Scientific resilience: How Italian nuclear physics changed after the Chernobyl disaster

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What do you see?

Trino Vercellese power plant. Designed as a nuclear plant in 1986, after the Chernobyl disaster it was converted into a thermoelectric power plant. It was inaugurated in 1998

Main Questions

- How does human capital adapt to sectoral shocks?
- Are scientific competences completely sector-specific?
- Are scientists able to push the scientific frontier outside their main field?

This paper

- This paper exploits a natural and political shock: the 1986 Chernobyl disaster.
  - Italy was the only country in the world to hold a referendum on the stoppage of production of nuclear energy.
  - Funds to nuclear research were also reduced.
- This paper focuses on the effects in academia
  - Were scientists able to successfully relocate?
  - Did they make significant contributions to new fields?

Preview of Results

- I find that the amount of papers in nuclear fission was reduced by 50% with respect to a counterfactual scenario in which fission was not de-funded.
- Researchers who had already published in fission experienced a reduction of 25% in their citations, and 10% in published papers.
- Compared to non-nuclear scientists, they neither moved more frequently, nor contributed permanently to new fields.

Contribution to the Literature

1. **Science Funding**:
   - Innovation spillovers of large public projects, in defence (Moretti, Steinwender, and Van Reenen 2019; Bhattacharya 2021), pharmaceutics (Azoulay, Joshua S Graff Zivin, et al. 2019) or with state nationalisation programs (Akcigit, Hanley, and Serrano-Velarde 2021).
   - Management and long-run effects of public research investments (Gross and Sampat 2020a; Gross and Sampat 2020b)
   - I show that a single-sector shock did not generate positive research spillovers in contiguous fields.

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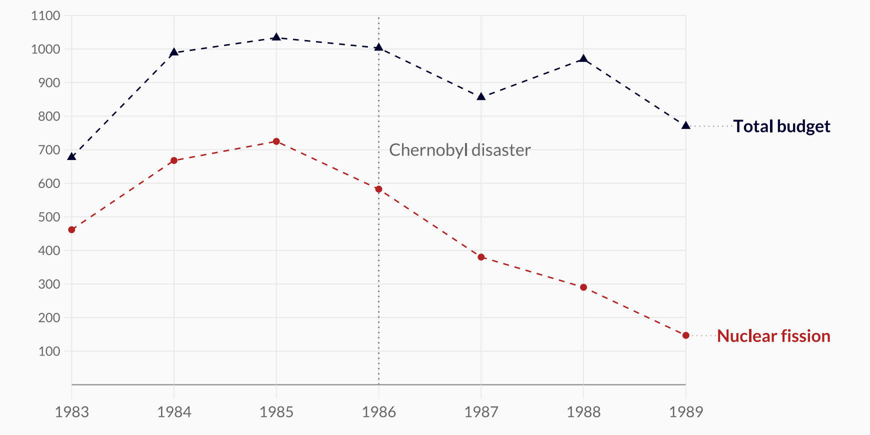
   - Management and long-run effects of public research investments (Gross and Sampat 2020a; Gross and Sampat 2020b)
   - I show that a single-sector shock did not generate positive research spillovers in contiguous fields.
2. **Researchers' careers**:
   - Collaboration (Waldinger 2010; Ductor et al. 2014) and competition (Borjas and Doran 2012) among peers in research.
   - Advancements of the tech. frontier slowed down by superstar scientists (Azoulay, Joshua S. Graff Zivin, and Wang 2010) or sudden stops in collaboration (Iaria, Schwarz, and Waldinger 2018; Jia et al. 2022).
   - I show that nuclear fission researchers were not fully able to contribute to new fields, as their careers slowed down.

A brief history of nuclear energy

- The first nuclear power plants were built in the 50s in Soviet Union, the UK and the US.
- Italy built its first power plants in the 60s, and planned to expand the use of nuclear energy in the 80s
- In April 1986 the Chernobyl disaster happened. The no-nukes movements issued a referendum on the use of nuclear energy in Italy
- In November 1987 80% of the Italian voters (65% turnout) decided to stop the production of nuclear energy.

Funding nuclear research: ENEA budget

- The main institution for research in Nuclear science in Italy was called ENEA
- Before Chernobyl, around 70% of its budget was spent for nuclear fission



Source: *Decreto-legge n.151* (1989). Figures in billion liras

Data: Microsoft Academic Graph

- Data on scientific publications are downloaded from Microsoft Academic Graph
- Publications in nuclear physics in years 1980-1995 are considered.
- Additional data sources:
    - Marx and Fuegi (2022) on patents that cite academic publications
    - *Decreto-legge n.151* (1989) on ENEA budgetary data

Academic production in nuclear fission

Country	Authors	Papers	Institutions	Private inst.	Private papers
IT	126	67	17	3	12 (18%)
FR	272	158	23	1	86 (54%)
US	3823	2998	278	56	1364 (46%)
JP	1053	594	65	13	157 (26%)
DE	539	335	35	6	200 (60%)
GB	297	194	56	8	35 (18%)
RU	137	60	8	0	0 (0%)

Years: 1980-1995
Source: Microsoft Academic Graph

- The US accounted for the largest share of authors and papers
- Nuclear research in Italy was mostly public

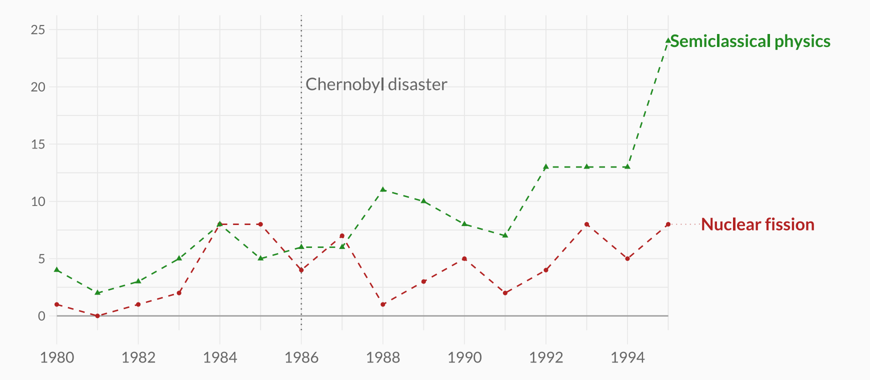
Nuclear fission papers cited in patents

Country	Published Papers	Cited in patents	Produced by privates
IT	67	1	0 (0%)
FR	158	3	1 (33%)
US	2998	92	28 (30%)
JP	594	22	10 (45%)
DE	335	4	2 (50%)
GB	194	12	6 (50%)
RU	60	0	0

Years 1980-1995 are considered.
Data source: Marx and Fuegi (2022)

- Only 3% of the published papers were cited in patents
- In Italy the academia-patenting link seems even weaker

Time series of scientific publications



Source: Microsoft Academic Graph database

- After Chernobyl, publications in nuclear fission did not grow
- Other fields (e.g. semicl. physics) saw the yearly publications increase.

Aggregate results: the model

$$y_{ft} = \alpha + \beta\, Treat_f + \gamma Post_t + \delta Post_t \times Treat_f + \theta_t + \epsilon_{ft}$$

- y_{ft} is the yearly number of publications in each field
- $Treat_f$ is a dummy variable for the treated field (fission)
- $Post_t$ is a dummy variable being equal to 1 if the observation relates to year 1986 or later
- $Post_t \times Treat_f$ is the interaction term in the DiD
- θ_t are year-specific fixed effects

Impact of Chernobyl on aggregate publications

	Nr. pubs		Log nr. pubs		Asinh nr. pubs	
	(1)	(2)	(3)	(4)	(5)	(6)
Post × *Treat*	−5.233**	−7.109***	−0.274	−0.561**	−0.233	−0.604*
	(2.099)	(1.579)	(0.283)	(0.259)	(0.351)	(0.322)
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
N	32	32	32	32	32	32
R^2	0.841	0.920	0.859	0.906	0.854	0.902

*p<0.1; **p<0.05; ***p<0.01

Years 1980-1995 are considered.
Cols. (1), (3) and (5) use semi-classical physics as a control.
Cols. (2), (4) and (6) use a synthetic control in the spirit of Abadie, Diamond, and Hainmueller (2010).

- Synth. control estimates point towards a reduction of 50% of the yearly papers after Chernobyl. ▸ Event study plot

Individual careers: the model

$$y_{it} = \alpha_i + \beta Treat_i + \gamma Post_t + \delta Post_t \times Treat_i + \theta_t + \epsilon_{ft}$$

- y_{ft} is the yearly number of publications (or citations) per author
- α_i is an author-specific fixed effect
- $Treat_i$ is a dummy variable that is equal to 1 if the author had published in fission pre-1986
- $Post_t$ is a dummy variable being equal to 1 if the observation relates to year 1986 or later
- $Post_t \times Treat_i$ is the interaction term in the DiD
- θ_t are year-specific fixed effects

Impact of Chernobyl on individual publications

	Nr. of publications	Log nr. publications	Asinh nr. publications
	(1)	(2)	(3)
Post × *Treat*	-0.937***	-0.102*	-0.121*
	(0.184)	(0.054)	(0.070)
Year F.E.	Yes	Yes	Yes
Author F.E.	Yes	Yes	Yes
N	89,240	89,240	89,240
R^2	0.335	0.335	0.572

*p<0.1; **p<0.05; ***p<0.01

Years 1980-2020 are considered. Every observation is an author-year pair.
The control group is made of authors who published before 1986 in semiclassical physics, medical physics, engineering physics, theoretical physics and quantum mechanics.

- Authors who had published in fission faced a reduction of 10% in their number of publications ▸ Event study plot

Impact of Chernobyl on individual citations

	Nr. of citations	Log nr. citations	Asinh nr. citations
	(1)	(2)	(3)
Post × *Treat*	-53.186***	-0.253**	-0.276**
	(5.400)	(0.115)	(0.135)
Year F.E	Yes	Yes	Yes
Author F.E.	Yes	Yes	Yes
N	89,240	89,240	89,240
R^2	0.196	0.550	0.553

*p<0.1; **p<0.05; ***p<0.01

Years 1980-2020 are considered. Every observation is an author-year pair.
The control group is made of authors who published before 1986 in semiclassical physics, medical physics, engineering physics, theoretical physics and quantum mechanics.

- Authors who had published in fission faced a reduction of 25% in their number of citations ▸ Event study plot

Defining changes of field

- I focus on the frequency of change, i.e. how many times an author has published in a "new field".
- The analysis is performed at author-paper level. I define three alternative indicators for the author-paper pairs.
- $Newfield_{ik}$ is equal to 1 if the $k-th$ paper by author i is associated to at least a field of studies that had not been explored by author i in her previous $k-1$ papers.
- $Newfieldtr_{ik}$ is constructed as $Newfield_{ik}$, but the first paper of every author is such that $Newfieldtr_{i1} = 0$. It captures only transitions after the first paper by any author.
- $Somenewfields_{ik}$ is such that $Somenewfields_{i1} = 0$. Then, for $k > 1$, $Somenewfields_{ik} = 1$ only if at least 50 percent of the fields of studies paper k is associated to have not been explored by all the previous $k-1$ papers by author i.

Frequency of change: the model

$$y_{ip} = \alpha_i + \beta Treat_i + \gamma Post_p + \delta Post_p \times Treat_i + \epsilon_{ip}$$

- y_{ip} can be either $newfield_{ip}$, $newfieldtr_{ip}$ or $Somenewfields_{ip}$
- α_i is an author-specific fixed effect
- $Treat_i$ is a dummy variable that is equal to 1 if the author had published in fission pre-1986
- $Post_p$ is a dummy variable being equal to 1 if the observation relates to year 1986 or later
- $Post_t \times Treat_i$ is the interaction term in the DiD

Frequency of change: results

	New field	New field tr	Some new fields
	(1)	(2)	(3)
Post × *Treat*	-0.083	-0.009	-0.174
	(0.113)	(0.140)	(0.166)
Treat	0.111	0.037	0.111
	(0.106)	(0.134)	(0.149)
Year F.E.	Yes	Yes	Yes
Author F.E.	Yes	Yes	Yes
N	68,134	68,134	68,134
R^2	0.815	0.798	0.752

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Every observation is an author-year pair. Authors who published in nuclear fission before 1986 are considered as treated.
The control group is made of authors who published before 1986 in semiclassical physics, medical physics, engineering physics, theoretical physics and quantum mechanics.

- Nuclear fission scientists did not move to more new fields.

Defining changes of field

- Now I focus only on the transitions to fields that had not been explored before Chernobyl.
- As before, I define three alternative indicators for the author-paper pairs.
- $Newfield_{ik}$ is equal to 1 only if paper k belongs to at least one field of studies that had not been explored by author i before 1986.
- $Somenewfields_{ik}$ is equal to 1 only if at least 50 percent of the fields of studies of paper k have not been associated to any paper of author i before 1986.
- $Brandnewfield_{ik}$ is equal to 1 only if all the fields of studies of paper k have not been associated to any paper of author i before 1986

Post-1986 transition: the model

$$y_{ip} = \alpha_i + \delta Treat_i + \epsilon_{ip}$$

- y_{ip} can be either $Post86 - newfield_{ip}$, $Post86 - somenewfields_{ip}$ or $Post86 - brandnewfield_{ip}$
- α_i is an author-specific fixed effect
- $Treat_i$ is a dummy variable that is equal to 1 if the author had published in fission pre-1986

Post-1986 transition: results

	New field	Some new fields	Brand-new field
	(1)	(2)	(3)
Post × *Treat*	0.028	-0.042	-0.056
	(0.028)	(0.058)	(0.050)
Year F.E.	Yes	Yes	Yes
Author F.E.	Yes	Yes	Yes
N	60,564	60,564	60,564
R^2	0.701	0.527	0.763

*p$<$0.1; **p$<$0.05; ***p$<$0.01

Every observation is an author-year pair. Authors who published in nuclear fission before 1986 are considered as treated.
The control group is made of authors who published before 1986 in semiclassical physics, medical physics, engineering physics, theoretical physics and quantum mechanics.

- Nuclear fission scientists did not expand their pre-1986 stock of knowledge more than other scientists.

Conclusions

- Italian nuclear scientists have not been able to successfully relocate after the defunding of their field.
- They were not able to open the gates of new areas of research, and their careers suffered (both in terms of citations and publications).
- However, the article presents some shortcomings
  - First, the number of authors is relatively small. Next versions should try to enlarge the number of fields that relate to nuclear fission.
  - The Chernobyl shock is interpreted as a shock to science funding. However, in absence of granular budgetary data, it is not possible to compute the elasticity of scientific production w.r.t. fundings
  - When the transition to new fields is studied, measures of network similarity of fields of studies are not taken into account.

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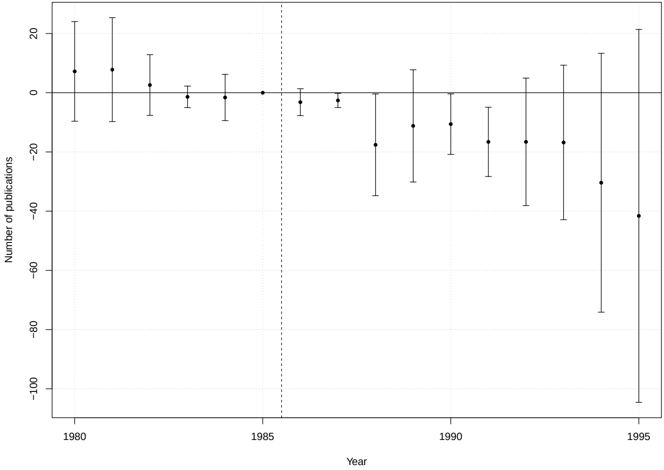
Event study for aggregate publications



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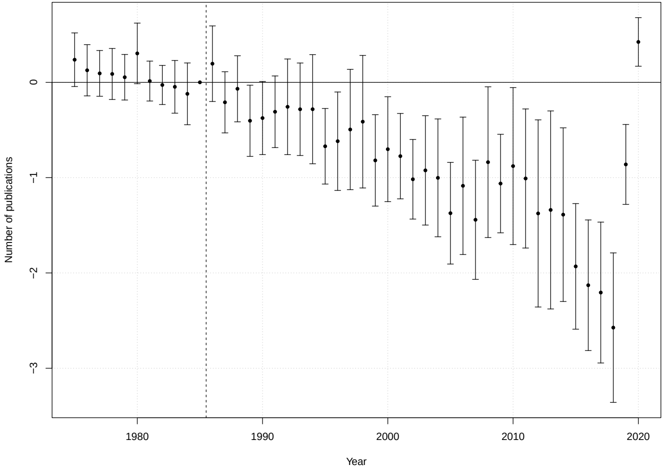
Event study for individual publications



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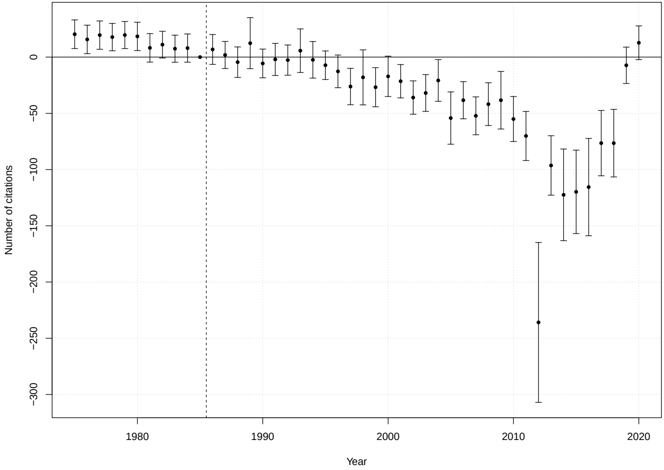
Event study for individual citations



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