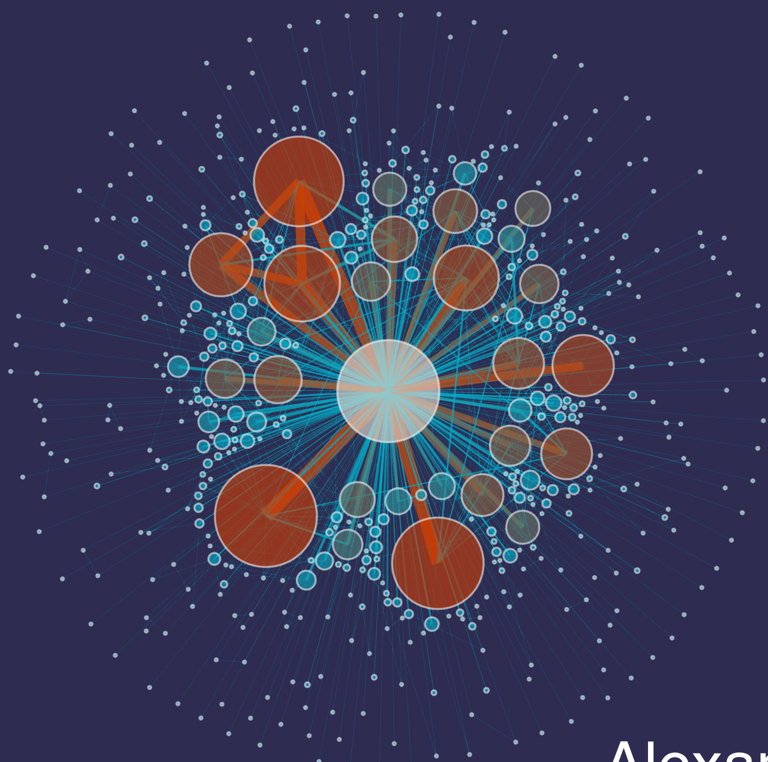
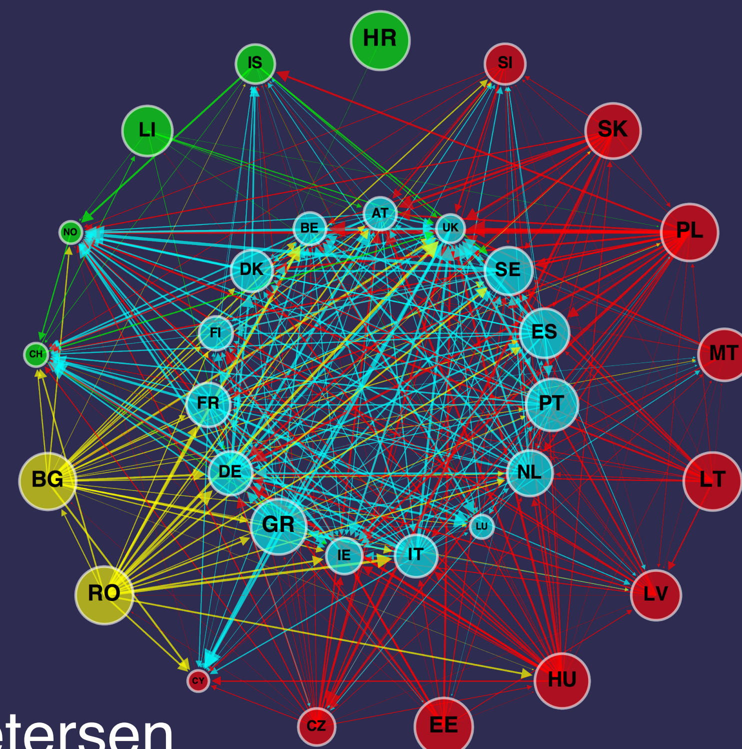
The dynamics of collaboration and its implications — from careers to Europe

LANET’17 - Puebla MX

Paul Erdös collaboration network



EU high-skilled mobility ‘brain-drain’ network

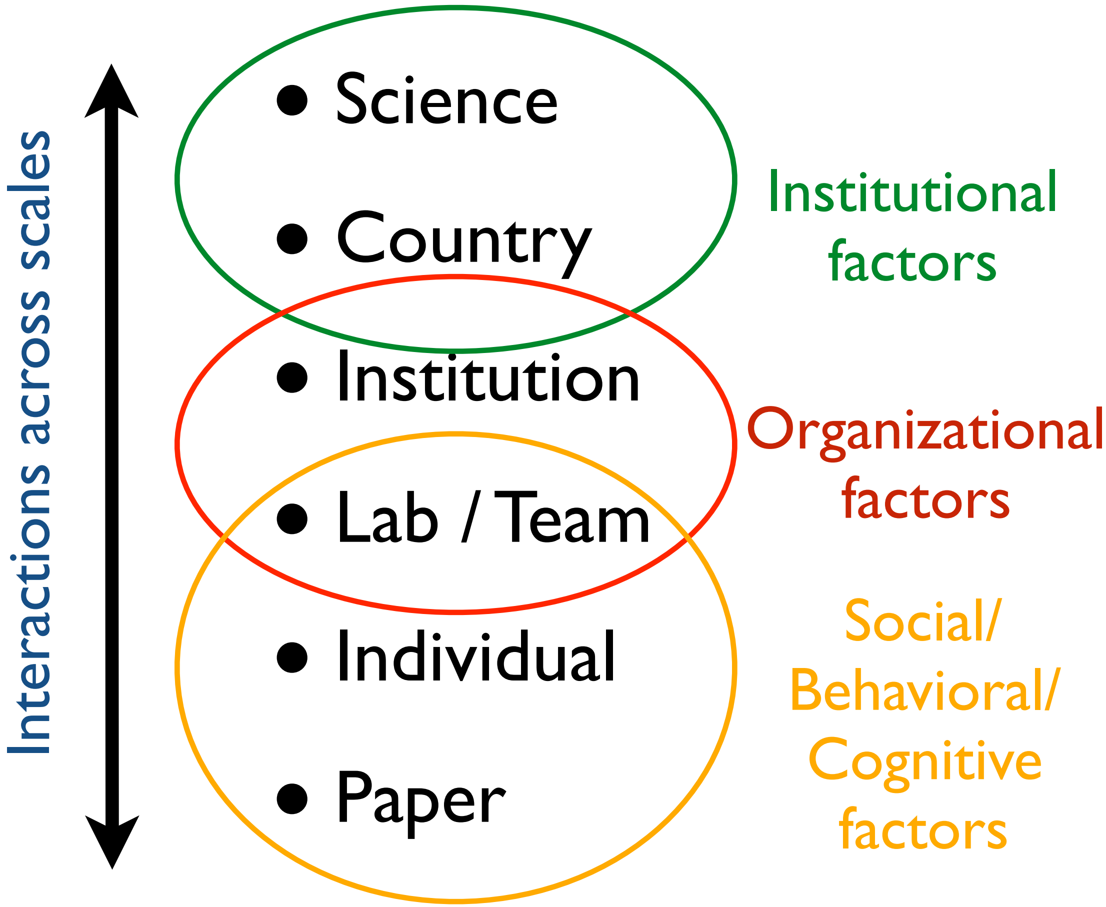


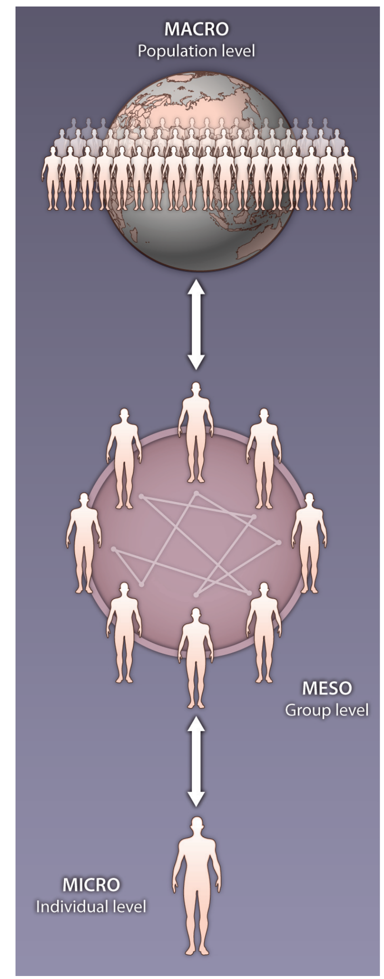
Alexander M. Petersen
Management of Complex Systems Department, mist.ucmerced.edu
UCMERCED
UNIVERSITY OF CALIFORNIA

— *Science of Science* —

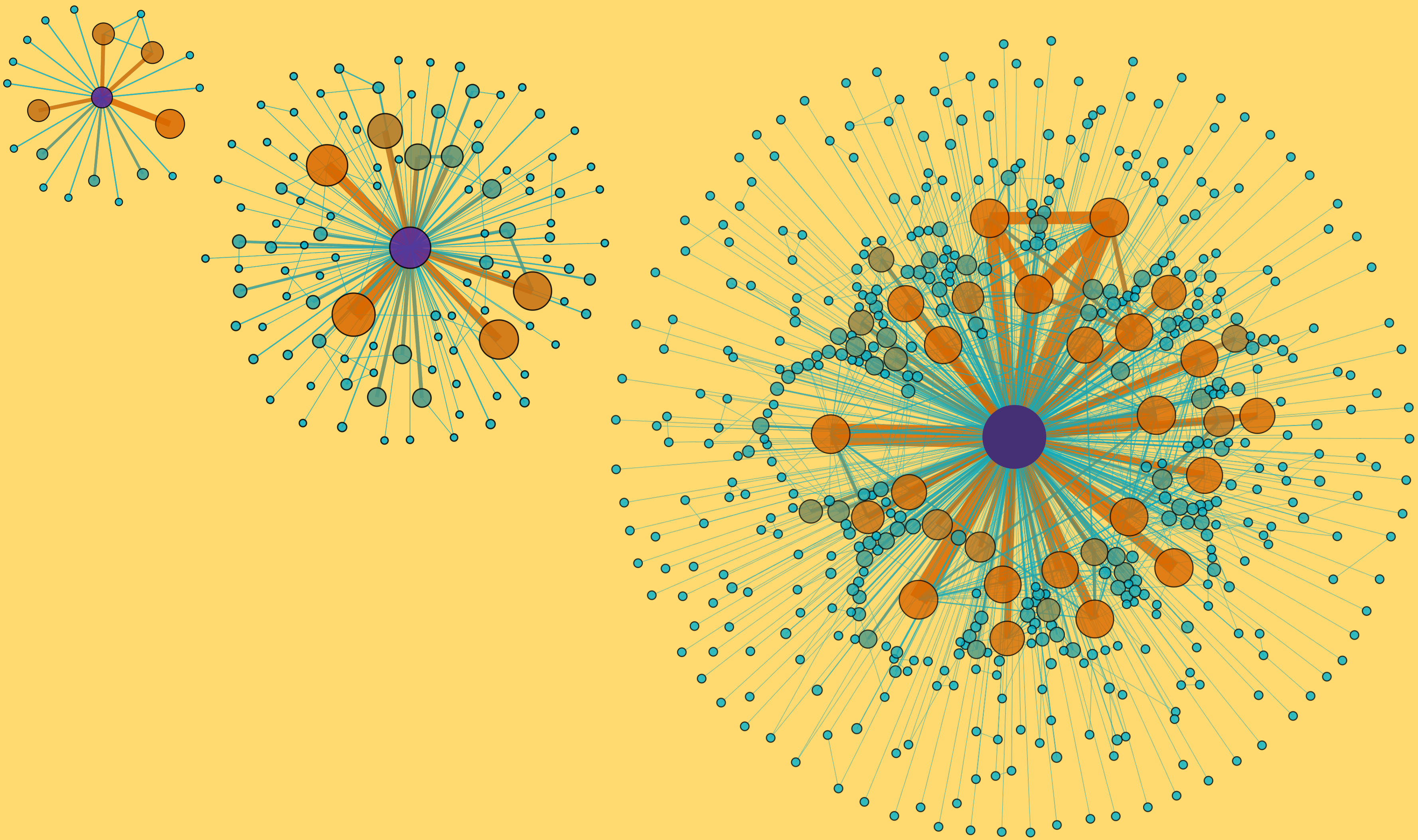
Science is a multi-scale system with emergent complexity. A very practical question is How to measure scientific output and impact at various scales while accounting for systemic heterogeneity

K. Börner, et al. A multi-level systems perspective for the science of team science. Sci. Transl. Med. 2, 49cm24 (2010).





The evolution of careers from a collaboration perspective



Paul Erdös (1913-1996): collaboration network at career age 10, 30, present day*

Ego collaboration network: quantifying *dynamic* & *heterogenous* patterns of collaboration within scientific careers

Sir Andre K. Geim

 # publications, N_i (2012) = 217

S_i = 303 coauthors

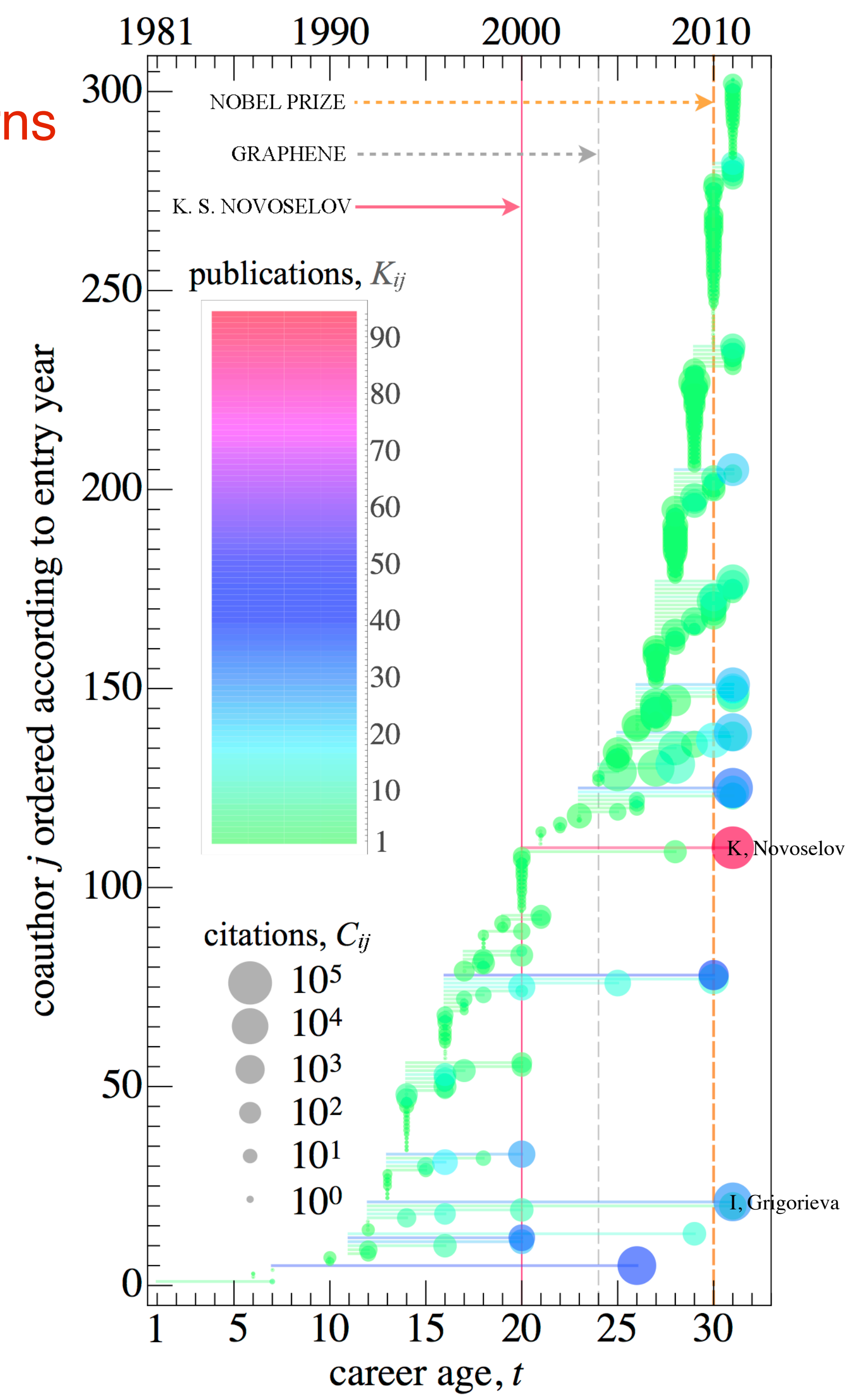
The average copublication duration

$\langle L_i \rangle$ = 2.1 years, $\langle K_i \rangle$ = 3.7 pubs.

- Measuring the duration L_{ij} of the tie (time b/w 1st and last copublication)
- Measuring the intensity K_{ij} of the tie (# of copublications)
- Measuring the net scientific impact C_{ij} of the tie (net citation tally for pubs. between *i* and *j*)

How important are academic "Life partners"?

- Division/Diversity of labor
- Breadth/Depth of expertise
- Risk/Reward sharing
- Ethics of credit distribution & free-riding



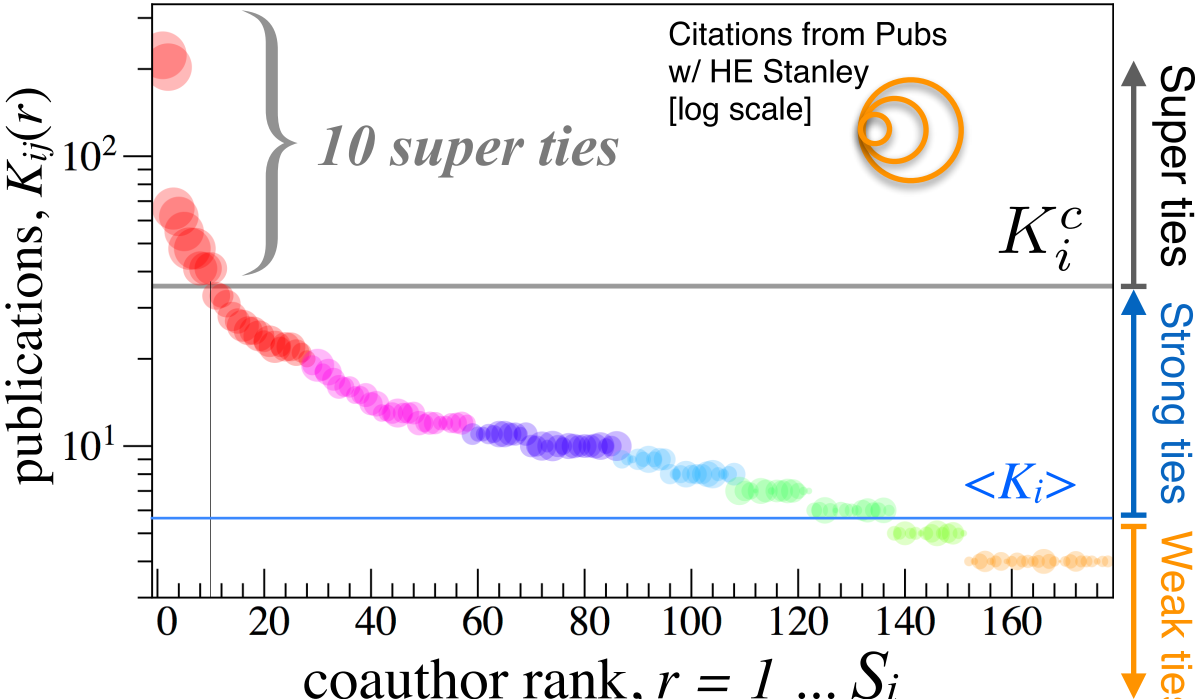
Weak ties, strong ties, and super ties

H. Eugene Stanley

$N_i\,(2010) = 909$ *publications*

$S_i = 541$ *coauthors*

$\langle K_i \rangle = 5.7$ *papers*



rank		K_{ij}	%
1	HAVLIN, S	223	25
2	BULDYREV, SV	203	22
3	AMARAL, LAN	66	7
4	SCIORTINO, F	62	6
5	IVANOV, PC	55	5
6	GOLDBERGER, A	48	
7	PENG, CK	48	
8	GOPIKRISHNAN,	41	
9	PLEROU, V	41	
10	STARR, FW	41	
11	DOKHOLYAN, NV	33	4
12	PAUL, G	33	
13	BUNDE, A	31	3
14	GIOVAMBATTISTA	28	
15	MAKSE, HA	27	
16	CONIGLIO, A	26	
17	URBANC, B	25	
18	CRUZ, L	25	
19	SCALA, A	24	
20	LARRALDE, H	23	
21	MANTEGNA, RN	23	
22	POOLE, PH	22	2

Mathematical definition for extreme outlier in an exponential distribution:

"super tie" threshold $K_i^c = (\langle K_i \rangle - 1)\, Ln(S_i)$

Do super-ties correlate with higher citations?

On average:
- 1 in 25 collaborators qualify as a super-tie
- 1 in 2 publications include a super-tie

Unit of analysis : publication p

Hierarchical "fixed effects" model : 473 researchers indexed by i

Dependent variable = $z_{i,p}$ = the citation impact $c_{i,p,y}$ of publication p normalized to baseline citation levels defined by other papers published in the same year y.

$$z_{i,p} = \frac{(\ln c_{i,p,y} - \langle \ln c_y \rangle)}{\sigma[\ln c_y]}$$

This measure maps $c_{i,p,y}$ to a stable normal distribution N(0,1) >> appropriate for comparing citation impact across time.

$R_{i,p}$ A super-tie indicator variable = 1 if at least one of the coauthors is a super tie, and 0 otherwise. 52% of publications have R=1.

$N_i(t_p)$ number of papers up to year t_p ≈ prestige measure

$a_{i,p}$ number of coauthors ≈ proxy for coordination costs and technology level

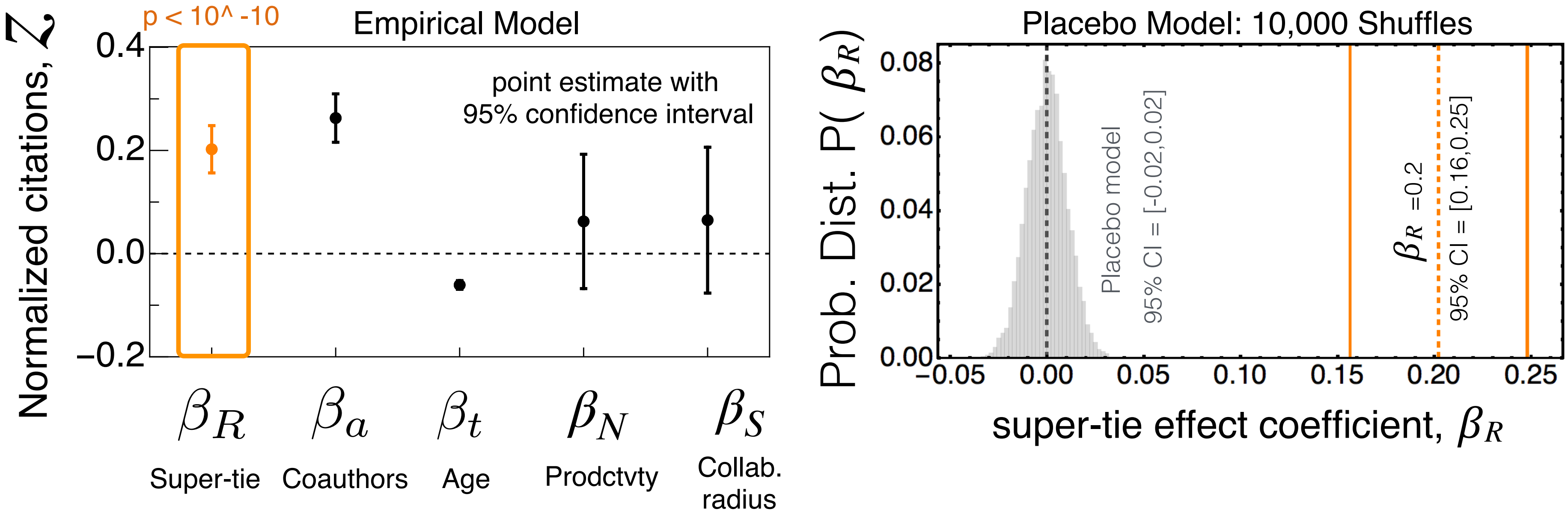
$S_i(t_p)$ number of distinct coauthors up to year t_p ≈ collaboration radius measuring access to new/old team members

t_p publication year of p, measured as a career age, accounting for aging and cumulative advantage effects, learning and prestige

Fixed-effects model - measures each researcher against his/her baseline $z_{i,p}$

$$z_{i,p} = \beta_R R_{i,p} + \beta_a \ln a_{i,p} + \beta_t t_{i,p} + \beta_N \ln N_i(t_p) + \beta_S \ln S_i(t_p) + \beta_i + \epsilon_{i,p}$$

The significant + value of super-ties



Comparing publications with and without a super-tie — **within a researcher's publication portfolio** (i.e. fixed effects) — compared to the author's publications with R=0 (the counterfactual), tho publications with R=1 have 0.2 σ_z higher citations.

In terms of real citations, this citation boost corresponds to a roughly 20% citation increase at the publication level!

Emphasizes ***who*** in addition to ***how many*** coauthors

Plausible explanations: compounding self-citations, reputation arising from larger formal and informal social network; added value of skill complementarity, trust, conviction, commitment, experience, collocation, moral support, risk-profit sharing

Quantifying the impact of weak, strong, and super ties in scientific careers. *PNAS,* 2015

Is Europe Evolving Toward an Integrated Research Area?

Geopolitical borders

EU borders

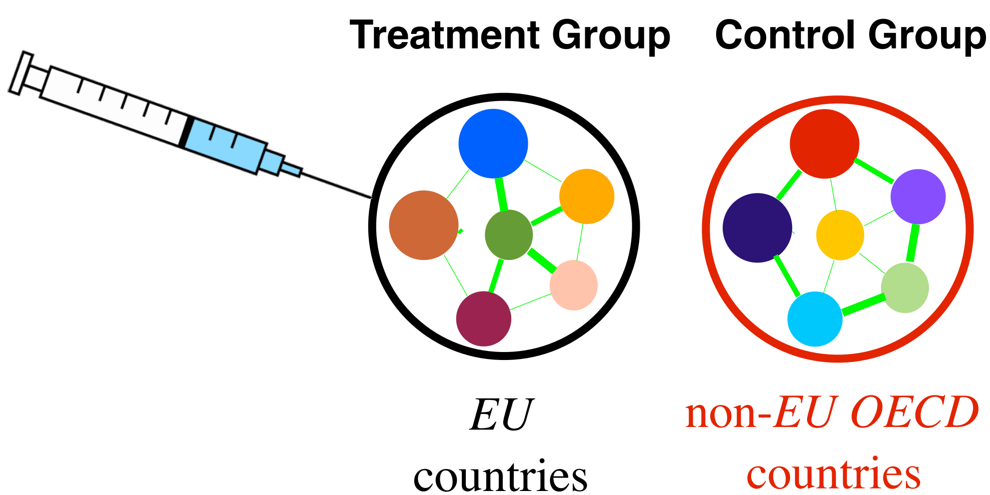
How does this question manifest in the cross-border mobility/collaboration activities in Europe?

Quantifying the impact of EU policies on cross-border R&D integration

EU Horizon 2020 Impact Assessment: one of the 5 key objectives is to “encourage cross-border training and career development, and supporting research infrastructures”

The EU spends ~ 10% of government level R&D budget on programs with explicit cross-border criteria, compared to < 1% for non-EU countries

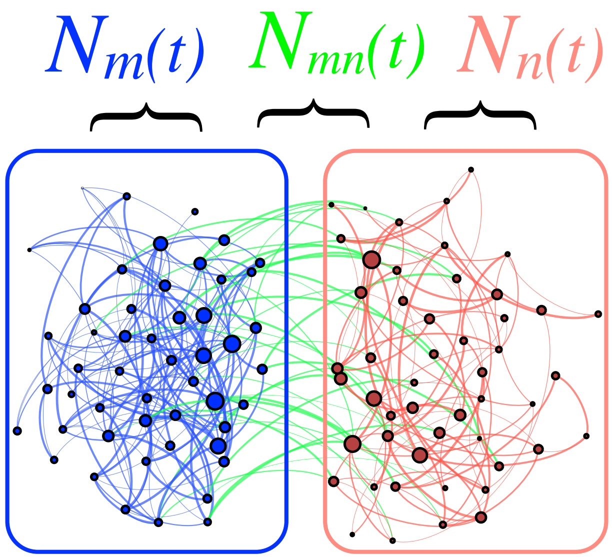
Thus, EU initiatives aimed at integrating the “European Research Area” (ERA) serves as a “treatment”



Methods and Data

NUTS3 regions ≈ province/ district/ county size

<u>Complex networks approach</u>



Country m *Country n*

NUTS3 region in country m

NUTS3 region in country n

cross-border link

<u>Geocoded data</u>

(a) 2.4 million patents filed in the EPO and (b) 0.26 million scientific publications

<u>4 patent networks</u>

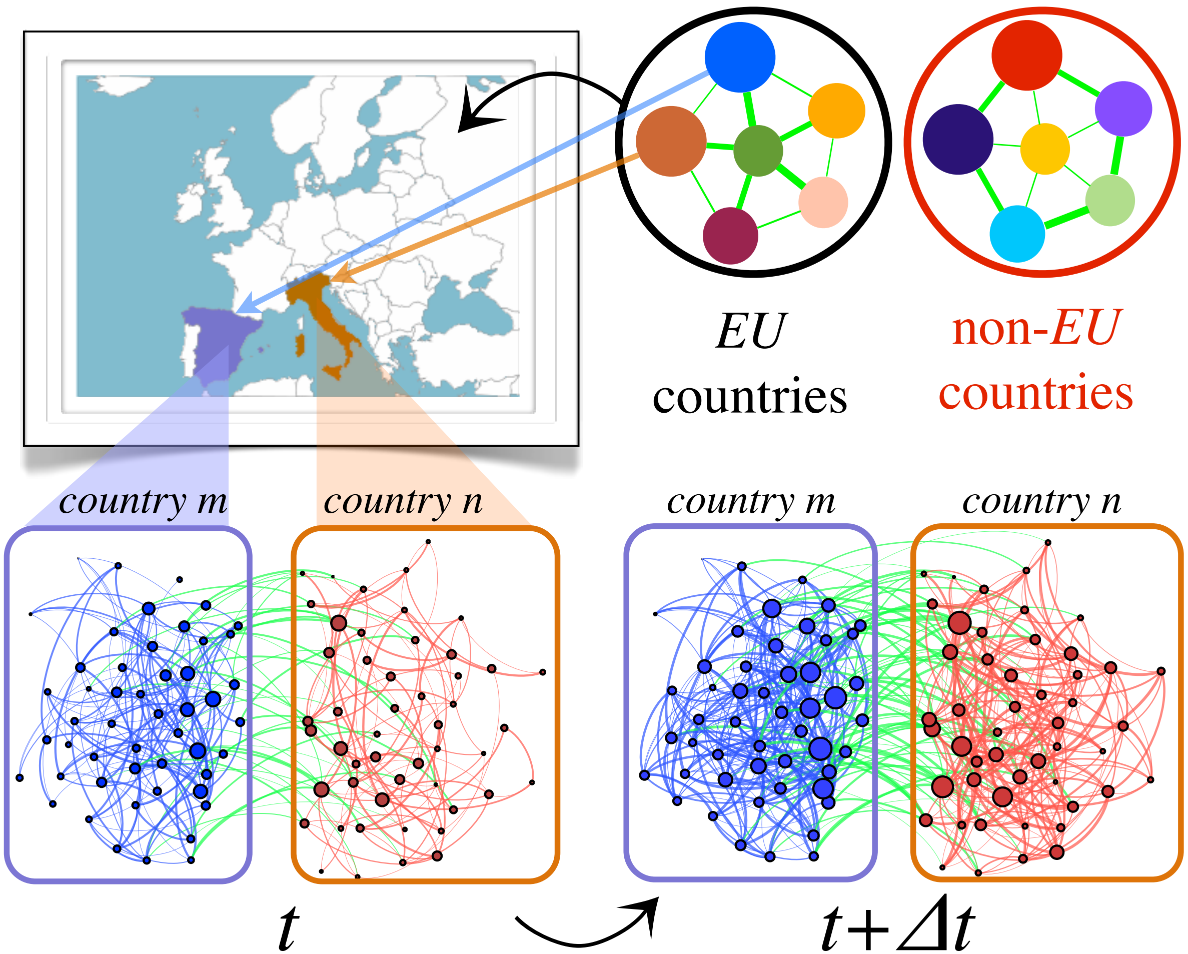
(i) co-inventor
(ii) co-applicant
(iii) citations
(iv) mobility

<u>1 publication network</u>

(v) co-author

Methods and Data

Intra-country -vs- Cross-border Networks



<u>Geocoded data</u>

(a) 2.4 million patents filed in the EPO and
(b) 0.26 million scientific publications

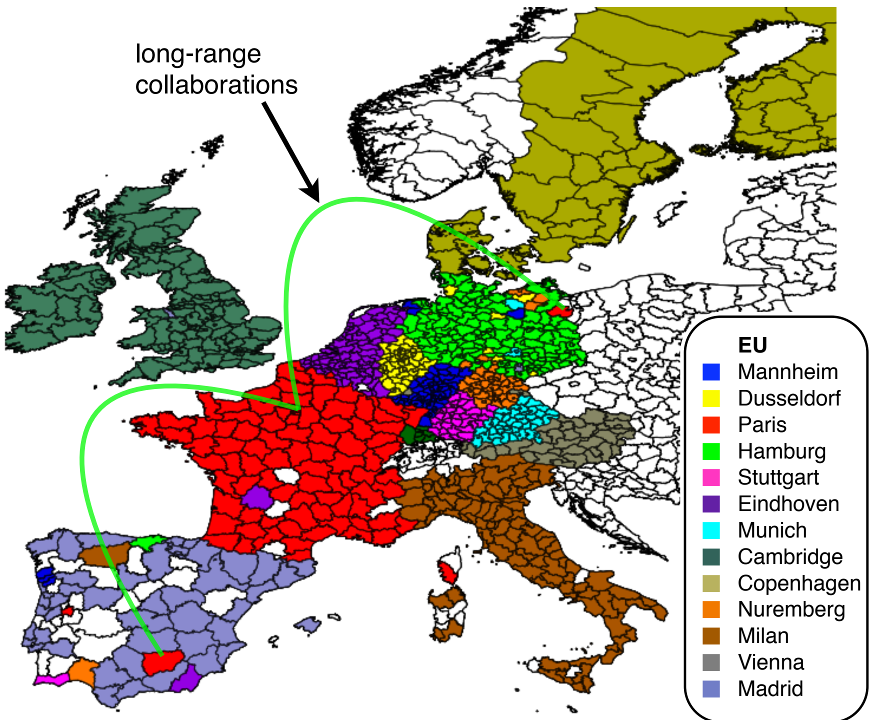
<u>4 patent networks</u>

(i) co-inventor
(ii) co-applicant
(iii) citations
(iv) mobility

<u>1 publication network</u>

(v) co-author

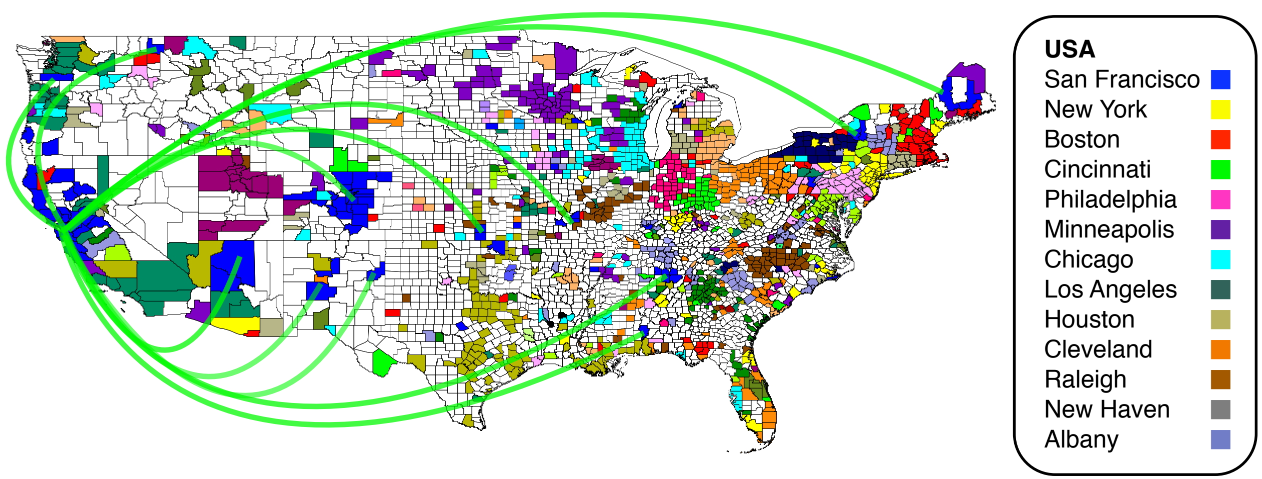
Comparing the community structure of the 2009 EU-15 and US coinventor networks



Q1: Are the scientific borders in the EU any different than the geo-political borders?

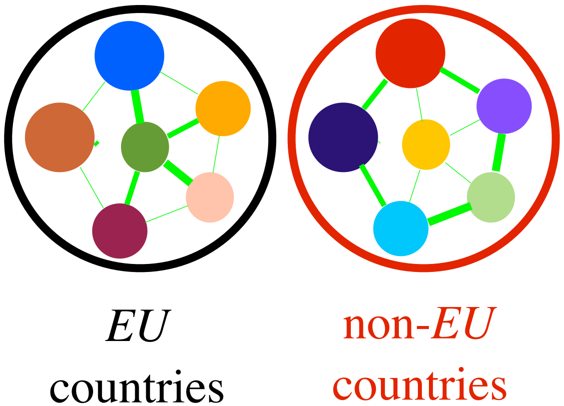
Q2: has there been an intensification in cross-border R&D activity in Europe vis-a-vis other OECD countries (control group used to quantify the "treatment effect")

Community structure of the 2009 EU-15 and USA coinventor network. Communities are labeled by their most-central region and were generated using the Louvain algorithm — communities are sub-sets of nodes (NUTS3 regions) more strongly linked to one another than to nodes outside.

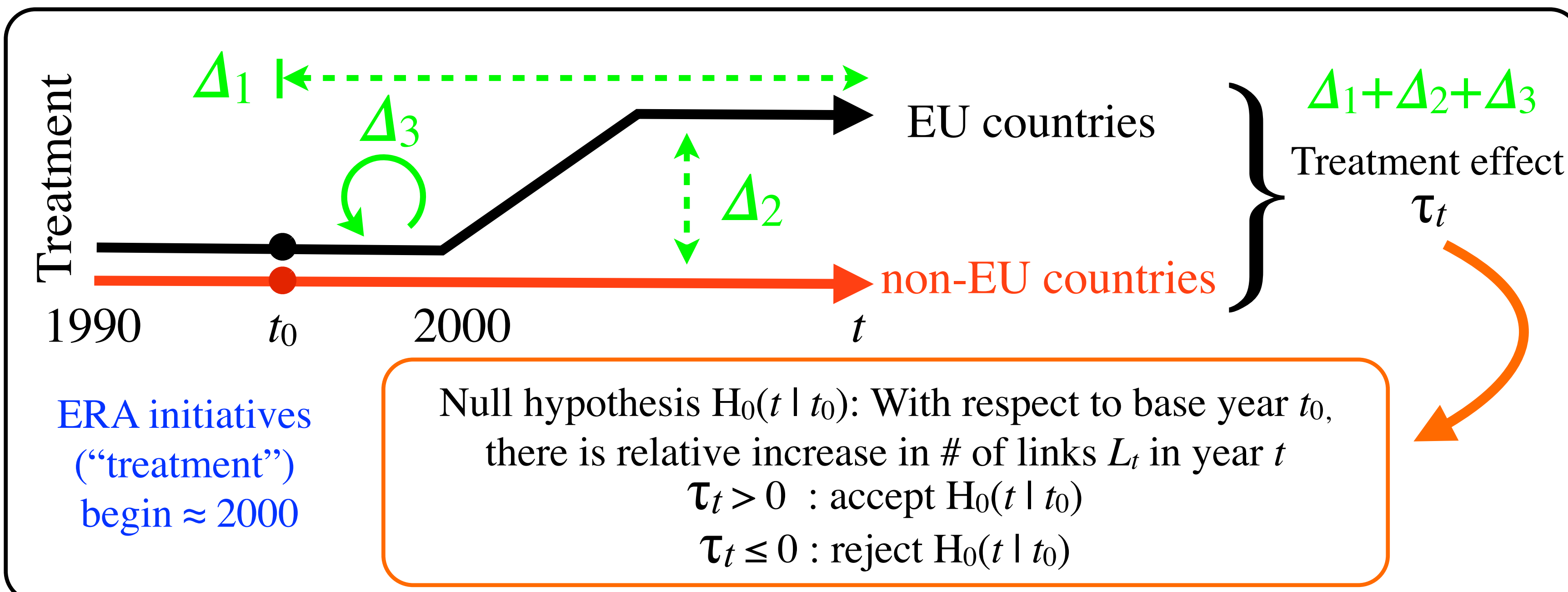


Quantifying the impact of EU policies on cross-border R&D integration

Q: do “treated” EU countries have different cross-border collaboration patterns than “untreated” non-EU countries above global trends



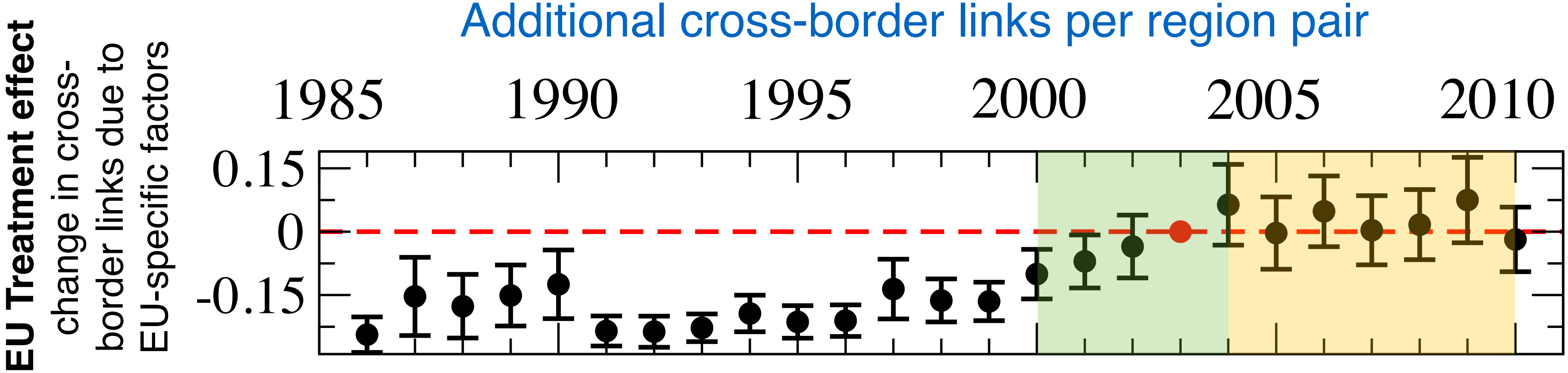
Econometric ZINB model controlling for: borders, distance, technological distance, neighbors, EU vs non-EU



Q2: Is there any positive trend in the rate of cross-border activity within the EU — relative to the world?

Causal (DiDiD) model: We measured the effect of EU institutional integration policies by quantifying the relative rate of cross-border links — comparing a) **within** versus **across**-borders links, b) **EU** vs **Non-EU** links, c) and across time.

Patent co-inventor network:
Additional cross-border links per region pair



Period of positive relative integration

Period of stagnation

Why stagnation since 2004???

Is Europe Evolving Toward an Integrated Research Area? Science, 2014

The evolution of networks of innovators within and across borders: Evidence from patent data Research Policy, 2015

Divergence in Eastern - Western integration within the global science system

With globalization, the rate of international collaboration has largely been increasing, however there is considerable regional variation.

For example, comparing the decade before and after 2004, while Western Europe and North America experienced a 36-42% increase in the rate of cross-border collaboration (per publication), Eastern Europe and Asia have experienced much slower 9% growth.

These diverging trends point to the importance of historical, socio-technological, and geographic factors underlying the globalization of science.

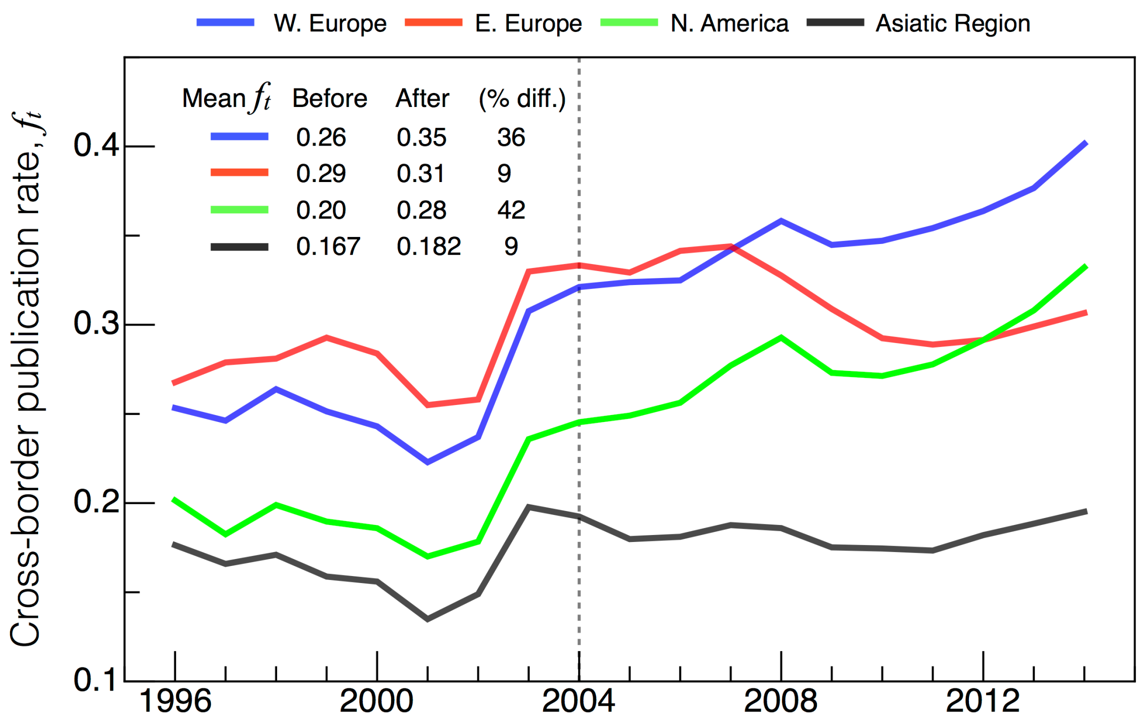


FIG. S1: Global trends in cross-border collaboration by international region: 1996–2014. Source: SCImago Journal & Country Rank based on Scopus [26].

So why have Western and Eastern Europe followed different cross-border collaboration paths?

Estimating cross-border collaboration rates in Europe under the counterfactual — no 2004 EU enlargement — using the Synthetic Control Method (SCM)

RUBIN CAUSALITY MODEL

D. Rubin. "Causal Inference Using Potential Outcomes", J. Am. Stat. Assoc., 2005

If you give a little kid a balloon, how do you really know it makes them happy? And happier by how much?

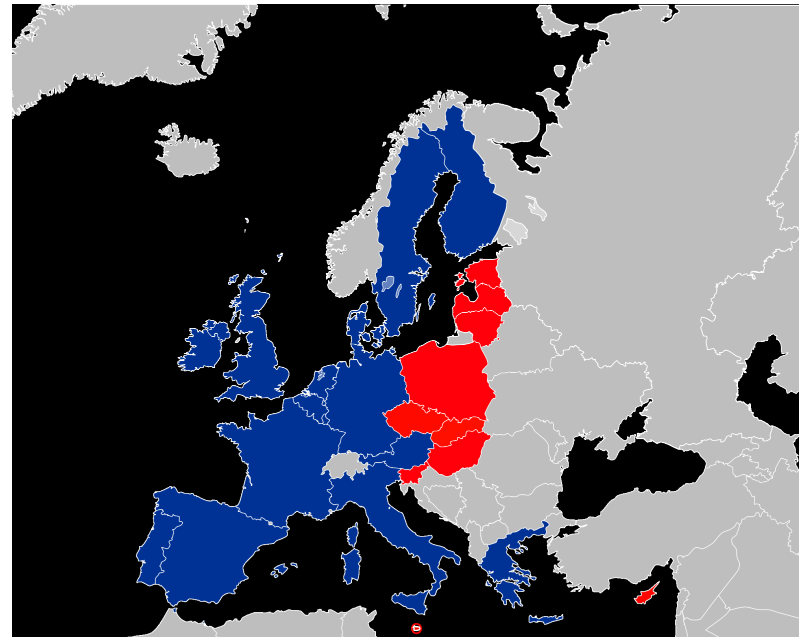
W = 1 : State in which receives balloon
W = 0 : State in which does not receive balloon

W = 1  **W = 0** 

Y(1) : Outcome of child i if W=1
Y(0) : Outcome of *same child* i if W=0

Causal "treatment" effect = Y(1) - Y(0)

Fundamental Challenge: How to measure the counterfactual outcome in a world where there is only one reality — i.e. only one observed outcome, either Y(1) or Y(0) ??



Pre-existing 2004 EU   New 2004 EU

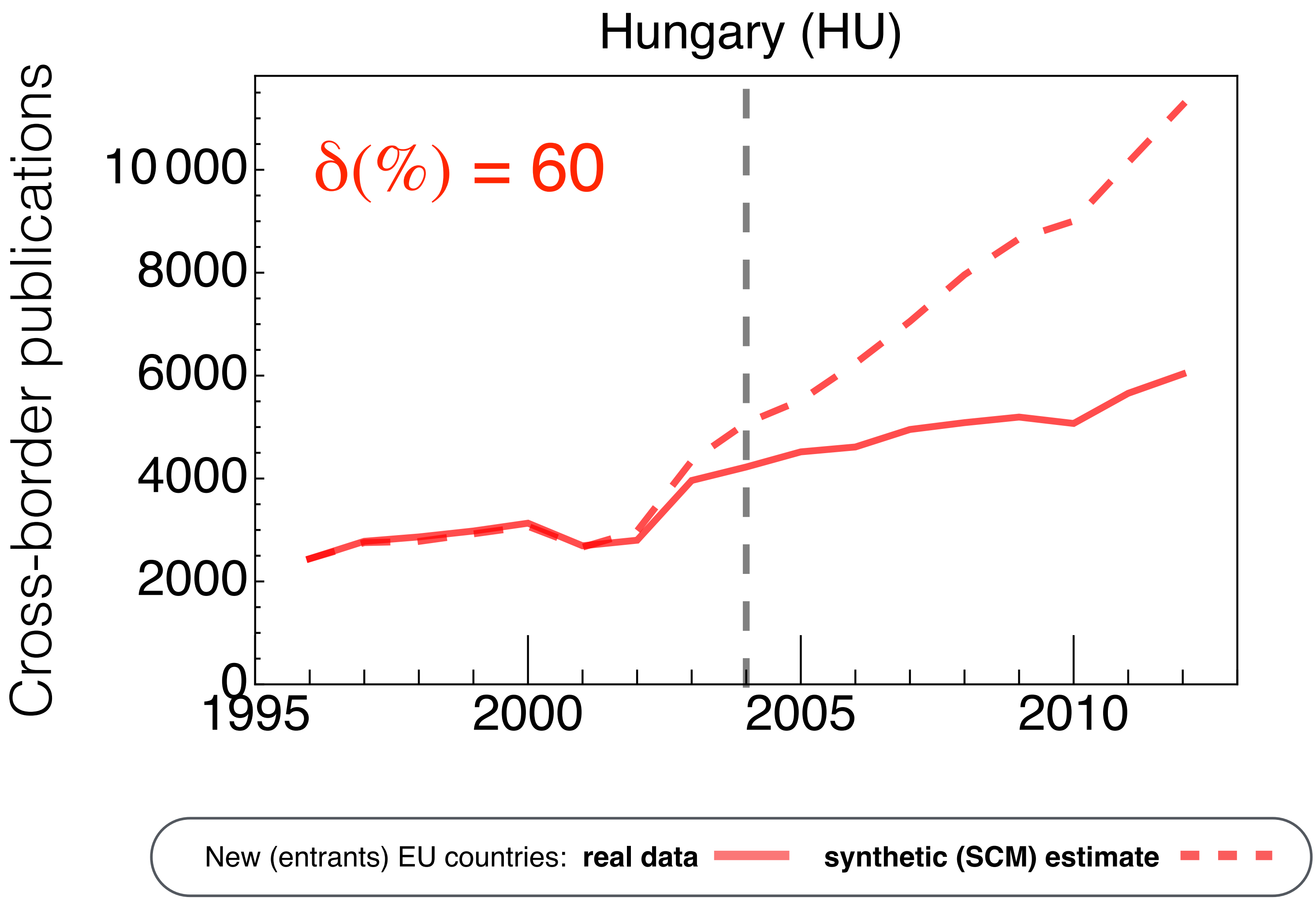
26 non-EU control group countries:
AR, AM, AZ, BY, CA, CN, CO, CU, IN, IL, JP, KZ, KW, KG, MG, MX, MN, PA, RU, RS, SG, KR, TT, TR, UA, US

Country-level control/matching variables:
[Scimago] Cross-border pubs, Total pubs, Citations
[World Bank] GDPpercapita, Govt. Expenditure on R&D

SCM: Abadie et al., *American Economic Review* **93** (2003)

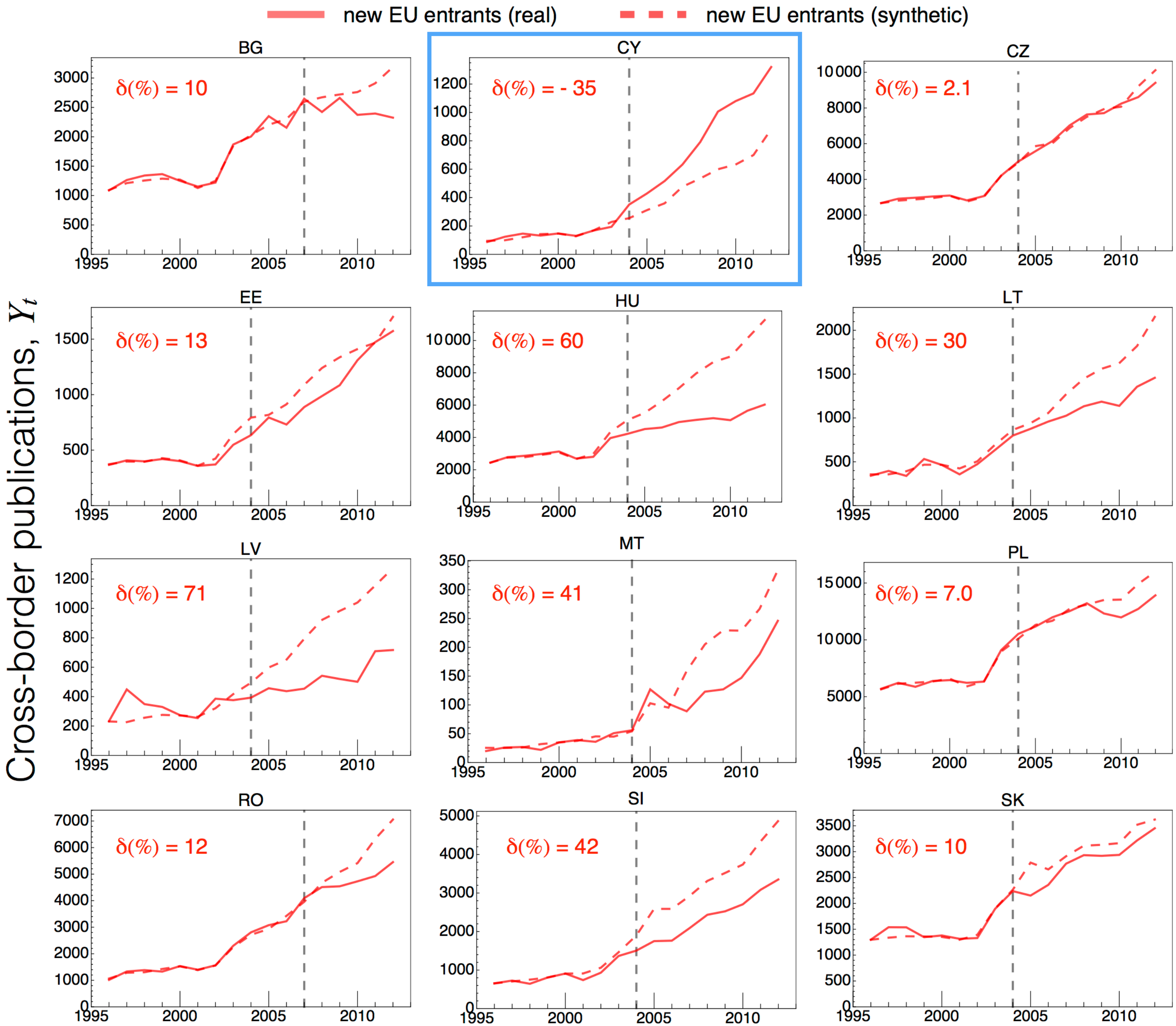
Abadie et al., *J. Amer. Stat. Assoc.* **105** (2010)

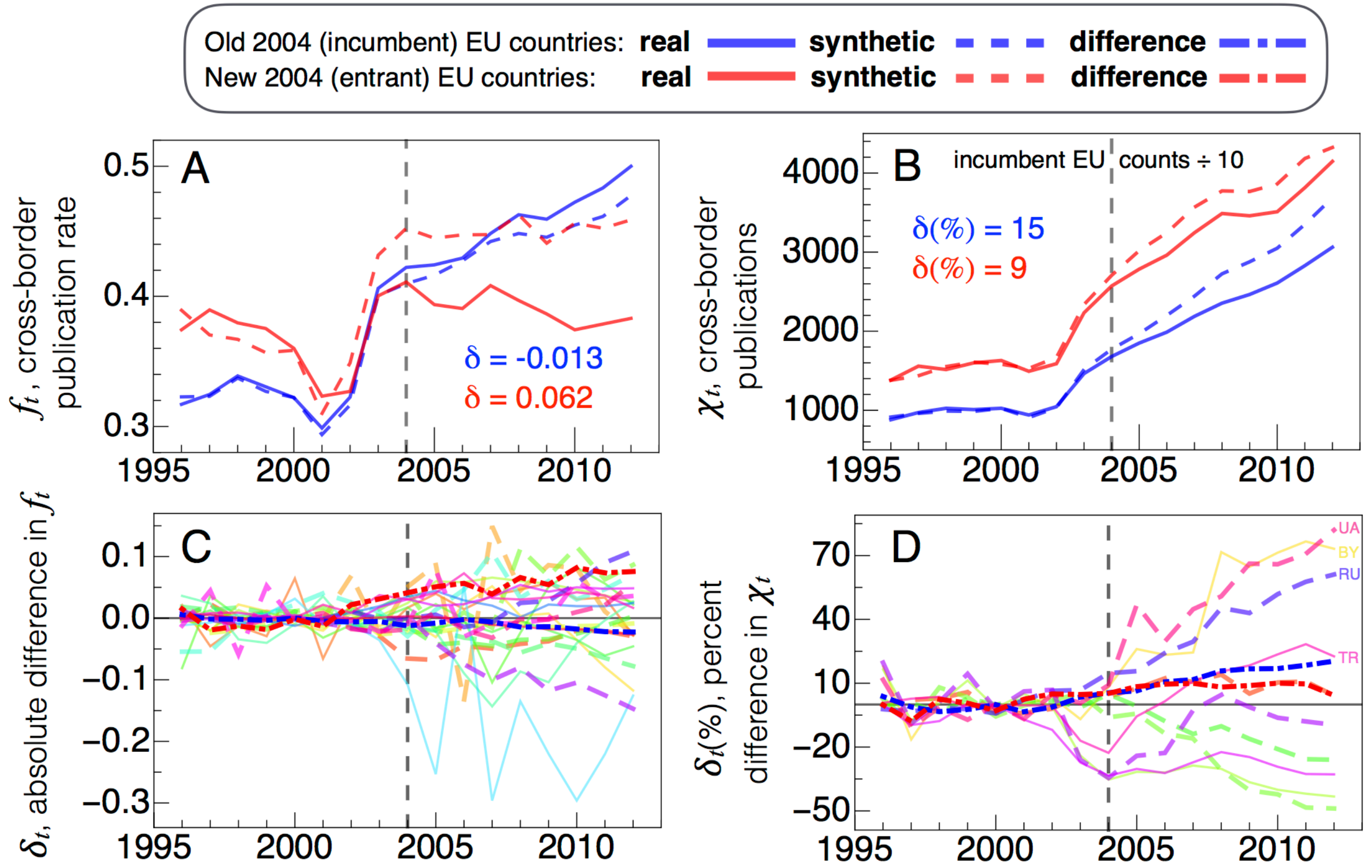
What would have happened had there NOT BEEN a 2004 expansion of the European Union??



Counterintuitively, there would have been MORE cross-border integration had there been no European Union enlargement!!

Twelve 2004/2007 Entrant Countries





(A) SCM results for the fraction f_t of cross-border publications and **(B)** the total number χ_t of cross-border publications. The solid curves represent the real data, while the dashed curves represent the estimates for the counter-factual scenario of no 2004 EU enlargement.

- Note that the χ_t that represent the incumbent pre-2004 EU countries are divided by 10 in order to facilitate visualizing all the curves on the same scale.
- δ and $\delta(\%)$ represent the difference between the real and synthetic curves after 2004, providing estimates of the "2004 EU Entry" effect on cross-border European integration.
- **(C,D)** Estimation of the significance level of the SCM results using the "permutation test"

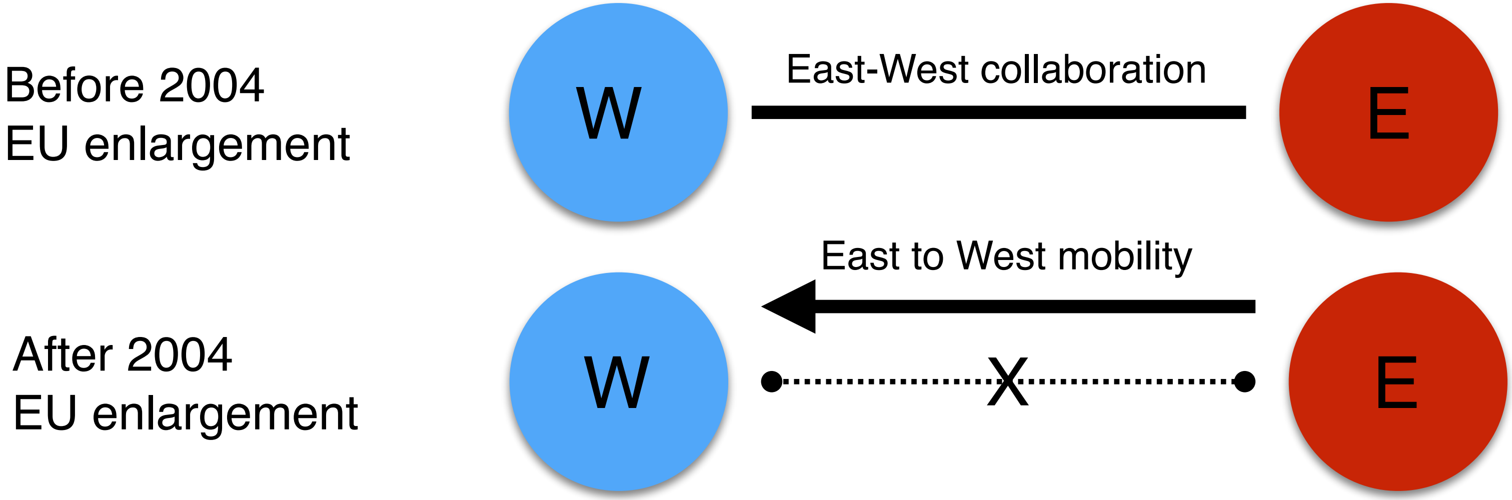
Unintended consequence: there would have been more cross-border integration without EU enlargement

Why?? Brain drain: largely from Eastern to Western European countries

1997-2004

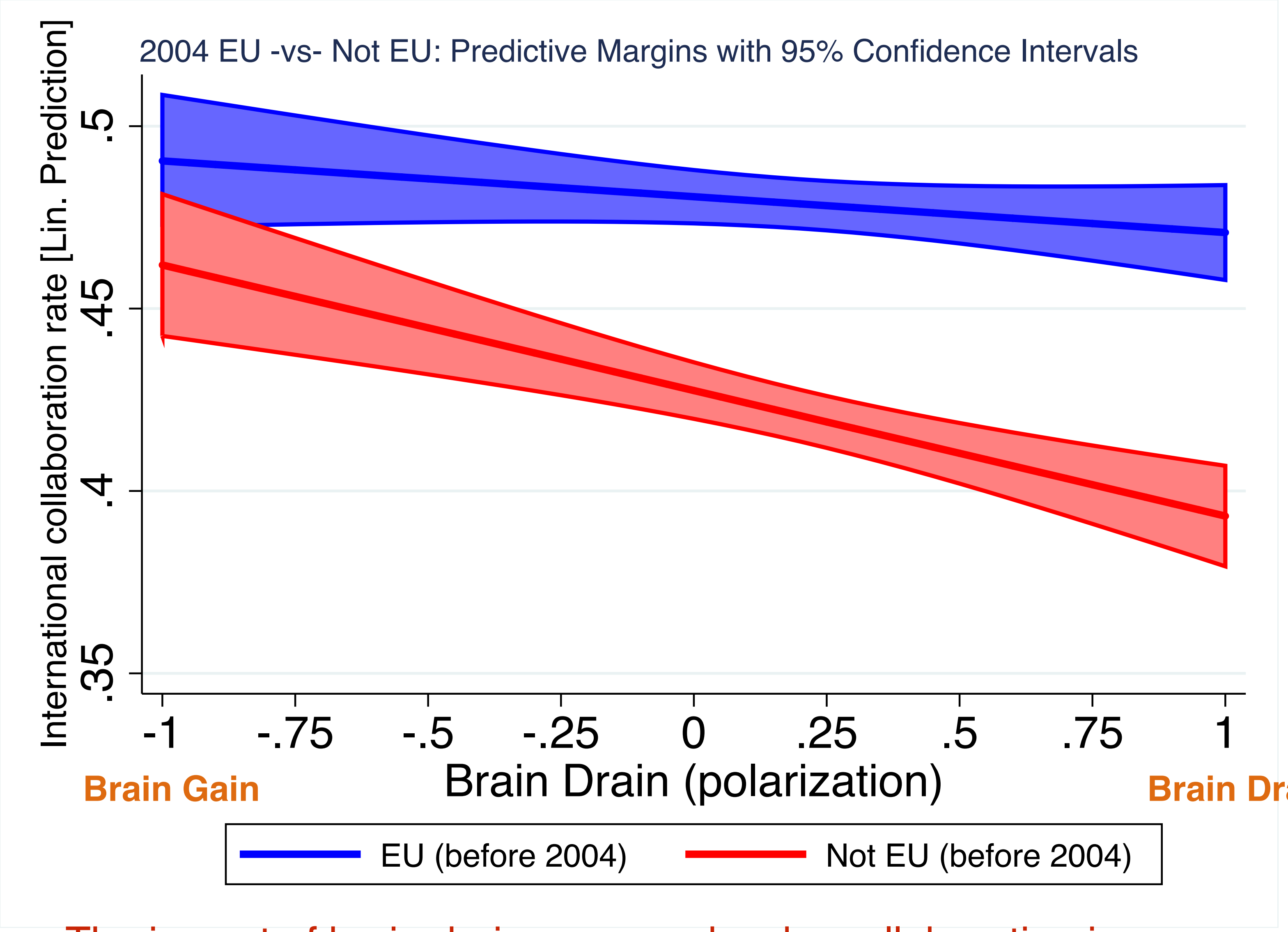
2005-2013

The micro-level mechanism connecting X-border collab. & brain drain



Quantifying the negative impact of brain drain on the integration of European science.
Science Advances, 2017

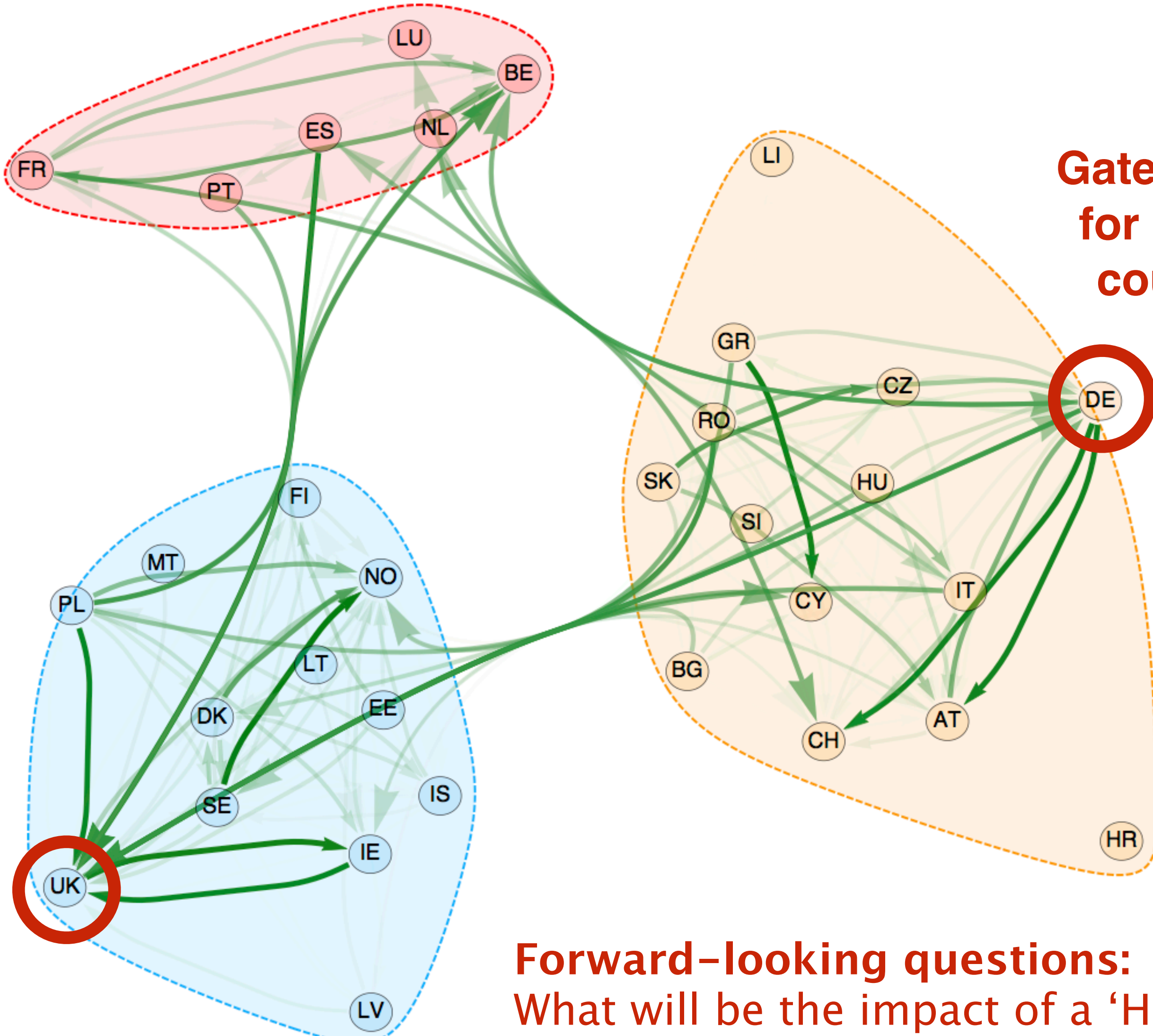
What is the marginal impact of 'brain-drain' (B_i) on the international collaboration rate (f_i) of the average country within each EU group?



The impact of brain drain on cross-border collaboration is even more negative for the new 2004 EU members

Human & Social capital perspectives on the value of EU membership

Gateway hub for Eastern countries



Two central hubs within the high-skilled mobility network: UK and DE

Gateway hub for Northern countries

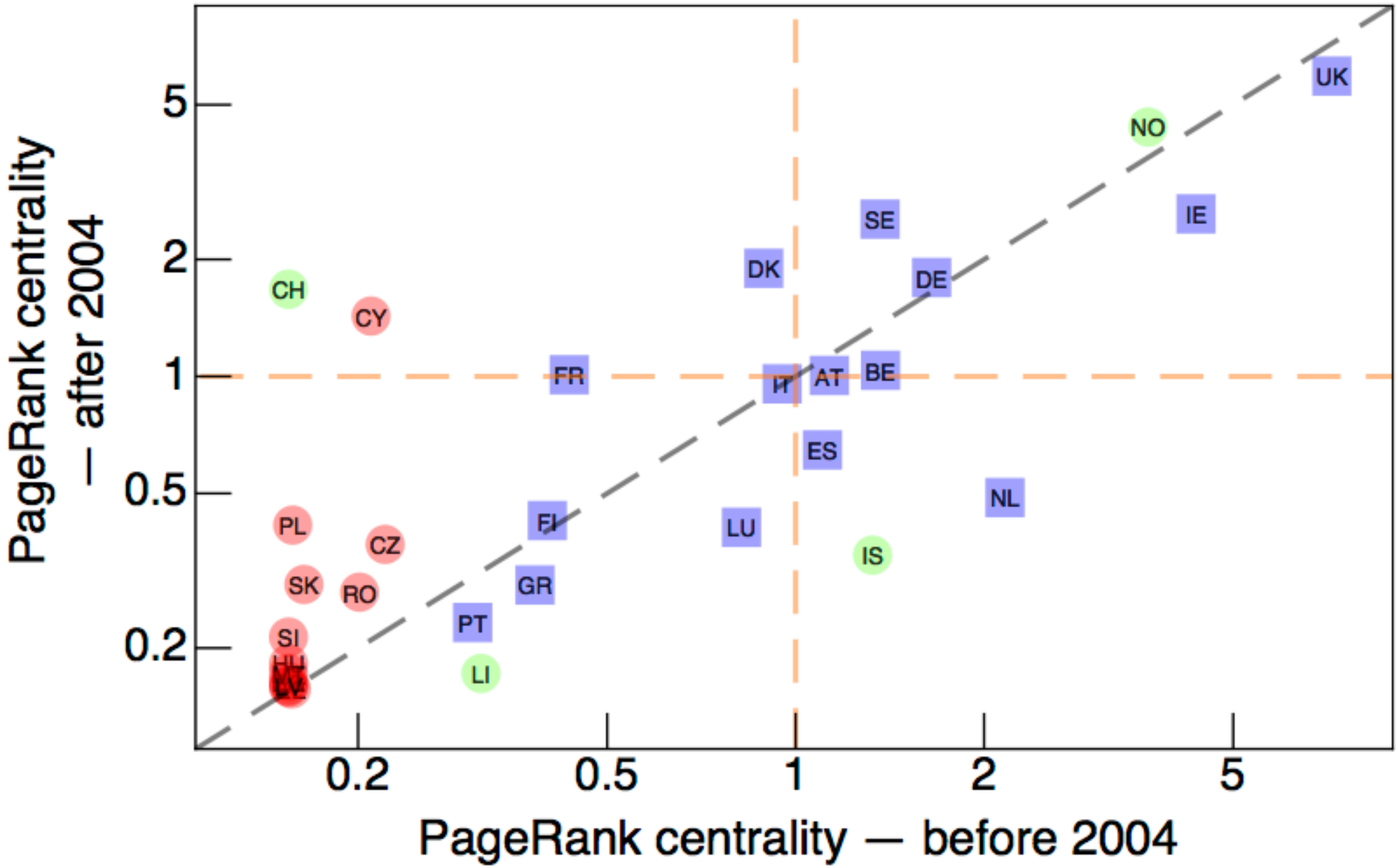
Forward-looking questions:

What will be the impact of a 'Hard Brexit' on :

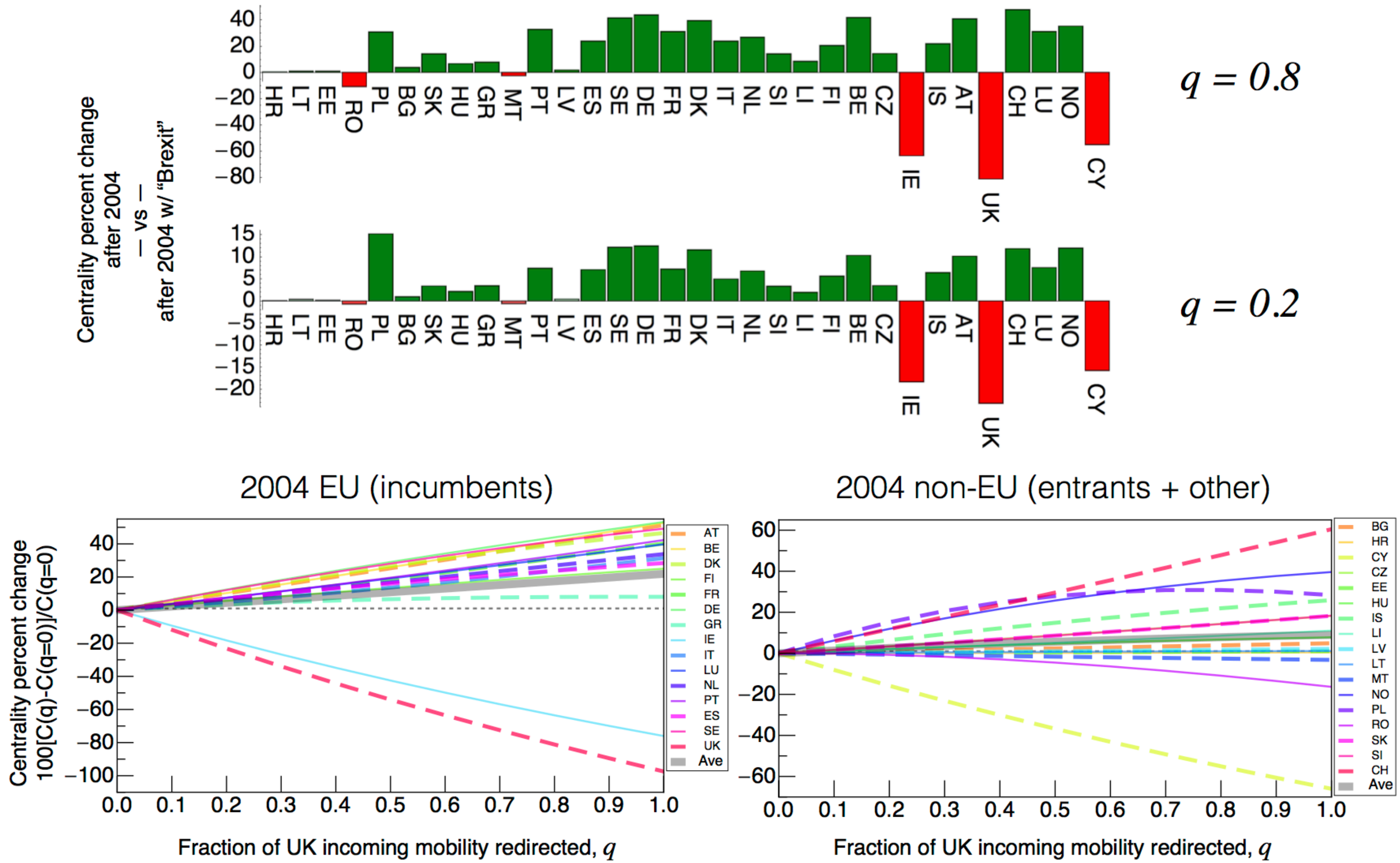
(a) the import/export of high-skilled labor between the UK & EU? (human capital)

(b) the social capital (i.e. research networks) in Europe?

Centrality in the high-skilled mobility network — before and after the 2004 enlargement

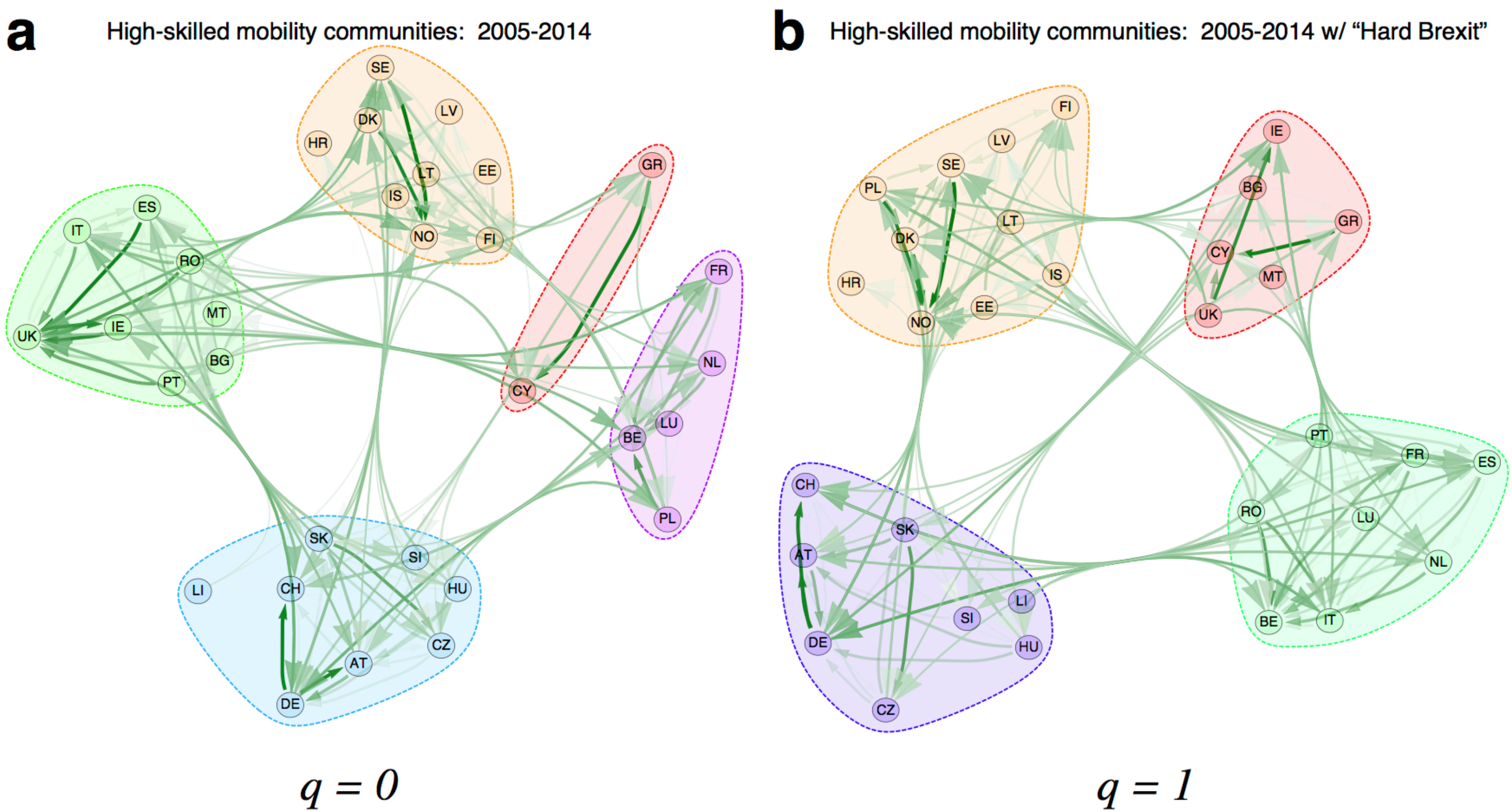


How might the ‘hardness’ of Brexit affect EU high-skilled mobility networks?



High-skilled labour mobility in Europe before and after the 2004 enlargement. J. Royal Society Interface, 2017

Reorganization of high-skilled mobility pathways in Europe in a hypothetical "Hard Brexit" scenario



Empirical: real data

Hypothetical: Brexit scenario with severe restrictions on international mobility to the UK

Thank you!

A special thanks to my collaborators:

Omar Doria, Andrea Morescalchi, Fabio Pammolli, Orion Penner, Michelangelo Puliga

Papers available at:

http://physics.bu.edu/~amp17/

- ***Quantifying the impact of weak, strong, and super ties in scientific careers**. A. M. Petersen. Proc. Natl. Acad. Sci. USA, 2015.*
- ***Is Europe Evolving Toward an Integrated Research Area?** A. Chessa, A. Morescalchi, F. Pammolli, O. Penner, A. M. Petersen, M. Riccaboni. Science, 2013*
- ***The evolution of networks of innovators within and across borders: Evidence from patent data.** A. Morescalchi, F. Pammolli, O. Penner, A. M. Petersen, M. Riccaboni. Research Policy, 2015.*
- ***Quantifying the negative impact of brain drain on the integration of European science.** O. A. Doria Arrieta, F. Pammolli, A. M. Petersen. Science Advances, 2017*
- ***High-skilled labour mobility in Europe before and after the 2004 enlargement.** A. M. Petersen & M. Puliga. J. Royal Society Interface, 2017*

The dynamics of collaboration and its implications — from careers to Europe

Collaboration in science is intrinsically interpersonal, and as a result, the networks of (in)formal relations are characteristically dynamic. In this talk I will discuss recent work on how these dynamics impact career paths, with implications as far-reaching as the evolution of entire national research systems. In the first part I will focus on the remarkably wide variation of collaborative strengths within research careers. In order to demonstrate the added value of long-term interpersonal partnership on career outcomes, I will present the results of a within-career (i.e. researcher fixed-effects) regression model showing that publications authored by a given scientist that include her strongest collaborators have higher citation impact relative to those publications that do not. These results point to the advantage of "super" social ties characterized by trust, conviction, and commitment. In the second part I will discuss the aggregate implications of collaboration dynamics at the level of the European Research Area (ERA) — a longstanding vision of the European Union to develop a competitive and integrated innovation system through directed cross-country policies. In order to measure the EU's progress towards the establishment of the ERA, we analyzed the rate of international publication for 32 European countries using data extracted from millions of academic publications from 1996 to 2012. We then used the EU 2004/2007 enlargement, a large policy intervention representing a multi-country and multi-stage "quasi-experiment", to provide causal insights into the interaction between two types of cross-border activity: human mobility and international collaboration. Our results reveal a counterintuitive result — that the twelve 2004/2007 entrant EU countries would have had higher rates of cross-border collaboration had they not joined the EU— thereby identifying an unintended consequence of labor market integration in Europe. Together, these results identify East-to-West European brain drain as a mechanism underlying the stalled integration of the ERA.