Online Appendix for: Filling the Gap: The Consequences of Collaborator Loss in Corporate R&D

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Content

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A1 Description of the data construction

We created a novel, linked inventor biography dataset—INV-BIO ADIAB 1980-2014, in the following: INV-BIO—which is based on inventor and patent information obtained from patent register data that is linked to administrative labor market career data on individuals and their employing establishments (for a detailed description, see Dorner et al. (2018)).

The INV-BIO data set records complete biographies of 152,350 inventors from 1980 until 2014. For this period, inventor track records based on patent registers of the European Patent Office (EPO) and the German Patent and Trademark Office (DPMA), and labor market biographies originating from social security data obtained from the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB) were combined in a research data set.

A1.1 Creation of the dataset

The sampling frame of the INV-BIO data is the population of inventors who are listed on patent applications filed with the EPO between 1999 and 2011 and resided in Germany at the time of the patent filing. The data were obtained from PATSTAT[1], the Worldwide Statistical Database offered by the EPO, which contains bibliographical and legal status patent data from leading industrialized and developing countries.

To identify unique inventors, a name disambiguation approach was needed. We used a methodological approach combining record linkage and techniques from machine learning. This approach enabled us to create disambiguated inventor IDs. The inventor names and residential addresses extracted from the patent records were used to identify inventors in the social security data between 1999 and 2011. In a subsequent step, we created consistent patent track records for the period between 1980 and 2014. To evaluate the data linkages, we used predictive methods from a machine learning toolkit.

Cases of inventors identified in the patent data, but not matched with the labor market data, arise mainly because they belong to a group of individuals that are not covered by general social security. In the IAB employment data, self-employed inventors, freelancers, civil servants, retirees, or students are not covered. Data quality issues are another reason. The latter are, however, not a major concern since the probabilistic record linkage algorithms that we used for the data generation enable fuzzy matchings and account for misspellings of the names and addresses. Hence, we are confident that we identified the population of inventors except for the inventors not covered by

[1] See https://www.epo.org/searching-for-patents/business/patstat.html, accessed on January 1, 2022.

social security data.

The INV-BIO dataset only contains inventors who were at least listed on one European (EP) patent during the time window 1999-2011 (see identification step in figure A1.1). Individuals who made inventions for which no patent was filed because the inventors or their employers preferred secrecy over patenting are not included in our data. To get an understanding of the share of inventors we cover in our data, we use the average number of individuals with an academic degree that are reported as employees in research and development in the period 1999-2011. The number of reported individuals amounts to 637,308 individuals. The inventors in our dataset, hence, equal nearly 25% of the potentially patenting population of employees. These figures show that there is still a large number of potential inventors we do not cover in our data that observes inventors conditional on one EP patent filed between 1999 and 2011. We further conducted extensive checks of the quality of the data matches. Part of these checks is documented in the Appendix of Dorner et al. (2018).

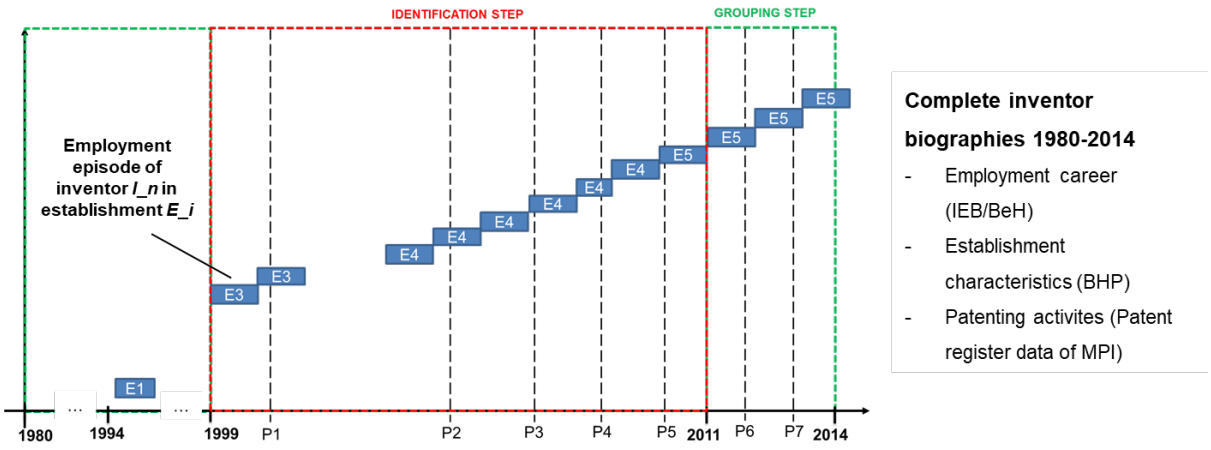
The linked-employer-employee data liked with patent data contain socio-demographic characteristics of the individuals, information on employment, benefit receipts, job search activities, and variables describing the residential location. It also contains structural information about the German establishments the inventors in our data had been employed with throughout their careers as well as a comprehensive set of indicators describing the workforce of these establishments (e.g., number of employees, the share of workers by the level of education, occupation, wage level, demography), the precise location of the site, and the industrial classification of economic activities in the NACE scheme.

In the next step, we added the patent histories of the inventors comprising all patents filed between 1980 and 2014 with the EPO, the DPMA, or the World Intellectual Property Office (WIPO) (see grouping step in figure A1.1). The matching was done based on inventor names, as well as on applicant/employer data recorded in the patent register and the labor market data. To ensure high-quality matches, we conducted various checks, including a manual check of a randomly drawn subsample of the data. The INV-BIO data include 643,856 patent families, as represented by patent documents covering a single invention and having exactly the same priority rights (leading to an identical date of first filing). This represents approximately 71.4% of the inventions for which an EP patent was filed by at least one inventor residing in Germany during the time window from 1999 until 2011. The patent data were supplemented with bibliographic and procedural data on the respective patents, including filing and grant dates, the technology classes assigned to the invention, the countries in which patent protection was requested by the applicant(s), and the forward citations

the patents received from subsequent patents.

The structure of the dataset is displayed in figure A1.1 below.

Figure A1.1: Structure of the linked inventor biography dataset INV-BIO



A1.2 Quality checks

To check the representativeness of our data for the population of all EP and all DE (German) patents, we conducted two tests. First, we compared the number of DOCDB patent families (each patent family consists of all patent documents that cover a single invention and that all have exactly the same first filing date) linked to unique inventors in our data with the total number of DE patent applications that included at least one German inventor. Our sample represents about 71.4% (yearly average) of this population of patent families between 1999 and 2011. The maximum coverage of almost 80% is realized in 2008. As a result of the cohort approach adopted, the representativeness drops outside of the 1999-2011 time window to a level of about 30%.

Second, we calculated the ratio of German patents by five technology main areas (mechanical engineering, process engineering, chemicals/pharma, instruments, and other areas) that are represented in the inventor-patent data of the INV-BIO dataset. We find some variation in the representativeness of our data across main technical areas. The best representation of patents in the 1999-2011 time window is achieved in chemistry. In some filing years, even more than 90% of the DE patent applications protecting inventions that were classified as chemistry by the patent examiners are in our dataset. On average, the representation remains very high at a level of above 80%. Also, the population of electrical engineering patents is largely represented in the INV-BIO data. Fields such as instruments and mechanical engineering show similar coverage rates of about 70% on average in the 1999-2011 time window. However, the coverage of patents assigned to the main area 'other' field is lower. One reason for the lower representation rate is that a large part of these patents is

filed in civil engineering, an industrial segment in which public sector civil servants, researchers, and self-employed architects presumably play an important role. Both groups are not recorded in the social security data.

Given the large size of the sample in the 1999-2011 time window, we argue that estimates obtained from the data will yield a good approximation to population estimates. However, due to the lack of information on the actual inventor population, no inventor-level weights can be provided for statistical projection to the population level.

A1.3 Data availability

The linked inventor data (INV-BIO ADIAB 1980-2014) was made available to third parties in February 2019. The data can be used for non-commercial research projects via the FDZ of the BA at the IAB. The data access is carried out via an obligatory initial guest stay in Nuremberg (or one of the other FDZ locations) and the option of remote data access via JoSuA (see https://fdz.iab.de/en/FDZ_Individual_Data/INV-BIO-ADIAB/INV-BIO-ADIAB8014.aspx, accessed on January 1, 2022).

To protect the privacy of the individuals and establishments in the data and to limit the threat of potential de-anonymization, some information from the original register has been classified as sensitive. For instance, the information on work and residential location of the employee is only available at the level of cities and districts (NUTS 3 level). Furthermore, the technology and industry classifications are grouped, and patent characteristics, such as forward citations, are right-tail coarsened. For our work, we had access to un-grouped and un-coarsened data.

A2 Description of the variables

Table A2.1: Short variable descriptions

Variable	Description	Source
	Inventive productivity variables	
Patents	Short-hand for Patents (simple counts)	
Patents (simple counts)	Number of patent families with earliest filing year in the current year.	Inv
Patents (fractional counts)	Number of patent families, counting fractional shares by the number of inventors on a patent	Inv
Patents (simple counts excluding lost collaborator)	Patents (simple counts), but excluding patents with the (pseudo-)deceased co-inventor	Inv, Own
Patents (Lifetime)	Patents, cumulative until the current year. For matching, we coarsen the patent count to groups of 10-14, 15-19, 10s between 20 and 100, 50s between 100 and 300, and 400+ (for the dyadic variable, see below)	Inv
Patents (citation-weighted counts)	Patents, weighted by the number of EP citations received within 5 years	Inv
Patents (breakthrough patent counts)	Number of patent families which are in the top 10% of their technology-year cohort in terms of citations	Inv, Own
Patents (family size-weighted counts)	Number of patent families, weighted by the size of the global DOCDB patent family. For details, see footnote 4 in the main text.	Inv, Own
Patents (granted patent counts)	Number of patent families which comprise at least one granted patent (EP/DE)	Inv, Own
Patents with (only) new collaborator(s)	Number of patent families with at least one (alternatively, only) new co-inventor(s), i.e., inventors whom the remaining inventor had not worked with previously	Inv, Own
Patents with only old collaborators	Number of patent families without new co-inventors, i.e., only with inventors whom the remaining inventor had worked with previously	Inv, Own
Patents with newly hired collaborator(s)	Number of patent families with inventors who, at the time of filing, were recently (within two years) hired at their organization	Inv, Own
Patents (not) relying on organization knowledge	Number of patent families which cite any (none) earlier patent created by inventors who were employed by the remaining inventor's organization when the earlier patent was filed	Inv, Own
Patents with small (large) team	Patents (Simple), separated by patents with few (≤ 3) or many (> 4) inventors	Inv, Own
Team size (average)	Average number of inventors per patent of all patents filed in a given year/period	Inv, Own
	Inventor-level characteristics	
Death (date)	Exit date from the social security data with reason death	Base
Age	Age of the inventor in the current year	Base
Male	Gender of the inventor (Male=1)	Base
Science & engineering worker	Occupation classification and education level indicate high-skilled worker in science and engineering	Base
Organization tenure	Number of years of employment at current organization	Base
Organization size	Number of full-time employees of an organization. While matching, organization size is coarsened in groups of <50, 50-249, 250-999, and 1,000+ employees.	Base
Organization age	Age in years of the organization in the social security data, censored in 1975	Base
Technological focus	Inventor's modal technology field (chemistry, instruments, electrical engineering, mechanical engineering, other)	Inv
Years since last patenting	Years between the latest earliest filing date of a patent application and the current time	Inv

Continued on the next page ...

Table A2.1: Short variable descriptions

Variable	Description	Source
Labor market density (narrow, wide)	Number of inventors in the year, geographic region (district or regional labor market) and technology (wide: 34 technology areas, or narrow: IPC4) as the inventor	Inv, Own
	Inventor-collaborator-level characteristics	
Internal loss	Whether a (pseudo-)deceased co-inventor and remaining inventor worked in the same organization at the time of the (pseudo-)death	Own
Knowledge compementarity: Patent class similarity	Cosine similarity between the IPC4-level patenting shares of remaining and (pseudo-)deceased co-inventor. Complementarity is indicated by low values of similarity.	Inv, Own
Knowledge compementarity: Patent class overlap	Overlap between the IPC4-level patenting shares of the remaining and (pseudo-)deceased co-inventors by summing the minimum values of their respective shares across all classes. Specifically, for each class, we identify the lesser share between the two inventors, then sum these minimum values to determine the overall overlap. Complementarity is indicated by low values of overlap.	Inv, Own
Collaborator network size (excluding common inventors)	Number of unique inventors that the (pseudo-)deceased co-inventor filed a patent with, that the remaining inventor had not filed a patent with	Own
Collaborator network size (including common inventors)	Number of unique inventors that the (pseudo-)deceased co-inventor filed a patent with	Own
Collaborator network size (same technology specialization)	Number of unique inventors in the organization of the (pseudo-)deceased co-inventor with the same modal lifetime IPC4 technology	Own
Collaboration intensity (recency)	Years since the last joint patent of remaining inventor and (pseudo-)deceased co-inventor	Base, Own
Collaboration intensity (joint patents)	Number of patents two inventors jointly applied for	Inv, Own
Collaboration intensity (recent joint patents)	Number of patents two inventors jointly applied for in the last four years	Inv, Own
Collaboration intensity (joint tenure)	Number of years two inventors worked in the same establishment	Base, Own
Collaborator inventive productivity	Cumulative patent count of the (pseudo-)deceased co-inventor at the time of death.	Inv, Own
Collaborator inventive productivity (residualized)	Residual of collaborative inventive productivity in a regression with age, year, firm size, and technology area fixed effects	Inv, Own
	Organizational capabilities	
Knowledge management capabilities	Share of patents with self-citations to same organization without an overlap in the inventor team relative to all patents with self-citations	Inv, Own
Hiring capabilities	Share of inventors in the organization who joined in the year before the co-inventor death relative to all inventors in the organization	Inv, Own
	Robustness variables	
Promotion	Promotion event caused by a change in occupation from non-senior to senior (i.e., managerial occupation), by default excluding moves across employers.	Base, Own
Leave	Mobility event caused by a change in the establishment to unemployment or to another employer	Base, Own

Notes: Data source: Base = IAB base data; Inv = INV-BIO ADIAB 8014; Own = Own calculation. In own calculations, we draw on additional data from PATSTAT (citation links, ...).

A3 Descriptive tables and figures

Table A3.1: Summary statistics and pairwise correlations

Remaining inventors	Summary		Pairwise correlations							
Variable	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Patents (simple counts)	0.65	1.18	1.00							
(2) Patents (lifetime)	9.21	10.19	0.42	1.00						
(3) Patents (citation-weighted counts)	0.68	1.65	0.75	0.30	1.00					
(4) Patents with at least one new collaborator	0.42	0.93	0.83	0.29	0.70	1.00				
(5) Patents relying on organization knowledge	0.27	0.78	0.69	0.36	0.57	0.59	1.00			
(6) Age	44.03	10.65	-0.05	0.35	-0.06	-0.07	-0.02	1.00		
(7) Male	0.93	0.26	0.05	0.09	0.01	0.02	0.02	0.14	1.00	
(8) Science & engin. worker	0.50	0.50	0.08	0.13	0.06	0.07	0.07	-0.05	0.07	1.00
(9) Organization tenure	10.02	8.08	0.03	0.11	0.01	0.01	0.11	0.40	0.06	-0.09
(10) Organization size (000)	5.05	9.61	0.07	0.12	0.05	0.07	0.09	-0.03	-0.00	0.07
(11) Years since last patenting	2.71	3.35	-0.50	-0.24	-0.37	-0.41	-0.31	0.33	-0.05	-0.08
(12) Internal collaborator	0.52	0.50	0.04	0.00	0.03	0.03	0.11	-0.05	-0.01	0.02
(13) Knowledge similarity	0.70	0.29	-0.02	-0.06	-0.01	-0.02	0.01	-0.04	-0.02	-0.06
(14) Knowledge overlap	0.54	0.26	-0.04	-0.09	-0.02	-0.03	-0.00	-0.04	-0.03	-0.07
(15) Collaborator network size (excl. common inv.)	11.29	15.75	0.07	0.14	0.07	0.08	0.07	-0.06	-0.09	0.06
(16) Collaborator network size (incl. common inv.)	17.30	18.17	0.10	0.19	0.10	0.11	0.10	-0.06	-0.09	0.04
(17) Collaborator network size (same tech. spec.)	35.09	60.32	0.11	0.15	0.09	0.10	0.11	-0.05	-0.04	0.08
(18) Collaboration intensity (recency)	4.61	2.81	-0.04	0.09	-0.03	-0.03	-0.07	0.21	0.00	-0.01
(19) Collaboration intensity (joint patents)	2.29	3.52	0.16	0.28	0.13	0.11	0.13	0.03	0.03	0.04
(20) Collaboration intensity (joint tenure)	5.23	6.89	0.03	0.04	0.02	0.02	0.11	0.10	0.01	-0.02
(21) Collaborator inventive productivity	17.83	23.76	0.13	0.22	0.10	0.11	0.10	-0.04	-0.04	0.06
(22) Collaborator inventive productivity (resid.)	10.45	23.49	0.13	0.21	0.10	0.11	0.10	-0.05	-0.04	0.06
(23) Knowledge management capabilities	0.86	0.18	0.07	0.11	0.07	0.07	0.11	-0.01	-0.02	0.05
(24) Hiring capabilities	0.11	0.20	-0.02	-0.02	-0.01	-0.01	-0.03	-0.04	0.01	-0.03

	Pairwise correlations (continued)															
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
(9)	1.00															
(10)	0.14	1.00														
(11)	0.01	-0.04	1.00													
(12)	0.21	0.11	-0.09	1.00												
(13)	0.00	-0.12	0.03	0.17	1.00											
(14)	-0.00	-0.12	0.06	0.17	0.92	1.00										
(15)	-0.02	0.20	-0.04	-0.02	-0.18	-0.21	1.00									
(16)	-0.02	0.19	-0.05	0.00	-0.11	-0.14	0.95	1.00								
(17)	0.02	0.26	-0.09	0.15	0.07	0.04	0.24	0.27	1.00							
(18)	0.10	-0.00	0.20	-0.20	-0.07	-0.08	0.08	0.05	-0.03	1.00						
(19)	0.01	0.02	-0.09	0.09	0.19	0.19	0.07	0.17	0.04	-0.10	1.00					
(20)	0.55	0.13	-0.04	0.73	0.13	0.12	0.00	0.01	0.13	-0.04	0.08	1.00				
(21)	-0.03	0.07	-0.08	-0.02	-0.09	-0.12	0.76	0.74	0.24	0.07	0.31	0.01	1.00			
(22)	-0.04	0.06	-0.08	-0.02	-0.08	-0.11	0.75	0.74	0.23	0.05	0.31	-0.01	1.00	1.00		
(23)	0.09	0.09	-0.06	0.18	0.01	0.00	0.13	0.14	0.12	0.02	0.06	0.13	0.10	0.10	1.00	
(24)	-0.13	-0.06	0.01	-0.11	0.02	0.01	-0.02	0.01	-0.11	-0.05	-0.02	-0.19	-0.05	-0.04	-0.03	1.00

Notes: Full estimation sample. For variable descriptions, see Table A2.1.

Table A3.2: Pre-death characteristics of deceased and remaining inventors (Full sample)

Lost collaborator	Deceased (N = 845)			Pseudo-deceased (N = 845)				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Patents (Lifetime)	6.04	3.00	7.57	5.95	3.00	7.33	0.09	0.804
Age	49.25	51.00	7.34	49.25	51.00	7.34	0.00	1.000
Male	0.96	1.00	0.20	0.96	1.00	0.20	0.00	1.000
Organization tenure	12.03	10.00	9.18	11.89	10.00	8.91	0.14	0.755
Organization size	4041.19	777.50	9229.49	3504.52	790.00	7961.90	536.67	0.204
Organization age	22.38	26.00	11.73	22.29	26.00	11.68	0.08	0.887
Years since last patenting	3.43	2.00	3.43	3.37	2.00	3.30	0.05	0.740
Science & engin. worker	0.39	0.00	0.49	0.41	0.00	0.49	−0.02	0.333

Inventors	Deceased (N = 3574)			Pseudo-deceased (N = 3409)				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Patents (Lifetime)	11.44	7.00	10.34	10.94	7.00	10.17	0.51	0.039**
Age	45.62	45.00	9.15	45.40	44.00	9.35	0.22	0.312
Male	0.93	1.00	0.25	0.92	1.00	0.27	0.01	0.043**
Organization tenure	10.22	8.00	8.15	9.96	8.00	8.01	0.26	0.195
Organization size	5088.44	1394.00	9634.85	4898.03	1388.00	9401.36	190.41	0.424
Organization age	22.52	27.00	11.82	22.87	28.00	11.91	−0.35	0.242
Years since last patenting	2.01	1.00	2.37	2.03	1.00	2.30	−0.02	0.659

Characteristics of the lost collaborator	Deceased (N = 3574)			Pseudo-deceased (N = 3409)				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Internal collaborator	0.50	1.00	0.50	0.53	1.00	0.50	−0.03	0.033**
Knowledge similarity	0.70	0.78	0.28	0.69	0.78	0.29	0.01	0.175
Knowledge overlap	0.54	0.53	0.26	0.53	0.53	0.26	0.01	0.233
Collab. network size (excl. common inv.)	12.25	5.00	17.85	10.75	6.00	13.61	1.50	0.000***
Collab. network size (incl. common inv.)	18.08	11.00	20.13	16.92	11.00	16.25	1.16	0.008***
Collab. intensity (recency)	4.73	4.00	2.82	4.66	4.00	2.80	0.07	0.277
Collab. intensity (joint patents)	2.27	1.00	3.45	2.29	1.00	3.51	−0.02	0.807
Collab. intensity (joint tenure)	5.18	0.56	7.06	5.34	2.09	6.80	−0.16	0.343
Collab. inventive productivity (pre-death)	19.92	9.00	27.11	16.51	9.00	21.99	3.40	0.000***

Organizational characteristics	Deceased (N = 3574)			Pseudo-deceased (N = 3409)				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Knowledge management capabilities	0.86	0.92	0.18	0.86	0.91	0.18	0.00	0.371
Hiring capabilities	0.11	0.05	0.22	0.09	0.05	0.18	0.02	0.000***

Notes: This table presents summary statistics of pre-death characteristics of deceased co-inventors and their matched control group. The unit of observation is at the deceased co-inventor (first part) or remaining inventor (second and third part) level. Reported p-values based on an unpaired t-test. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Table A3.3: Pre-death characteristics of remaining inventors with internal collaborator loss

Inventors	Deceased (N = 1800)			Pseudo-deceased (N = 1804)				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Patents (Lifetime)	11.26	7.00	10.15	11.15	7.00	10.25	0.11	0.754
Age	45.23	45.00	8.18	44.63	44.00	8.41	0.60	0.031**
Male	0.93	1.00	0.25	0.91	1.00	0.28	0.02	0.049**
Organization tenure	11.85	10.00	8.20	11.41	10.00	8.08	0.44	0.104
Organization size	6040.71	1760.00	10 793.53	5865.13	1627.00	10 561.42	175.58	0.622
Organization age	23.72	28.00	11.34	23.98	29.00	11.46	−0.26	0.488
Years since last patenting	1.68	1.00	2.24	1.62	1.00	2.01	0.06	0.413

Characteristics of the lost collaborator	Deceased (N = 1800)			Pseudo-deceased (N = 1804)				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Internal collaborator	1.00	1.00	0.00	1.00	1.00	0.00	0.00	
Knowledge similarity	0.74	0.83	0.26	0.74	0.83	0.26	0.00	0.970
Knowledge overlap	0.58	0.58	0.25	0.58	0.59	0.24	0.01	0.506
Collab. network size (excl. common inv.)	12.25	5.00	19.69	10.31	6.00	12.88	1.94	0.000***
Collab. network size (incl. common inv.)	18.10	10.00	22.31	17.05	11.00	16.08	1.05	0.104
Collab. intensity (recency)	4.19	4.00	2.78	4.13	4.00	2.77	0.06	0.511
Collab. intensity (joint patents)	2.52	1.00	4.07	2.61	1.00	4.05	−0.09	0.526
Collab. intensity (joint tenure)	10.29	9.31	6.82	10.09	9.17	6.28	0.20	0.362
Collab. inventive productivity (pre-death)	19.91	8.00	28.35	15.87	8.00	20.15	4.04	0.000***

Organizational characteristics	Deceased (N = 1800)			Pseudo-deceased (N = 1804)				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Knowledge management capabilities	0.89	0.92	0.13	0.88	0.92	0.14	0.01	0.070*
Hiring capabilities	0.08	0.05	0.17	0.08	0.05	0.16	0.00	0.656

Notes: This table presents summary statistics of pre-death characteristics of deceased co-inventors and their matched control group. The unit of observation is at the deceased co-inventor (first part) or remaining inventor (second and third part) level. Reported p-values based on an unpaired t-test. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Table A3.4: Pre-death characteristics of remaining inventors with external collaborator loss

Inventors	Deceased (N = 1774)			Pseudo-deceased (N = 1605)				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Patents (Lifetime)	11.63	7.00	10.52	10.70	7.00	10.08	0.94	0.008***
Age	46.02	44.00	10.03	46.26	45.00	10.24	−0.24	0.492
Male	0.93	1.00	0.25	0.93	1.00	0.26	0.01	0.421
Organization tenure	8.26	6.00	7.64	7.97	6.00	7.49	0.29	0.314
Organization size	3945.33	1071.00	7879.01	3576.25	1059.00	7332.63	369.08	0.200
Organization age	21.09	26.00	12.23	21.35	25.00	12.34	−0.26	0.572
Years since last patenting	2.34	2.00	2.46	2.49	2.00	2.50	−0.15	0.074*
Characteristics of the lost collaborator	**Deceased (N = 1774)**			**Pseudo-deceased (N = 1605)**				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Internal collaborator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Knowledge similarity	0.66	0.74	0.30	0.63	0.71	0.31	0.02	0.022**
Knowledge overlap	0.50	0.49	0.26	0.48	0.48	0.27	0.01	0.124
Collab. network size (excl. common inv.)	12.25	6.00	15.78	11.25	6.00	14.37	1.00	0.055*
Collab. network size (incl. common inv.)	18.06	11.00	17.65	16.78	11.00	16.45	1.28	0.030**
Collab. intensity (recency)	5.27	5.00	2.76	5.25	5.00	2.72	0.03	0.763
Collab. intensity (joint patents)	2.01	1.00	2.64	1.93	1.00	2.75	0.08	0.384
Collab. intensity (joint tenure)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Collab. inventive productivity (pre-death)	19.93	10.00	25.80	17.24	9.00	23.87	2.69	0.002***
Organizational characteristics	**Deceased (N = 1774)**			**Pseudo-deceased (N = 1605)**				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Knowledge management capabilities	0.82	0.91	0.23	0.82	0.89	0.22	0.00	0.702
Hiring capabilities	0.14	0.05	0.26	0.10	0.05	0.19	0.04	0.000***

Notes: This table presents summary statistics of pre-death characteristics of deceased co-inventors and their matched control group. The unit of observation is at the deceased co-inventor (first part) or remaining inventor (second and third part) level. Reported p-values based on an unpaired t-test. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Table A3.5: Pre-death characteristics of remaining inventors (Internal vs external collaborator loss)

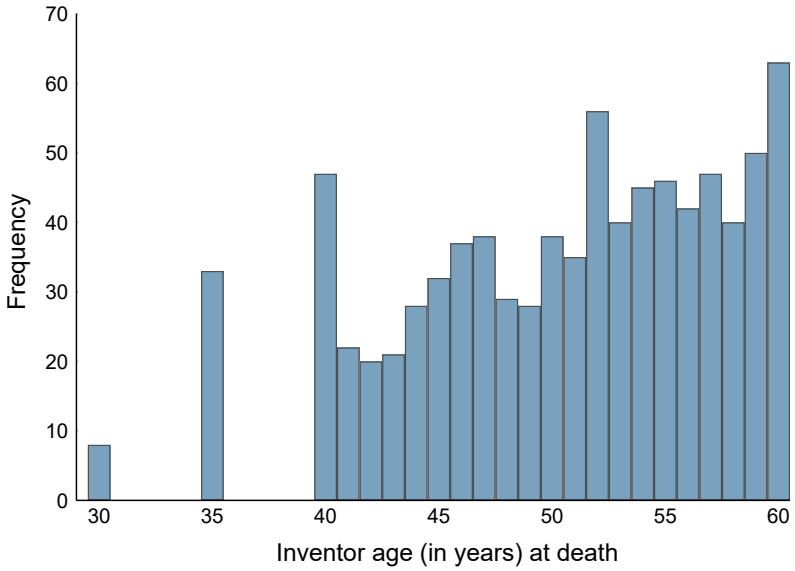
Inventors	Internal collaborators			External collaborators				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Patents (Lifetime)	11.20	7.00	10.20	11.19	7.00	10.32	0.02	0.950
Age	44.93	44.00	8.30	46.13	45.00	10.13	−1.21	0.000***
Male	0.92	1.00	0.27	0.93	1.00	0.26	−0.01	0.289
Organization tenure	11.63	10.00	8.14	8.13	6.00	7.57	3.51	0.000***
Organization size	5952.84	1668.00	10676.89	3772.59	1059.00	7629.05	2180.25	0.000***
Organization age	23.85	28.00	11.40	21.21	26.00	12.28	2.64	0.000***
Years since last patenting	1.65	1.00	2.13	2.41	2.00	2.48	−0.76	0.000***

Characteristics of the lost collaborator	Internal collaborators			External collaborators				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Internal collaborator	1.00	1.00	0.00	0.00	0.00	0.00	1.00	
Knowledge similarity	0.74	0.83	0.26	0.65	0.73	0.30	0.10	0.000***
Knowledge overlap	0.58	0.58	0.24	0.49	0.49	0.26	0.09	0.000***
Collab. network size (excl. common inv.)	11.28	5.00	16.66	11.78	6.00	15.13	−0.49	0.196
Collab. network size (incl. common inv.)	17.58	11.00	19.45	17.45	11.00	17.10	0.12	0.778
Collab. intensity (recency)	4.16	4.00	2.78	5.26	5.00	2.74	−1.10	0.000***
Collab. intensity (joint patents)	2.56	1.00	4.06	1.98	1.00	2.69	0.59	0.000***
Collab. intensity (joint tenure)	10.19	9.17	6.56	0.00	0.00	0.00	10.19	0.000***
Collab. inventive productivity (pre-death)	17.88	8.00	24.67	18.65	9.00	24.93	−0.77	0.194

Organizational characteristics	Internal collaborators			External collaborators				
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.	p-value
Knowledge management capabilities	0.89	0.92	0.14	0.82	0.90	0.23	0.07	0.000***
Hiring capabilities	0.08	0.05	0.16	0.12	0.05	0.23	−0.04	0.000***

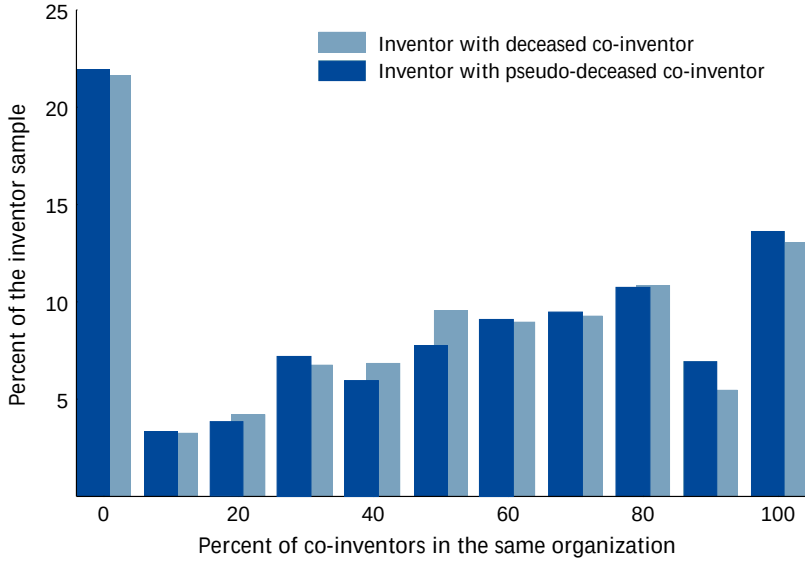
Notes: This table presents summary statistics of pre-death characteristics of inventors experiencing internal collaborator loss (N=3379) and inventors experiencing external collaborator loss (N=3604). The unit of observation is at the remaining inventor level. Reported p-values based on an unpaired t-test. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Figure A3.1: Age of deceased co-inventors



Notes: The graph plots the age of the deceased co-inventors at the time of death. Age below 40 is coarsened in this graph to adhere to data confidentiality regulations of the IAB.

Figure A3.2: Co-inventors in the same organization



Notes: For the remaining inventors in the estimation sample, the graph plots the percent of their co-inventors employed in the same establishment in the year prior to the death event. Only co-inventors on patents prior to the death are considered. Inventor-level shares are rounded to the closest 10% to adhere to data confidentiality regulations of the IAB.

A4 Main results

Table A4.1: Impact of internal and external collaborator loss on inventive productivity – simple and citation-weighted patent counts (Event study estimates)

	Patents (simple counts)			Patents (citation-weighted)		
	(1)	(2)		(3)	(4)	
Death year	All	External	Internal	All	External	Internal
−11/−10	0.025	−0.013	0.056	−0.034	−0.083	0.007
	(0.054)	(0.061)	(0.072)	(0.069)	(0.087)	(0.083)
−9/−8	−0.019	−0.039	−0.006	−0.086	−0.107	−0.070
	(0.052)	(0.064)	(0.073)	(0.069)	(0.090)	(0.087)
−7/−6	0.019	0.055	−0.019	0.021	0.087	−0.042
	(0.047)	(0.060)	(0.063)	(0.058)	(0.080)	(0.082)
−5/−4	0.030	0.070	−0.009	0.012	0.056	−0.030
	(0.040)	(0.059)	(0.059)	(0.053)	(0.070)	(0.073)
−3/−2	0.025	0.036	0.013			
	(0.032)	(0.047)	(0.050)			
−1				−0.106*	−0.130	−0.082
				(0.055)	(0.080)	(0.078)
0/1	−0.005	−0.063	0.048	−0.098**	−0.193***	−0.010
	(0.033)	(0.043)	(0.050)	(0.049)	(0.073)	(0.071)
2/3	−0.004	−0.062	0.049	−0.049	−0.165**	0.058
	(0.035)	(0.050)	(0.050)	(0.053)	(0.076)	(0.075)
4/5	−0.048	−0.117**	0.015	−0.085	−0.151*	−0.025
	(0.039)	(0.050)	(0.056)	(0.062)	(0.081)	(0.083)
6/7	−0.022	−0.011	−0.032	−0.107	−0.136	−0.080
	(0.046)	(0.061)	(0.060)	(0.065)	(0.086)	(0.086)
8	0.066	0.033	0.093	−0.020	−0.074	0.026
	(0.046)	(0.067)	(0.065)	(0.065)	(0.085)	(0.094)
Inventor FE	Yes	Yes		Yes	Yes	
Inventor age FE	Yes	Yes		Yes	Yes	
Match group×rel. year FE	Yes	Yes		Yes	Yes	
Clusters	856	856		856	856	
Observations	124168	124168		124168	124168	
Adj. R2	0.37	0.37		0.30	0.30	
DV mean	0.65	0.65		0.69	0.69	

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. In regressions (1) and (2), the dependent variable is the simple patent count, and in (3) and (4), patents are weighted by forward citations. The dependent variables are winsorized at the 95th percentile. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Estimates are for years relative to the death year of the deceased co-inventor. For citation-weighted outcomes, we normalize effects to the two-year bin $t-3/t-2$, as they can already be affected in the pre-period if future, citation-generating patents are never filed due to the collaborator death. For patent-related outcomes, such potential contamination is likely less severe. * p<0.1, ** p<0.05, *** p<0.01.

Table A4.2: Impact of collaborator loss on inventive productivity – regression results for Figure 4 (DiD estimates)

	Knowledge complementarity		Collaborator network size			Collaboration intensity			
	(1) Patent class similarity	(2) Patent class overlap	(3) Excluding common inv.	(4) Including common inv.	(5) Same tech. specializ.	(6) Recency	(7) Joint patents	(8) Recent joint pat.	(9) Joint tenure
Internal collaborator loss:	−0.001	0.051	0.058*	0.032	0.040	0.022	0.010	−0.001	0.015
– Less relevant collaborators	(0.055)	(0.054)	(0.033)	(0.032)	(0.032)	(0.035)	(0.034)	(0.045)	(0.046)
Internal collaborator loss:	0.033	0.017	−0.063	−0.062	−0.020	0.027	0.034	0.047	0.032
– More relevant collaborators	(0.034)	(0.036)	(0.065)	(0.066)	(0.060)	(0.054)	(0.050)	(0.039)	(0.039)
External collaborator loss:	0.037	0.030	−0.029	−0.036	−0.076**	−0.065*	−0.092**	−0.073*	−0.081**
– Less relevant collaborators	(0.067)	(0.067)	(0.034)	(0.033)	(0.036)	(0.036)	(0.038)	(0.041)	(0.034)
External collaborator loss:	−0.106***	−0.106***	−0.217**	−0.245***	−0.134	−0.149**	−0.072	−0.097*	
– More relevant collaborators	(0.036)	(0.038)	(0.085)	(0.090)	(0.094)	(0.072)	(0.057)	(0.052)	
Δ External-Internal	0.038	−0.021	−0.087*	−0.069	−0.116**	−0.087*	−0.102*	−0.072	−0.113**
– Less relevant collaborators	(0.085)	(0.087)	(0.050)	(0.048)	(0.047)	(0.050)	(0.054)	(0.061)	(0.052)
Δ External-Internal	−0.140***	−0.123**	−0.154*	−0.184*	−0.114	−0.176**	−0.106	−0.144**	
– More relevant collaborators	(0.051)	(0.050)	(0.093)	(0.098)	(0.104)	(0.085)	(0.075)	(0.065)	
Inventor FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	856	856	856	856	851	856	856	856	856
Observations	124168	124168	124168	124168	123692	124168	124168	124168	124168
Adj. R2	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
DV mean	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (e.g., row Δ External-Internal – Less relevant collaborators reports $\beta^{real}_{Ext,Less\,rel.} - \beta^{real}_{Int,Less\,rel.}$). More relevant collaborators are such with low patent class similarity or overlap, many (non-common) co-inventors or colleagues, low joint patenting recency, many joint patents or high joint tenure. For external collaborator loss, joint tenure is zero by definition, so the 'more relevant collaborator' estimate is missing. We split the sample at the 75th percentile, except for joint patenting recency, where more relevant collaborators are those at the 25th percentile and below. * p<0.1, ** p<0.05, *** p<0.01.

Table A4.3: Impact of collaborator loss on inventive productivity – knowledge management capabilities (DiD estimates)

	Patents	Patents with ... collaborator(s)				Patents relying on ...	
	(1) All	(2) at least one new	(3) only new	(4) only old	(5) at least one newly hired	(6) organization knowledge	(7) only other knowledge
Internal collaborator loss:	−0.064	−0.005	0.034*	−0.020	−0.015	−0.057*	−0.004
– Low capabilities	(0.051)	(0.033)	(0.019)	(0.029)	(0.028)	(0.034)	(0.042)
Internal collaborator loss:	0.107**	0.041	0.037*	0.015	0.021	0.158**	−0.014
– High capabilities	(0.046)	(0.036)	(0.020)	(0.040)	(0.037)	(0.067)	(0.075)
External collaborator loss:	−0.097	−0.048	−0.013	−0.052	−0.044	−0.056	−0.029
– Low capabilities	(0.064)	(0.038)	(0.023)	(0.039)	(0.033)	(0.039)	(0.052)
External collaborator loss:	−0.095	−0.031	−0.010	−0.048	0.036	−0.065	−0.037
– High capabilities	(0.060)	(0.040)	(0.022)	(0.035)	(0.038)	(0.047)	(0.054)
Δ Internal loss: High–Low	0.171**	0.045	0.003	0.035	0.036	0.215**	−0.010
	(0.076)	(0.054)	(0.031)	(0.054)	(0.051)	(0.085)	(0.099)
Δ External loss: High–Low	0.002	0.017	0.003	0.004	0.080	−0.009	−0.008
	(0.088)	(0.053)	(0.028)	(0.055)	(0.051)	(0.064)	(0.078)
Inventor FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	695	695	695	695	695	695	695
Observations	100118	100118	100118	100118	100118	100118	100118
Adj. R2	0.37	0.27	0.13	0.27	0.23	0.33	0.31
DV mean	0.72	0.47	0.25	0.22	0.21	0.33	0.47

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (e.g., row Δ Internal loss: High–Low reports $\beta^{real}_{Int,High} - \beta^{real}_{Int,Low}$). The table splits the sample by the knowledge management capabilities of the inventor's organization (median splits within the internal/external collaborator loss subsamples). The dependent variables are simple patent counts winsorized at the 95% level. In columns 2-7, the dependent variables are counts of patents of the remaining inventor that were joint with at least one other inventor they had never co-patented with previously (2), exclusively with other inventors they had never co-patented with (3), etc. In column 5, at least one other inventor joined the organization in t or the preceding two years. Column (6) counts patents with at least one backward citation to a previous patent of the inventor's organization, and (7) counts patents without any such backward citation. * p<0.1, ** p<0.05, *** p<0.01.

Table A4.4: Impact of collaborator loss on inventive productivity – hiring capabilities (DiD estimates)

	Patents	Patents with ... collaborator(s)				Patents relying on ...	
	(1) All	(2) at least one new	(3) only new	(4) only old	(5) at least one newly hired	(6) organization knowledge	(7) only other knowledge
Internal collaborator loss:	−0.001	−0.006	0.024*	−0.008	−0.018	0.044	−0.019
– Low capabilities	(0.031)	(0.023)	(0.013)	(0.022)	(0.020)	(0.036)	(0.040)
Internal collaborator loss:	0.165**	0.124**	0.082***	0.042	0.112**	0.056	0.097
– High capabilities	(0.082)	(0.049)	(0.030)	(0.048)	(0.047)	(0.055)	(0.061)
External collaborator loss:	−0.103**	−0.068**	−0.035**	−0.035	−0.034	−0.047**	−0.051
– Low capabilities	(0.041)	(0.030)	(0.015)	(0.023)	(0.026)	(0.023)	(0.036)
External collaborator loss:	0.010	0.007	0.019	−0.030	0.031	−0.051	0.037
– High capabilities	(0.075)	(0.054)	(0.028)	(0.038)	(0.045)	(0.048)	(0.058)
Δ Internal loss: High–Low	0.166*	0.130**	0.058*	0.050	0.129**	0.012	0.116
	(0.089)	(0.057)	(0.035)	(0.055)	(0.055)	(0.071)	(0.080)
Δ External loss: High–Low	0.113	0.075	0.053*	0.005	0.065	−0.004	0.088
	(0.088)	(0.067)	(0.032)	(0.048)	(0.057)	(0.056)	(0.073)
Inventor FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	856	856	856	856	856	856	856
Observations	124168	124168	124168	124168	124168	124168	124168
Adj. R2	0.37	0.27	0.13	0.27	0.23	0.34	0.31
DV mean	0.65	0.42	0.23	0.20	0.19	0.27	0.45

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (e.g., row Δ Internal loss: High–Low reports $\beta^{real}_{Int,High} - \beta^{real}_{Int,Low}$). The table splits the sample by the hiring capabilities of the inventor's organization (75th percentile split, but excluding values of one—which are more likely cases of ID changes or other organizational reconfiguration). The dependent variables are simple patent counts winsorized at the 95% level. In columns 2-7, the dependent variables are counts of patents of the remaining inventor that were joint with at least one other inventor they had never co-patented with previously (2), exclusively with other inventors they had never co-patented with (3), etc. In column 5, at least one other inventor joined the organization in t or the preceding two years. Column (6) counts patents with at least one backward citation to a previous patent of the inventor's organization, and (7) counts patents without any such backward citation. * p<0.1, ** p<0.05, *** p<0.01.

Table A4.5: Impact of collaborator loss on inventive productivity with internal collaborator loss – knowledge management and hiring capabilities in combination (DiD estimates)

	(1)	(2)	(3)
Low capabilities knowledge management and hiring	−0.176***		−0.185***
	(0.061)		(0.060)
High capabilities knowledge management and hiring		0.611***	0.644***
		(0.166)	(0.157)
Remainder	0.161***	−0.016	0.113**
	(0.045)	(0.036)	(0.047)
Inventor FE	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes
Clusters	466	466	466
Observations	59320	59320	59320
Adj. R2	0.39	0.39	0.39
DV mean	0.73	0.73	0.73

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$). For variable definitions, see notes of Table A4.3 and Table A4.4. * p<0.1, ** p<0.05, *** p<0.01.

Table A4.6: Impact of collaborator loss on inventive productivity – collaborator inventive productivity (DiD estimates)

	(1) By collaborator inventive productivity (pre-death)	(2) By collaborator inventive productivity (pre-d., residualized)
Internal collaborator loss: Low	0.073	0.056
	(0.045)	(0.050)
Middle	0.069*	0.078**
	(0.040)	(0.037)
High	−0.158**	−0.173**
	(0.073)	(0.070)
External collaborator loss: Low	0.013	−0.073
	(0.053)	(0.061)
Middle	−0.054	−0.025
	(0.037)	(0.035)
High	−0.237**	−0.241**
	(0.118)	(0.116)
Inventor FE	Yes	Yes
Inventor age FE	Yes	Yes
Match group×rel. year FE	Yes	Yes
Clusters	856	849
Observations	124168	123022
Adj. R2	0.37	0.37
DV mean	0.65	0.65

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$). Low and high refer to the lowest and highest quintile of collaborator inventive productivity, middle to the remainder. * p<0.1, ** p<0.05, *** p<0.01.

A5 Robustness

Table A5.1: Impact of collaborator loss on inventive productivity – previous co-work / did the lost collaborator move (DiD estimates)

	Patents (simple counts)		
	(1)	(2)	(3)
Internal collaborator loss	0.024	0.026	0.027
	(0.029)	(0.029)	(0.029)
External collaborator loss	−0.081**		
	(0.034)		
Ext: Never coworkers		−0.107**	−0.107**
		(0.048)	(0.048)
Ext: Previously coworkers		−0.058	
		(0.044)	
- Collaborator moved			−0.119**
			(0.060)
- Collaborator stayed			−0.003
			(0.060)
Inventor FE	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes
Clusters	856	856	856
Observations	124168	124168	124168
Adj. R2	0.37	0.37	0.37
DV mean	0.65	0.65	0.65

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$). We separate external collaborator loss by whether the inventors were previously coworkers (column 2) and, if so, the lost collaborator had moved or stayed with their organization since the last episode of co-working. * p<0.1, ** p<0.05, *** p<0.01.

Table A5.2: Impact of internal and external collaborator loss on inventive productivity – alternative dependent variables (DiD estimates, part 1)

	Patents (simple count)					
	(1) Bin	(2) Bin	(3) W95	(4) W95	(5) W99	(6) PPML-W95
Collaborator loss	−0.012*		−0.027			
	(0.007)		(0.022)			
Internal collaborator loss		0.002		0.024	0.031	−0.001
		(0.010)		(0.029)	(0.047)	(0.052)
External collaborator loss		−0.026**		−0.081**	−0.092*	−0.150**
		(0.011)		(0.034)	(0.053)	(0.071)
Δ Internal loss − External loss		0.028*		0.105**	0.123*	0.148*
		(0.016)		(0.045)	(0.069)	(0.087)
Clusters	856	856	856	856	856	850
Observations	124168	124168	124168	124168	124168	105331
DV mean	0.31	0.31	0.65	0.65	0.80	0.77
	Patents (citation-weighted counts)					
	(1) Bin	(2) Bin	(3) W95	(4) W95	(5) W99	(6) PPML-W95
Collaborator loss	−0.015**		−0.054*			
	(0.006)		(0.030)			
Internal collaborator loss		0.000		0.028	0.050	0.055
		(0.008)		(0.038)	(0.080)	(0.081)
External collaborator loss		−0.030***		−0.141***	−0.193**	−0.195*
		(0.009)		(0.044)	(0.092)	(0.111)
Δ Internal loss − External loss		0.030**		0.169***	0.243**	0.250*
		(0.012)		(0.057)	(0.117)	(0.139)
Clusters	856	856	856	856	856	748
Observations	124168	124168	124168	124168	124168	79490
DV mean	0.20	0.20	0.69	0.69	1.03	1.07
	Patents (family size-weighted counts)					
	(1) Bin	(2) Bin	(3) W95	(4) W95	(5) W99	(6) PPML-W95
Collaborator loss	−0.012*		−0.213**			
	(0.007)		(0.101)			
Internal collaborator loss		0.002		0.032	−0.060	−0.039
		(0.010)		(0.133)	(0.243)	(0.062)
External collaborator loss		−0.026**		−0.473***	−0.683**	−0.174**
		(0.011)		(0.163)	(0.300)	(0.085)
Δ Internal loss − External loss		0.028*		0.505**	0.622	0.135
		(0.016)		(0.216)	(0.386)	(0.113)
Clusters	856	856	856	856	856	850
Observations	124168	124168	124168	124168	124168	105331
DV mean	0.31	0.31	2.78	2.78	3.72	3.27

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). The dependent variables are simple patent counts (first table segment), citation-weighted patent counts (second table segment), and family size-weighted patent counts (third segment). In each segment, the dependent variables are binarized (columns 1-2), winsorized at the 95th percentile (columns 3-4), the 99th percentile (column 5), and estimated via Poisson regression (column 6). The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A5.3: Impact of internal and external collaborator loss on inventive productivity – alternative dependent variables (DiD estimates, part 2)

	Patents (breakthrough)					
	(1) Bin	(2) Bin	(3) W95	(4) W95	(5) W99	(6) PPML-W95
Collaborator loss	−0.009*		−0.009*			
	(0.005)		(0.005)			
Internal collaborator loss		0.005		0.005	0.009	0.047
		(0.006)		(0.006)	(0.011)	(0.082)
External collaborator loss		−0.024***		−0.024***	−0.029**	−0.249**
		(0.008)		(0.008)	(0.013)	(0.112)
Δ Internal loss − External loss		0.029***		0.029***	0.038**	0.297**
		(0.011)		(0.011)	(0.018)	(0.136)
Clusters	856	856	856	856	856	585
Observations	124168	124168	124168	124168	124168	51682
DV mean	0.10	0.10	0.10	0.10	0.14	0.23
	Patents (granted)					
	(1) Bin	(2) Bin	(3) W95	(4) W95	(5) W99	(6) PPML-W95
Collaborator loss	−0.010		−0.015			
	(0.007)		(0.012)			
Internal collaborator loss		−0.001		0.001	−0.001	−0.025
		(0.009)		(0.015)	(0.024)	(0.073)
External collaborator loss		−0.019*		−0.031*	−0.030	−0.122
		(0.010)		(0.017)	(0.028)	(0.099)
Δ Internal loss − External loss		0.018		0.031	0.029	0.097
		(0.014)		(0.022)	(0.034)	(0.132)
Clusters	856	856	856	856	856	793
Observations	124168	124168	124168	124168	124168	85272
DV mean	0.21	0.21	0.29	0.29	0.38	0.43

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). The dependent variables are breakthrough patent counts (first table segment), and counts of granted patents (second segment). In each segment, the dependent variables are binarized (columns 1-2), winsorized at the 95th percentile (columns 3-4), the 99th percentile (column 5), and estimated via Poisson regression (column 6). The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A5.4: Impact of internal and external collaborator loss on inventive productivity – alternative dependent variables (DiD estimates, part 3)

	Patents (simple count, excluding joint with lost coll.)					
	(1) Bin	(2) Bin	(3) W95	(4) W95	(5) W99	(6) PPML-W95
Collaborator loss	−0.003		−0.009			
	(0.008)		(0.022)			
Internal collaborator loss		0.018*		0.057*	0.075	0.092
		(0.011)		(0.030)	(0.050)	(0.059)
External collaborator loss		−0.026**		−0.077**	−0.088	−0.154*
		(0.012)		(0.035)	(0.054)	(0.082)
Δ Internal loss − External loss		0.045***		0.134***	0.164**	0.246**
		(0.017)		(0.046)	(0.072)	(0.099)
Clusters	856	856	856	856	856	727
Observations	124168	124168	124168	124168	124168	90142
DV mean	0.27	0.27	0.56	0.56	0.68	0.76
	Patents (fractional count)					
	(1) Bin	(2) Bin	(3) W95	(4) W95	(5) W99	(6) PPML-W95
Collaborator loss	−0.012*		−0.007			
	(0.007)		(0.008)			
Internal collaborator loss		0.002		0.007	0.009	0.006
		(0.010)		(0.010)	(0.018)	(0.047)
External collaborator loss		−0.026**		−0.023**	−0.027	−0.141**
		(0.011)		(0.011)	(0.018)	(0.070)
Δ Internal loss − External loss		0.028*		0.030**	0.036	0.147*
		(0.016)		(0.015)	(0.025)	(0.083)
Clusters	856	856	856	856	856	850
Observations	124168	124168	124168	124168	124168	105331
DV mean	0.31	0.31	0.20	0.20	0.26	0.24

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). The dependent variables are simple patent counts excluding patents joint with the lost collaborator (first table segment) and fractional patent counts (second table segment). In each segment, the dependent variables are binarized (columns 1-2), winsorized at the 95th percentile (columns 3-4), the 99th percentile (column 5), and estimated via Poisson regression (column 6). The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A5.5: Impact of internal and external collaborator loss on inventive productivity – alternative transformations (DiD estimates)

	log(1+Patents)		ihs(Patents)		log(1+Cit-w. pat)		ihs(Cit-w. pat)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Collaborator loss	−0.014		−0.018		−0.022*		−0.029*	
	(0.012)		(0.015)		(0.013)		(0.017)	
Internal collaborator loss		0.008		0.010		0.009		0.011
		(0.016)		(0.020)		(0.017)		(0.021)
External collaborator loss		−0.036**		−0.048**		−0.055***		−0.071***
		(0.018)		(0.023)		(0.020)		(0.024)
Δ Internal loss − External loss		0.044*		0.058*		0.064**		0.082***
		(0.024)		(0.031)		(0.025)		(0.031)
Inventor FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	856	856	856	856	856	856	856	856
Observations	124168	124168	124168	124168	124168	124168	124168	124168
Adj. R2	0.38	0.39	0.38	0.38	0.32	0.32	0.32	0.32
DV mean	0.36	0.36	0.46	0.46	0.31	0.31	0.40	0.40

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). * p<0.1, ** p<0.05, *** p<0.01.

Table A5.6: Impact of internal and external collaborator loss on inventive productivity – alternative cluster levels (DiD estimates)

Cluster level	(1) (Remaining) Inventor	(2) (Pseudo)-deceased co-inventor	(3) Deceased co-inventor	(4) Rem. inv.'s organization	(5) (P-)dec. co-inv.'s organization	(6) Dec. co-inv.'s organization
Internal collaborator loss	0.024	0.024	0.024	0.024	0.024	0.024
	(0.029)	(0.030)	(0.034)	(0.030)	(0.029)	(0.035)
External collaborator loss	−0.081***	−0.081**	−0.081**	−0.081**	−0.081**	−0.081**
	(0.029)	(0.034)	(0.038)	(0.033)	(0.034)	(0.040)
Δ Internal loss − External loss	0.105***	0.105**	0.105**	0.105**	0.105**	0.105**
	(0.040)	(0.046)	(0.045)	(0.045)	(0.045)	(0.047)
Inventor FE	Yes	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster count	6912	1278	713	1633	856	544
Observations	124168	124168	124168	124168	124168	124168
Adj. R2	0.37	0.37	0.37	0.37	0.37	0.37
DV mean	0.65	0.65	0.65	0.65	0.65	0.65

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The unit of observation is at the inventor-year level. The dependent variable is the simple patent count. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). Column 5 shows the default clustering level, the (pseudo)-deceased co-inventor's organization (both for external and internal remaining inventors). For comparison, in column 1, clustering is at the (remaining) inventor level. In column 2, clustering is at the (pseudo)-deceased co-inventor (collaborator) level. In column 3, clustering is at the deceased co-inventor level, which is equivalent to the match group. In column 4, clustering is at the level of the organization of the (remaining) inventor. In column 6, clustering is at the organization of the deceased co-inventor. Cluster counts deviate from observation numbers reported in other parts of the paper due to singleton observations with respect to match group × year FE. * p<0.1, ** p<0.05, *** p<0.01.

Table A5.7: Impact of internal and external collaborator loss on inventive productivity – alternative FE, subsamples, and matching (DiD estimates)

	Match group×rel. year FE omitted		Recent joint patenting only		Within-organization matching		No soft match		Mahalanobis distance	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Collaborator loss	−0.032		−0.048		−0.066**		−0.012		−0.056**	
	(0.033)		(0.034)		(0.029)		(0.025)		(0.023)	
Internal collaborator loss		0.032		−0.008		−0.020		0.055*		−0.004
		(0.042)		(0.038)		(0.045)		(0.031)		(0.030)
External collaborator loss		−0.093**		−0.104*		−0.139***		−0.081**		−0.115***
		(0.039)		(0.054)		(0.030)		(0.037)		(0.039)
Δ Internal loss − External loss		0.124**		0.096		0.119**		0.136***		0.111**
		(0.049)		(0.062)		(0.054)		(0.046)		(0.052)
Inventor FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Relative year FE	Yes	Yes	No	No	No	No	No	No	No	No
Match group×rel. year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	909	909	602	602	861	861	853	853	915	915
Observations	125443	125443	77681	77681	132657	132657	124270	124270	130791	130791
Adj. R2	0.32	0.32	0.39	0.40	0.36	0.36	0.37	0.37	0.38	0.38
DV mean	0.65	0.65	0.68	0.68	0.68	0.68	0.66	0.66	0.68	0.68

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). Columns 1-2 omit the match group × relative year fixed effects. Columns 3-4 restrict the sample to inventors that had a joint patent with the lost collaborator in the last 4 years, the median of the full sample. Columns 5-6 apply an alternative matching strategy, where pseudo-deceased co-inventors are selected only within the same organization as the deceased co-inventor. In the default specification, the pseudo-deceased co-inventors are selected only outside of the deceased co-inventor's organization to avoid contamination. The same matching criteria are used, but as a series of soft matching criteria to allow for the much reduced number of matching candidates. Columns 7-8 apply an alternative matching strategy, where instead of the soft matching criteria, we randomly retain one pseudo-deceased co-inventor among all candidates. Columns 9-10 apply an alternative matching strategy, where the matching is based on coarsened matching only of gender, technology and organization size group, and the Mahalanobis distance of all remaining characteristics otherwise. See Section 3.3 for details. * p<0.1, ** p<0.05, *** p<0.01.

Table A5.8: Impact of internal and external collaborator loss on inventive productivity – alternative selection of deceased co-inventors (DiD estimates)

	Patents						
	(1) Base	(2) Work (1y)	(3) Work (3y)	(4) Non-zero Salary	(5) All (2)-(4)	(6) All, died $\leq$ 2010	(7) All, died age $\leq$ 55
Internal collaborator loss	0.024	0.029	0.027	0.006	0.016	0.025	0.004
	(0.029)	(0.032)	(0.032)	(0.036)	(0.037)	(0.043)	(0.042)
External collaborator loss	−0.081**	−0.104***	−0.123***	−0.101***	−0.134***	−0.129***	−0.097*
	(0.034)	(0.039)	(0.039)	(0.039)	(0.042)	(0.047)	(0.050)
Δ Internal loss − External loss	0.105**	0.133***	0.150***	0.107**	0.150***	0.154**	0.102
	(0.045)	(0.050)	(0.049)	(0.054)	(0.056)	(0.060)	(0.063)
Inventor FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	856	738	724	631	580	439	440
Observations	124168	102610	101601	86863	77893	60261	58154
Adj. R2	0.37	0.36	0.37	0.36	0.36	0.36	0.36
DV mean	0.65	0.65	0.66	0.65	0.65	0.63	0.66

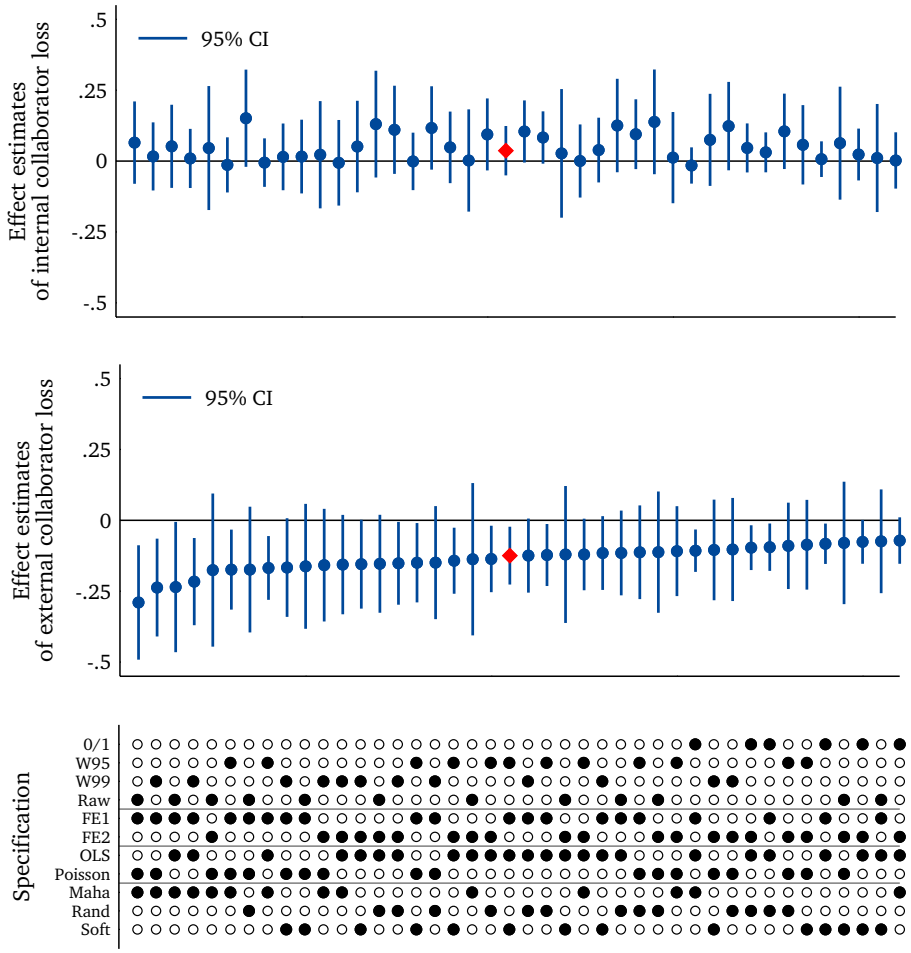
Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). Column 1 reports the baseline, with lost collaborators who died aged 60 or younger and in 2013 or earlier. Columns 2 and 3 further omit cases where the deceased co-inventor was not regularly employed on 30 among the last 365 days or 60 out of the last 1095 days, respectively. Column 4 omits cases with any zero-salary employment in the last three years, which can, for example, arise due to sick leave. Column 5 combines the restrictions of columns 2-4. Column 6 further restricts to deaths up to 2010, which guarantees a longer post-treatment without sample attrition. Column 7 restricts to deaths of inventors aged 55 and below. * p<0.1, ** p<0.05, *** p<0.01.

Table A5.9: Impact of collaborator loss on inventive productivity – size of the inventor's organization (DiD estimates)

	(1)	(2)		
	Base	Internal	External	Difference
<50 employees	−0.017	0.228	−0.084	−0.312
	(0.110)	(0.195)	(0.115)	(0.208)
50-249 employees	−0.037	0.028	−0.067	−0.096
	(0.052)	(0.075)	(0.063)	(0.094)
250-999 employees	−0.004	0.084	−0.103	−0.188**
	(0.042)	(0.056)	(0.067)	(0.093)
≥1000 employees	−0.035	−0.006	−0.097*	−0.091
	(0.032)	(0.037)	(0.054)	(0.062)
Inventor FE	Yes		Yes	
Inventor age FE	Yes		Yes	
Match group×rel. year FE	Yes		Yes	
Clusters	823		823	
Observations	114057		114057	
Adj. R2	0.37		0.37	
DV mean	0.67		0.67	

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$). Column 1 reports the treatment effect of *Death* by firm size. The three columns under (2) report estimates from a regression that separates the treatment effect of *Death* by organization size and whether the loss occurred internally or externally. The third column reports differences between internal and external loss estimates. * p<0.1, ** p<0.05, *** p<0.01.

Figure A5.1: Specification curve for the effect estimates of internal and external collaborator loss



Notes: The figure plots effect estimates from various regression specifications in the form of a specification curve (Simonsohn et al., 2020). 95% confidence intervals. To ease comparison, coefficients are presented as semi-elasticities, i.e., for OLS estimates, we divide the coefficient by the dependent variable mean. The default specification is marked by a red (diamond) point estimate. 0/1 refers to a binarized DV, W95 and W99 to different winsorization levels, and raw to the unwinsorized patent count. FE1 are the default specification following Bernstein et al. (2022), with inventor, age, and deceased co-inventor × relative year fixed effects. FE2 include inventor, relative year, and age fixed effects. Maha, Rand and Soft refer to different matching approaches, see Section 3.3.

A6 Alternative mechanisms

Table A6.1: Impact of collaborator loss on inventive productivity – labor market density (DiD estimates)

	Regional labor market		District	
	(1) Wide	(2) Narrow	(3) Wide	(4) Narrow
Internal collaborator loss: – Low values	0.038	0.129**	0.099	0.065
	(0.057)	(0.057)	(0.067)	(0.056)
Internal collaborator loss: – High values	0.017	−0.003	0.002	0.013
	(0.035)	(0.035)	(0.036)	(0.035)
External collaborator loss: – Low values	−0.012	−0.015	−0.036	−0.058
	(0.056)	(0.064)	(0.062)	(0.056)
External collaborator loss: – High values	−0.129***	−0.120***	−0.110**	−0.097**
	(0.046)	(0.045)	(0.047)	(0.049)
Δ Internal loss: High–Low	−0.021	−0.131*	−0.096	−0.052
	(0.070)	(0.072)	(0.083)	(0.071)
Δ External loss: High–Low	−0.117	−0.105	−0.074	−0.039
	(0.075)	(0.080)	(0.081)	(0.075)
Inventor FE	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes
Clusters	824	824	824	824
Observations	114135	114135	114135	114135
Adj. R2	0.37	0.37	0.37	0.37
DV mean	0.67	0.67	0.67	0.67

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (e.g., row Δ Internal loss: High–Low reports $\beta^{real}_{Int,High} - \beta^{real}_{Int,Low}$). We split by the labor market density of inventors. We count the number of inventors by year and geographic region in the same technological area (wide) or IPC4 category (narrow), with narrow categories indicating the highest replacement suitability. There are 402 districts ("Kreis", 331 in our data), which are grouped into 141 regional labor markets ("Regionale Arbeitsmärkte", 127 in our data). We separate out low values (bottom 25%). * p<0.1, ** p<0.05, *** p<0.01.

Table A6.2: Impact of collaborator loss on inventor resources – team size (DiD estimates)

	Full sample		Years with patents	Collapsed panel
	(1) Patents w. small team	(2) Patents w. large team	(3) Team size (avg)	(4) Team size (avg)
Internal collaborator loss	0.019	0.011	−0.037	−0.048
	(0.023)	(0.022)	(0.093)	(0.110)
External collaborator loss	−0.047*	−0.051**	0.088	0.064
	(0.024)	(0.025)	(0.119)	(0.129)
Δ Internal loss − External loss	0.066**	0.062*	−0.125	−0.112
	(0.032)	(0.033)	(0.162)	(0.162)
Inventor FE	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	No
Match group×rel. year FE	Yes	Yes	Yes	No
Match group FE	No	No	No	Yes
Clusters	856	856	674	648
Observations	124168	124168	34472	6960
Adj. R2	0.32	0.32	0.48	0.37
DV mean	0.33	0.39	4.22	4.12

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). In columns 1 and 2, the dependent variable is the simple patent count separated by patents with few (3 or less) or many (4 or more) inventors, winsorized at the 95th percentile. In columns 3 and 4, the dependent variable is the patents' average inventor team. In column 3, only observations with non-zero patenting are considered, as the averages are undefined otherwise. In columns 1-4, the unit of observation is at the inventor-year level. The collapsed panel regression in column 4 only retains one pre- and one post-treatment observation for each inventor that patented before or after the treatment, respectively. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (rows Δ – e.g., $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). * p<0.1, ** p<0.05, *** p<0.01.

Table A6.3: Impact of collaborator loss on inventive productivity – excluding promotion/leave events (DiD estimates)

	Baseline	Excl. Promotions		Excl. leavers	
	(1)	(2) Post-Death	(3) Post Death-2	(4) Post Death	(5) Post Death-2
Internal collaborator loss	0.024	0.021	0.017	0.008	0.023
	(0.029)	(0.028)	(0.029)	(0.039)	(0.042)
External collaborator loss	−0.081**	−0.069*	−0.078**	−0.108***	−0.112**
	(0.034)	(0.035)	(0.036)	(0.040)	(0.047)
Δ Internal loss − External loss	0.105**	0.090**	0.096**	0.117**	0.135**
	(0.045)	(0.044)	(0.045)	(0.059)	(0.063)
Inventor FE	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes	Yes
Clusters	856	808	795	672	631
Observations	124168	101739	96070	75802	66486
Adj. R2	0.37	0.37	0.36	0.37	0.37
DV mean	0.65	0.63	0.62	0.69	0.70

Notes: This table reports the estimates for β^{real} from a linear regression with inventor, inventor age, and deceased co-inventor times relative year fixed effects. The dependent variable is the simple patent count. The unit of observation is at the inventor-year level. Standard errors clustered at the level of the (pseudo-)deceased co-inventor's organization are in parentheses. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). In column 2, we exclude all inventors who experienced a promotion event on or after the death year. In column 3, we also exclude inventors who had promotion events in the two years prior to death. Columns 4 and 5 implement the same restrictions but with leave events. * p<0.1, ** p<0.05, *** p<0.01.

Table A6.4: Impact of collaborator loss on inventive productivity – inverse probability weighting (DiD estimates)

DV	Patents							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Internal collaborator loss	0.024	0.009			0.095**	0.050		
	(0.029)	(0.031)			(0.046)	(0.044)		
External collaborator loss	−0.081**	−0.103**	−0.206***	−0.170***			−0.246***	−0.182***
	(0.034)	(0.044)	(0.046)	(0.047)			(0.046)	(0.047)
Δ Internal loss − External loss	0.105**	0.111**						
	(0.045)	(0.052)						
Subsample 1	All treated inv.		External treated		Internal treated		External treated	
Subsample 2	All control inv.		Internal control		External control		Internal treated	
Weighting	–	IPW	–	IPW	–	IPW	–	IPW
Inventor FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inventor age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match group×rel. year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster count	856	695	448	448	440	440	348	348
Observations	124168	100118	49663	49663	47043	47043	50431	50431
Adj. R2	0.37	0.37	0.38	0.39	0.38	0.39	0.40	0.41
DV mean	0.65	0.72	0.74	0.74	0.73	0.69	0.75	0.73

Notes: This table shows estimates adjusted for inverse probability weighting (IPW) estimated using the characteristics in footnote 2, compared with unweighted estimates. Otherwise, the specifications follow Table 3. Each reported estimate stands for the treatment effect for the relevant subgroup (e.g., $\beta^{real}_{C_i=1}$) or their difference (row Δ Internal loss − External loss reports $\beta^{real}_{C_i=1} - \beta^{real}_{C_i=0}$). Column 1 shows the default specification from the paper, and in columns 2, we adjust the estimation sample for probability weights. The remaining columns differ in the considered samples, where columns 3, 5 and 7 use unweighted estimates and columns 4, 6 and 8 show IPW-adjusted estimates. Columns 3 and 4 retain treated inventors with external collaborator loss and control inventors with (pseudo) internal collaborator loss. Columns 5 and 6 retain treated inventors with internal collaborator loss and control inventors with (pseudo) external collaborator loss. Columns 7 and 8 retain only treated inventors and compare those with external against those with internal collaborator loss. In columns 2, 4 and 6, IPW balances for treatment (death) vs control, whereas in column 8, IPW balances for internal vs external collaborator loss within the treatment (death) sample. Table A6.5 shows balancing after IPW.
* p<0.1, ** p<0.05, *** p<0.01.

Table A6.5: Difference in pre-death characteristics (samples with inverse probability weighting)

Comparison:	All treated vs all control inv.			Ext. treated vs. int. control			Int. treated vs. ext. control			Ext. treated vs. int. treated		
Variable	Diff.	Std. Err	p-value	Diff.	Std. Err	p-value	Diff.	Std. Err	p-value	Diff.	Std. Err	p-value
Patents (Lifetime)	0.008	(0.281)	0.976	−0.050	(0.461)	0.914	0.182	(0.471)	0.699	−0.006	(0.451)	0.990
Age	−0.003	(0.225)	0.991	0.202	(0.403)	0.616	−0.430	(0.470)	0.360	−0.267	(0.383)	0.485
Male	0.000	(0.007)	0.996	0.001	(0.012)	0.918	0.005	(0.013)	0.719	0.003	(0.012)	0.819
Organization tenure	−0.011	(0.218)	0.961	0.457	(0.416)	0.272	−0.528	(0.544)	0.332	−0.610	(0.436)	0.162
Organization size	−0.005	(0.268)	0.985	0.671	(0.602)	0.265	−0.113	(0.574)	0.845	−0.573	(0.569)	0.314
Organization age	−0.019	(0.303)	0.949	−0.081	(0.471)	0.863	−0.456	(0.535)	0.395	−0.546	(0.534)	0.306
Years since last patenting	0.001	(0.064)	0.987	−0.001	(0.098)	0.989	−0.025	(0.120)	0.838	0.042	(0.107)	0.692
Knowledge similarity	0.000	(0.008)	0.995	0.007	(0.013)	0.595	−0.003	(0.013)	0.844	−0.007	(0.012)	0.584
Knowledge overlap	0.005	(0.007)	0.477	0.004	(0.012)	0.754	0.010	(0.011)	0.403	0.003	(0.011)	0.813
Collab. network size (excl. common inv.)	0.062	(0.440)	0.888	−0.337	(0.636)	0.596	0.026	(0.785)	0.973	0.579	(0.725)	0.425
Collab. network size (incl. common inv.)	−0.572	(0.500)	0.252	−1.076	(0.717)	0.134	−0.572	(0.889)	0.520	0.288	(0.818)	0.725
Collab. intensity (recency)	0.012	(0.075)	0.873	−0.005	(0.119)	0.969	0.036	(0.133)	0.785	0.035	(0.120)	0.773
Collab. intensity (joint patents)	0.002	(0.101)	0.984	−0.052	(0.162)	0.746	0.118	(0.147)	0.423	0.027	(0.146)	0.852
Collab. inventive productivity (pre-death)	0.098	(0.704)	0.890	−0.487	(1.060)	0.646	−0.053	(1.303)	0.968	0.576	(1.070)	0.590
Knowledge management capabilities	0.000	(0.005)	0.993	−0.001	(0.008)	0.886	0.004	(0.008)	0.666	−0.003	(0.009)	0.715
Hiring capabilities	0.001	(0.005)	0.830	−0.001	(0.011)	0.911	0.004	(0.010)	0.685	0.024	(0.015)	0.110

Notes: Differences between subsample 1 and subsample 2 for each of the columns in Table A6.4.

References

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