 1926				-0.005* (0.003)	-0.006** (0.003)	-0.006** (0.003)	-0.004** (0.002)	-0.005** (0.002)	-0.005** (0.002)
% Destruction * 1931				-0.009*** (0.002)	-0.009*** (0.003)	-0.009*** (0.003)	-0.008*** (0.002)	-0.009*** (0.002)	-0.009*** (0.002)
% Destruction * 1950				-0.002 (0.002)	-0.003 (0.002)	-0.005** (0.002)	-0.002 (0.002)	-0.003 (0.002)	-0.005** (0.002)
% Destruction * 1961				0.000 (0.002)	-0.000 (0.002)	-0.000 (0.001)	0.000 (0.002)	-0.000 (0.002)	-0.002 (0.001)
% Destruction * 1970				0.004* (0.002)	0.005** (0.002)	0.003 (0.002)	0.004* (0.002)	0.005* (0.002)	0.003 (0.002)
% Destruction * 1980				0.001 (0.003)	0.001 (0.003)	0.000 (0.004)	0.001 (0.003)	0.001 (0.003)	0.000 (0.003)
Department FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes			yes			yes		
Subject*Year FE		yes	yes	yes	yes	yes	yes	yes	yes
Occupation Zone * Post1945 Dummies			yes	yes		yes			yes
Observations	714	714	714	714	714	714	714	714	714
R-squared	0.590	0.650	0.678	0.518	0.582	0.607	0.606	0.668	0.692

***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 a department. The variable is normalized to have a zero mean and a standard deviation of one. *Number of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *% Destruction * 1926* is equal to the percentage of destruction due to allied bombings between 1940 and 1945 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, excluded category: mathematics) with year dummies. *Occupation Zone * Post1945 Dummies* is an interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post 1945 dummy.

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

Dependent Variable:	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		
	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	Citation weighted Publications	
Number of Dismissals * 1926	-0.093 (0.076)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)	-0.100 (0.078)
Number of Dismissals * 1940	-0.181*** (0.063)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)	-0.188*** (0.062)
Number of Dismissals * 1950	-0.195*** (0.030)	-0.201*** (0.036)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)	-0.196*** (0.031)
Number of Dismissals * 1961	-0.190*** (0.036)	-0.207*** (0.041)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)	-0.202*** (0.042)
Number of Dismissals * 1970	-0.210*** (0.047)	-0.220*** (0.049)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)	-0.215*** (0.053)
Number of Dismissals * 1980	-0.129* (0.065)	-0.142** (0.059)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)	-0.141** (0.061)
% Destruction * 1926																			
% Destruction * 1931																			
% Destruction * 1950																			
% Destruction * 1961																			
% Destruction * 1970																			
% Destruction * 1980																			
Department FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes																		
Subject*Year FE		yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Occupation Zone * Post1945 Dummies																			
Observations	714	714	714	714	714	714	714	714	714	714	714	714	714	714	714	714	714	714	714
R-squared	0.460	0.484	0.496	0.496	0.496	0.496	0.442	0.442	0.462	0.462	0.472	0.472	0.476	0.476	0.498	0.498	0.498	0.507	0.507

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

The dependent variable *Citation weighted Publications* is the sum of publications published by all scientists in a department. The variable is normalized to zero mean and a standard deviation of one. *Number of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *% Destruction * 1926* is equal to the percentage of destruction due to allied bombings between 1940 and 1945 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, excluded category: mathematics) with year dummies. *Occupation Zone * Post1945 Dummies* is an interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post 1945 dummy.

Table 5: Robustness Checks

Dependent Variable:	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)		(12)		
	Publi- cations	Citation weighted Pubs.	Publi- cations	Citation weighted Pubs.	Publi- cations	East Germany	Citation weighted Pubs.	Publi- cations	Dropping Germany	Publi- cations	Dropping Austria and East Germany	Citation weighted Pubs.	Publi- cations	Adjusting productivity for changing age structure	Publi- cations	Citation weighted Pubs.	Publi- cations	Only 1933-34 dismissals	Publi- cations	Citation weighted Pubs.	Publi- cations	Using uni. level destruction	Citation Pubs.	Citation Pubs.	
# of Dismissals * 1926	0.019 (0.029)	-0.092 (0.081)	0.018 (0.041)	-0.161* (0.090)	0.018 (0.042)	-0.156* (0.089)	0.042 (0.040)	-0.087 (0.089)	0.079** (0.037)	-0.089 (0.102)	0.017 (0.027)	-0.100 (0.079)													
# of Dismissals * 1940	-0.153*** (0.038)	-0.172** (0.063)	-0.136*** (0.037)	-0.248*** (0.054)	-0.101*** (0.032)	-0.237*** (0.052)	-0.152*** (0.040)	-0.183** (0.069)	-0.149*** (0.049)	-0.190** (0.077)	-0.175*** (0.038)	-0.189*** (0.061)													
# of Dismissals * 1950	-0.201* (0.103)	-0.181*** (0.033)	-0.071* (0.036)	-0.186*** (0.049)	-0.026 (0.025)	-0.168*** (0.053)	-0.192 (0.121)	-0.183*** (0.034)	-0.123 (0.122)	-0.149*** (0.040)	-0.219** (0.100)	-0.196*** (0.032)													
# of Dismissals * 1961	-0.235*** (0.081)	-0.189*** (0.044)	-0.139** (0.061)	-0.199*** (0.067)	-0.095* (0.054)	-0.184** (0.071)	-0.249** (0.097)	-0.204*** (0.041)	-0.179* (0.099)	-0.162*** (0.056)	-0.255*** (0.081)	-0.203*** (0.042)													
# of Dismissals * 1970	-0.266*** (0.082)	-0.196*** (0.051)	-0.173** (0.078)	-0.218*** (0.077)	-0.146* (0.076)	-0.202** (0.078)	-0.276*** (0.100)	-0.227*** (0.047)	-0.218** (0.088)	-0.180*** (0.064)	-0.284*** (0.083)	-0.216*** (0.049)													
# of Dismissals * 1980	-0.211*** (0.068)	-0.170*** (0.059)	-0.135* (0.070)	-0.154** (0.064)	-0.132* (0.068)	-0.185*** (0.063)	-0.180** (0.078)	-0.142** (0.069)	-0.207** (0.080)	-0.141*** (0.044)	-0.208*** (0.070)	-0.146** (0.068)													
% Destruction * 1926	-0.005*** (0.002)	-0.003 (0.002)	-0.005* (0.003)	-0.001 (0.002)	-0.006* (0.003)	-0.001 (0.002)	-0.005** (0.002)	-0.003 (0.002)	-0.006** (0.003)	-0.003 (0.002)	-0.006*** (0.002)	-0.003 (0.002)													
% Destruction * 1931	-0.009*** (0.002)	-0.005* (0.003)	-0.009*** (0.002)	-0.003 (0.003)	-0.012*** (0.002)	-0.003 (0.003)	-0.009*** (0.002)	-0.005* (0.003)	-0.011*** (0.002)	-0.007** (0.003)	-0.008*** (0.002)	-0.006*** (0.002)													
% Destruction * 1950	-0.006** (0.002)	-0.003 (0.002)	-0.004* (0.002)	-0.002 (0.002)	-0.005** (0.002)	-0.001 (0.002)	-0.004** (0.002)	-0.003* (0.002)	-0.005** (0.002)	-0.003 (0.002)	-0.007*** (0.003)	-0.005** (0.002)													
% Destruction * 1961	-0.003* (0.002)	-0.003 (0.003)	0.000 (0.002)	-0.000 (0.003)	-0.000 (0.002)	-0.001 (0.004)	-0.002 (0.002)	-0.002 (0.003)	-0.002 (0.002)	-0.002 (0.004)	-0.003 (0.004)	-0.004 (0.003)													
% Destruction * 1970	0.001 (0.002)	0.005 (0.003)	0.005* (0.003)	0.008** (0.004)	0.003 (0.003)	0.008* (0.004)	0.003 (0.002)	0.006* (0.003)	-0.001 (0.002)	0.005 (0.004)	-0.000 (0.002)	0.003 (0.002)													
% Destruction * 1980	-0.004 (0.003)	-0.004 (0.005)	0.002 (0.004)	0.001 (0.005)	-0.003 (0.004)	-0.003 (0.005)	0.001 (0.004)	0.001 (0.005)	-0.001 (0.005)	0.001 (0.005)	-0.005 (0.005)	-0.009 (0.006)													
Department FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Subject*Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Occupation Zone	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
* Post1945 Dummies																									
Observations	609	609	588	588	483	483	714	714	714	714	483	483	714	714	714	714	714	714	714	714	714	714	714	714	714
R-squared	0.692	0.512	0.657	0.515	0.657	0.519	0.673	0.501	0.673	0.501	0.519	0.519	0.501	0.673	0.501	0.501	0.320	0.568	0.320	0.568	0.686	0.686	0.507	0.507	

***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 a department. The dependent variable *Citation weighted Pubs* reported in even columns is the sum of publications published by all scientists in a department. Dependent variables are normalized to have zero mean and a standard deviation of one. *Number of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *% Destruction * 1926* is equal to the percentage of destruction due to allied bombings between 1940 and 1945 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, excluded category: mathematics) with year dummies. *Occupation Zone * Post1945 Dummies* is an interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post 1945 dummy.

Table 6: Individual Subjects

Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)
	Publications	Citation weighted Pubs.	Publications	Citation weighted Pubs.	Publications	Citation weighted Pubs.
	Physics		Chemistry		Mathematics	
Number of Dismissals * 1926	0.141 (0.138)	-0.059 (0.277)	0.032 (0.020)	0.027 (0.038)	-0.187 (0.160)	-0.484** (0.181)
Number of Dismissals * 1940	-0.069 (0.043)	-0.185 (0.217)	-0.167*** (0.056)	-0.036** (0.014)	-0.305* (0.155)	-0.569*** (0.173)
Number of Dismissals * 1950	0.002 (0.139)	-0.082 (0.227)	-0.261** (0.127)	-0.103** (0.043)	-0.419*** (0.149)	-0.612*** (0.178)
Number of Dismissals * 1961	-0.144** (0.071)	-0.220 (0.180)	-0.247** (0.095)	-0.084* (0.043)	-0.414*** (0.146)	-0.486** (0.204)
Number of Dismissals * 1970	-0.198*** (0.039)	-0.235 (0.205)	-0.278** (0.108)	-0.093** (0.037)	-0.377** (0.153)	-0.491** (0.195)
Number of Dismissals * 1980	-0.203** (0.082)	-0.304* (0.161)	-0.166* (0.092)	0.088 (0.086)	-0.286** (0.129)	-0.424*** (0.154)
% Destruction * 1926	-0.008** (0.004)	-0.004 (0.002)	-0.002 (0.003)	-0.001 (0.003)	-0.005 (0.003)	-0.003 (0.004)
% Destruction * 1931	-0.004** (0.002)	0.001 (0.003)	-0.008** (0.003)	-0.006* (0.004)	-0.014*** (0.004)	-0.006 (0.006)
% Destruction * 1950	-0.005 (0.004)	-0.002 (0.003)	-0.003 (0.003)	-0.001 (0.003)	-0.007* (0.004)	-0.006 (0.004)
% Destruction * 1961	0.000 (0.003)	-0.001 (0.002)	-0.001 (0.003)	-0.001 (0.006)	-0.007 (0.004)	-0.004 (0.004)
% Destruction * 1970	0.005 (0.004)	0.005* (0.003)	0.002 (0.003)	0.011 (0.007)	0.002 (0.004)	0.002 (0.004)
% Destruction * 1980	0.002 (0.008)	0.007 (0.013)	0.007* (0.004)	0.010 (0.007)	-0.009 (0.008)	-0.017** (0.008)
Department FE	yes	yes	yes	yes	yes	yes
Subject*Year FE	yes	yes	yes	yes	yes	yes
Occupation Zone * Post1945 Dummies	yes	yes	yes	yes	yes	yes
Observations	238	238	238	238	238	238
R-squared	0.668	0.460	0.799	0.647	0.688	0.597

***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 a department. The dependent variable *Citation weighted Pubs* reported in even columns is the sum of publications published by all scientists in a department. Dependent variables are normalized to have zero mean and a standard deviation of one. *Number of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *% Destruction * 1926* is equal to the percentage of destruction due to allied bombings between 1940 and 1945 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, excluded category: mathematics) with year dummies. *Occupation Zone * Post1945 Dummies* is an interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post 1945 dummy.

Table 7: Dismissal of Top Scientists

	(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.	
	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations	Publi-cations
Number of Dismissals * 1926	0.020 (0.027)	-0.098 (0.080)	0.041 (0.031)	-0.113 (0.077)	0.037 (0.060)	-0.177 (0.139)	-0.078 (0.067)	-0.487** (0.210)	-0.237 (0.237)	-0.813* (0.465)
Number of Dismissals * 1940	-0.168*** (0.036)	-0.184*** (0.063)	-0.267*** (0.038)	-0.258*** (0.084)	-0.331*** (0.064)	-0.368*** (0.113)	-0.554*** (0.155)	-0.729*** (0.156)	-0.868*** (0.264)	-1.228*** (0.307)
Number of Dismissals * 1950	-0.217** (0.100)	-0.195*** (0.032)	-0.332** (0.156)	-0.277*** (0.065)	-0.391* (0.230)	-0.367*** (0.131)	-0.719** (0.322)	-0.762*** (0.143)	-0.866 (0.537)	-1.135*** (0.367)
Number of Dismissals * 1961	-0.251*** (0.080)	-0.201*** (0.043)	-0.413*** (0.097)	-0.260*** (0.069)	-0.508*** (0.151)	-0.356*** (0.128)	-0.793*** (0.250)	-0.687*** (0.188)	-1.040*** (0.348)	-1.239*** (0.330)
Number of Dismissals * 1970	-0.276*** (0.082)	-0.209*** (0.050)	-0.454*** (0.088)	-0.276*** (0.082)	-0.561*** (0.137)	-0.409*** (0.107)	-0.860*** (0.257)	-0.824*** (0.152)	-1.231*** (0.350)	-1.420*** (0.324)
Number of Dismissals * 1980	-0.200*** (0.067)	-0.137** (0.058)	-0.321*** (0.084)	-0.188 (0.133)	-0.453*** (0.098)	-0.343*** (0.112)	-0.689*** (0.192)	-0.685*** (0.135)	-1.124*** (0.285)	-1.447*** (0.358)
Controlling for Destruction	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Department FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Subject*Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Occupation Zone * Post1945 Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	714	714	714	714	714	714	714	714	714	714
R-squared	0.692	0.507	0.701	0.500	0.694	0.506	0.687	0.526	0.661	0.535

***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 a department. The dependent variable *Citation weighted Pubs.* reported in even columns is the sum of publications published by all scientists in a department. Dependent variables are normalized to have zero mean and a standard deviation of one. In columns (1) and (2) *Number of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. In columns (3) and (4) *Number of Dismissals * 1926* is equal to the number of dismissals of scientists in the top 50th percentile interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. Quality to measure high quality dismissals is measured using citation weighted publications in the 5 year window around 1931. Coefficients for the interaction of % destruction with year dummies are included in the regression but not reported. *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, excluded category: mathematics) with year dummies. *Occupation Zone * Post1945 Dummies* is an interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post 1945 dummy.

Table 8: Persistence of Dismissal and Bombing Shocks - Department Size

Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Department Size	Department Size	Department Size	Department Size	Department Size	Department Size	Department Size	Department Size	Department Size
Number of Dismissals * 1926	-0.243*** (0.058)	-0.239*** (0.056)	-0.239*** (0.056)	-0.000 (0.007)	-0.001 (0.007)	-0.001 (0.007)	0.001 (0.008)	0.001 (0.008)	0.001 (0.008)
Number of Dismissals * 1940	-0.573*** (0.098)	-0.578*** (0.097)	-0.578*** (0.097)	-0.004 (0.006)	-0.005 (0.007)	-0.005 (0.007)	-0.002 (0.005)	-0.002 (0.005)	-0.002 (0.005)
Number of Dismissals * 1950	-1.464*** (0.430)	-1.460*** (0.446)	-1.417*** (0.335)	0.011 (0.018)	0.014 (0.019)	-0.012 (0.017)	0.009 (0.018)	0.010 (0.018)	-0.015 (0.017)
Number of Dismissals * 1961	-1.229*** (0.332)	-1.321*** (0.355)	-1.278*** (0.203)	0.037 (0.023)	0.031 (0.023)	0.005 (0.024)	0.035 (0.023)	0.028 (0.023)	0.003 (0.024)
Number of Dismissals * 1970	-1.107*** (0.489)	-1.245*** (0.513)	-1.202*** (0.323)	0.097*** (0.032)	0.088*** (0.032)	0.062*** (0.027)	0.095*** (0.032)	0.086*** (0.033)	0.060*** (0.028)
Number of Dismissals * 1980	0.300 (0.746)	0.139 (0.696)	0.116 (0.662)	0.057 (0.060)	0.044 (0.061)	0.024 (0.059)	0.060 (0.059)	0.047 (0.060)	0.027 (0.059)
% Destruction * 1926				yes	yes	yes	yes	yes	yes
% Destruction * 1931				yes	yes	yes	yes	yes	yes
% Destruction * 1950				yes	yes	yes	yes	yes	yes
% Destruction * 1961				yes	yes	yes	yes	yes	yes
% Destruction * 1970				yes	yes	yes	yes	yes	yes
% Destruction * 1980				yes	yes	yes	yes	yes	yes
Department FE									
Year FE									
Subject*Year FE									
Occupation Zone * Post1945 Dummies									
Observations	714	714	714	714	714	714	714	714	714
R-squared	0.809	0.832	0.849	0.803	0.824	0.839	0.818	0.838	0.853

***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. *Number of Dismissals * 1926* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *% Destruction * 1926* is equal to the percentage of destruction due to allied bombings between 1940 and 1945 interacted with a dummy variable which is equal to 1 for observations from 1926. The other interactions are defined accordingly. *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, excluded category: mathematics) with year dummies. *Occupation Zone * Post1945 Dummies* is an interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post 1945 dummy.

Table 9: Quality of New Hires

	(1)	(2)	(4)	(3)	(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
Number of Dismissals * 1940	-0.056*** (0.013)	-0.094*** (0.017)	-0.144*** (0.034)	-0.244*** (0.037)	-0.428*** (0.116)
Number of Dismissals * 1950	-0.062*** (0.014)	-0.101*** (0.022)	-0.150*** (0.041)	-0.247*** (0.047)	-0.423*** (0.124)
Number of Dismissals * 1961	-0.061*** (0.010)	-0.098*** (0.019)	-0.145*** (0.036)	-0.240*** (0.045)	-0.440*** (0.109)
Number of Dismissals * 1970	-0.062*** (0.015)	-0.100*** (0.024)	-0.151*** (0.033)	-0.278*** (0.037)	-0.502*** (0.110)
Number of Dismissals * 1980	-0.072*** (0.011)	-0.123*** (0.023)	-0.182*** (0.044)	-0.298*** (0.053)	-0.541*** (0.137)
Controlling for Destruction	yes	yes	yes	yes	yes
Department FE	yes	yes	yes	yes	yes
Subject*Year FE	yes	yes	yes	yes	yes
Occupation Zone * Post1945 Dummies	yes	yes	yes	yes	yes
Observations	602	602	602	602	602
R-squared	0.379	0.383	0.400	0.417	0.435

***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. Quality of hires is measured by the career average of lifetime citations. The variable is normalized to have zero mean and a standard deviation of one. *Number of Dismissals * 1940* is equal to the number of dismissals in Nazi Germany between 1933 and 1940 interacted with a dummy variable which is equal to 1 for observations from 1940. The other interactions are defined accordingly. Coefficients for the interaction of % destruction with year dummies are included in the regression but not reported. *Subject*Year FE* is the interaction of subject indicators (for physics, chemistry, excluded category: mathematics) with year dummies. *Occupation Zone * Post1945 Dummies* is an interaction of occupation zone indicators (English zone, French zone, Soviet zone, excluded category U.S. zone) with a post 1945 dummy.

8 Appendix

8.1 Appendix Tables

Table A1: 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 Preussischen 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
Journal 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 A2: 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	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

8.2 Data Appendix

8.2.1 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 dataset of German scientists at 7 points in time between 1926 and 1980. The KDG covers all researchers in German speaking universities. To compile the calendar the editors contacted all German speaking universities to obtain faculty lists and then sent out questionnaires to all members of faculty. 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.

There sometimes was a slight delay 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 she may not appear in the 1926 volume because she was not a privatdozent at the time the questionnaire was sent to departments to ask them for staff lists. 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 the faculty in a certain department in the relevant years.

The KDG 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 includes all ordinary professors, extraordinary professors, honorary professors, and privatdozenten. The Nazi government renamed the privatdozent position into dozent which affects the data in 1941. To have a comparable set of researchers I also add all dozenten to the data.

8.2.2 Productivity 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).

The list of historical top journals is obtained in three steps. First I obtain all German science journals published in the 1920s to 1940s that are included in the Web of Science. Secondly, 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 relevant outlets for German scientists.

Current top journals

The definition of top journals for German (and international) scientists changed substantially between the 1920 and the 1980s. To reflect this change in my productivity 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. I therefore obtain the current most cited mathematics journals from a commonly used ranking provided by the University of Texas.

Downloading Articles in Top Journals Published Between 1920 and 1985

The overall list of top journals includes 51 journals. I download all articles published in all 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. In those cases I download all articles since the creation of the journal. The publication of a few journals was interrupted towards the end of World War II. These are therefore missing from the data for these years. Furthermore, some journals have missing data in the Web of Science for some years even though the journal was actually published. It is important to note that I include year fixed effects in all regressions reported below. As all scientists in a given year are similarly affected by these coverage gaps, year fixed effects will control for this problem.

8.2.3 Data on Bombings of German Science Departments

As outlined in the main text the data on bombing destruction of German science departments is obtained by contacting all university archivists and asking them to provide destruction information for buildings used by physicists, chemists, and mathematicians. If a department was based in 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 used by the respective department.

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

“completely destroyed”	100%
“heaviest destruction”	75%
“heavy destruction”	50%
“part destruction”	25%
“light destruction”	10%