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Peer Effects in Science

Evidence from the Dismissal of Scientists in Nazi Germany

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Abstract

This paper analyzes peer effects among university scientists. Specifically, it investigates whether the quality and the number of peers affect the productivity of researchers in physics, chemistry, and mathematics. The usual endogeneity problems related to estimating peer effects are addressed by using the dismissal of scientists by the Nazi government in 1933 as a source of exogenous variation in the peer group of scientists staying in Germany. To investigate localized peer effects, I construct a new panel dataset covering the universe of scientists at the German universities from 1925 to 1938 from historical sources. I find no evidence for peer effects at the local level. Even very high quality scientists do not affect the productivity of their local peers.

1 Introduction

It is widely believed that localized peer effects are important among academic researchers. Individual researchers do not necessarily take these effects into account when they decide where to locate. This may result in misallocation of talent and underinvestment in academic research. Having a good understanding of peer effects is therefore crucial for researchers and policy makers alike. In this paper I analyze localized peer effects among scientists whose research is often believed to be an important driver of technological progress. Understanding these effects may therefore be particularly important for science policy-makers in a knowledge based society.

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Despite the widespread belief in the presence of peer effects in academia, there is very little empirical evidence for these effects. Obtaining causal estimates of peer effects is very challenging. An important problem is the sorting of individuals. Highly productive scientists often choose to locate in the same universities. Sorting may therefore introduce a positive correlation of scientists' productivities within universities which has not been caused by peer effects. Another problem complicating the estimation of peer effects is the presence of unobservable factors which affect a researcher's productivity but also the productivity of his peers. Measurement problems further increase the difficulty of obtaining unbiased estimates for peer effects. A promising empirical strategy would therefore be a setup where a scientist's peer group changes due to reasons which are unrelated to his own productivity.

In this paper I propose the dismissal of scientists by the Nazi government in 1933 as an exogenous change in the peer group of researchers in Germany. Only 66 days after Hitler's National Socialist party secured power the Nazi government dismissed all Jewish and so called "politically unreliable" scholars from German universities. Around 13 to 18 percent of university scientists were dismissed between 1933 and 1934 (13.6 percent of physicists, 13.1 of chemists, and 18.3 percent of mathematicians). Many of the dismissed scholars were outstanding members of their profession, among them the famous physicist and Nobel Laureate Albert Einstein, the chemist Georg von Hevesy who received the Nobel Prize in 1943, and the Hungarian mathematician Johann von Neumann. Scientists in affected departments were therefore exposed to a dramatic change in their peer group. Researchers in departments which had not employed Jewish or "politically unreliable" scholars did not experience any dismissals and therefore no changes to their peer groups.

I use a large number of historical sources to construct the dataset for my analysis. From historical university calendars I construct a panel of the universe of physicists, chemists, and mathematicians working at German universities from 1925 to 1938.¹ I combine this data with a complete list of all dismissals and with publication data to measure productivity.

The data allow me to obtain the first clean estimate of localized peer effects among scientists using exogenous variation in the quality and quantity of peers in a researcher's department. Contrary to the common belief of most researchers, I do not find any evidence for peer effects within a scientist's department. This finding is robust to narrowing the peer group to peers from the same specialization only; i.e. by considering only theoretical physicists when constructing the peer group for theoretical physicists. Recent work on life scientists suggests that "star scientists" have a particularly large effect on their colleagues' productivity (Azoulay, Zivin, and Wang, 2010 and Oettl 2009). As the dismissals include some of the most prominent scientists of their time, I can investigate how the loss of top quality peers affects the productivity of scientists staying in Germany. The results indicate that even the loss of very high quality peers does not have a negative impact on the productivity of stayers.

One may be concerned that the dismissals affected the productivity of stayers through other channels than peer effects. Most of these expected biases, such as an increased teaching load or

¹I do not consider the years after 1938 because of the start of World War II in 1939.

an increase in administrative duties, would lead me to overestimate the effect of peers. There are, however, a few other potential biases that could lead to an underestimation of peer effects. I discuss these threats to the identification strategy below and show evidence that the dismissals are uncorrelated with changing incentives, changes in funding, and the number of ardent Nazi supporters in the affected departments. Furthermore, I show that different productivity trends in affected and unaffected departments cannot explain my findings.

Few papers have empirically analyzed localized spillovers among university scientists. One example is Weinberg (2007) who analyzes peer effects among Nobel Prize winners in physics. He finds that physicists arriving in a city where other Nobel Laureates are working are more likely to start Nobel Prize winning work. It is, however, not clear how much of this effect is driven by sorting of scientists. Dubois, Rochet, and Schlenker (2010) investigate externalities among mathematicians in the United States. Similarly to the findings in this paper they do not find evidence for peer effects at the local level. While they have an extensive dataset of mathematicians all over the world, they cannot rely on exogenous variation to identify peer effects. Similarly, Kim, Morse, and Zingales (2009) investigate peer effects in economics and finance faculties and find evidence for positive peer effects in the 1970s and 1980s but negative peer effects for the 1990s. While they address selection of researchers into particular universities in other specifications, they do not address the selection of researchers in the specification that directly tests the impact of peers on the productivity of researchers.²

Recently a number of studies have suggested that falling communication costs reduced the importance of location in academic research (Kim, Morse, and Zingales, 2009, Adams et al. 2005, Agrawal and Goldfarb 2008, and Rosenblat and Mobius, 2004). The findings of this paper, however, suggest that location was already “dead” in the 1920s and 1930s - at least in Germany.^{3,4}

The remainder of the paper is organized as follows: the next section gives a brief description of historical details. Section 3 describes the construction of the dataset and section 4 outlines the identification strategy. The effect of the dismissals on the productivity of scientists remaining in Germany is analyzed in section 5. I then use the dismissals as an exogenous source to identify localized peer effects in section 6. Section 7 discusses the findings and concludes.

²In addition to papers analyzing peer effects among university researchers there is a growing literature examining peer effects in other, mostly low skill, work environments (e.g. Mas and Moretti, 2008 and Bandiera, Barankay, and Rasul, 2010).

³Similarly, Dubois, Rochet, and Schlenker (2010) who analyze mathematicians do not find evidence that the importance of location decreased between 1984 and 2006.

⁴Another related strand of the literature focuses on regional spillover effects of patent citations. Jaffe, Trajtenberg, and Henderson (1993) use an ingenious method to control for pre-existing regional concentration of patent citations. They find that citations of patents are highly geographically clustered. Thompson and Fox-Keane (2005) challenge those findings in a later paper.

2 The Expulsion of Jewish and ‘Politically Unreliable’ Scholars from German Universities

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, 1933. The law served as the legal basis to expel all Jewish and “politically unreliable” persons from the German civil service.⁵ The relevant paragraphs read:

Paragraph 3: Civil servants who are not of Aryan descent are to be placed in retirement... (this) does not apply to officials who had already been in the service since the 1st of August, 1914, or who had fought in the World War at the front for the German Reich or for its allies, or whose fathers or sons had been casualties in the World War.

Paragraph 4: Civil servants who, based on their previous political activities, cannot guarantee that they have always unreservedly supported the national state, can be dismissed from service.

["Law for the Restoration of the Professional Civil Service", quoted after Hentschel (1996)]

In a further implementation decree, “Aryan descent” was specified as follows: “Anyone descended from Non-Aryan, and in particular Jewish, parents or grandparents, is considered non-Aryan. It is sufficient that one parent or one grandparent be non-Aryan.” Christian scientists were therefore dismissed if they had a least one Jewish grandparent. In many cases, scientists would not have known that their colleague had Jewish grandparents. It is therefore unlikely that the majority of the dismissed had been treated differently by their colleagues before the rise of the Nazi party. The decree also specified that all members of the Communist Party were to be expelled under paragraph 4. The law was immediately implemented and resulted in a wave of dismissals and early retirements from German universities. More than 1,000 academics were dismissed between 1933 and 1934 (Hartshorne, 1937). This amounts to about 15 percent of all 7,266 university researchers. Most dismissals occurred in 1933 immediately after the law was implemented.

The law allowed exceptions for scholars of Jewish origin who had been in office since 1914, or who had lost a close family member in the First World War. Nonetheless, many of these scholars decided to leave voluntarily; for example the Nobel Laureate James Franck, who resigned from his professorship at the physics department in Göttingen, and Fritz Haber, a Nobel Laureate in chemistry who resigned from the University of Berlin. These resignations merely anticipated a later dismissal, as the Reich citizenship laws (Reichsbürgergesetz) of 1935 revoked all exception clauses.

⁵At that time, most German university professors were civil servants. Therefore the law was directly applicable to them. Via additional ordinances the law was also applied to other university employees who were not civil servants.

The vast majority of dismissed scientists emigrated and most of them obtained positions in foreign universities. The most important emigration destinations were the United States, the United Kingdom, Switzerland, Turkey, and the British Mandate of Palestine (later Israel). For the purposes of this paper it is important to note that most emigrations took place immediately after the researchers were dismissed from their university positions. Further collaborations with researchers staying in Germany were therefore extremely difficult. A very small minority of the dismissed did not leave Germany. Most of them died in concentration camps or committed suicide. Extremely few managed to stay in Germany and survive the Nazi regime. Even scientists staying in Germany were no longer allowed to use university laboratories and other resources. The possibility of ongoing collaboration of the dismissed with scientists staying in Germany was therefore extremely limited.

According to my calculations, 13.6 percent of physicists, 13.1 of chemists, and 18.3 percent of mathematicians were dismissed between 1933 and 1934 (Table 1).⁶ The vast majority of dismissals occurred between 1933 and 1934. Later dismissals affected researchers who could initially stay under the exception clause or if political reasons for a dismissal were discovered later on. In order to have a sharp dismissal measure I therefore focus on the dismissals in 1933 and 1934.

My data does not allow me to identify whether the researchers were dismissed because they were Jewish or for political reasons. Previous historical work indicates that the vast majority of the dismissed were either Jewish or of Jewish descent. Deichmann (2001), for example, finds that about 87 percent of the dismissed chemists were of Jewish origin. Siegmund-Schultze (1998) estimates that about 79 percent of the dismissed mathematicians were of Jewish descent.

The aggregate number of dismissals hides the fact that German science departments were affected very differently. Some departments lost more than half of their personnel while others did not experience any dismissals. Even within a university there was a lot of variation across different departments (Table 2). Whilst 40 percent of physicists and almost 60 percent of mathematicians were dismissed from the renowned University of Göttingen there were no dismissals in chemistry.

The top panel of Table 3 gives a more detailed picture of the quantitative and qualitative loss in the three subjects. As has already been documented (Fischer, 1991) dismissed physicists were younger than the average age but made above average scientific contributions, received more Nobel Prizes (either before or after 1933), published more papers in top journals, and received more citations.⁷ In chemistry, the dismissed were also of higher than average quality but the difference to the stayers was less pronounced. In mathematics many of the dismissed were truly outstanding members of their profession and of much higher quality than the average mathematician.

⁶These numbers are consistent with the numbers obtained by historians who have studied the dismissal of scientists in Nazi Germany. Fischer (1991) reports that 15.5 percent of physicists were dismissed between 1933 and 1940. Deichmann (2001) calculates a loss of about 24 percent of chemists between 1933 and 1939. Her figure is higher than mine because she considers all dismissals between 1933 and 1939 (while I focus on the 1933 to 1934 dismissals) and because my sample includes 5 additional universities with below average dismissals.

⁷For a more detailed description of the publications data see the data section.

Table 3 also reports collaboration patterns before and after the dismissals. In physics, about 33 percent of the publications in top journals were coauthored. About 11 percent of all publications were coauthored with a colleague holding a faculty position at a German university. This percentage is lower than the overall level of coauthoring because faculty level physicists coauthored extensively with assistants, Ph.D. students, and senior colleague at research institutes or foreign universities. The table also shows a low level of cooperation within departments; only about 4 percent of all publications were coauthored with a faculty level researcher from the same university. In chemistry, 76 percent of papers were coauthored, 12 percent were coauthored with a colleague holding a faculty position, and only 5 percent were coauthored with a faculty member from the same department. In mathematics these numbers were 11 percent, 6 percent, and 3 percent, respectively.

The table also shows that before 1933, the fraction of stayers' publications that were coauthored with scientists who were later dismissed was always higher than the fraction of the dismissed in the population. While 13.6 percent of physicists were dismissed, 19 percent ($= (2.0/10.3)*100$) of faculty coauthoring of the stayers occurred with physicists who were later dismissed. In chemistry, stayers coauthored 15 percent of faculty collaborations with the dismissed, and in mathematics stayers coauthored 39 percent of faculty collaborations with the dismissed.

The bottom part of table 3 shows publication and collaboration patterns for the post dismissal period. It shows that the productivity of the dismissed dropped substantially because they were first relocating and then restarting their career abroad. The panel also shows that collaborations of stayers with dismissed scientists became now very rare. Only 0.6 percent of the papers published by staying physicists were published with the dismissed scientists. For chemistry (0.4 percent) and mathematics (0 percent) these numbers were even lower. Figure A1 in the appendix shows collaboration patterns between stayers and dismissed scientists by year. Not surprisingly, stayers and dismissed still copublished in 1933 and 1934 (as the dismissals did not occur until April 1933 and I also consider dismissals in 1934). After that, collaborations fall sharply and were 0 in many years.

For comparison reasons, I report current collaboration patterns for the top 10 science and economics departments in Germany and the United States focusing on tenured faculty (Table A1).⁸ Current collaboration patterns for German and U.S. science departments look relatively similar.⁹ There is little coauthoring with researchers from the same department. The big exception is physics with a high level of collaboration within departments. This is mostly driven, however, by physicists conducting research involving particle accelerators; a technology that was invented by E. Lawrence in Berkeley in 1930 and became first available in Germany in 1944 (and thus after the time period analyzed in this paper). The publications involving results from particle accelerators usually list hundreds of authors (often more than 500, one article

⁸See the data appendix for more details on the data of current science and economics departments.

⁹As collaborations are measured with publications in top journals (see data appendix) the data on within department level collaborations is not very informative economics in Germany because only 33 of the 218 German economists have published in a top 5 journal since 2000.

in the Physical Review Letters even has 744 authors). For physicists working with particle accelerators, copublication does therefore not seem a very good measure for close collaboration. If one excludes these physicists from the analysis (about 15 percent of physicists overall), current collaboration patterns are more similar to the historical data even for physicists.

3 Construction of a Panel Dataset of German Scientists

3.1 Data on Dismissed Scholars

I obtain data on dismissals from a number of historical sources. The main source is the List of Displaced German Scholars (1937) from which I extract all dismissed physicists, chemists, and mathematicians. The list was compiled by the relief organization “Emergency Alliance of German Scholars Abroad”, which supported dismissed scholars in finding positions in foreign universities. It contains about 1650 names of dismissed university researchers from all subjects. The data appendix shows a sample page from the physics section of the list. The page shows four physicists who had already received the Nobel Prize or were to receive it in later years (Figure A6).

For various reasons, for example if the dismissed died before the List of Displaced German Scholars (1937) was compiled, a small number of dismissed researchers did not appear in the list. To get a more complete measure of the dismissals I complement the data on dismissals with information from secondary sources (Biographisches Handbuch, 1983, Beyerchen, 1977, Deichmann, 2001, Siegmund-Schulze, 1998).¹⁰ The data appendix contains more detail on data construction and the secondary sources.

3.2 Data on all Scientists at German Universities between 1925 and 1938

To investigate the impact of the dismissals on scientists who stayed in Germany, I obtain data on all scientists in German universities from 1925 to 1938. The data originate from historical University Calendars (see data appendix for details) from which I compile an annual roster of scientists in all physics, chemistry, and mathematics departments from winter semester 1924/1925 (lasting from November 1924 until April 1925) to winter semester 1937/1938.¹¹ The data contain all scientists who were at least “Privatdozent”. That is the first university position a researcher could obtain after the “*venia legendi*” and would allow the researcher to give lectures at German universities.

¹⁰Slightly less than 20 percent of 1933 to 1934 dismissals only appear in the additional sources but not in the “List of Displaced German Scholars”.

¹¹Data for the technical universities were only published from winter semester 1927/1928 onwards.

In some specifications I use the scientists' specialization to identify their relevant peer group. The data on specializations come from seven volumes of "Kürschners deutscher Gelehrten-Kalender". The books are listings of German researchers compiled at irregular intervals since 1925. I obtain the scientists' specialization for about 90 percent of my sample. For the 10 percent of scientists who did not list their specialization in the "Gelehrtenkalender" I conduct an internet search to find their specialization. Overall, I obtain information on the specialization of scientists for 98 percent of my sample.¹² Appendix Table A2 gives an overview of all specializations and the fraction of scientists in each of them.

3.3 Publication Data

To measure the productivity of scientists I construct a dataset containing the publications of each researcher in the top academic journals of the time. In the period under consideration, most German scientists published in German journals. German journals were of very high quality because many of the German physicists, chemists, and mathematicians were among the leaders in their profession. This is especially true for the time before the dismissals, as is exemplified by the following quote; "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)). Historical research indicates that the journals considered in the analysis did not change substantially between 1933 and 1938 (Simonsohn, 2007). It is important to note, that the identification strategy outlined below relies on changes in publications of researchers in German departments that were differentially affected by the dismissals. A decline in the quality of the considered journals would therefore not affect my results, as all regressions are estimated including year fixed effects.

The top publications measure is based on articles contained in the online database "ISI Web of Science". The database is provided by Thomson Scientific and contains all contributions in a large number of science journals. In 2004, the database was extended to include articles in journals published between 1900 and 1945. The journals included in that backward extension were all journals that had published the most relevant articles in the years 1900 to 1945. The publication measure used in this paper therefore measures publications in the top journals of the time.

I extract all German speaking general science, physics, chemistry, and mathematics journals that are included in the database for the time period 1925 to 1938. Furthermore, I add the leading general science journals that were not published in Germany, namely Nature, Science, and the Proceedings of the Royal Society of London. I also include four non-German top specialized journals that were suggested by historians of science as journals of some importance

¹²Some researchers name more than one specialization. Physicists and chemists therefore have up to two specializations and mathematicians up to four.

for the German scientific community (see data appendix for details). Appendix Table A3 lists all journals used in the analysis.¹³

For each researcher I calculate two different yearly productivity measures. The first measure is equal to the sum of publications in top journals in a given year. In order to quantify an article's quality I also construct a second measure which accounts for the number of times the article was cited in any journal included in the Web of Science in the first 50 years after its publication. This includes citations in journals that are not in my list of journals but that appear in the Web of Science. As a result, this measure includes citations from the entire international scientific community. It is therefore less heavily based on German science. I call this measure "citation weighted publications" and it is defined as the sum of citations to all articles published in a certain year.

Appendix Table A4 lists the top 20 researchers for each subject according to the citation weighted publications measure. It is reassuring to realize that the vast majority of these top 20 researchers are very well known in the scientific community. Economists will find it interesting that Johann von Neumann who emigrated to the Institute of Advanced Studies in Princeton was the most cited mathematician. The large number of Nobel laureates among the top 20 researchers indicates that citation weighted publications are a good measure of a scholar's productivity.

4 Identification

4.1 Estimating Peer Effects

Using this panel dataset I estimate peer effects among scientists. The collaboration of researchers can take different levels of intensity. A very direct way of peer interaction is the collaboration on joint research projects involving joint publication of results. In many cases, however, peer interactions are more subtle. Scientists discuss research ideas and comment on each other's work without copublishing. Yet another way in which peers may affect a researcher's productivity is through peer pressure. Furthermore, peers may attract more research funding to the department, or have better contacts to influential persons in the profession. In this paper I estimate the sum of all aforementioned peer effects.

The standard approach when estimating peer effects consists of regressing an individual's productivity on the average productivity of his peers. The productivity of academic researchers, however, is not only affected by the average quality of peers but also by the number of peers he can interact with.

As university departments differ substantially in quality and size, it is important to distinguish these two dimensions of peer effects among scientists. I therefore propose the following

¹³See the data appendix for more details on merging articles to scientists.

regression which will be estimated for all scientists staying in Germany (in the following I will refer to as "stayers"):¹⁴

$$(1) \quad \# \text{ Publications}_{iut} = \beta_1 + \beta_2(\text{Avg. Peer Quality})_{ut} + \beta_3(\# \text{ of Peers})_{ut} \\ + \beta_4 \text{Age Dummies}_{iut} + \beta_5 \text{YearFE}_t + \beta_6 \text{UniversityFE}_u + \beta_7 \text{IndividualFE}_i + \varepsilon_{iut}$$

I regress the number of publications of scientist i in university u and year t on measures of his peer group and other controls. The regressions will be estimated separately for physics, chemistry, and mathematics because the subjects under consideration have different publication and collaboration patterns. Average peer quality is calculated as the mean of the average productivity of a researcher's peers.^{15,16} Over time changes in average peer quality will only occur if the composition of the department changes. Yearly fluctuations in publications of the same set of peers will not affect the peer group measure. The underlying assumption is that Albert Einstein always had the same effect on his peers independently of how much he published in a given year.

It is likely that the effect of peers is only measurable after a certain time lag. Peers influence the creation of new ideas and papers before the actual date of publication. Another delay is caused by publication lags. Science research is published much faster than research in other subjects like economics. Anecdotal evidence suggests that the effect of peers should be measured with a lag of about one year. An illustrative example for the timing of peer interactions in science at the relevant time is the postulation of the "uncertainty principle" by Heisenberg in 1927. In 1926, Heisenberg started working with Niels Bohr in Copenhagen. It is reported that during that time Heisenberg and Bohr spent many hours discussing the concepts of quantum mechanics in order to refine them. Early in 1927, Heisenberg discovered and formulated his famous "uncertainty principle". He published this discovery in the "Zeitschrift für Physik" in 1927.¹⁷

Collaboration patterns of scientists staying in Germany with colleagues who were dismissed in 1933 and 1934 allow me to get a further insight into the timing of peer interactions. Figure A1 reports the fraction of papers that stayers coauthored with dismissed scientists. As chemists not only copublished a larger amount of their papers but also published more papers on average, the data for chemistry is especially informative. The number of stayers' publications with the dismissed scientists plummeted in 1935, exactly the year after the dismissals considered in this paper. I therefore use a one year lag for the peer group variables when estimating equation (1). Using different lags does not affect the results.

¹⁴In different specifications I explore how very high quality peers affect scientists' productivity (see section 6.4).

¹⁵Say a department has 3 researchers in 1930. One published on average 10 citation weighted publications between 1925 and 1938. The other two have 20 and 15 citation weighted publications, respectively. Average peer quality for researcher 1 in 1930 will therefore be $(20+15)/2 = 17.5$. Average peer quality for researcher 2 will be $(10+15)/2 = 12.5$ and so on.

¹⁶To measure average peer quality I use the department mean of individual productivities calculated between 1925 and 1938. An alternative way of measuring average peer quality uses only pre-dismissal years. This measure, however, is not defined for researchers coming into the sample after 1933. I therefore present results using the first measure. Using the alternative measure does not affect my findings.

¹⁷For a detailed historic description of the discovery of the uncertainty principle see Lindley (2007).

The regression also includes a full set of 5-year age-group dummies to control for life-cycle changes in productivity.¹⁸ Year fixed effects control for yearly fluctuations in publications which affect all researchers in the same way. To control for differences in a researcher's talent I add individual fixed effects to all specifications. Furthermore, I add university fixed effects to control for university specific factors affecting a researcher's productivity. These can be separately identified because some scientists change universities.

4.2 Using the Dismissals as Instruments for the Number and Quality of Peers

Estimating equation (1) using OLS would lead to biased estimates of β_2 and β_3 . Since a researcher's productivity is affected by his peers yet at the same time the researcher affects the productivity of his peers complicates the estimation of equation (1). Manski (1993) refers to this problem as the reflection problem. Estimated effects will therefore be total effects after all productivity adjustments have taken place.

Other problems, however, are potentially more severe in this context. An important problem is caused by selection. Selection not only occurs because scientists self-select into departments with peers of similar quality but also because departments appoint professors of similar productivity. The inclusion of university fixed effects would in principle address this issue. Differential time trends, however, make selection an important problem even in models which include university fixed effects.

Omitted variables, such as the construction of a new laboratory that may not be observed by the econometrician, may further complicate the estimation of peer effects. Omitted factors may affect all scientists in a certain department. Not controlling for unobserved factors would therefore introduce a correlation of the error term and the peer group variables and therefore lead to biased OLS estimates.

Furthermore, measurement error in particular of peer quality could bias the regression estimates. Even good measures of peer quality, such as the average number of citation weighted publications, are by no means perfect measures of peer influence.

To address these problems I propose the dismissal of scientists by the Nazi government as an instrument for the peer group of scientists. Figure 1 shows the effect of the dismissal on the peer group of physicists.

¹⁸Levin and Stephan (1991) show that age is an important determinant of scientists' productivity.

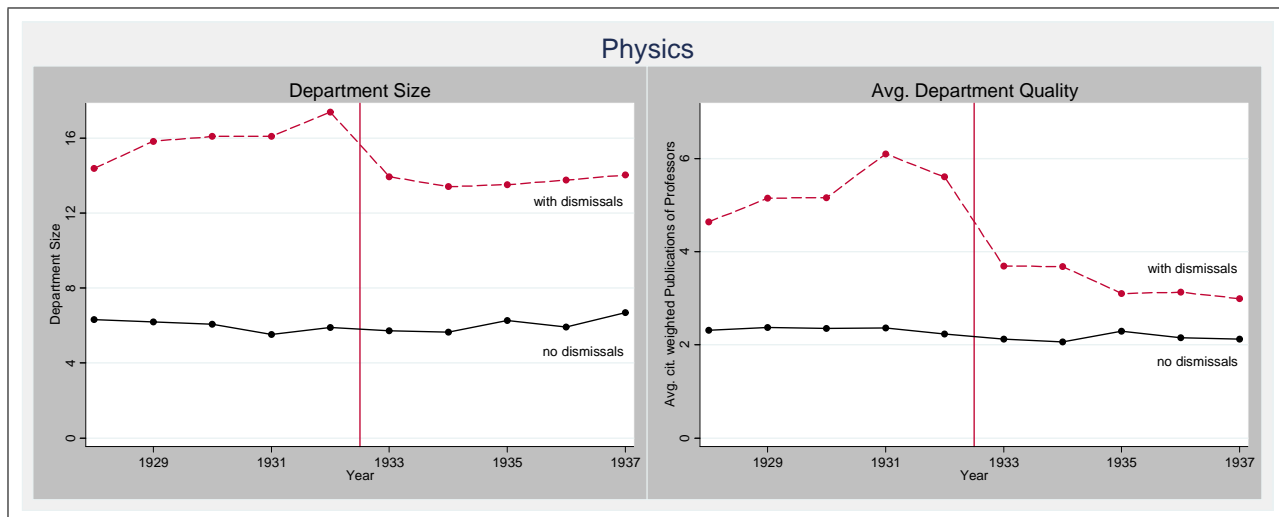


Figure 1: Effect of Dismissals on Department Size and Peer Quality

The left-hand panel shows the average department size for two groups of physicists: physicists in departments with dismissals in 1933 or 1934 and physicists in departments without dismissals. The figure shows that affected departments were of above average size and that the dismissals led to a strong and permanent reduction in department size. The dismissed were not immediately replaced because of a lack of suitable researchers without a position and slow appointment procedures.¹⁹ The right-hand panel of Figure 1 shows the evolution of average peer quality in departments with dismissals and in departments without dismissals. The dismissed were on average more productive than physicists who were not dismissed. As a result, average peer quality in affected departments fell after 1933. The graph only shows averages for the two groups of departments and therefore understates the variation I am using in the regression specifications. As can be seen from Table 2, some departments with dismissals also lost below average quality peers. Average department quality increased in those departments. Overall, however, the dismissal reduced average department quality in physics.

Appendix figures A2 and A3 show the evolution of department size and quality for chemistry and mathematics. In chemistry, affected departments were of above-average quality but the difference was less pronounced than in physics. Despite the fact that the dismissals did not have a large effect on peer quality for the average across all departments it strongly affected average quality in many departments as can be seen from Table 2. The effects in departments with reductions in average peer quality and in departments with improvements in peer quality, however, almost cancel out in the aggregate. In mathematics, departments with dismissals were on average larger and better. After 1933 department size and peer quality fell sharply in

¹⁹Successors for dismissed chaired professors, for example, could only be appointed if the dismissed scholars ceded all pension rights because they were originally placed into early retirement. The employers did not want to pay the salary for the replacement and the pension for the dismissed professor at the same time. It thus took years to fill open positions in most cases. Highlighting this problem, Max Wien a physicist in Jena, wrote a letter to Bernhard Rust the Minister of Education in late November 1934. Describing the situation for chaired professorships at the German universities he wrote that “out of the 100 existing [chaired professor] teaching positions, 17 are not filled at present, while under natural retirements maybe two or three would be vacant. This state of affairs gives cause for the gravest concern...” (cited after Hentschel, 1996).

affected departments.

The fact that most of the dismissals occurred in bigger and better departments does not invalidate the identification strategy as level effects will be taken out by including university and individual fixed effects. The crucial assumption for the difference-in-differences type strategy is that trends in affected versus unaffected departments were the same prior to the dismissal. Below, I show in various ways that this was indeed the case.²⁰

I use the dismissals to instrument for average peer quality and the number of peers. The two first stage regressions are:

$$(2) \quad \text{Avg. Peer Quality}_{ut} = \gamma_1 + \gamma_2(\text{Dismissal induced Fall in Peer Quality})_{ut} + \gamma_3(\# \text{ Dismissed})_{ut} \\ + \gamma_4 \text{Age Dummies}_{iut} + \gamma_5 \text{YearFE}_t + \gamma_6 \text{UniversityFE}_u + \gamma_7 \text{IndividualFE}_i + \varepsilon_{iut}$$

$$(3) \quad \# \text{ of Peers}_{ut} = \delta_1 + \delta_2(\text{Dismissal induced Fall in Peer Quality})_{ut} + \delta_3(\# \text{ Dismissed})_{ut} \\ + \delta_4 \text{Age Dummies}_{iut} + \delta_5 \text{YearFE}_t + \delta_6 \text{UniversityFE}_u + \delta_7 \text{IndividualFE}_i + \varepsilon_{iut}$$

Equation (2) is the first stage regression for average peer quality. The crucial instrument for average peer quality is called “dismissal induced fall in average peer quality”. It measures how much peer quality fell because of the dismissals. The variable is 0 until 1933 in all departments. After 1933 it is defined as follows:

$$\text{Dismissal induced Fall in Peer Quality} = (\text{Avg. Peer Quality before 1933}) - (\text{Avg. Peer Quality before 1933} | \text{Stayer})$$

After 1933, “dismissal induced fall in peer quality” is positive for scientists in departments with dismissals of above average department quality. The variable remains 0 for researchers in departments without dismissals or for scientists who lost peers whose quality was below the department average.²¹ The instrument is based on changes in peer quality measured by 1925-1932 productivity measures. Using quality measures after 1933 in the construction of the instrumental variable would be problematic because post 1933 productivity may be affected by the dismissals.

The second instrument is the number of dismissals in a given department. The variable is 0 until 1933 and equal to the number of dismissals thereafter.²²

²⁰The fact that mostly bigger and better departments were affected by the dismissals affects the interpretation of the IV estimates. According to the LATE interpretation of IV (Imbens and Angrist, 1994), IV estimates the effect of changes in size and quality for large and high quality departments. As nowadays most science departments are bigger than in the average in the early 20th century this LATE effect is potentially more interesting than the corresponding ATE.

²¹The implicit assumption is that below average dismissals did not affect the productivity of scientists. An alternative way of defining “dismissal induced fall in peer quality” would be to allow the dismissal of below average peers to have a positive impact on the productivity of scientists. In specifications not reported in this paper I have explored this. The results do not change.

²²The variable is 0 until 1933 for all departments (as I use a one year lag in the peer group variables it is 0 for 1933 inclusive). In 1934 it is equal to the number of researchers who were dismissed in 1933 in a given department. From 1935 onwards it is equal to the number of dismissals in 1933 and 1934. I use the example of Göttingen to illustrate the definition of the IV. Göttingen experienced 10 dismissals in mathematics in 1933 and one dismissal in 1934. The # dismissed variable for mathematicians in Göttingen will therefore take the value 0 until 1933. It will be 10 in 1934 and 11 from 1935 onwards. Dismissal induced reduction in peer quality is defined accordingly.

The dismissals may have caused some scientists to change university after 1933. The change is likely to be endogenous and thus have a direct effect on researchers' productivity. I therefore assign each scientist the dismissal variables for the department he attended at the beginning of 1933. As the dismissal effect is likely to be correlated for all stayers in a department I cluster standard errors at the university level.

4.3 Potential Threats to the Identification Strategy

Using the dismissals as instrumental variables relies on the assumption that the dismissals only affected scientists' productivity through its effect on the researchers' peer groups. It is important to note that any factor affecting all researchers in Germany in a similar way such as a possible decline of journal quality will be captured by the year fixed effects and would thus not invalidate the identification strategy. Because unaffected departments act as a control group, only factors changing at the same time as the dismissal and exclusively affecting departments with dismissals (or only those without dismissals) may be potential threats to the identification strategy. Most of the potentially worrying biases, such as disruption effects or increased teaching loads, would bias the IV estimates in favor of finding peer effects. As I do not find evidence for localized peer effects, one has to worry less about these biases.

Some violations of the exclusion restriction, however, would lead me to underestimate peer effects. In the following discussion, I investigate potential concerns which may bias the IV coefficients in the direction of not finding an effect.

One may worry that the dismissals changed the incentive structure for stayers in the affected departments. Researchers in departments with many dismissals may have an incentive to work harder to obtain one of the free chairs within the department. Their incentives could also be affected in the opposite direction if they lost an important mentor who was fostering their career. In order to address this concern I regress a promotion indicator on the dismissal variables and the same controls as in the regressions proposed before. The coefficients on the dismissal variables are very small and none of them is significantly different from 0 (see Table A5, columns (1) and (2)). This suggests that changing incentives are unlikely to affect my findings.

Extremely few scientists who were not dismissed left the German universities during the time period studied in this paper, mainly for two reasons. First, "[m]any hoped that the Nazi regime had reached its peak and that it was only a matter of time before it would go the way of the many previous weak and short-lived Weimar coalitions." (Hentschel, 1996). Second, Germany was still the leading country for scientific research (particularly in the minds of German academics). Nonetheless, any such voluntary resignations could potentially bias my findings, as those who were exempted from being dismissed but voluntarily resigned may have done so because the departmental colleagues with whom they interacted most were being deported. If this were the case, it would tend to bias my results towards not finding peer effects. To explore this concern I regress an indicator for leaving the sample on the dismissal variables. Reassuringly, the probability that a scientist leaves the sample is unrelated to the dismissals

(Table A5, columns (3) and (4)).

Another worry is that departments with more ardent Nazi supporters would increase their productivity because they received more research funding or other privileges. This would threaten the identification strategy if the number of Nazi supporters was correlated with the number of dismissals. Looking at the number of party members to investigate this concern would not be informative because the vast majority of university researchers eventually joined the Nazi party. In November 1933, however, 839 university professors (out of more than 10,000 professors in Germany) signed the “Commitment of Professors at the German Universities (...) to Adolf Hitler and the National Socialist State...” This list signalled the professors’ support of the new government and was widely publicized in newspapers. Most people signing the list were strong supporters of the Nazi regime and would therefore have benefited from any differential treatment. I regress a dummy for signing the support list on the dismissal variables and other controls. The coefficients on the dismissal variables are all small and none of them is significantly different from 0, indicating that strong support of the Nazi party was not different in departments with dismissals (Table A5, columns (5) and (6)).

Another worry is that scientists in departments with many dismissals took over laboratories from the dismissed and thus increased their productivity. I show below that the results are very similar for mathematicians and theoretical physicists. This is reassuring because these scientists usually carry out their research outside the laboratory.

The identification strategy might also be invalidated if the Nazi government increased the funding of affected departments to counteract negative dismissal effects. Salaries for university employees were paid by the states and were closely linked to the position or the researcher. They hardly changed over the time period and certainly not differentially across different departments. Scientists could apply for funding of individual research projects. The main provider of research grants in the 1920s and 1930s was the “Emergency Association of German Science” (Notgemeinschaft der Deutschen Wissenschaft) which was jointly funded by the state and donations from private companies.²³ The grants were approved by a panel of specialists based on the quality of the grant proposal and each grant covered costs for experiments, such as materials or expensive equipment. Unfortunately, there is no consistent yearly data on supported scientists. Nonetheless, I obtained comparable data on scientists who received funding for two years: the academic year 1928/1929 before the dismissal and for 1937/1938 after the dismissal. The data is relatively coarse as the reports only state whether a scientist received funding from the Notgemeinschaft but not how much he received. To check whether funding patterns changed after the dismissal, I regress an indicator of receiving funding on the dismissal variables on the sample of stayers in the two years. The coefficients for chemistry and mathematics are very small and not significantly different from 0 indicating that changes in funding are not related to the dismissal (Table A5, columns (7) and (8)). The coefficient on "dismissal induced fall in peer quality" for physics is negative indicating that stayers in departments with

²³The Notgemeinschaft was renamed in “Deutsche Gemeinschaft zur Erhaltung und Förderung der Forschung” in 1937 and is still the main funding source for individual researchers in Germany under the name “Deutsche Forschungsgemeinschaft”.

high quality dismissals received less funding after the dismissals. There is therefore little worry that compensatory funding can explain my results. Any bias due to changing funding patterns would go against my finding that peer effects in physics are not important.

Even if the probability of receiving a grant was unrelated to changes in peer quality, the amount awarded to scientists in affected departments might have increased. Deichmann (2001) provides funding levels for the most funded chemists during the post dismissal period. While I cannot replicate the previous analysis looking at changes in funding I can analyze whether chemists in affected departments received higher funding amounts after 1933. I regress the amount of funding in 1000 Reichsmark on the dismissal variables. The results suggest that chemists in departments with many and high quality dismissals received less post 1933 funding than chemists in unaffected departments. This would bias my findings towards finding positive peer effects.

Lastly any difference-in-differences type strategy relies on the assumption that treatment and control groups did not follow differential time trends. I address this potential concern in two ways. First, I show that the results are not affected by including linear university specific time trends in the regressions. This approach would not address the problem if differential trends were nonlinear. I therefore estimate a placebo experiment using the pre-dismissal period, only, and moving the dismissals from 1933 to 1930. The results indicate that stayers in departments with dismissals were not following different productivity trends before 1933 (Table A6).

5 The Effect of Dismissals on Scientists who remained in Germany

I first analyze how the dismissals affected scientists who stayed at the German universities. Did their research productivity suffer because they had less productive and fewer peers?

I start by plotting yearly publications of stayers in physics departments with and without dismissals (Figure 2). While yearly fluctuations in top journal publications are relatively large, the dismissal does not seem to have an obvious effect on publications of stayers. Equivalent figures for chemistry and mathematics show very similar patterns (Figures A4 and A5).

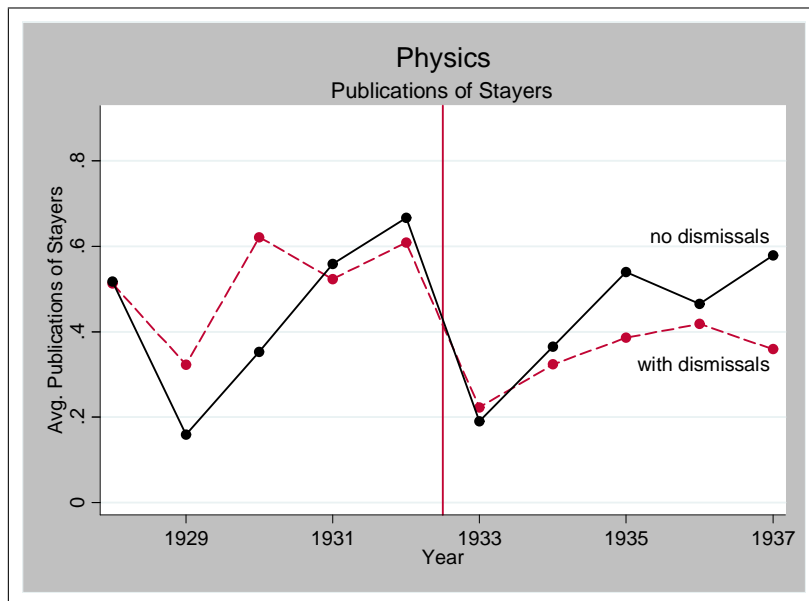


Figure 2: Effect of Dismissals on Stayers

The figure understates the variation that can be used in the empirical analysis because departments were affected very differently by the dismissals. To obtain a quantitative estimate of the dismissal effect I therefore estimate the following reduced form equation.

$$(4) \quad \# \text{ Publications}_{iut} = \beta_1 + \beta_2(\text{Dismissal induced Fall in Peer Quality})_{ut} + \beta_3(\# \text{ Dismissed})_{ut} \\ + \beta_4 \text{Age Dummies}_{iut} + \beta_5 \text{YearFE}_t + \beta_6 \text{UniversityFE}_u + \beta_7 \text{IndividualFE}_i + \varepsilon_{iut}$$

Using only stayers below 70 years of age, I regress a researcher's (citation-weighted) publications in each year on the instruments proposed above.²⁴ The dismissal variables are 0 for researchers in departments which were not affected. For stayers in departments with dismissals, the dismissal variables are 0 until 1933 and then take the relevant value for the department to which they were affiliated at the beginning of 1933. This regression is essentially a difference-in-differences estimate of the dismissal effect. It compares the change in publications from the pre- to the post-dismissal period for researchers in the affected departments to the change between the two periods for unaffected researchers. If the dismissals had a negative effect on the productivity of stayers, one would expect negative coefficients on the dismissal variables.

Estimated coefficients are all very close to 0 and only one coefficient on the number of dismissals is significantly negative (Table 4). Coefficients are larger for regressions using citation-weighted publications as dependent variable because the mean of citation weighted publications is much larger. Coefficients on the dismissal induced fall in peer quality are not only insignificant but most of them have a positive sign. This is particularly surprising as peer quality is usually believed to be the main driver of peer effects.

It is interesting to investigate which effect sizes can be ruled out given the 95 percent confidence intervals of my results. For the number of dismissals one can rule out a reduction in

²⁴I focus on stayers below the age of 70, the usual retirement age for university professors in the early years of my sample period. Older scientists, who were still teaching at a very high age are therefore not very representative. Including older scientists hardly affects the results.

publications of more than 0.06 after losing one peer in physics (the mean of publications in the pre-dismissal period is 0.47). For chemistry and mathematics one can rule out effects larger (in absolute magnitude) than 0.036 (mean of publications is 1.69) and 0.052 (mean of publications is 0.33).

To evaluate which effect size can be ruled out at 95 percent confidence for the reduction in peer quality, I use the following thought experiment: Suppose a department of average quality and average size loses one Nobel Laureate (of average Nobel Laureate quality) due to the dismissal. How much of a drop in stayers' publications can I rule out with 95 percent confidence? This is an appealing question as this may be related to a top department today that loses a Nobel Laureate to another university. The results indicate that the effect of losing a Nobel Laureate would reduce yearly publications of stayers in physics by at most 0.0017 publications (the mean of publications is 0.47).²⁵ In chemistry the quality loss associated with losing a Nobel Laureate would not reduce publications by more than 0.027 (the mean of publications is 1.69). In mathematics one can rule out a fall in publications of 0.055 for losing a top 20 mathematician (as there is no Nobel prize in mathematics).

Publications and citation weighted publications are count data with a relatively large proportion of zeros and can never be negative. Instead of OLS one may therefore prefer to estimate the reduced form using a model that specifically addresses the nature of the data. Table A7 reports Poisson regressions of the reduced form. The results are very similar.²⁶

Overall, the findings suggest that the dismissal of scientists did not affect the productivity of researchers who remained in Germany.

6 Using the Dismissals to Identify Localized Peer Effects in Science

6.1 Department Level Peer Effects

In this section, I use the dismissals to provide exogenous variation in an empirical model that explicitly estimates localized peer effects. I first estimate the two first stage equations; one for average peer quality and the other one for the number of peers.

“Dismissal induced fall in peer quality” has a very strong and significant effect on average peer quality (Table 5, columns (1) and (2)). The number of dismissals does not significantly

²⁵This is calculated as follows. Average department quality in 1933 was 5.35. Average department size in 1933 was 13.18. The average Nobel Laureate's quality was 17.22. Department quality after the dismissal falls by 0.97 to 4.38. The estimated reduced form coefficient is 0.03 with a 95 percent confidence interval of [-0.0017 0.062]. The reduction in peer quality therefore has at most an effect of $-0.0017 \cdot 0.97 = 0.0017$.

²⁶As Santos Silva and Tenreyro (2010) point out, including a fixed effect for a scientist who never publishes leads to convergence problems as the (pseudo) maximum likelihood does not exist in this case. Standard regression packages do not address this problem and will therefore lead to non-convergence of the estimator. I therefore use the `ppml` command as suggested by Santos Silva and Tenreyro (2011).

affect average peer quality in physics and chemistry but is significant for mathematics.

The first stage regression for the number of peers is reported in columns (3) and (4) of Table 5. “Dismissal induced fall in peer quality” does not affect the number of peers, but the number of dismissals has a very strong and significant effect on the number of peers. This pattern is reassuring as it indicates that the dismissals indeed provide two orthogonal instruments: one for average peer quality and one for department size.²⁷

Table 6 reports results from estimating the peer effects model according to equation (1). The OLS results are not very informative due to the problems illustrated in the identification section. I therefore turn immediately to discussing IV results where I use the dismissals to instrument for the peer group variables. While columns (3) and (4) report results for publications as dependent variable, columns (7) and (8) report results for citation weighted publications. Coefficients on the peer group variables are very small and none is significantly different from 0. The coefficient on average peer quality even has a negative sign in most specifications. The results indicate that the number, and in particular the quality of peers is unlikely to affect the productivity of scientists. The result holds for the two different productivity measures. This indicates that differences in citations for articles from scientists in departments with or without dismissals cannot explain the findings. Furthermore, the result is robust across the three different subjects. In the following I investigate the robustness of these findings.

6.2 Robustness of Department Level IV Results

It is surprising that I do not find evidence for peer effects at the local level. To investigate whether these results are driven by disruption affecting the whole academic system during the early dismissal years I re-estimate the IV results dropping 1933 and 1934 from the regression. Omitting those turbulent years does not affect my findings (Table 7, column (1)).²⁸

Peer effects may be especially important in either the early or the later stages of a scientist’s career. I investigate this hypothesis by splitting the sample into two groups: scientists below 50 and scientists of 50 or older. There is no indication that peer effects are especially important for certain age groups as none of the coefficients is significantly different from 0 (columns (2) and (3)).

I furthermore investigate the importance of peer effects in large versus small departments (columns (4) and (5)) and high quality versus low quality departments (columns (6) and (7)). Cutting the sample along these potentially important dimensions for peer effects gives very similar results.

²⁷The model is just identified as the number of instruments is equal to the number of endogenous variables. Therefore one has to worry less about bias due to weak instruments. Stock and Jogo (2005) characterize instruments to be weak not only if they lead to biased IV results but also if hypothesis tests of IV parameters suffer from severe size distortions. They propose values of the Cragg-Donald (1993) minimum eigenvalue statistic for which a Wald test at the 5 percent level will have an actual rejection rate of no more than 10 percent. For two endogenous regressors and two instruments the critical value is 7.03 and thus always below the Cragg-Donald EV statistics reported in Table 5.

²⁸Table 7 reports robustness checks using publications as the dependent variable. Equivalent robustness checks for citation weighted publications are reported in appendix Table A8. The results are very similar.

An important check to rule out differential productivity trends in affected versus unaffected departments is to include university specific time trends in the regressions. The inclusion of university specific time trends hardly affects the results (column (8)). This provides further reassurance that differential time trends cannot explain the absence of peer effects.

A further worry is that stayers may have taken over laboratories or experiments from the dismissed in affected departments. This may have had a positive effect on their productivity counteracting any possible negative effects from the loss of peers. The mathematics results should not be contaminated by such behavior and are indeed very similar to the results for the other two subjects. An additional way of exploring whether taking over laboratories may be driving the results is to estimate the regression for theoretical physicists only. Even though the results are less precisely estimated, the findings show no evidence for peer effects in theoretical physicists (column (9)).

6.3 Specialization Level Peer Effects

The definition of the peer group in the previous regressions relied on all peers in a scientist's department. It is, however, possible that the productivity of scientists is only affected by peers who work in very similar fields. To investigate this hypothesis I use the scientists specialization to define their peer group. According to this definition of the peer group, the relevant peers of an experimental physicist will only be the other experimentalists in his department, not theoretical physicists, technical physicists or astrophysicists.²⁹

Similarly to the department level results, the coefficients on the peer group variables are very small and none of them is significantly different from 0 (Table 8). Furthermore, the coefficients on peer quality mostly have the wrong sign if one were expecting positive peer effects. The results for mathematics are less precisely estimated because most mathematicians did not confine their research to only one or two specializations. Many of them were working on very different topics that even today cannot be precisely assigned to particular specializations. Nonetheless, there is no evidence for any significant peer effects in mathematics. It could be that peer effects occur at even more specialized subfields. As the mean number of researchers in the specializations I consider here is about 3.5 these even smaller subfields would have to be extremely specialized.

6.4 Peer Effects from High Quality Peers

Recent research on life scientists in the United States has indicated that star scientists have a particularly large impact on coauthors (Azoulay, Zivin, and Wang, 2010). In the previous regressions I have investigated how average peer quality affects productivity. It may well be the case that only colleagues of very high quality affect the productivity of scientists.

²⁹See Table A2 for a list of all specializations.

To investigate this hypothesis I start by regressing yearly productivity on the number of peers (instrumenting with the number of dismissals). I then investigate how the number of peers of above median quality (now instrumenting with the number of dismissals for above median quality colleagues) affects productivity; continuing with the number of peers in the top quartile, in the top 10 percentile, and the top 5 percentile always instrumenting with the number of dismissed peers in the relevant quality group. Since many of the dismissed scientists were of very high quality I have enough variation in peer quality even at very high quality levels.

First stage regressions are reported in Table A10 and are highly significant (with first stage F-statistics between 8.2 and 701.6; only two of the 30 first stage regressions have a F-statistic below 10 and many have F-statistics above 100). Instrumental variable regressions are reported in Table 9. Unlike previous tables, Table 9 reports different regressions for 5 different definitions of the relevant peers (number of peers, number of above median quality peers, number of peers in top quartile, and so on). Strikingly, 57 of the estimated IV coefficients are not significantly different from 0 and many of them even have a negative sign. 3 coefficients are significantly different from 0 at the 5 percent level but have the wrong sign if one expected that high quality peers have a positive effect on their colleagues' productivity. These results provide further evidence that peers, even very high quality ones, do not seem to affect the productivity of scientists.

7 Discussion and Conclusion

I have used the dismissal of scientists as exogenous variation in the quality and quantity of peers and have shown that peers do not seem to affect the productivity of scientists. The finding is robust to analyzing different subjects and across many different specifications. This is a surprising result given that many researchers believe that local peer effects are important.

While only suggestive, there are a number of possible explanations for the lack of localized peer effects. First I do not investigate long-run run effects as my data ends 5 years after the 1933 dismissals. As outlined above, scientific research was published very quickly at the time (and indeed still is). Five years should therefore be long enough to pick up important effects. Nonetheless, I cannot rule out that potential peer effects only operate in the very long run.

A second explanation for not finding peer effects may be that I analyze relatively established researchers. It is quite likely that peer interactions become less important once one has established a scientific career. In fact, in a different paper I show that the dismissal of high quality mathematics professors had very large negative effects on Ph.D. student outcomes in mathematics (Waldinger, 2010).

A further possible explanation for the absence of localized peer effects is that the scientific community in Germany before the Second World War was extremely integrated. Conferences were common and scientists were very mobile within Germany. One famous example are the famous summer lectures of theoretical physics in Göttingen. In the summer of 1922, Niels Bohr

from Copenhagen held a two week lecture series on theoretical physics and many experts in quantum theory from all over Europe, and especially from Germany gathered in Göttingen; amongst them were Sommerfeld (University of München), Ehrenfest (Leiden, Netherlands), Lande (Frankfurt), Pauli (Copenhagen), Heisenberg (Göttingen), and many others (Hund, Maier-Leibnitz, and Mollwo, 1988). A further example is the annual conference of German scientists (Versammlung deutscher Naturforscher und Ärzte) was attended by a very large proportion of scholars from all over Germany. Geographic location of researchers was therefore not very important for more established researchers.

A further reason for the absence of localized peer effects may be that science is much more specialized than other subjects such as economics. It may therefore be very difficult to find somebody in the same department who is working on a topic that is close enough to another's research.

An important question is whether evidence on peer effects in the 1920s and 1930s can help us understand peer interactions today. A number of reasons suggest that the findings of this study may be relevant for understanding spill-overs among present-day researchers. The three subjects studied in this paper were already well established at that time, especially in Germany. In fact, Germany was the leading country for scientific research in the first half of the 20th century. Of the Nobel prizes awarded between 1910 and 1940, 27 percent of the prizes in physics and 42 percent of the chemistry prizes were given to scientists affiliated with a German university; a much larger fraction than that of any other country at the time. If peer effects are an important determinant of scientific productivity they are likely to be especially important in a flourishing research environment such as Germany in the early 20th century. Scientific research at the time followed practices and conventions which were very similar to current research methods. Scientists were publishing their results in refereed academic journals, conferences were common, and researchers were surprisingly mobile within the German speaking scientific community. Unlike today, they could not communicate via E-mail. They did, however, vividly discuss their research in very frequent mail correspondence with their colleagues in other universities.

Table A1 provides some additional information on the similarity between current science (and economics) and the historical data. The table summarizes collaboration patterns for today's scientists in Germany and the United States. With the exception of physicists who are running experiments involving particle accelerators collaboration patterns of today's scientists are relatively similar to collaboration patterns in the historical data.

Recent research on today's scientists also seems to suggest that localized spillovers are unlikely to be important. Dubois, Rochet, and Schlenker (2010), for example, show that localized spillovers do not affect the productivity of mathematicians between 1984 and 2006. Furthermore, Azoulay, Zivin, and Wang (2010) find that the loss of a local coauthor does not have a larger impact on the productivity of life scientists than losing a coauthor who was located in a different university.

The question remains why scientists behave as if local peers are a key input in the ideas production process. One potential explanation is that being surrounded by esteemed peers

is purely a private benefit, i.e. it enters a scientist's utility function but does not affect his productivity. Another explanation could be that localized spillovers are important but they are extremely localized. As the specialization results are estimated using average peer group sizes of about 3.5 these sub-departmental peer groups would have to be extremely small, however.

The findings of this paper also improve our understanding of the decline of German science after the Second World War. Many popular accounts emphasize the role of the dismissals in Nazi Germany as an important driver of Germany's decline and the rise of the United States. It is important to emphasize that the findings of this paper do not indicate that the dismissals did not affect the overall level of scientific productivity in Germany. In fact, total quality in affected departments fell sharply and did not recover until 1938. The findings of this paper suggest, however, that the loss to German science was not exacerbated by reducing the productivity of local peers. If peer effects were important at the national level (say at the level of a subfield such as theoretical physics) spillovers from the dismissals may still have harmed German science. Evidence on PhD students (Waldinger, 2010) indicates that the dismissals had negative effects that persisted in the long-run. Further research is needed to quantify the role of the dismissals in Germany's decline and the rise of the United States as the scientific power house.

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8 Tables

Table 1: Number of Dismissed Scientists across different Subjects

| Year of Dismissal | Physics | | Chemistry | | Mathematics | |
|-------------------|----------------------|-----------------------------|----------------------|---------------------------|----------------------|---------------------------------|
| | Number of Dismissals | % of all Physicists in 1933 | Number of Dismissals | % of all Chemists in 1933 | Number of Dismissals | % of all Mathematicians in 1933 |
| 1933 | 33 | 11.5 | 50 | 10.7 | 35 | 15.6 |
| 1934 | 6 | 2.1 | 11 | 2.4 | 6 | 2.7 |
| 1935 | 4 | 1.4 | 5 | 1.1 | 5 | 2.2 |
| 1936 | 1 | 0.3 | 7 | 1.5 | 1 | 0.4 |
| 1937 | 1 | 0.3 | 3 | 0.6 | 2 | 0.9 |
| 1938 | 1 | 0.3 | 4 | 0.9 | 1 | 0.4 |
| 1939 | 1 | 0.3 | 2 | 0.4 | 1 | 0.4 |
| 1940 | 1 | 0.3 | 0 | 0.0 | 1 | 0.4 |
| 1933 - 1934 | 39 | 13.6 | 61 | 13.1 | 41 | 18.3 |

Table 2: Dismissals across different Universities

| University | Physics | | | | Chemistry | | | | Mathematics | | | |
|-----------------|-------------------------|---------------------------|------|---|-------------------------|---------------------------|------|--|-------------------------|---------------------------|------|---|
| | Scien- tists 1933 | Dismissed 1933-34 # | in % | Dismissal Induced Δ to Dep. Quality | Scien- tists 1933 | Dismissed 1933-34 # | in % | Dismissal Δ to Dep. Quality | Scien- tists 1933 | Dismissed 1933-34 # | in % | Dismissal Induced Δ to Dep. Quality |
| | | | | | | | | | | | | |
| Aachen TU | 3 | 0 | 0 | 0 | 12 | 2 | 16.7 | + | 7 | 3 | 42.9 | + |
| Berlin | 38 | 8 | 21.1 | -- | 45 | 15 | 33.3 | - | 13 | 5 | 38.5 | -- |
| Berlin TU | 21 | 6 | 28.6 | - | 41 | 13 | 31.7 | - | 14 | 2 | 14.3 | + |
| Bonn | 12 | 1 | 8.3 | + | 16 | 1 | 6.3 | - | 7 | 1 | 14.3 | + |
| Braunschweig TU | 4 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Breslau | 12 | 2 | 16.7 | + | 10 | 1 | 10.0 | - | 6 | 3 | 50.0 | -- |
| Breslau TU | 1 | 0 | 0 | 0 | 14 | 2 | 14.3 | - | 5 | 2 | 40.0 | -- |
| Darmstadt TU | 9 | 1 | 11.1 | + | 18 | 5 | 27.8 | -- | 9 | 1 | 11.1 | + |
| Dresden TU | 6 | 1 | 16.7 | -- | 17 | 1 | 5.9 | -- | 10 | 0 | 0 | 0 |
| Erlangen | 4 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Frankfurt | 12 | 1 | 8.3 | - | 18 | 5 | 27.8 | + | 8 | 1 | 12.5 | + |
| Freiburg | 8 | 0 | 0 | 0 | 15 | 3 | 20.0 | + | 9 | 1 | 11.1 | - |
| Giessen | 5 | 1 | 20.0 | -- | 10 | 0 | 0 | 0 | 7 | 1 | 14.3 | + |
| Göttingen | 21 | 9 | 42.9 | -- | 17 | 0 | 0 | 0 | 17 | 10 | 58.8 | -- |
| Greifswald | 6 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Halle | 4 | 0 | 0 | 0 | 9 | 1 | 11.1 | + | 7 | 1 | 14.3 | + |
| Hamburg | 11 | 2 | 18.2 | + | 11 | 2 | 18.2 | + | 8 | 0 | 0 | 0 |
| Hannover TU | 3 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 6 | 0 | 0 | 0 |
| Heidelberg | 8 | 0 | 0 | 0 | 18 | 1 | 5.6 | + | 5 | 1 | 20.0 | + |
| Jena | 13 | 1 | 7.7 | + | 10 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| Karlsruhe TU | 8 | 0 | 0 | 0 | 14 | 4 | 28.6 | + | 6 | 1 | 16.7 | 0 |
| Kiel | 8 | 1 | 12.5 | - | 11 | 0 | 0 | 0 | 5 | 2 | 40.0 | + |
| Köln | 8 | 1 | 12.5 | + | 4 | 1 | 25.0 | -- | 6 | 2 | 33.3 | + |
| Königsberg | 8 | 0 | 0 | 0 | 11 | 1 | 9.1 | -- | 5 | 2 | 40.0 | - |
| Leipzig | 11 | 2 | 18.2 | + | 24 | 2 | 8.3 | - | 8 | 2 | 25.0 | - |
| Marburg | 6 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| München | 12 | 3 | 25.0 | + | 18 | 1 | 5.6 | - | 9 | 0 | 0 | 0 |
| München TU | 10 | 1 | 10 | + | 15 | 0 | 0 | + | 5 | 0 | 0 | 0 |
| Münster | 5 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| Rostock | 3 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Stuttgart TU | 5 | 0 | 0 | 0 | 9 | 1 | 11.1 | + | 6 | 0 | 0 | 0 |
| Tübingen | 2 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 6 | 0 | 0 | 0 |
| Würzburg | 3 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |

This table reports the total number of scientists in 1933. # Dismissed indicates how many scientists were dismissed in each department. % Dismissed indicates the percentage of dismissed scientists in each department. The column "Dismissal Induced Δ to Peer Quality" indicates how the dismissal affected average department quality: -- indicates a more than 50% drop in average department quality; - a drop in average department quality between 0 and 50%; 0 indicates no change in department quality; + indicates an improvement in average department quality between 0 and 50%.

Table 3: Quality of Dismissed Scholars

| | Physics | | | | Chemistry | | | | Mathematics | | | |
|---------------------------------------|---------|----------|-----------------|--------|-----------|----------|-----------------|--------|-------------|----------|-----------------|--------|
| | All | Stay-ers | Dismissed 33-34 | | All | Stay-ers | Dismissed 33-34 | | All | Stay-ers | Dismissed 33-34 | |
| | | | # | % Loss | | | # | % Loss | | | # | % Loss |
| Researchers (beginning of 1933) | 287 | 248 | 39 | 13.6 | 466 | 405 | 61 | 13.1 | 224 | 183 | 41 | 18.3 |
| # of Chaired Profs. | 109 | 97 | 12 | 11.0 | 156 | 136 | 20 | 12.8 | 117 | 99 | 18 | 15.4 |
| Average Age (1933) | 49.5 | 50.2 | 45.1 | - | 50.4 | 50.5 | 49.7 | - | 48.7 | 50 | 43 | - |
| # of Nobel Laureates | 15 | 9 | 6 | 40.0 | 14 | 11 | 3 | 21.4 | - | - | - | - |
| Publications 1925-1932 | | | | | | | | | | | | |
| Avg. publications | 0.47 | 0.43 | 0.71 | 20.5 | 1.69 | 1.59 | 2.31 | 17.9 | 0.33 | 0.27 | 0.56 | 31.1 |
| Avg. publications (citation weighted) | 5.10 | 3.53 | 14.79 | 39.4 | 17.25 | 16.07 | 25.05 | 19.0 | 1.45 | 0.93 | 3.71 | 46.8 |
| % coauthored | 32.0 | 32.1 | 31.4 | - | 75.2 | 74.8 | 76.9 | - | 16.9 | 15.1 | 20.3 | - |
| % coauthored with faculty | 11.1 | 10.3 | 14.5 | - | 11.8 | 12.3 | 9.7 | - | 9.9 | 9.7 | 10.2 | - |
| (with dismissed) | (3.1) | (2.0) | (8.1) | - | (1.9) | (1.9) | (2.0) | - | (4.6) | (3.8) | (6.1) | - |
| % coauthored with faculty (same uni) | 3.7 | 2.9 | 7.4 | - | 4.3 | 4.4 | 4.1 | - | 2.6 | 1.8 | 4.3 | - |
| (with dismissed) | (1.5) | (0.5) | (5.9) | - | (0.9) | (0.9) | (1.1) | - | (1.7) | (1.2) | (2.7) | - |
| Publications 1935-1938 | | | | | | | | | | | | |
| Avg. publications | 0.35 | 0.32 | 0.32 | 0.32 | 1.24 | 1.24 | 0.55 | 0.20 | 0.20 | 0.20 | 0.15 | 0.15 |
| Avg. publications (citation weighted) | 2.53 | 11.12 | 11.12 | 11.12 | 13.61 | 13.61 | 5.28 | 0.80 | 0.80 | 0.80 | 0.57 | 0.57 |
| % coauthored | 43.0 | 50.0 | 50.0 | 50.0 | 81.0 | 81.0 | 69.6 | 14.9 | 14.9 | 14.9 | 28.0 | 28.0 |
| % coauthored with faculty | 6.9 | 7.0 | 7.0 | 7.0 | 3.9 | 3.9 | 2.0 | 6.0 | 6.0 | 6.0 | 4.0 | 4.0 |
| (with dismissed) | (0.6) | (4.0) | (4.0) | (4.0) | (0.4) | (0.4) | (2.0) | (0.0) | (0.0) | (0.0) | (4.0) | (4.0) |
| % coauthored with faculty (same uni) | 2.6 | - | - | - | 0.9 | 0.9 | - | 0 | 0 | 0 | - | - |
| (with dismissed) | (0.0) | - | - | - | (0.1) | (0.1) | - | (0.0) | (0.0) | (0.0) | - | - |

Note: Avg. publications are average publications in top journals per year (see data section for list of top journals). Avg. publications (citation weighted) weights publications by citations in any journal covered by the Web of Science in the 50 years after publication. % coauthored measures the percentage of publications which were published with coauthors. % coauthored with faculty measures the percentage of all publications that was coauthored with other faculty from the German universities. % coauthored with faculty (same uni) measures the percentage of all publications which were coauthored with other faculty who were ever at the same university. % Loss is calculated as the fraction of the dismissals among all researchers or as the fraction of Nobel Laureates, publications, and citation weighted publications which were contributed by the dismissed.

Table 4: Reduced Form (Department Level Peers)

| | (1) | (2) | (3) | (4) |
|--|--------------------|-------------------|----------------------------|-------------------|
| <i>Dependent Variable:</i> | Publications | | Cit. Weighted Publications | |
| Physics | | | | |
| Dismissal Induced Fall in Peer Quality | 0.029 (0.015) | 0.030 (0.016) | 0.312 (0.235) | 0.357 (0.252) |
| Number Dismissed | -0.021 (0.017) | -0.025 (0.019) | -0.017 (0.302) | -0.125 (0.323) |
| <i>Observations</i> | 2261 | 2261 | 2261 | 2261 |
| <i># of researchers</i> | 258 | 258 | 258 | 258 |
| <i>R-squared</i> | 0.39 | 0.40 | 0.25 | 0.27 |
| Chemistry | | | | |
| Dismissal Induced Fall in Peer Quality | 0.012 (0.015) | 0.013 (0.014) | 0.383 (0.303) | 0.403 (0.312) |
| Number Dismissed | -0.018 (0.009)* | -0.017 (0.009) | -0.130 (0.222) | -0.065 (0.217) |
| <i>Observations</i> | 3584 | 3584 | 3584 | 3584 |
| <i># of researchers</i> | 413 | 413 | 413 | 413 |
| <i>R-squared</i> | 0.67 | 0.68 | 0.54 | 0.55 |
| Mathematics | | | | |
| Dismissal Induced Fall in Peer Quality | 0.022 (0.031) | 0.027 (0.037) | -0.464 (0.337) | -0.304 (0.346) |
| Number Dismissed | -0.018 (0.015) | -0.019 (0.016) | -0.016 (0.167) | -0.003 (0.143) |
| <i>Observations</i> | 1538 | 1538 | 1538 | 1538 |
| <i># of researchers</i> | 183 | 183 | 183 | 183 |
| <i>R-squared</i> | 0.32 | 0.34 | 0.20 | 0.20 |
| Age Dummies | <i>yes</i> | <i>yes</i> | <i>yes</i> | <i>yes</i> |
| Year Dummies | <i>yes</i> | <i>yes</i> | <i>yes</i> | <i>yes</i> |
| Individual FE | <i>yes</i> | <i>yes</i> | <i>yes</i> | <i>yes</i> |
| University FE | | <i>yes</i> | | <i>yes</i> |

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

Publications is the sum of a scientist's publications in top journals in one year.

Citation Weighted Publications are defined as the sum of subsequent citations (in the first 50 years after publication in any journal included in the "Web of Science", including international journals) of all articles published in a given year.

Dismissal induced Fall in Peer Quality is 0 for all researchers until 1933. In 1934 it is equal to (Avg. quality of total department before dismissal) - (Avg. quality of researchers not dismissed in 1933) if this number > 0. From 1935 onwards it will be equal to (Avg. quality of total department before dismissal) - (Avg. quality of researchers not dismissed in 1933 and 1934) if this number is > 0. Scientists in departments with above average quality dismissals will have a positive value of the quality dismissal variable after 1933 and a value of 0 until 1933. The variable will always be 0 for all other scientists. Average quality is measured as the department level average of citation weighted publications between 1925 and 1932 such that any changes after the dismissal do not affect the values of the average.

Number dismissed is equal to the number of dismissed scientists in a researcher's department. The variable is 0 until 1933 for researchers in all departments. In 1934 it is equal to the number of dismissals in 1933 at a researcher's department. From 1935 onwards it is equal to the number of dismissals in 1933 and 1934 in a researcher's department.

Table 5: First Stages (Department Level Peers)

| | (1) | (2) | (3) | (4) |
|---|--------------------------|--------------------------|---------------------|---------------------|
| <i>Dependent Variable:</i> | Avg. Quality of Peers | Avg. Quality of Peers | Department Size | Department Size |
| Physics | | | | |
| Dismissal Induced Fall in Peer Quality | -0.644** (0.099) | -0.614** (0.114) | -0.147 (0.130) | -0.112 (0.118) |
| Number Dismissed | 0.017 (0.098) | -0.034 (0.110) | -0.570** (0.117) | -0.515** (0.111) |
| <i>F - Test on Instruments</i> | 81.9 | 79.1 | 103.10 | 108.25 |
| <i>Cragg-Donald EV Statistic</i> | 12.8 | 13.4 | 12.8 | 13.4 |
| Chemistry | | | | |
| Dismissal Induced Fall in Peer Quality | -1.114** (0.196) | -1.131** (0.197) | 0.011 (0.110) | -0.001 (0.101) |
| Number Dismissed | -0.047 (0.162) | -0.024 (0.172) | -0.998** (0.091) | -0.963** (0.105) |
| <i>F - Test on Instruments</i> | 18.3 | 18.2 | 64.3 | 45.3 |
| <i>Cragg-Donald EV Statistic</i> | 89.8 | 104.2 | 89.8 | 104.2 |
| Mathematics | | | | |
| Dismissal Induced Fall in Peer Quality | -1.355** (0.149) | -1.369** (0.167) | -0.228 (0.174) | 0.154 (0.193) |
| Number Dismissed | 0.160** (0.053) | 0.157* (0.059) | -0.470** (0.062) | -0.529** (0.063) |
| <i>F - Test on Instruments</i> | 47.8 | 39.9 | 66.2 | 79.4 |
| <i>Cragg-Donald EV Statistic</i> | 46.7 | 68.9 | 46.7 | 68.9 |
| Age Dummies | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes |
| University FE | | yes | | yes |

**significant at 1% level

*significant at 5% level

(All standard errors clustered at the university level)

Table 6: Instrumental Variables (Department Level Peers)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | |
|---------------------------------|-------------------|-------------------|-------------------|-------------------|---------------------|--------------------------------|-------------------|-------------------|--|
| <i>Dependent Variable:</i> | | Publications | | | | Citation Weighted Publications | | | |
| | OLS | OLS | IV | IV | OLS | OLS | IV | IV | |
| Physics | | | | | | | | | |
| Peer Quality | 0.004 (0.005) | 0.003 (0.004) | -0.054 (0.035) | -0.059 (0.044) | -0.048 (0.075) | -0.044 (0.080) | -0.488 (0.496) | -0.633 (0.592) | |
| Department Size | -0.007 (0.004) | -0.003 (0.005) | 0.035 (0.034) | 0.053 (0.051) | -0.177** (0.062) | -0.196 (0.111) | 0.016 (0.553) | 0.286 (0.760) | |
| <i>Observations</i> | 2261 | 2261 | 2261 | 2261 | 2261 | 2261 | 2261 | 2261 | |
| <i># of researchers</i> | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 | |
| <i>R-Squared</i> | 0.39 | 0.40 | | | 0.25 | 0.27 | | | |
| <i>Cragg-Donal EV Statistic</i> | | | 12.79 | 13.38 | | | 12.79 | 13.38 | |
| Chemistry | | | | | | | | | |
| Peer Quality | 0.006 (0.003) | 0.005 (0.003) | -0.010 (0.015) | -0.011 (0.014) | 0.085 (0.057) | 0.055 (0.050) | -0.342 (0.265) | -0.356 (0.268) | |
| Department Size | -0.011 (0.007) | -0.011 (0.007) | 0.019 (0.010) | 0.018 (0.010) | 0.089 (0.193) | 0.060 (0.263) | 0.147 (0.218) | 0.076 (0.213) | |
| <i>Observations</i> | 3584 | 3584 | 3584 | 3584 | 3584 | 3584 | 3584 | 3584 | |
| <i># of researchers</i> | 413 | 413 | 413 | 413 | 413 | 413 | 413 | 413 | |
| <i>R-Squared</i> | 0.67 | 0.68 | | | 0.54 | 0.55 | | | |
| <i>Cragg-Donal EV Statistic</i> | | | 89.76 | 104.17 | | | 89.76 | 104.17 | |
| Mathematics | | | | | | | | | |
| Peer Quality | 0.014 (0.015) | 0.015 (0.014) | -0.022 (0.026) | -0.017 (0.026) | 0.517** (0.167) | 0.513** (0.178) | 0.318 (0.262) | 0.231 (0.262) | |
| Department Size | 0.004 (0.010) | 0.005 (0.013) | 0.032 (0.026) | 0.031 (0.027) | 0.041 (0.067) | 0.001 (0.079) | 0.143 (0.322) | 0.074 (0.301) | |
| <i>Observations</i> | 1538 | 1538 | 1538 | 1538 | 1538 | 1538 | 1538 | 1538 | |
| <i># of researchers</i> | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 | |
| <i>R-Squared</i> | 0.32 | 0.34 | | | 0.20 | 0.21 | | | |
| <i>Cragg-Donal EV Statistic</i> | | | 46.73 | 68.91 | | | 46.73 | 68.91 | |
| Age Dummies | yes | yes | yes | yes | yes | yes | yes | yes | |
| Year Dummies | yes | yes | yes | yes | yes | yes | yes | yes | |
| Individual FE | yes | yes | yes | yes | yes | yes | yes | yes | |
| University FE | | yes | | yes | | yes | | yes | |

**significant at 1% level

*significant at 5% level

(All standard errors clustered at the university level)

Table 7: Robustness Checks Instrumental Variables (Department Level Peers)

| <i>Sample:</i> | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---------------------------------|-------------------|--------------------|-------------------|----------------------|----------------------|---------------------|--------------------|-------------------|------------------------|
| | omitting 33-34 | younger than 50 | 50 or older | Large Departments | Small Departments | Good Departments | Bad Departments | Full Sample | Theoretical Physics |
| <i>Dependent Variable:</i> | Publications | Publications | Publications | Publications | Publications | Publications | Publications | Publications | Publications |
| Physics | | | | | | | | | |
| Peer Quality | -0.005 (0.037) | -0.079 (0.054) | -0.031 (0.098) | -0.132 (0.173) | -0.018 (0.036) | -0.049 (0.035) | 0.054 (0.041) | -0.104 (0.108) | -0.061 (0.103) |
| Department Size | -0.004 (0.046) | 0.107 (0.061) | 0.038 (0.102) | 0.122 (0.178) | 0.174 (0.116) | 0.026 (0.041) | 0.094 (0.341) | 0.110 (0.092) | 0.023 (0.078) |
| <i>Observations</i> | 1866 | 1203 | 1058 | 1156 | 1105 | 1356 | 905 | 2261 | 464 |
| <i># of researchers</i> | 256 | 181 | 147 | 149 | 147 | 170 | 121 | 258 | 50 |
| <i>EV Statistic</i> | 6.2 | 5.6 | 3.75 | 2.62 | 6.77 | 8.31 | 0.36 | 6.54 | 4.1 |
| Chemistry | | | | | | | | | |
| Peer Quality | -0.008 (0.016) | -0.014 (0.024) | -0.004 (0.020) | -0.020 (0.013) | 0.049 (0.144) | 0.002 (0.022) | -0.081* (0.035) | 0.050 (0.041) | |
| Department Size | 0.022 (0.015) | 0.011 (0.020) | 0.007 (0.017) | 0.016 (0.011) | 0.680 (1.549) | 0.024 (0.020) | 0.018 (0.023) | 0.002 (0.037) | |
| <i>Observations</i> | 2926 | 1825 | 1759 | 1814 | 1770 | 1819 | 1765 | 3584 | |
| <i># of researchers</i> | 410 | 265 | 241 | 236 | 220 | 234 | 224 | 413 | |
| <i>EV Statistic</i> | 72.5 | 31.8 | 58.4 | 65.94 | 0.68 | 41.45 | 20.4 | 16.90 | |
| Mathematics | | | | | | | | | |
| Peer Quality | -0.025 (0.031) | -0.030 (0.040) | 0.033 (0.026) | -0.010 (0.023) | 0.034 (0.085) | 0.001 (0.017) | 10.251 (19.352) | -0.016 (0.035) | |
| Department Size | 0.040 (0.050) | 0.056 (0.032) | -0.015 (0.042) | 0.030 (0.032) | -0.018 (0.080) | 0.035 (0.028) | -2.172 (4.371) | 0.036 (0.018) | |
| <i>Observations</i> | 1256 | 899 | 639 | 858 | 680 | 709 | 829 | 1538 | |
| <i># of researchers</i> | 183 | 125 | 97 | 116 | 101 | 95 | 116 | 138 | |
| <i>EV Statistic</i> | 19 | 40.7 | 18.8 | 63.46 | 5.13 | 34.5 | 0.02 | 65.3 | |
| Age Dummies | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| University FE | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| University specific Time Trends | | | | | | | | | |

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

Table 8: Instrumental Variables (Specialization Level Peers)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|-------------------------------------|--------------------|-------------------|-------------------|-------------------|--------------------------------|-------------------|--------------------|--------------------|
| <i>Dependent Variable:</i> | | | | | | | | |
| | Publications | | | | Citation Weighted Publications | | | |
| | OLS | OLS | IV | IV | OLS | OLS | IV | IV |
| Physics | | | | | | | | |
| Peer Quality | 0.004 (0.004) | 0.005 (0.004) | -0.021 (0.029) | -0.022 (0.028) | -0.020 (0.059) | -0.028 (0.059) | -0.410 (0.581) | -0.401 (0.546) |
| Department Size | -0.010 (0.011) | -0.008 (0.017) | -0.021 (0.029) | -0.009 (0.031) | -0.275 (0.142) | -0.375 (0.263) | -0.727 (0.482) | -0.621 (0.547) |
| <i>Observations</i> | 2257 | 2257 | 2257 | 2257 | 2257 | 2257 | 2257 | 2257 |
| <i># of researchers</i> | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 256 |
| <i>R-Squared</i> | 0.386 | 0.398 | | | 0.253 | 0.270 | | |
| <i>Minimum Eigenvalue Statistic</i> | | | 81.80 | 87.55 | | | 81.80 | 87.55 |
| Chemistry | | | | | | | | |
| Peer Quality | -0.001 (0.002) | -0.001 (0.002) | -0.010 (0.009) | -0.010 (0.008) | -0.015 (0.035) | -0.015 (0.037) | -0.029 (0.127) | -0.005 (0.122) |
| Department Size | -0.057* (0.025) | -0.050 (0.028) | 0.010 (0.040) | 0.006 (0.041) | -0.280 (0.336) | -0.426 (0.381) | -0.725 (0.881) | -0.976 (0.845) |
| <i>Observations</i> | 3567 | 3567 | 3567 | 3567 | 3567 | 3567 | 3567 | 3567 |
| <i># of researchers</i> | 405 | 405 | 405 | 405 | 405 | 405 | 405 | 405 |
| <i>R-Squared</i> | 0.670 | 0.677 | | | 0.541 | 0.547 | | |
| <i>Minimum Eigenvalue Statistic</i> | | | 73.69 | 79.38 | | | 73.69 | 79.38 |
| Mathematics | | | | | | | | |
| Peer Quality | 0.003 (0.016) | 0.007 (0.017) | -0.429 (3.457) | -0.645 (7.566) | 0.361* (0.140) | 0.378* (0.161) | 3.822 (28.153) | 6.348 (70.136) |
| Department Size | 0.004 (0.013) | -0.003 (0.017) | 0.465 (3.487) | 0.732 (8.231) | 0.005 (0.121) | -0.047 (0.132) | -3.450 (28.298) | -6.674 (76.269) |
| <i>Observations</i> | 1538 | 1538 | 1538 | 1538 | 1538 | 1538 | 1538 | 1538 |
| <i># of researchers</i> | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 |
| <i>R-Squared</i> | 0.323 | 0.336 | | | 0.201 | 0.209 | | |
| <i>Minimum Eigenvalue Statistic</i> | | | 0.23 | 0.13 | | | 0.23 | 0.13 |
| Age Dummies | yes | yes | yes | yes | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes | yes | yes | yes | yes |
| University FE | | yes | | yes | | yes | | yes |

**significant at 1% level

*significant at 5% level

(All standard errors clustered at the university level)

Table 9: Instrumental Variables High Quality Peers

| <i>Dependent Variable:</i> | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|-------------------------------------|-------------------|-------------------|-------------------|-------------------|--------------------------------|--------------------|--------------------|--------------------|
| | Publications | | | | Citation Weighted Publications | | | |
| | OLS | OLS | IV | IV | OLS | OLS | IV | IV |
| Physics | | | | | | | | |
| Number of Peers | -0.006 (0.004) | -0.002 (0.005) | -0.003 (0.013) | 0.003 (0.017) | -0.183** (0.064) | -0.203 (0.109) | -0.329 (0.198) | -0.254 (0.231) |
| <i>First Stage F-Statistic</i> | | | 195.5 | 133.7 | | | 195.5 | 133.7 |
| Number of Top 50th Percentile Peers | -0.006 (0.004) | -0.002 (0.005) | -0.003 (0.009) | 0.001 (0.011) | -0.198** (0.060) | -0.223* (0.101) | -0.221 (0.142) | -0.168 (0.156) |
| <i>First Stage F-Statistic</i> | | | 241.1 | 305.1 | | | 241.1 | 305.1 |
| Number of Top 25th Percentile Peers | 0.004 (0.012) | 0.004 (0.012) | -0.015 (0.016) | -0.007 (0.018) | -0.358* (0.152) | -0.335* (0.152) | -0.637* (0.239) | -0.526* (0.225) |
| <i>First Stage F-Statistic</i> | | | 423.7 | 304.5 | | | 423.7 | 304.5 |
| Number of Top 10th Percentile Peers | 0.012 (0.028) | 0.023 (0.025) | -0.011 (0.032) | -0.003 (0.035) | -0.389 (0.367) | -0.297 (0.376) | -0.695 (0.395) | -0.585 (0.353) |
| <i>First Stage F-Statistic</i> | | | 29.6 | 29.8 | | | 29.6 | 29.8 |
| Number of Top 5th Percentile Peers | 0.054 (0.057) | 0.046 (0.055) | -0.031 (0.043) | -0.015 (0.046) | 0.133 (0.630) | 0.067 (0.616) | -1.336* (0.626) | -1.081 (0.534) |
| <i>First Stage F-Statistic</i> | | | 201.6 | 341.5 | | | 201.6 | 341.5 |
| Chemistry | | | | | | | | |
| Number of Peers | -0.010 (0.007) | -0.010 (0.007) | 0.016 (0.010) | 0.015 (0.011) | 0.104 (0.196) | 0.071 (0.267) | 0.041 (0.231) | -0.030 (0.239) |
| <i>First Stage F-Statistic</i> | | | 126.7 | 90.4 | | | 126.7 | 90.4 |
| Number of Top 50th Percentile Peers | -0.013 (0.008) | -0.015 (0.009) | 0.027 (0.017) | 0.024 (0.017) | 0.172 (0.352) | 0.091 (0.455) | 0.174 (0.364) | 0.051 (0.365) |
| <i>First Stage F-Statistic</i> | | | 362.6 | 587.9 | | | 362.6 | 587.9 |
| Number of Top 25th Percentile Peers | 0.016 (0.014) | 0.009 (0.015) | 0.026 (0.017) | 0.025 (0.018) | 0.444 (0.531) | 0.320 (0.630) | 0.000 (0.419) | -0.105 (0.451) |
| <i>First Stage F-Statistic</i> | | | 488.6 | 540.1 | | | 488.6 | 540.1 |
| Number of Top 10th Percentile Peers | 0.029 (0.027) | 0.029 (0.027) | 0.076 (0.048) | 0.075 (0.049) | 1.110 (0.852) | 1.142 (1.002) | -0.545 (1.011) | -0.803 (1.100) |
| <i>First Stage F-Statistic</i> | | | 19.4 | 19.5 | | | 19.4 | 19.5 |
| Number of Top 5th Percentile Peers | 0.046 (0.042) | 0.029 (0.041) | 0.160 (0.126) | 0.109 (0.104) | 0.867 (1.029) | 0.747 (1.165) | 0.805 (2.516) | -0.185 (2.297) |
| <i>First Stage F-Statistic</i> | | | 8.2 | 8.2 | | | 8.2 | 8.2 |
| Mathematics | | | | | | | | |
| Number of Peers | 0.006 (0.009) | 0.007 (0.012) | 0.022 (0.017) | 0.024 (0.021) | 0.119 (0.066) | 0.066 (0.077) | 0.284 (0.380) | 0.181 (0.432) |
| <i>First Stage F-Statistic</i> | | | 104.9 | 144.8 | | | 104.9 | 144.8 |
| Number of Top 50th Percentile Peers | 0.007 (0.009) | 0.007 (0.012) | 0.019 (0.016) | 0.019 (0.018) | 0.106 (0.067) | 0.051 (0.084) | 0.219 (0.335) | 0.119 (0.352) |
| <i>First Stage F-Statistic</i> | | | 94.4 | 86.8 | | | 94.4 | 86.8 |
| Number of Top 25th Percentile Peers | 0.010 (0.014) | 0.008 (0.020) | 0.001 (0.016) | -0.002 (0.017) | 0.291 (0.156) | 0.237 (0.197) | 0.140 (0.336) | -0.009 (0.319) |
| <i>First Stage F-Statistic</i> | | | 485.8 | 701.6 | | | 485.8 | 701.6 |
| Number of Top 10th Percentile Peers | 0.026 (0.026) | 0.012 (0.030) | 0.004 (0.030) | -0.005 (0.039) | 0.757 (0.373) | 0.735 (0.427) | 0.439 (0.616) | 0.146 (0.775) |
| <i>First Stage F-Statistic</i> | | | 39.6 | 29.0 | | | 39.6 | 29.0 |
| Number of Top 5th Percentile Peers | 0.041 (0.037) | 0.032 (0.036) | 0.026 (0.020) | 0.022 (0.023) | 1.234* (0.500) | 1.183 (0.583) | 0.686 (0.570) | 0.488 (0.677) |
| <i>First Stage F-Statistic</i> | | | 46.0 | 38.0 | | | 46.0 | 38.0 |
| Age Dummies | yes | yes | yes | yes | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes | yes | yes | yes | yes |
| University FE | | yes | | yes | | yes | | yes |

9 Appendix

9.1 Appendix Figures and Tables

Figure A1: Coauthoring between Stayers and Dismissed Scientists

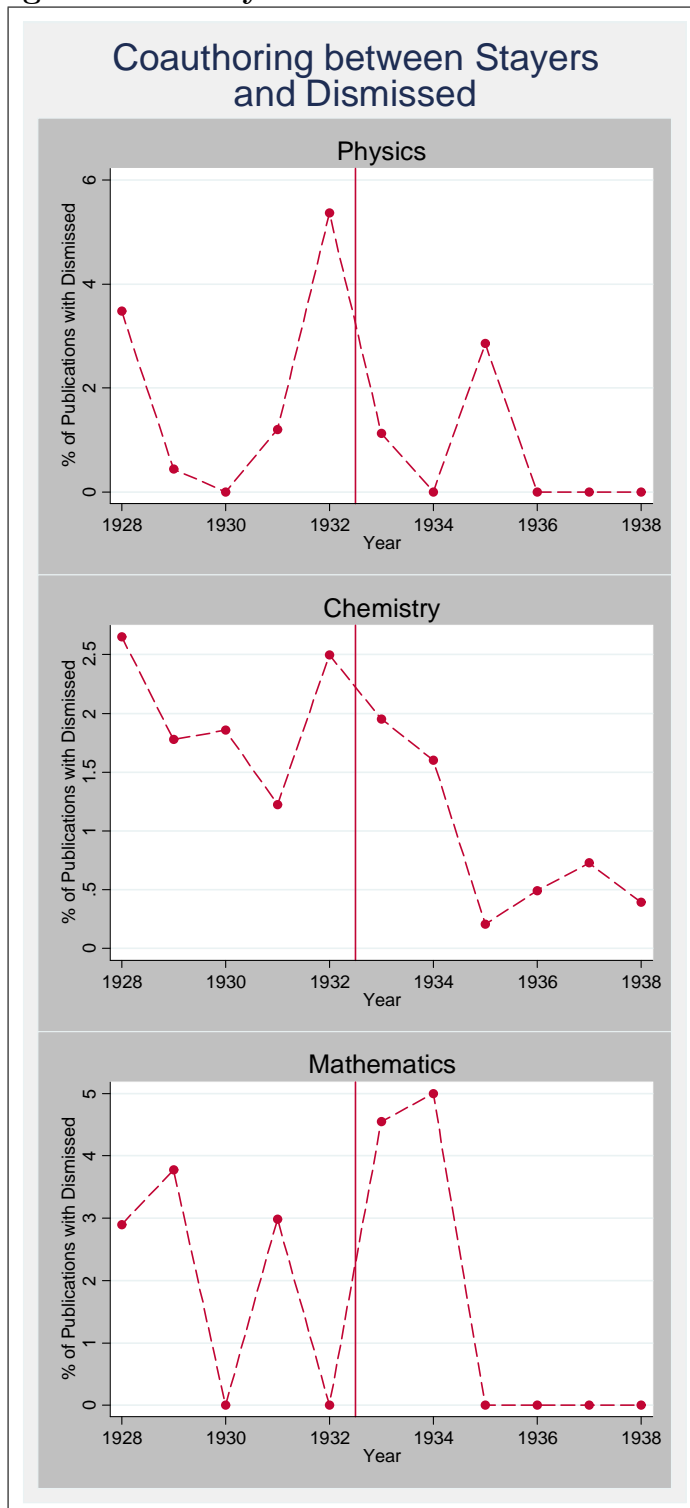


Figure A2: Effect of Dismissal on Department Size and Peer Quality Chemistry

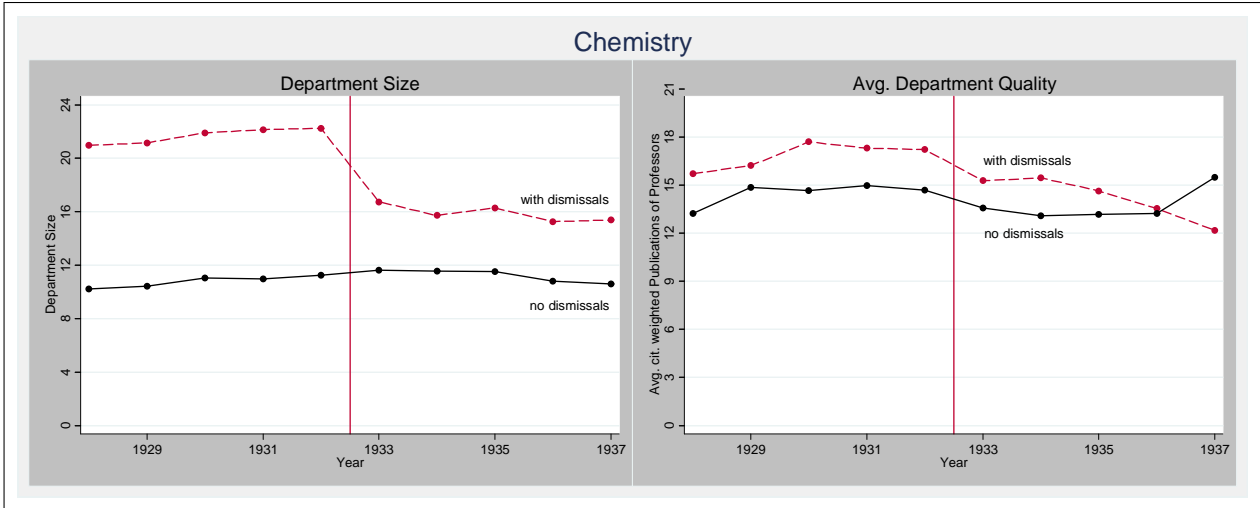


Figure A3: Effect of Dismissal on Department Size and Peer Quality Chemistry

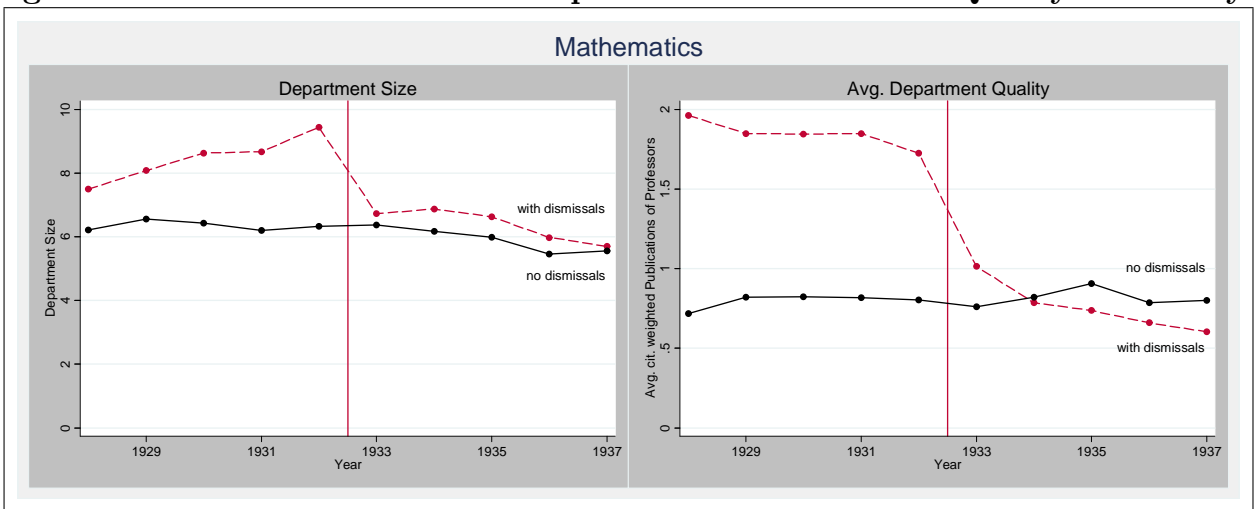


Figure A4: Effect of Dismissal on Stayers in Chemistry

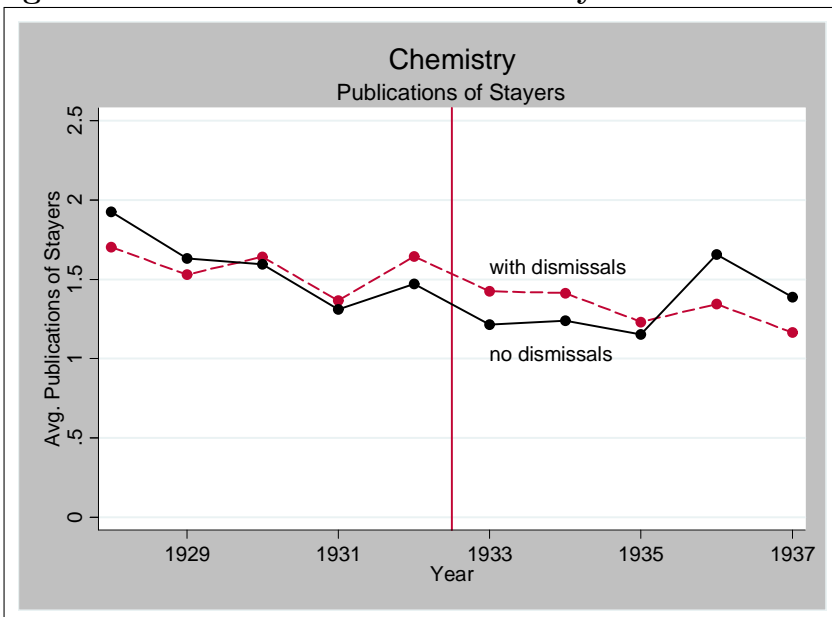


Figure A5: Effect of Dismissal on Stayers in Mathematics

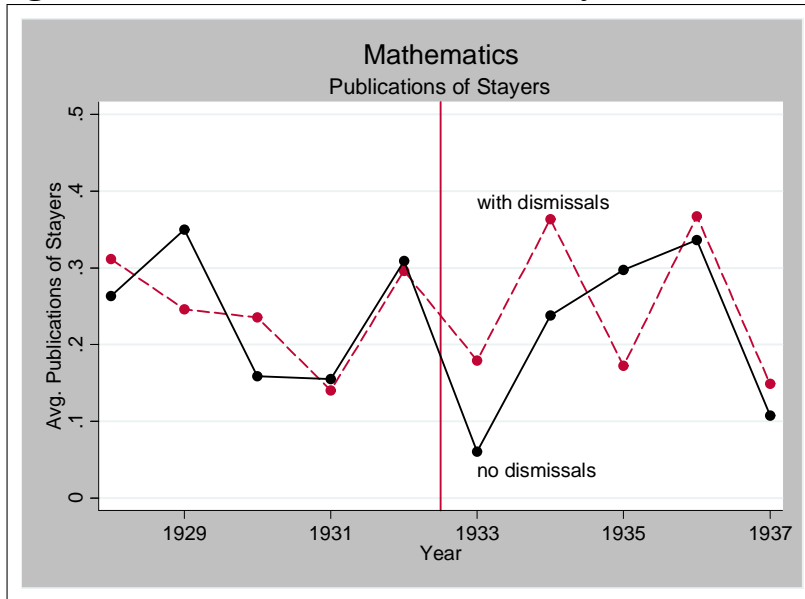


Table A1: Collaborations Science Departments 2000-2010

| Sample | (1) | (2) | (3) | (4) | (5) |
|---|-------------|------------------------------|-------------|-------------|-------------|
| | Physics | | Chemistry | Mathematics | Economics |
| | Full Sample | without particle accelerator | Full Sample | Full Sample | Full Sample |
| Panel A: Germany 2000-2010 | | | | | |
| # of Researchers in top 10 departments 2010 | 449 | 382 | 347 | 332 | 218 |
| Avg. yearly publications 2000-2010 (top journals) | 2.46 | 2.39 | 1.02 | 0.02 | 0.03 |
| Average publications (citation weighted) | 77.1 | 73.3 | 32.4 | 0.2 | 0.8 |
| % coauthored | 98.6 | 98.4 | 97.7 | 82.6 | 85.9 |
| % coauthored with faculty (top 10 departments) | 37.6 | 28.8 | 15.1 | 4.7 | 2.8 |
| % coauthored with faculty (same uni) | 19.2 | 16.6 | 11.0 | 2.3 | 0 |
| Panel B: USA 2000-2010 | | | | | |
| # of Researchers in top 10 departments 2010 | 476 | 402 | 341 | 456 | 349 |
| Avg. yearly publications 2000-2010 (top journals) | 6.34 | 4.14 | 2.09 | 0.13 | 0.31 |
| Average publications (citation weighted) | 152.6 | 116.3 | 88.0 | 1.9 | 8.1 |
| % coauthored | 98.9 | 98.1 | 97.6 | 75.2 | 82.9 |
| % coauthored with faculty (top 10 departments) | 60.5 | 22.3 | 12.7 | 21.2 | 29.5 |
| % coauthored with faculty (same uni) | 33.2 | 7.7 | 9.9 | 3.1 | 9.9 |

Table A2: Specializations

| Physics | | Chemistry | | Mathematics | |
|----------------------|--------------------------------|---------------------|--------------------------------|----------------------------|--------------------------------|
| Specialization | % scientists in specialization | Specialization | % scientists in specialization | Specialization | % scientists in specialization |
| Experimental Physics | 47.4 | Organic Chemistry | 26.2 | Analysis | 46.4 |
| Theoretical Physics | 22.3 | Physical Chemistry | 23.2 | Applied Mathematics | 36.2 |
| Technical Physics | 22.0 | Technical Chemistry | 19.1 | Geometry | 31.7 |
| Astronomy | 15.0 | Anorganic Chemistry | 18.2 | Algebra | 20.1 |
| | | Pharmacology | 10.1 | Number Theory | 13.8 |
| | | Medical Chemistry | 7.7 | Meta Mathematics | 5.4 |
| | | Biochemistry | 6.7 | Topology | 4.9 |
| | | | | Foundations of Mathematics | 4.5 |

Percentages add to more than 100 percent because some physicists and chemists have two specializations. Mathematicians have up to four specializations.

Table A3: Top Journals

| Journal Name | Published in |
|---|--------------|
| General Journals | |
| Naturwissenschaften | Germany |
| Sitzungsberichte der Preussischen Akademie der Wissenschaften Physikalisch Mathematische Klasse | Germany |
| Nature | UK |
| Proceedings of the Royal Society of London A (Mathematics and Physics) | UK |
| Science | USA |
| Physics | |
| Annalen der Physik | Germany |
| Physikalische Zeitschrift | Germany |
| Physical Review | USA |
| Chemistry | |
| Berichte der Deutschen Chemischen Gesellschaft | Germany |
| Biochemische Zeitschrift | Germany |
| Journal für Praktische Chemie | Germany |
| Justus Liebig's Annalen der Chemie | Germany |
| Kolloid Zeitschrift | Germany |
| Zeitschrift für Anorganische Chemie und Allgemeine Chemie | Germany |
| Zeitschrift für Elektrochemie und Angewandte Physikalische Chemie | Germany |
| Zeitschrift für Physikalische Chemie | Germany |
| Journal of the Chemical Society | UK |
| Mathematics | |
| Journal für die reine und angewandte Mathematik | Germany |
| Mathematische Annalen | Germany |
| Mathematische Zeitschrift | Germany |
| Zeitschrift für angewandte Mathematik und Mechanik | Germany |
| Acta Mathematica | Sweden |
| Proceedings of the London Mathematical Society | UK |

Another major journal for physicists at the time was the "Zeitschrift für Physik". Unfortunately, the Web of Science does not include the articles in that journal after 1927. Therefore, I exclude the "Zeitschrift für Physik" from the analysis.

Table A4: Top Researchers 1925-1932 (Citation weighted Publications Measure)

| Name | University beginning of 1933 | First Specialization | Second Specialization | Third Specialization | Avg. Cit weighted Publ. | Avg. Publ. | Nobel Prize | Dis-missed 33-34 |
|------------------------|------------------------------|----------------------|-----------------------|----------------------|-------------------------|------------|-------------|------------------|
| Physics | | | | | | | | |
| Fritz London | Berlin | Theo. Phy. | | | 149.3 | 1.3 | | ✓ |
| Lothar Nordheim | Göttingen | Theo. Phy. | | | 110.0 | 0.7 | | ✓ |
| Gerhard Herzberg | Darmstadt TU | Exp. Phy. | | | 78.0 | 2.0 | ✓ | |
| Carl Ramsauer | Berlin TU | Exp. Phy. | | | 75.6 | 3.0 | | |
| Max Born | Göttingen | Theo. Phy. | | | 62.5 | 1.3 | ✓ | ✓ |
| Hans Falkenhagen | Köln | Theo. Phy. | | | 57.5 | 1.9 | | |
| Arnold Sommerfeld | München | Theo. Phy. | | | 44.4 | 1.8 | | |
| Eugen Wigner | Berlin TU | Theo. Phy. | | | 44.3 | 0.5 | ✓ | ✓ |
| Heinrich Kuhn | Göttingen | Exp. Phy. | Theo. Phy. | | 42.0 | 4.0 | | ✓ |
| Harry Dember | Dresden TU | Exp. Phy. | | | 40.8 | 1.0 | | ✓ |
| Karl Herzfeld | | Theo. Phy. | | | 33.7 | 1.3 | | |
| Richard Gans | Königsberg | Exp. Phy. | | | 29.4 | 1.6 | | |
| Walter Gerlach | München | Exp. Phy. | | | 29.1 | 3.1 | | |
| Wolfgang Pauli | | Theo. Phy. | | | 28.0 | 3.8 | ✓ | |
| Max Wien | Jena | Exp. Phy. | | | 25.4 | 2.0 | | |
| Werner Heisenberg | Leipzig | Theo. Phy. | | | 25.3 | 1.0 | ✓ | |
| Ludwig Prandtl | Göttingen | Tech. P. | | | 23.3 | 1.1 | | |
| Fritz Kirchner | München | Exp. Phy. | | | 22.5 | 2.5 | | |
| Johannes Malsch | Köln | Exp. Phy. | | | 22.0 | 1.5 | | |
| Emil Rupp | Berlin TU | Exp. Phy. | | | 21.4 | 5.2 | | ✓ |
| Chemistry | | | | | | | | |
| Werner Kuhn | Karlsruhe TU | Physical C. | | | 262.0 | 7.0 | | |
| Max Bergmann | Dresden TU | Organic C. | Biochem. | | 250.2 | 6.8 | | ✓ |
| Karl Lohmann | Heidelberg | Medical C. | | | 224.0 | 6.0 | | |
| Ernst Bergmann | Berlin | Physical C. | | | 223.3 | 17.0 | | ✓ |
| Carl Neuberg | Berlin | Biochem. | | | 184.9 | 15.1 | | |
| Carl Wagner | Jena | Physical C. | | | 177.5 | 5.0 | | |
| Otto Meyerhof | Heidelberg | Medical C. | | | 176.3 | 5.8 | ✓ | |
| Otto Ruff | Breslau TU | Anorganic C. | | | 133.4 | 7.2 | | |
| Wolfgang Ostwald | Leipzig | Anorganic C. | | | 127.0 | 8.6 | | |
| Hermann Staudinger | Freiburg | Organic C. | | | 126.8 | 8.5 | ✓ | |
| Gustav Tammann | Göttingen | Physical. C. | | | 118.4 | 19.0 | | |
| Michael Polanyi | Berlin TU | Physical. C. | | | 116.8 | 5.6 | | ✓ |
| Max Volmer | Berlin TU | Physical. C. | | | 114.0 | 4.2 | | |
| Karl Freudenberg | Heidelberg | Organic C. | | | 111.8 | 7.0 | | |
| Ulrich Hofmann | Berlin TU | Anorganic C. | Physical C. | | 109.0 | 6.0 | | |
| Richard Johann Kuhn | Heidelberg | Physical C. | Medical C. | | 92.1 | 8.0 | ✓ | |
| Max Trautz | Heidelberg | Physical C. | | | 91.9 | 5.3 | | |
| Wilhelm Klemm | Hannover TU | Anorganic. C. | | | 91.4 | 5.2 | | |
| Mathematics | | | | | | | | |
| Johann von Neumann | Berlin | Applied Math | Foundations | Analysis | 36.3 | 1.5 | | ✓ |
| Richard Courant | Göttingen | Analysis | Applied Math | | 22.3 | 1.3 | | ✓ |
| Richard von Mises | Berlin | Applied Math | Analysis | | 15.6 | 0.9 | | ✓ |
| Heinz Hopf | | Algebra | Topology | Geometry | 13.3 | 1.3 | | |
| Paul Epstein | Frankfurt | Geometry | Number Th. | Algebra | 11.5 | 0.6 | | |
| Oskar Perron | München | Algebra | Analysis | | 10.6 | 1.5 | | |
| Willy Prager | Göttingen | Applied Math | | | 10.0 | 0.4 | | ✓ |
| Gabiel Szegö | Königsberg | Applied Math | Geometry | | 9.4 | 1.4 | | ✓ |
| Werner Rogosinski | Königsberg | Number Th. | Analysis | | 9.1 | 0.6 | | |
| Wolfgang Krull | Erlangen | Algebra | | | 8.9 | 1.4 | | |
| Erich Rothe | Breslau TU | Analysis | Applied Math | | 8.0 | 1.0 | | ✓ |
| Hans Petersson | Hamburg | Number Th. | Analysis | | 8.0 | 2.0 | | |
| Adolf Hammerstein | Berlin | Number Th. | Analysis | | 8.0 | 0.5 | | |
| Alexander Weinstein | Breslau TU | Applied Math | | | 6.3 | 0.7 | | ✓ |
| Erich Kamke | Tübingen | Number Th.. | Foundations | Analysis | 6.3 | 0.8 | | |
| Hellmuth Kneser | Greifswald | Applied Math | Analysis | Topology | 6.3 | 0.6 | | |
| Bartel van der Waerden | Leipzig | Algebra | Geometry | | 5.8 | 1.8 | | |
| Max Müller | Heidelberg | Analysis | | | 5.3 | 0.3 | | |
| Richard Brauer | Königsberg | Algebra | | | 5.0 | 0.6 | | ✓ |
| Leon Lichtenstein | Leipzig | Analysis | Applied Math | | 4.9 | 1.5 | | ✓ |

The university in 1933 is missing for researchers, who retire before before 1933.

Table A5: Identification Robustness Checks

| <i>Dependent Variable:</i> | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|-----------------------------------|--------------------------|--------------------|-----------------|-----------------|-----------------|------------------------------------|-------------------------------------|------------------|-----------------------------|-----------------------------|
| | Probability of Promotion | | Leave Sample | | Signing Support | | Receiving | | Post 1933 Funding Levels | |
| | Promotion Dummy | Promotion Dummy | Leave Sample | Leave Sample | Signing List | List for Hitler Signing List | Notgemeinschaft Funding Dummy | Funding Dummy | Total Funding in 1000 RM | Total Funding in 1000 RM |
| Physics | | | | | | | | | | |
| Dismissal Induced Fall | -0.010 | -0.007 | 0.007 | 0.009 | 0.027 | 0.048 | -0.062** | -0.068** | - | - |
| in Peer Quality | (0.008) | (0.007) | (0.009) | (0.009) | (0.018) | (0.035) | (0.015) | (0.016) | | |
| Number Dismissed | 0.013 | 0.009 | -0.010 | -0.011 | -0.025 | -0.019 | 0.037* | 0.038 | - | - |
| | (0.008) | (0.007) | (0.008) | (0.008) | (0.015) | (0.023) | (0.018) | (0.021) | | |
| <i>Observations</i> | 2261 | 2261 | 2337 | 2337 | 202 | 202 | 347 | 347 | | |
| <i># of researchers</i> | 258 | 258 | 258 | 258 | 0.604 | 0.604 | 228 | 228 | | |
| <i>R-Squared</i> | 0.722 | 0.755 | 0.199 | 0.206 | 0.202 | 0.202 | 0.696 | 0.794 | | |
| <i>Mean of dependent variable</i> | 0.75 | 0.75 | 0.03 | 0.03 | 0.07 | 0.07 | 0.08 | 0.08 | | |
| Chemistry | | | | | | | | | | |
| Dismissal Induced Fall | 0.003 | 0.001 | 0.002 | 0.002 | -0.006 | 0.000 | 0.004 | 0.006 | -0.751* | -2.526** |
| in Peer Quality | (0.003) | (0.002) | (0.001) | (0.001) | (0.004) | (0.001) | (0.009) | (0.010) | (0.314) | (0.112) |
| Number Dismissed | -0.003 | -0.003 | 0.001 | 0.001 | -0.005 | -0.000 | -0.005 | -0.006 | 0.153 | -0.794** |
| | (0.002) | (0.002) | (0.001) | (0.001) | (0.003) | (0.001) | (0.013) | (0.015) | (0.298) | (0.149) |
| <i>Observations</i> | 3584 | 3584 | 3690 | 3690 | 332 | 332 | 567 | 567 | | 332 |
| <i># of researchers</i> | 413 | 413 | 413 | 413 | 332 | 332 | 367 | 367 | | 332 |
| <i>R-Squared</i> | 0.764 | 0.787 | 0.205 | 0.209 | 0.054 | 0.498 | 0.670 | 0.713 | | 0.098 |
| <i>Mean of dependent variable</i> | 0.73 | 0.73 | 0.03 | 0.03 | 0.05 | 0.05 | 0.12 | 0.12 | | 8.82 |
| Mathematics | | | | | | | | | | |
| Dismissal Induced Fall | -0.006 | -0.020 | -0.011 | 0.002 | -0.015 | 0.039 | -0.002 | -0.005 | - | - |
| in Peer Quality | (0.032) | (0.028) | (0.016) | (0.018) | (0.045) | (0.117) | (0.009) | (0.020) | | |
| Number Dismissed | 0.011 | 0.019 | 0.006 | 0.004 | -0.003 | -0.027 | 0.001 | 0.003 | - | - |
| | (0.016) | (0.017) | (0.006) | (0.006) | (0.031) | (0.065) | (0.006) | (0.012) | | |
| <i>Observations</i> | 1538 | 1538 | 1596 | 1596 | 144 | 144 | 244 | 244 | | |
| <i># of researchers</i> | 183 | 183 | 183 | 183 | 144 | 144 | 161 | 161 | | |
| <i>R-Squared</i> | 0.779 | 0.822 | 0.184 | 0.200 | 0.037 | 0.641 | 0.548 | 0.599 | | |
| <i>Mean of dependent variable</i> | 0.75 | 0.75 | 0.04 | 0.04 | 0.13 | 0.13 | 0.004 | 0.004 | | |
| Age Dummies | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| University FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |

**significant at 1% level *significant at 5% level (All standard errors clustered at the department level)

Table A6: Placebo Dismissal (Moving Dismissal to 1930)

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| | Physics | | Chemistry | | Mathematics | |
| Dismissal Induced Fall in Peer Quality | -0.040 (0.034) | -0.025 (0.031) | 0.004 (0.019) | 0.003 (0.019) | 0.050 (0.057) | 0.047 (0.060) |
| Number Dismissed | 0.051 (0.034) | 0.038 (0.033) | -0.003 (0.022) | -0.003 (0.023) | -0.009 (0.031) | -0.013 (0.032) |
| Age Dummies | yes | yes | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes | yes | yes |
| University FE | | yes | | yes | | yes |
| Observations | 1314 | 1314 | 2051 | 2051 | 875 | 875 |
| # of researchers | 237 | 237 | 389 | 389 | 170 | 170 |
| R-squared | 0.485 | 0.502 | 0.727 | 0.732 | 0.357 | 0.391 |

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

Table A7: Reduced Form Poisson Regression

| | (1) | (2) | (3) | (4) |
|---|-------------------|--------------------|--------------------------------|-------------------|
| <i>Dependent Variable:</i> | Publications | | Citation weighted Publications | |
| Physics | | | | |
| Dismissal Induced Fall in Peer Quality | 1.066 (1.226) | 1.092 (1.541) | 1.058 (0.466) | 1.146 (0.968) |
| Number Dismissed | 0.954 (-0.805) | 0.926 (-1.138) | 1.024 (0.151) | 0.925 (-0.424) |
| <i>Observations</i> | 2261 | 2261 | 2261 | 2261 |
| <i># of researchers</i> | 258 | 258 | 258 | 258 |
| <i>R-squared</i> | -1389.38 | -1385.76 | -8513.19 | -8504.06 |
| Chemistry | | | | |
| Dismissal Induced Fall in Peer Quality | 1.007 (0.502) | 1.007 (0.484) | 1.012 (0.339) | 1.021 (0.567) |
| Number Dismissed | 0.985 (-1.193) | 0.987 (-0.982) | 0.979 (-1.031) | 0.985 (-0.679) |
| <i>Observations</i> | 3584 | 3584 | 3584 | 3584 |
| <i># of researchers</i> | 413 | 413 | 413 | 413 |
| <i>R-squared</i> | -4269.86 | -4224.96 | -28665.83 | -27868.58 |
| Mathematics | | | | |
| Dismissal Induced Fall in Peer Quality | 1.050 (0.259) | 1.405 (1.505) | 0.621 (-1.147) | 0.952 (-0.111) |
| Number Dismissed | 0.893 (-1.660) | 0.824* (-2.381) | 0.985 (-0.139) | 0.947 (-0.480) |
| <i>Observations</i> | 1538 | 1538 | 1538 | 1538 |
| <i># of researchers</i> | 183 | 183 | 183 | 183 |
| <i>R-squared</i> | -672.63 | -654.82 | -2465.51 | -2401.39 |
| Age Dummies | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes |
| University FE | | yes | | yes |

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

Estimates are displayed as incidence rate ratios. A coefficient of 1 would indicate no effect of the dismissal. The coefficient reported in the first line of column 1 indicates that publications increased by 6.6 percent for a one unit fall in peer quality. The effect is not significant. The absolute value of z-statistics (clustered at the university level) is reported in brackets.

Table A8: Robustness Checks Instrumental Variables (Citation Weighted Publications)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|----------------------------|-------------------|--------------------|-------------------|----------------------|----------------------|---------------------|--------------------|-------------------|------------------------|
| Sample: | omitting 33-34 | younger than 50 | 50 or older | Large Departments | Small Departments | Good Departments | Bad Departments | Full Sample | Theoretical Physics |
| Dependent Variable: | Citations | Citations | Citations | Citations | Citations | Citations | Citations | Citations | Citations |
| Physics | | | | | | | | | |
| Peer Quality | -0.394 (0.781) | -1.614 (0.989) | 0.999 (0.750) | -1.092 (1.853) | 0.002 (0.375) | -0.478 (0.592) | 0.028 (0.430) | -0.735 (1.045) | -1.001 (2.400) |
| Department Size | -0.083 (0.992) | 1.984 (1.175) | -1.275 (0.683) | 0.707 (1.956) | 1.758 (1.599) | -0.157 (0.823) | 0.859 (3.273) | 0.516 (1.031) | -0.658 (1.587) |
| <i>Observations</i> | 1866 | 1203 | 1058 | 1156 | 1105 | 1356 | 905 | 2261 | 464 |
| <i># of researchers</i> | 256 | 181 | 147 | 149 | 147 | 170 | 121 | 258 | 50 |
| <i>EV Statistic</i> | 6.2 | 5.6 | 3.75 | 2.62 | 6.77 | 8.31 | 0.36 | 6.54 | 4.1 |
| Chemistry | | | | | | | | | |
| Peer Quality | -0.189 (0.174) | -0.520 (0.484) | -0.032 (0.288) | -0.514 (0.395) | 2.058 (4.124) | -0.503 (0.433) | -1.102 (0.533) | -0.478 (0.696) | |
| Department Size | 0.234 (0.196) | 0.027 (0.547) | -0.165 (0.216) | -0.080 (0.288) | 27.520 (46.827) | -0.092 (0.384) | 0.330 (0.305) | -0.044 (0.377) | |
| <i>Observations</i> | 2926 | 1825 | 1759 | 1814 | 1770 | 1819 | 1765 | 3584 | |
| <i># of researchers</i> | 410 | 265 | 241 | 236 | 220 | 234 | 224 | 413 | |
| <i>EV Statistic</i> | 72.5 | 31.8 | 58.4 | 65.94 | 0.68 | 41.45 | 20.4 | 16.90 | |
| Mathematics | | | | | | | | | |
| Peer Quality | 0.257 (0.341) | 0.335 (0.446) | 0.128 (0.415) | 0.117 (0.295) | 0.759 (0.797) | -0.084 (0.315) | -8.304 (18.602) | -0.198 (0.479) | |
| Department Size | 0.206 (0.537) | -0.126 (0.331) | -0.307 (0.572) | 0.221 (0.429) | -0.543 (0.707) | 0.199 (0.329) | 2.173 (3.939) | 0.112 (0.305) | |
| <i>Observations</i> | 1256 | 899 | 639 | 858 | 680 | 709 | 829 | 1538 | |
| <i># of researchers</i> | 183 | 125 | 97 | 116 | 101 | 95 | 116 | 138 | |
| <i>EV Statistic</i> | 19 | 40.7 | 18.8 | 63.46 | 5.13 | 34.5 | 0.02 | 65.3 | |
| Age Dummies | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Department FE | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Dep. specific, Time Trends | | | | | | | | | |

**significant at 1% level *significant at 5% level (All standard errors clustered at the department level)

Table A9: First Stages Specialization Level Peers

| | (1) | (2) | (3) | (4) |
|----------------------------|--|--|---------------------------------|---------------------------------|
| <i>Dependent Variable:</i> | Avg. Quality of Peers (Specialization) | Avg. Quality of Peers (Specialization) | # of Peers in Specialization | # of Peers in Specialization |
| Physics | | | | |
| Reduction in Peer Quality | -0.788** (0.269) | -0.811** (0.272) | 0.0345 (0.0447) | 0.0524 (0.0472) |
| Number Dismissed | 0.341 (0.275) | 0.298 (0.280) | -0.894** (0.133) | -0.815** (0.150) |
| Cragg-Donald EV Statistic | <i>81.80</i> | <i>87.55</i> | <i>81.80</i> | <i>87.55</i> |
| Chemistry | | | | |
| Reduction in Peer Quality | -0.913** (0.0899) | -0.919** (0.0850) | 0.0291 (0.0194) | 0.0225 (0.0171) |
| Number Dismissed | 0.639 (1.097) | 0.657 (1.121) | -1.031** (0.0895) | -1.010** (0.107) |
| Cragg-Donald EV Statistic | <i>73.69</i> | <i>79.38</i> | <i>73.69</i> | <i>79.38</i> |
| Mathematics | | | | |
| Reduction in Peer Quality | -0.385 (0.660) | -0.221 (0.670) | -0.293** (0.105) | -0.144 (0.102) |
| Number Dismissed | -0.275 (0.416) | -0.385 (0.412) | -0.344 (0.177) | -0.398* (0.162) |
| Cragg-Donald EV Statistic | <i>0.23</i> | <i>0.13</i> | <i>0.23</i> | <i>0.13</i> |
| Age Dummies | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes |
| Individual FE | yes | yes | yes | yes |
| University FE | | yes | | yes |

**significant at 1% level

*significant at 5% level

(All standard errors clustered at the university level)

Table A10: First Stages High Quality Peers

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| | Physics | | Chemistry | | Mathematics | |
| <i>Dependent Variable:</i> | # of Peers in Quality Group | # of Peers in Quality Group | # of Peers in Quality Group | # of Peers in Quality Group | # of Peers in Quality Group | # of Peers in Quality Group |
| Number of Dismissals | -0.685** (0.049) | -0.603** (0.052) | -0.995** (0.088) | -0.963** (0.101) | -0.537** (0.052) | -0.486** (0.040) |
| <i>First Stage F-Statistic</i> | 195.5 | 133.7 | 126.7 | 90.4 | 104.8 | 144.8 |
| Number of Top 50th Percentile Dismissals | -0.955** (0.0615) | -0.878** (0.0503) | -0.938** (0.0493) | -0.908** (0.0374) | -0.706** (0.0726) | -0.674** (0.0724) |
| <i>First Stage F-Statistic</i> | 241.1 | 305.1 | 362.6 | 587.9 | 94.4 | 86.8 |
| Number of Top 25th Percentile Dismissals | -0.723** (0.0351) | -0.723** (0.0414) | -1.003** (0.0454) | -0.975** (0.0420) | -0.767** (0.0348) | -0.746** (0.0282) |
| <i>First Stage F-Statistic</i> | 423.7 | 304.5 | 488.6 | 540.1 | 485.8 | 701.6 |
| Number of Top 10th Percentile Dismissals | -0.749** (0.138) | -0.760** (0.139) | -1.097** (0.249) | -1.086** (0.246) | -0.996** (0.158) | -0.956** (0.177) |
| <i>First Stage F-Statistic</i> | 29.6 | 29.8 | 19.4 | 19.5 | 39.6 | 29.0 |
| Number of Top 5th Percentile Dismissals | -0.649** (0.0457) | -0.669** (0.0362) | -1.311** (0.457) | -1.317** (0.460) | -1.129** (0.167) | -1.086** (0.176) |
| <i>First Stage F-Statistic</i> | 201.6 | 341.5 | 8.2 | 8.2 | 46.0 | 40.0 |
| Age Dummies | yes | yes | yes | yes | yes | yes |
| Year Dummies | yes | yes | yes | yes | yes | yes |
| University FE | yes | yes | yes | yes | yes | yes |
| Individual FE | | yes | | yes | | yes |
| Observations | 2261 | 2261 | 3584 | 3584 | 1538 | 1538 |

**significant at 1% level

*significant at 5% level

(All standard errors clustered at the university level)

9.2 Data Appendix

Data on Dismissed Scholars

As outlined in the main text, the primary data source for the dismissed scholars is the List of Displaced German Scholars (1937). It contains about 80 percent of the dismissed considered in this paper. Figure A6 shows a sample page from the physics section of the “List of Displaced German Scholars” including four scientists who had already received the Nobel Prize or who were to receive it after 1937.

Figure A6: Sample Page from List of Displaced German Scholars



Squares were added by the author to highlight the researchers who had already received the Noble prize or were to receive it after 1936.

To obtain a complete picture of all dismissals, I complement this information with information on dismissals from a number of secondary sources.

The main additional source is the “Biographisches Handbuch der deutschsprachigen Emigration nach 1933 - Vol. II : The arts, sciences, and literature”. The compilation of the handbook was initiated by the “Institut für Zeitgeschichte München” and the “Research Foundation for Jewish Immigration New York”. Published in 1983, it contains short biographies of artists and university researchers who emigrated from Nazi Germany.³⁰

In addition to these two main data sources, I obtain further information on dismissals from data compiled by historians who studied individual subjects during the Nazi era. Beyerchen (1977) included a list of dismissed physicists in his book about the physics community in Nazi Germany. Deichmann (2001) compiled an extensive list of dismissed chemists and Siegmund-Schultze (1998) published a list of dismissals in his book on mathematicians in the Nazi era. I combine the data from the various sources to compile the complete list of all dismissed scientists. My list of dismissals also contains a few researchers who were initially exempted from being dismissed but resigned voluntarily. The vast majority of them would have been dismissed due to the racial laws of 1935 and were therefore only anticipating their dismissal. All of these voluntary resignations were directly caused by the discriminatory policies of the Nazi regime.

Data on all Scientists at German Universities between 1925 and 1938

Data on all university scientists come from semi-official University Calendars. The university calendar was published by J.A. Barth. He collected official university calendars from all German universities and compiled them into one volume. Originally named “Deutscher Universitätskalender”. It was renamed into “Kalender der deutschen Universitäten und technischen Hochschulen” in 1927/1928. From 1929/1930 it was renamed into “Kalender der Deutschen Universitäten und Hochschulen”. In 1933 it was again renamed into “Kalender der reichs-deutschen Universitäten und Hochschulen”.

The University Calendar lists all lectures held by each scholar in a given department. If a researcher was not lecturing in the relevant semester he was still listed under the heading “not lecturing”. From this list of lectures I infer the subject of each researcher to construct yearly faculty lists of all physics, chemistry, and mathematics departments.

I extract all researchers who were at least Privatdozent from the calendar. This includes in ascending order Privatdozenten, extraordinary professors, and chaired professors. Privatdozenten were usually not civil servants. Universities employed different types of extraordinary professors at the time. First, they could be either civil servants (beamteter Extraordinarius) or not have the status of a civil servant (nichtbeamteter Extraordinarius). Universities also distinguished between extraordinary extraordinary professors (ausserplanmäßiger Extraordinarius) and planned extraordinary professors (planmäßiger Extraordinarius). Chaired/ordinary professors were always civil servants.

³⁰Kröner (1983) extracted a list of all dismissed university researchers from the handbook. I use Kröner’s list to append my list of all dismissed scholars.

Dismissal Date

It is crucial to assign each dismissed scientist the correct dismissal date. Dismissed researchers who were not civil servants (Privatdozenten and some extraordinary professors) all disappear from the University Calendar between winter semester 1932/1933 and winter semester 1933/1934. Some of the dismissed researchers who were civil servants (ordinary Professors and some extraordinary professors), however, were still listed in the calendars even after they were dismissed. The original law forced civil servants of Jewish origin into early retirement. As they remained on the states' payroll some universities still listed them in the university calendar even though they were not allowed to teach or do research anymore. In many cases the calendar reported that they had been placed into early retirement according to the "Law for the Restoration of the Professional Civil Service". Using the University Calendar to infer the correct dismissal year may therefore be problematic. My list of dismissals, however, includes the exact year after which somebody was barred from teaching and researching at a German university. I therefore use the dismissal data to determine the actual dismissal date and not the date a dismissed scholar disappears from the University Calendars.

Data on Specialization of Scientists

The data on specialization of scientists were collected from seven volumes of "Kürschers Deutscher Gelehrtenkalender". I consulted the volumes published in 1925, 1926, 1928/29, 1931, 1935, 1940/41, and 1950.

The editors of each volume obtained their data by sending out questionnaires to researchers asking them to provide information on their scientific career. Physicists, for example, would then specify whether they work on theoretical, experimental, technical or astrophysics. I use this information to ascertain a scientist's specialization. Because of the blurred boundaries of specializations in mathematics a lot of mathematicians did not specify their specialization. In those cases I infer the specialization from the main publications they list in the "Gelehrtenkalender". As outlined in the main text, about 10 percent of scientists did not list their specialization in the "Gelehrtenkalender" or were not listed altogether. For these scientists I conduct an internet search to obtain their specialization.

Publication Data

Journals from the Web of Science

The journals included in the Web of Science for the 1900 to 1944 period are very high quality journals. In 2004, Thomson Scientific extended the "Web of Science" backwards to include the major journals between 1900 and 1944. To decide which journals to cover for this period they judged their importance by later citations (cited between 1945 and 2004). For more details on the process see http://wokinfo.com/products_tools/backfiles/cos.

I download all German speaking science journals contained in the "Web of Science" for the years 1925 to 1938. I then add the leading international general science journals. Furthermore, I add non-German top specialist journals which were suggested by historians of science as important outlets for the German scientific community. The relevant chemistry journals were suggested by

Ute Deichmann and John Andraos who work on chemistry in the early 20th century. Additional journals for mathematics were suggested by Reinhard Siegmund-Schultze and David Wilkins who are specialists in the history of mathematics.

A very small number of contributions in the top journals were letters to the editor or comments. I restrict my analysis to contributions classified as “articles” as they provide a cleaner measure for a researcher’s productivity.

Merging Publication Data to Scientists

As the “Web of Science” only reports last names and the initial of the first name for each author there are some cases where I cannot unambiguously match researchers and publications. In these cases I assign the publication to the researcher whose subject is most closely related to the field of the journal in which the article was published. In the very few cases where this assignment rule is still ambiguous between two scientists I assign each researcher half of the (citation weighted) publications.

Another problem is the relatively large number of misspellings of authors’ names. All articles published between 1925 and 1938 were published on paper. In order to include these articles into the electronic database Thomson Scientific employees scanned all articles published in the historically most relevant journals. The scanning was error prone and thus lead to misspellings of some names. As far as I discovered these misspellings I have manually corrected them.

Publication Measures

For each scientist I calculate two yearly productivity measures. Publications and citation weighted publications counting the number of times a certain article was cited in the first 50 years after publication. The following simple example illustrates the construction of the citation weighted publications measure. Suppose a researcher published two top journal articles in 1932. One is cited 5 times the other 7 times in any journal covered by the Web of Science in the 50 years after its publication. The researcher’s citation weighed publications measure for 1932 is then $5+7=12$.

Data on Current Scientists and Economists

The data presented in Table A1 come form a dataset that I have constructed for this paper. It contains all tenured scientists in top 10 departments in the United States and Germany today. For comparison reasons I also obtained all economists in top 10 departments in the two countries. The ranking of top departments for the United States was obtained from “US News” (see <http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-science-schools>) while the rankings for German departments were obtained from CHE (e.g. http://www.che.de/downloads/CHE_Forschungsranking_Physik_2009).pdf). The list of top 10 departments is available upon request. I then downloaded complete faculty rosters (as of December 2010) for each of the departments from department websites focusing on tenured faculty. The dataset contains 476 physicists, 341 chemists, 456 mathematicians, and 349 economists from U.S. top departments. For the Germany it contains 449 physicists, 347 chemists, 332 mathematicians, and 218 economists.

I then merged top publications between 2000 and 2010 to these scientists using data from the ISI Web of Science focusing on current top journals. A current journal ranking for science subjects was obtained from SCImago. (2007). SJR — SCImago Journal & Country Ranking and includes the top 10 journals for each subject plus the top general science journals relevant for the subject (e.g. Nature and Science) (the full list of current top journals is available from the author upon request). For economics the top journals include the top five journals (American Economic Review, Econometrica, Journal of Political Economy, Quarterly Journal of Economics, and Review of Economic Studies).