The interdisciplinarity of economics

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Abstract

Economics has the reputation to be an insular discipline with little consideration for other social sciences and humanities (SSH). Recent research [Angrist et al, 2020, *JEL*] challenges this perception of economics: the perception would be historically inaccurate and especially at odds with the recent interdisciplinarity of economics. By systematically studying citation patterns since the 1950s in thousands of journals, we offer the best established conclusions to date on this issue. Our results do show that the discipline is uniquely insular from a historical point of view. But we also document an important turn after the 1990s that drastically transformed the discipline as it became more open, very quickly, to the influence of management, environmental sciences, and to a lesser degree, a variety of the SSH. While this turn made economics less uniquely insular, as of today economics remains the least outward-looking discipline with management among all SSH. Furthermore, unlike in the other major social sciences, the most influential journals in economics have not significantly contributed to the recent increase in the interdisciplinarity of the discipline. While economics is changing, it is too soon to claim that it has completed an interdisciplinary turn.

Keywords: Bibliometrics, Interdisciplinarity, Economics, Insularity, Extramural Influences, Credibility Revolution, Social Sciences and Humanities

JEL Codes: A10, A12, B20

1 Introduction

Economics has long been described as a 'separate science' (Hausman, 1992) or a potentially 'unsocial science' (Backhouse and Fontaine, 2010). Approaches distancing themselves from the mainstream have always strove to make economics more permeable to insights from other disciplines (Lee, 2009). However, when mainstream economists have considered interdisciplinarity, they often did so with imperialistic intents: economics allegedly being a superior science, it should transform other social sciences rather than being itself transformed by outside influence (Lazear, 2000).

In recent years, the theme of disciplinary imperialism has been revisited with economics as the invaded rather than the invader (Davis, 2008). More specifically, the emergence of many approaches in economics that have exotic lineages (e.g., behavioral economics, econophysics, complexity economics, neuroeconomics) has encouraged the development of narratives about the end of the separateness of economics. But while these approaches have made interdisciplinarity a subject of discussion, we should distinguish the discourse of interdisciplinarity from its actual practice (Larivière and Gingras, 2014, p. 188).

One way to look at the actual practices of researchers is through quantitative studies of citation patterns. In particular, a standard bibliometric proxy of the extent of interdisciplinarity is the proportion of references to other disciplines. Using this approach, two recent publications in major economics journals have produced conflicting conclusions. By focusing on the citations from five top journals in economics, an article in the *Journal of Economic Perspectives* concluded that '[t]hough all disciplines are in some way insular [...] this trait peculiarly characterizes economics.' (Fourcade, Ollion and Algan, 2015, p. 91) In the *Journal of Economic Literature*, Angrist et al. (2020, p. 4) have denounced this 'jaundiced view of economics' interactions with other disciplines.' Based on a set of 69 economics journals and a selection of hundreds of journals in 16 other disciplines, their study concludes that:

> [E]conomics is not uniquely insular: psychology is less outward looking than economics, and anthropology looks more like economics than like political science or sociology. We also document a clear trend showing economics to be increasingly

outward looking. (Angrist et al., 2020, p. 4)

These two articles contribute to the study of economics' interdisciplinarity, but their main goal lies elsewhere. Consequently, both contributions on interdisciplinarity suffer from important shortcomings from the points of view of scientometrics and the history of science. The present article focuses solely on the study of the interdisciplinary relations of economics using citation analysis. Our contributions include sorting out why the two sets of authors reach conflicting conclusions and which conclusion is better warranted. In short, our analysis indicates that Fourcade, Ollion and Algan (2015) are correct – contra Angrist et al. (2020) – in their assessment that economics has been uniquely insular among the social sciences, but Angrist et al. (2020) are right to point out – contra Fourcade, Ollion and Algan (2015) – that the degree of interdisciplinarity of economics has changed rather dramatically in the last two decades, although the most influential journals in the discipline do not participate in this transformation.

Our article makes other important contributions beyond sorting out the relative merits of the two camps in this debate. First, by drawing on methodological insights from scientometrics, our analysis is itself interdisciplinary. Paradoxically, the other bibliometric studies on the interdisciplinarity of economics make little use of resources from the scientific field specializing in bibliometric research since the 1950s (e.g., Garfield, 1955). Second, our coverage of journals is far wider than that of the previous studies on economics' interdisciplinarity: we analyze all citations to and from journals in the social sciences and humanities (SSH) that are indexed in Clarivate's *Web of Science* from 1950 to 2018. We thus use citation information from 20,216 journals (with 6,699 journals in the SSH). Finally, by using the existing literature in the history and philosophy of science (and, especially, the history and philosophy of economics), we provide a richer interpretation of our quantitative results that explicitly connects with the concerns of a variety of researchers.

The contribution of this article is not to argue for more or for less interdisciplinarity in economics. As we will describe in the next section, scholars have time and again taken stances on this issue. Our contribution is to better describe where economics stands in

regards to other disciplines in terms of interdisciplinarity as defined above. With this more accurate and detailed description of the changing citation practices of economics, scholars will have better footing to argue over whether economics should be more or less opened to other disciplines.

2 Literature Review

The study of interdisciplinarity in economics is an important topic for historians (Arena, Dow and Klaes, 2013; Backhouse and Fontaine, 2010; Ambrosino, Cedrini and Davis, 2021), philosophers (Mäki, 2016; Hédoin, 2018) and economists (Pieters and Baumgartner, 2002) alike. Interdisciplinarity has long been studied with the implicit normative view that it is desirable and strongly related to "integration" or "unification." The study of interdisciplinarity has become more diverse in recent years. Normative work now fleshes out the principles and conditions under which interdisciplinarity is desirable, rather than take its desirability for granted (Mäki and MacLeod, 2016; Herfeld and Lisciandra, 2019). This development happened in parallel to an increasing interest for quantitative approaches in the history and philosophy of economics (Claveau and Gingras, 2016; Cherrier and Svorenčík, 2018; Herfeld and Doehne, 2018; Aistleitner, Kapeller and Steinerberger, 2019; Glötzl and Aigner, 2019), including the issues related to the measurement of interdisciplinarity (Gingras and Schinckus, 2012; Braesemann, 2019).

A vast literature is dedicated to measuring and evaluating interdisciplinarity (Klein, 2008; Wagner et al., 2011; Repko, Szostak and Buchberger, 2017). One fundamental point of this body of work is that interdisciplinarity is multifaceted. Any study thus focuses on some dimensions at the expense of others. Pierce (1999) distinguishes between three forms of knowledge transfer: crossing, collaborating and borrowing. There are well-established methods in scientometrics to quantify each of these forms of knowledge transfer between scientific disciplines. Interdisciplinary crossing – i.e., publishing in a discipline that is not one's own – is measured by the share of articles that researchers publish outside their discipline (Le Pair, 1980; Rinia, van Leeuwen and van Raan, 2002). Interdisciplinary collaboration is assessed by

looking at the share of papers that have co-authors from more than one discipline (Abramo, D'Angelo and Di Costa, 2012). Finally, the extent of interdisciplinary borrowing is usually quantified with citations patterns (Porter and Chubin, 1985; Tomov and Mutafov, 1996; Morillo, Bordons and Gomez, 2001). In this study, we focus on interdisciplinary borrowing through citation patterns.

The popularity of interdisciplinarity as a discourse varies over time: there was a surge of interest in the 1970s, followed by a decline in the 1980s, and a new and steady upward trend from the 1990s on (Larivière and Gingras, 2014, p. 189).[1] Beyond the *discourse* of interdisciplinarity, the scientometric literature suggests that interdisciplinary borrowing as a *practice* has been overall on the rise in the last few decades. Larivière and Gingras (2014) measure steady increases of borrowing since the mid-1980s, with SSH being more interdisciplinary than the natural and medical sciences. Porter and Rafols (2009, p. 741) find an increasing interdisciplinarity between 1975 and 2005 in six research domains, but in 'small steps.' Focused on the social sciences, Levitt, Thelwall and Oppenheim (2011, p. 1127) find that interdisciplinarity decreased between 1980 and 1990, but rose again after to catch up with the level of 1980.

In the last 20 years, three studies published in major economics journals focus on the interdisciplinary borrowing and lending of economics. In the *Journal of Economic Literature*, Pieters and Baumgartner (2002) investigate the relationships between 42 economics journals and the top 5 journals of other disciplines (1995-1997), and conclude that, while economics is the main source of interdisciplinary knowledge for 6 out of the 9 disciplines they study, it is an asymmetric relationship that is not reciprocated by economics. One notable conclusion is that the relation with business disciplines is also asymmetric (e.g., accounting, management) with the exception of finance.

Following a comparable approach while focusing on five top economics journals, Fourcade, Ollion and Algan (2015) provide a similar picture of the asymmetric relationship between economics and other disciplines from 1950 to 2012. According to these authors, economics has

[1] In our technical appendix (section 3), we reproduce a similar result. The appendix can be found by following this shortened URL: https://rb.gy/9dargu

maintained its characteristic insularity overtime. One notable change they point out is the rise of finance and the fall of mathematics and statistics as the economics profession became more entangled with the business sector. This relative insularity has been observed multiple times in the scientometrics literature published outside of economics whether by measuring project collaboration and co-authoring (Karlovčec and Mladenić, 2015) or by using non-bibliographic techniques such as topic modeling (Eykens, Guns and Vanderstraeten, 2022). Insularity has also been observed when looking at the recent development of particular fields such as econophysics, which is rarely cited by mainstream economics though it does heavily cite the latter (Gingras and Schinckus, 2012).

More recently, a paper by Angrist et al. (2020) has challenged these claims about the insularity of economics. Based on a selection of 17 disciplines represented by approximately 50 journals each, they argue that economics is becoming more interdisciplinary in tandem to becoming more empirically oriented. It is 'less outward-looking than sociology and political science, but not uniquely or irredeemably insular' (Angrist et al., 2020, p. 10). They also find that finance is rising in economics, but not much faster than in other disciplines. In both cases, their core argument is that the situation of economics is not so unique when compared to other disciplines. In addition, Angrist et al. (2020, p. 49) also point out that economics is becoming more important for other disciplines over time, something they explained by their own 'credibility revolution' thesis (Angrist and Pischke, 2010). To them, the new orientation of economics toward more empirical work and the emerging attention paid to other disciplines make economics research more attractive to other disciplines:

> We see little in citation statistics to support the notion that economics is intellectually isolated. And, just as economists do, other social scientists primarily reference articles in journals central to economics scholarship. The growing links between economic research and a wide range of other disciplines reinforce our view that economics scholarship has never been more exciting or useful than it is today. (Angrist et al., 2020, p. 50)

In this study, we do not comment on whether economics is exciting or useful to non-

economists. We rather offer a more thorough citation analysis of economics interdisciplinarity.

3 Methodology

3.1 Data and discipline classification

Our data come from Clarivate's *Web of Science* (WoS). Like any bibliographic database, WoS does not include all academic journals ever published, but it covers the most visible and most cited ones. Its 75 million documents with their billion references cover all scientific fields and offer a representative coverage of the most cited literature in all fields, thus allowing detailed analysis of the relations between disciplines.

A crucial step in a bibliometric study of interdisciplinarity is to define each discipline using a set of journals. Previous research has used disciplinary classifications of journals to map the relations between disciplines (Boyack, Klavans and Börner, 2005). To adequately measure interdisciplinarity, the boundary between disciplines must not be arbitrarily drawn. Furthermore, if one aim is to compare the degree of interdisciplinarity of a set of disciplines – e.g., various social sciences – it is crucial to include all disciplines that are cited by this set to avoid biasing the count in favor of some disciplines.[2]

To avoid these pitfalls, we use a recognized classification of journals first constructed for the US National Science Foundation (NSF) in the 1970s and updated since then. This classification allocates each journal to one and only one of 143 fields of research (e.g., 'Botany' and 'Economics'). These fields are split into two sectors: the natural sciences, engineering and biomedical sciences (NSE for short) and the social sciences and humanities (SSH) (National Science Board, 2006, Appendix table 5-39).

Our only change to this classification has been to aggregate some of the fields to avoid having to interpret 143 by 143 matrices. We thus regrouped fields into larger categories that generally correspond to the disciplinary level. For example, we considered 'psychology' as a

[2]We will show in Section 6 that Angrist et al. (2020) are guilty of this methodological error: while they include disciplines like mathematics and statistics, they arbitrarily leave out biology and the neurosciences.

whole although it is split into nine fields in the database. We also created two categories: (1) 'Other Social Sciences' that combines 'General Social Sciences' and 'Miscellaneous Social Sciences' with some relatively small fields in the SSH (urban studies, science studies, area studies, criminology), and (2) 'Other Professional Fields' that regroups 'Miscellaneous Professional Field' with social work, communication and library science.

Discipline	Number of journals
Psychology	721
Management	459
Economics	384
Anthropology & Archaeology	219
Political Science & Public Administration	195
Sociology	160
Humanities	1760
Health	632
Other Social Sciences	608
Arts	390
Education	364
Other Professional Fields	342
Law	232
Geography	112
International Relations	88
Demography	33
TOTAL	6699

Table 1: Number of journals in the corpus distributed across disciplines in the social sciences and humanities (SSH). The six disciplines above the line are those that will be central to our analysis.

This procedure leaves us with 16 categories in the SSH, with a distribution of the 6,699 journals as shown in Table 1. Furthermore, all articles indexed in WoS in the sector of the 'Natural Sciences and Engineering' (which also includes the biomedical sciences) that either cite or are cited by articles in the SSH are included in the analysis and divided up into 13 categories (often much bigger than SSH disciplines). All in all, we use citation information from 20,216 journals.

For some of our analysis, we give detailed information only on 6 main social sciences: psychology, management, economics, anthropology & archaeology, political science & public administration, and sociology. When our results are not explicitly restricted to the main social sciences, they cover all the journals in Table 1. As we will see later (Section 6),

our method of analysis makes it possible for us to reproduce existing results in the literature simply by imposing further constraints on our classification. This fact confirms the usefulness and validity of our classification.

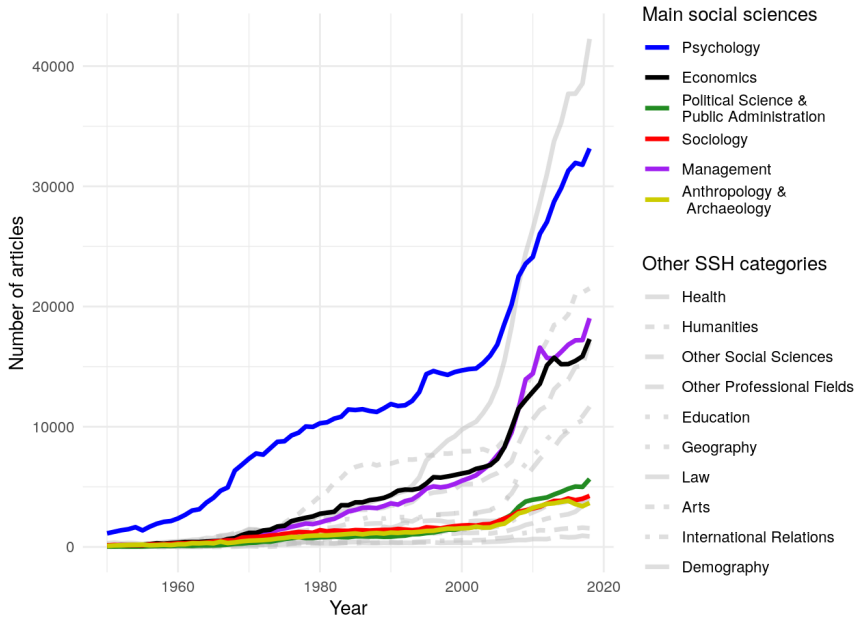


Figure 1: Number of articles published per year in SSH disciplines

Figure 1 presents the distribution of articles published each year in our 16 SSH categories. Two characteristics stand out. First, the annual number of articles grows fast, particularly since 2005. This trend reflects not only a real growth in the number of publications in all fields but also a growth in the number of journals covered by the WoS database. Second, the various fields vary widely in size. Among the six main social sciences, the output of psychology is roughly twice those of economics or management and six to nine times those of the three other disciplines. The other SSH categories have also markedly different output, with demography being 1/38th of psychology and 'health' being 27% bigger than psychology.

One limitation of our classification is our treatment of the management discipline, as all journals associated with the domains of finance, accounting and marketing are grouped together under management. We will see that this polymorphous discipline plays an important role in the recent history of economics interdisciplinarity. To have a more detailed picture of

what is occurring at the interface of economics and management, we devised a technique to isolate finance journals from all other journals in management (see Section 5.2.2 in our technical appendix). We use this more fine-grained classification at the end of Section 5.2 in this article, but more research is clearly needed to better understand the evolving relationships of economics with fields in management.

3.2 Measuring interdisciplinary borrowing

Citations are directed relations between a source and a target. Define d to be any node in a discipline and $\neg d$ to be any node in another discipline.[3] From the perspective of d, there are four types of citations inside the scientific field:

- $d \to d$: citations internal to the discipline
- $d \to \neg d$: a document from the discipline that cites a document outside the discipline
- $\neg d \to d$: a document outside the discipline that cites a document inside the discipline
- $\neg d \to \neg d$: citations totally external to the discipline (d being neither the source nor the target of the relation)

The existence of some $d \to \neg d$ indicates that the discipline is open to external influences and the ratio of outward citations to the total citations by the discipline is an indicator of the extent to which the discipline is outward looking:

$$\text{COC}_d = \frac{\#(d \to \neg d)}{\#(d \to d) + \#(d \to \neg d)},$$

where COC_d stands for 'Citations Outside Category' of d, which is a standard acronym for this ratio in bibliometric studies since its introduction by Porter and Chubin (1985).

To measure the extent to which other disciplines rely on d, a normalized measure is also needed. Indeed, the number of $\neg d \to d$ does not take into account that bigger disciplines are

[3] Note that $\neg d$ is a node actually *identified* as being in another discipline. Many citations have a target with no identified discipline (e.g., because the target is a book, a newspaper article, a court case).

more likely to be cited by the other disciplines simply due to their sheer size. The indicator we will be using is the ratio of the citations to d that come specifically from outside d to all the citations to d (from inside and outside d):

$$\text{CTC}_d = \frac{\#(\neg d \rightarrow d)}{\#(d \rightarrow d) + \#(\neg d \rightarrow d)},$$

where CTC_d stands for 'Citations Toward Category' d. Please note that our two measures share one term in the denominator. If the number of citations internal to d increases, both COC_d and CTC_d decrease.

We finish this sections with two more general methodological notes. First, our measures remain simple in contrast to some proposals in the scientometric literature (Leydesdorff, Wagner and Bornmann, 2019). More complex measures would make it harder to compare our results to the existing work on the interdisciplinary of economics and no measure has emerged as clearly better than the one we use (Wang and Schneider, 2020).

Second, the most recent bibliometric contribution to the study of economics interdisciplinarity (Angrist et al., 2020) weighs citations by the journal from which they originate. The idea is that a citation from a more influential journal should count more in the measure of interdisciplinary borrowing. Since there are different ways to compute the 'importance' of a journal, we refrain from adopting this option in our main article: in most of the results below, citations count equally irrespective of the journal where they are published. However, our technical appendix includes results with a weighing scheme. Our way of weighing citations is different from Angrist et al. (2020) because their method strikes us as unacceptable (see the appendix for details).

4 The insularity of economics

4.1 Extradisciplinary citations

To assess the interdisciplinarity of economics, we first measure the share of citations in economics that target other disciplines (COC_{econ}). We contrast it to the other social sciences

and also take the temporal evolution of economics into account.

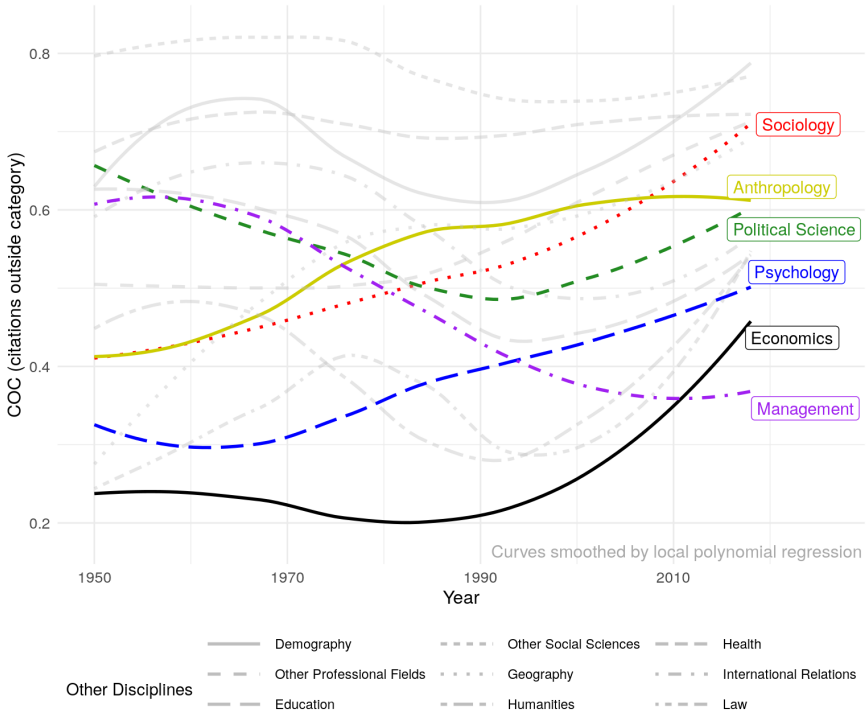


Figure 2: Extradisciplinary citations among SSH categories

Three properties stand out (see Figure 2):[4]

C1 Historically, economics has been uniquely inward looking among the social sciences.

C2 Since the late 1990s, economics has grown significantly more outward looking in absolute as well as in relative terms.

C3 Despite this recent evolution, economics remains one of the most insular SSH disciplines, with management being the only discipline that is now more inward looking.

From 1950 to 2000, economics stood out clearly with a share of outward citations averaging at 22%, far smaller than the average of 38% for all the main social sciences combined

[4]Note that all curves in our figures (except in Figure 1 and superimposed on bar plots) are smoothed using local polynomial regression.

(see Figure 3). Since 2000, the share of outward citations from economics has grown by 21 percentage points, which corresponds to an average annual growth rate of 3.4% between 2000 and 2018. Economics gave away its title of least outward-looking discipline to management in 2011.

While the turn in economics is significant, the discipline still remains in the lower tail of the distribution partly because the SSH as a whole has also grown more interdisciplinary since 2000, becoming more outward looking by 8 percentage points and getting really close to 50% in 2018 (Figure 3, see Larivière and Gingras, 2014 for a similar result). Economics has, however, partly caught up: COC_{econ} was 61% of the COC of all the main social sciences combined in 2000, while it grew to be 94.5% of it in 2018.[5]

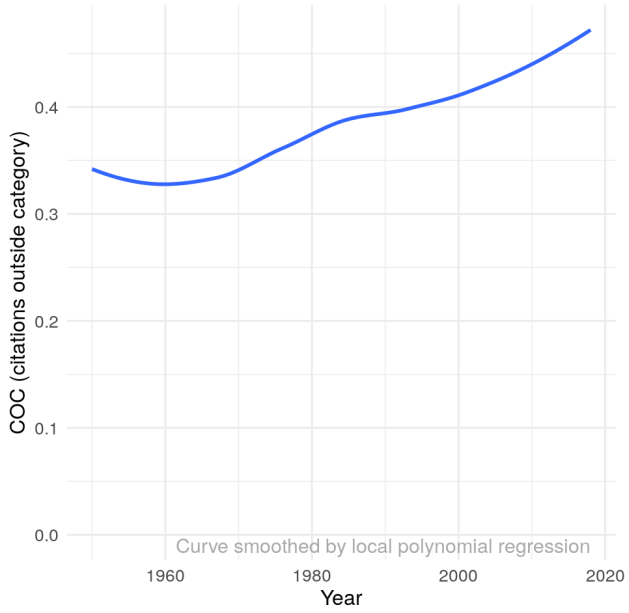


Figure 3: Extradisciplinary citations by the main social sciences

The disciplinary turn we observe in management is highly atypical. Between 1950 and 2000, the COC of management fell from above 60% to 37%. Other disciplines (e.g., political science and education) also became less interdisciplinary during this period, but they all

[5] As section 4.2 of our technical appendix shows, weighing citations by the 'importance' of each journal does not change the trend toward more interdisciplinarity, but it changes the intensity of the trend: under this alternative measure, COC_{econ} was 83.5% (instead of 94.5%) of the COC of all the main social sciences combined in 2018.

recovered some of their outward-looking tendency after 2000, all except management, which still had a rate of outward citation at 37% in 2018. Without disaggregating management to investigate the changing relationships between what some might perceive as disciplines on their own (finance, marketing, accounting), our analysis of this peculiar trajectory is limited. What we can says is that, compared to management, economics has behaved more like the other social sciences in the last decades.

Summing up, the citation practices of economics between 1950 and 2018 confirm the historical claim that economics has been quite uniquely a 'separate discipline' (Hausman, 1992). There is also evidence for a recent significant transformation of economics, which gives some support to the narrative of a 'credibility revolution' (Angrist and Pischke, 2010) in relation to a recent 'applied' and/or empirical turn (Hamermesh, 2013; Backhouse and Cherrier, 2017; Angrist et al., 2020). Although economics is still second to last in the rate of outward citations, the discipline is not anymore so uniquely insular.

4.2 Internal hierarchy of interdisciplinarity

In the previous section we took economics as a whole (384 journals) and compared its degree of interdisciplinarity to other disciplines. This is a uniquely broad take on the interdisciplinarity of economics. Indeed, Fourcade, Ollion and Algan (2015) focused on the five most important economics journals founded before the 1940s: *Quarterly Journal of Economics* (QJE), *Journal of Political Economy* (JPE), *American Economic Review* (AER), *Econometrica* and *Review of Economic Studies* (RESTUD). For their part, Angrist et al. (2020, table W1) have retained 69 economics journals in their analysis, but weigh them in an idiosyncratic fashion by starting with a unique "trunk journal" (the *Americian Economic Review*) to compute the importance of each journal. Because of the high rate of self-citations at the level of journals, this procedure implies that their trunk journal takes up the same proportion of the total weight (23%) as do their bottom 51 journals. Hence, both studies can be said to primarily study the 'top' journals in economics.

Our data allow us to study whether the interdisciplinarity of 'top' journals differs from

the interdisciplinarity of the rest of the discipline. Furthermore, we can investigate whether the contrast found in economics is shared by other SSH. We take each topic in turn.

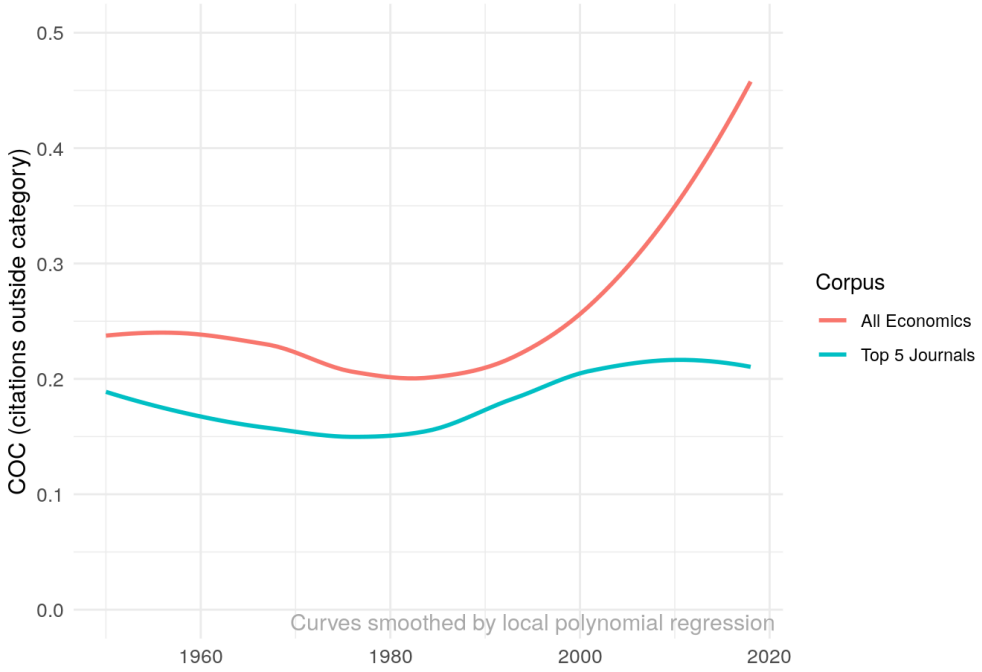


Figure 4: Extradisciplinary citations of economics

C4 In contrast to the discipline as a whole (**C2**), the five top journals (QJE, JPE, AER, Econometrica and RESTUD) have not grown significantly more outward looking since the late 1990s.

Figure 4 contrasts the COC of these 5 top journals with the COC of economics as a whole (reproduced from Figure 2). Over the period studied, the top journals have been consistently less interdisciplinary in terms of COC than the rest of the profession. From 1950 to 2000, the difference between the two groups was relatively stable at around 5 percentage points. Since then, the gap has widened considerably to 25 percentage points.

Now, to compare the situation of economics to other SSH, we can hardly rely on a top 5 of journals because such a list is not readily identifiable in the other disciplines. We instead construct an annual list of the top 5% of journals in each discipline based on our own 5-year

impact factor.[6] The number of journals in the top list changes with the size of the discipline in a given year – e.g., a discipline with only twenty journals would have a single journal in its top list while a discipline with 200 journals would count 10.

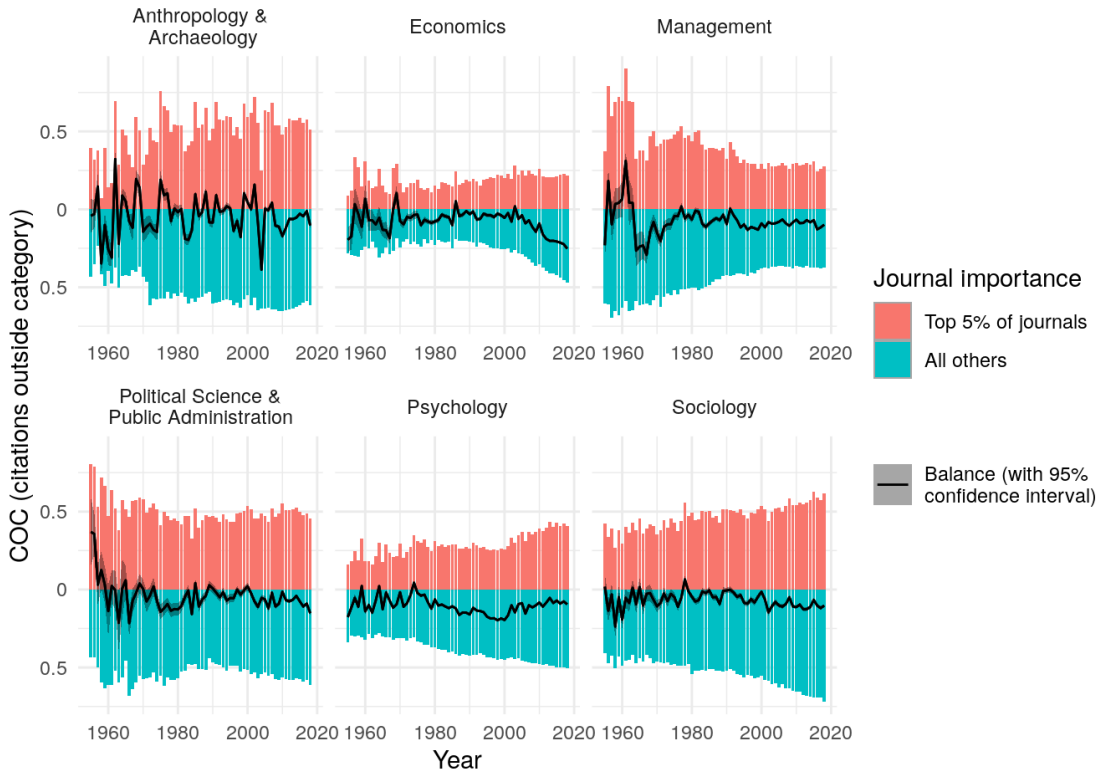


Figure 5: Extradisciplinary citations of top 5% vs bottom 95%. The COC of the bottom 95% is plotted downward, and the balance line is the difference between the two bars.

Two conclusions can be drawn by comparing the top 5% and the bottom 95% groups in each of the six main social sciences (see Figure 5).

C5 Since 1970, no discipline has been systematically more outward looking in its top journals than in the rest of its journals.

Indeed, the balance in Figure 5 tilts most frequently toward the bottom 95% of journals.[7]

[6] See the technical appendix for details. Note that we start Figure 5 in 1955 to have 5 years of data.

[7] This claim takes into account statistical uncertainty: a 95% confidence interval is shown in Figure 5 but it is so small in recent times (because of large samples) that it cannot be distinguished from the line itself. This confidence interval is the result of a two-sided test of equal proportions.

The discipline of anthropology & archaeology is closest to being balanced over the period. What is the least balanced discipline?

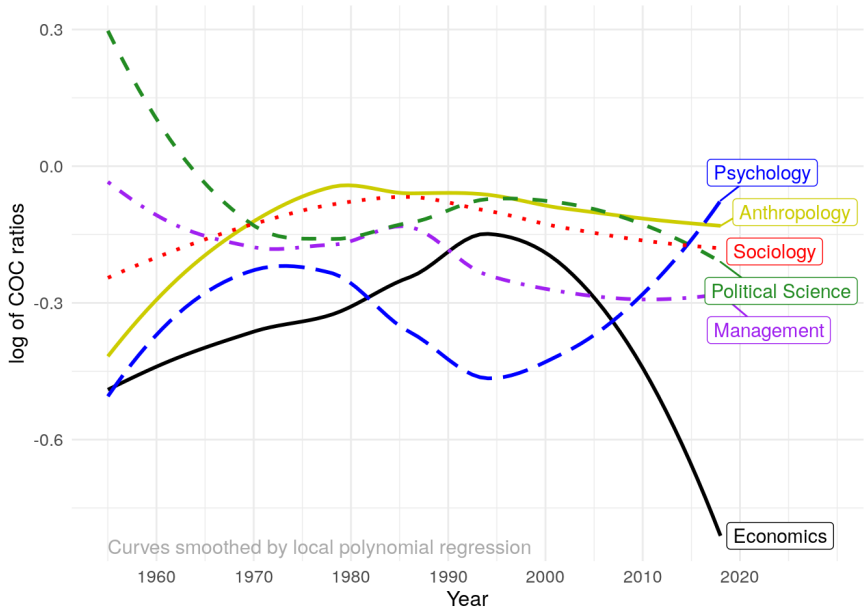


Figure 6: Extradisciplinary citations of top 5% vs bottom 95%. The ratio is the citations outside category (COC) of the most influential journals to the COC of all the other journals (we plot the logarithm).

C6 Among the main social sciences, the extent to which the most influential journals are less interdisciplinary is most extreme in economics.

This conclusion is especially clear when we take the ratio of COC in the top 5% to the bottom 95%, see Figure 6. Early in the period, psychology and economics were the disciplines with the lowest ratio. Psychology has now become the discipline with top journals most alike all other journals in terms of tendency to cite extradisciplinary sources. In contrast, the ratio of economics has plunged since the early 2000s: as most of the discipline rapidly becomes more interdisciplinary, the most influential journals lag behind, and the ratio depicted in Figure 6 thus decreases sharply.

We thus see the distinctiveness of the hierarchical structure of economics. We could expect that, across disciplines, interdisciplinarity is systematically higher in more specialized

journals than in more generalist ones. As is often emphasized in the literature on interdisciplinarity (Prud'homme and Gingras, 2015; MacLeod, 2018), working at the intersection of disciplines presents many institutional and epistemological obstacles that can interfere with research impact and the publication processes in the main journals of the discipline. Citations in the short term can be reduced by interdisciplinary approaches (Wang, Thijs and Glänzel, 2015) and journal rankings can suppress interdisciplinary research because, in some disciplines, the core journals tend to favor mono-disciplinary research (Rafols et al., 2012). This hypothesis fits well with the pattern found for economics, but less so for other core SSH disciplines.

4.3 The other side of insularity: Citations toward disciplines

Our study has focused so far on the extent to which disciplines are outward looking. We now look in the other direction: how much does a discipline attract attention from outside? We capture this outside attention by CTC_d, which measures the extent to which the work influenced by a discipline is work in other disciplines (see section 3.2).

Focusing on economics, a low CTC_{econ} would mean that most of the citations to economics come from inside the discipline. As we explained in Section 3.2, given that many more papers are published in economics than in, say, sociology (see Figure 1), the absolute numbers of $\neg d \rightarrow d$ for both disciplines is a partial indicator of interdisciplinary relations. This is why we take a ratio of $\#(\neg d \rightarrow d)$ to all the citations to d.

We draw two conclusions from the comparison of CTC between disciplines (see Figure 7):

C7 With psychology and, more recently, management, economics is among the disciplines that have been principally of interest to insiders – i.e., members of the discipline.

C8 Since the late 1990s, economics is increasingly attractive to other disciplines and it has now reached a level comparable to that of other social sciences (psychology, political science).

The first conclusion puts in perspective claims about the alleged central influence of eco-

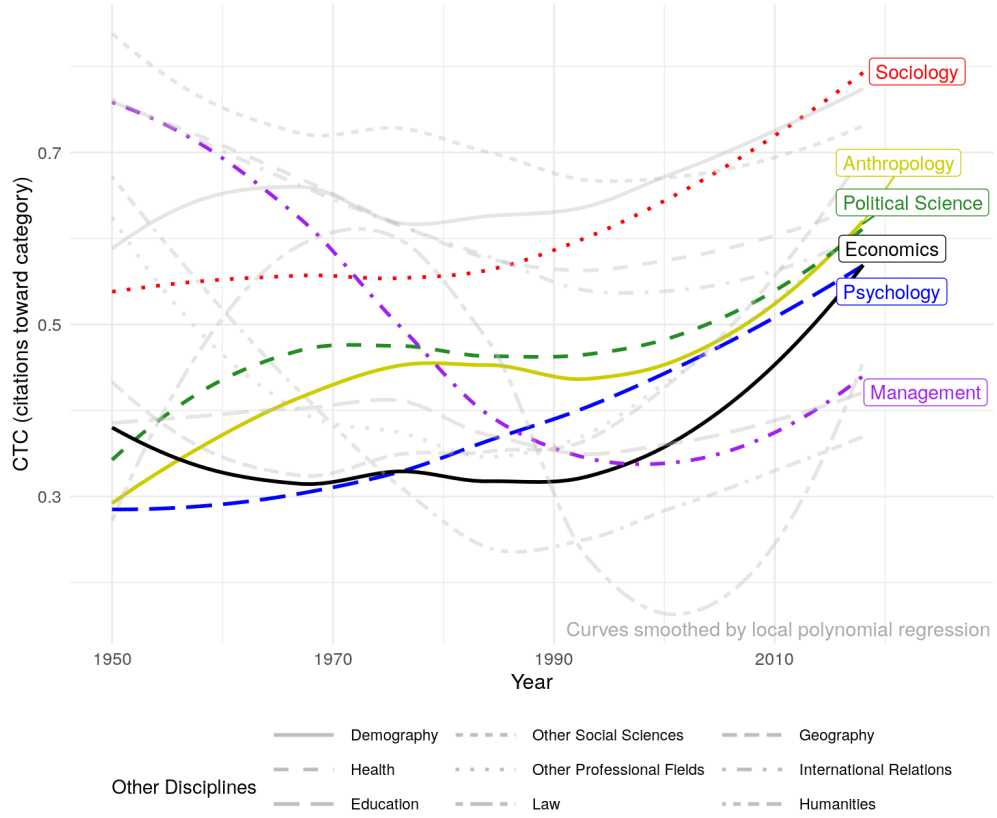


Figure 7: Citations toward the main SSH categories

nomics for the majority of the other SSH.[8] Although, economics was evidently not producing 'scholarship of interest only to those who create[d] it,' (Angrist et al., 2020, pp. 15-6) it was, together with psychology, the discipline where this statement was closer to truth up until the late 1990s. In contrast, sociology has stayed far above economics for the whole period in terms of attracting scholarly interest from outsiders.

The second conclusion signals again that the face of economics has changed since 2000:

[8]Instances of such claims include:

> Economics is the most influential social science in 7 out of the 16 extramural disciplines we examine, and economics is recently tied for first in two more (psychology and computer science). (Angrist et al., 2020, p. 49)

> Economics emerges as the primary source of knowledge in this network of social science and business disciplines. (Pieters and Baumgartner, 2002, p. 504)

while the external influence of all disciplines was on the rise, the rate of this rise was strongest for economics.

4.4 The balance of toward and outward citations

Now that we have looked at citations outward and toward a discipline (COC and CTC), the last step is to combine both in order to determine which direction of interdisciplinarity is stronger for each discipline. If COC is stronger than CTC for a discipline, we can say that it is a net borrower while a discipline with a CTC higher than its COC is a net lender.

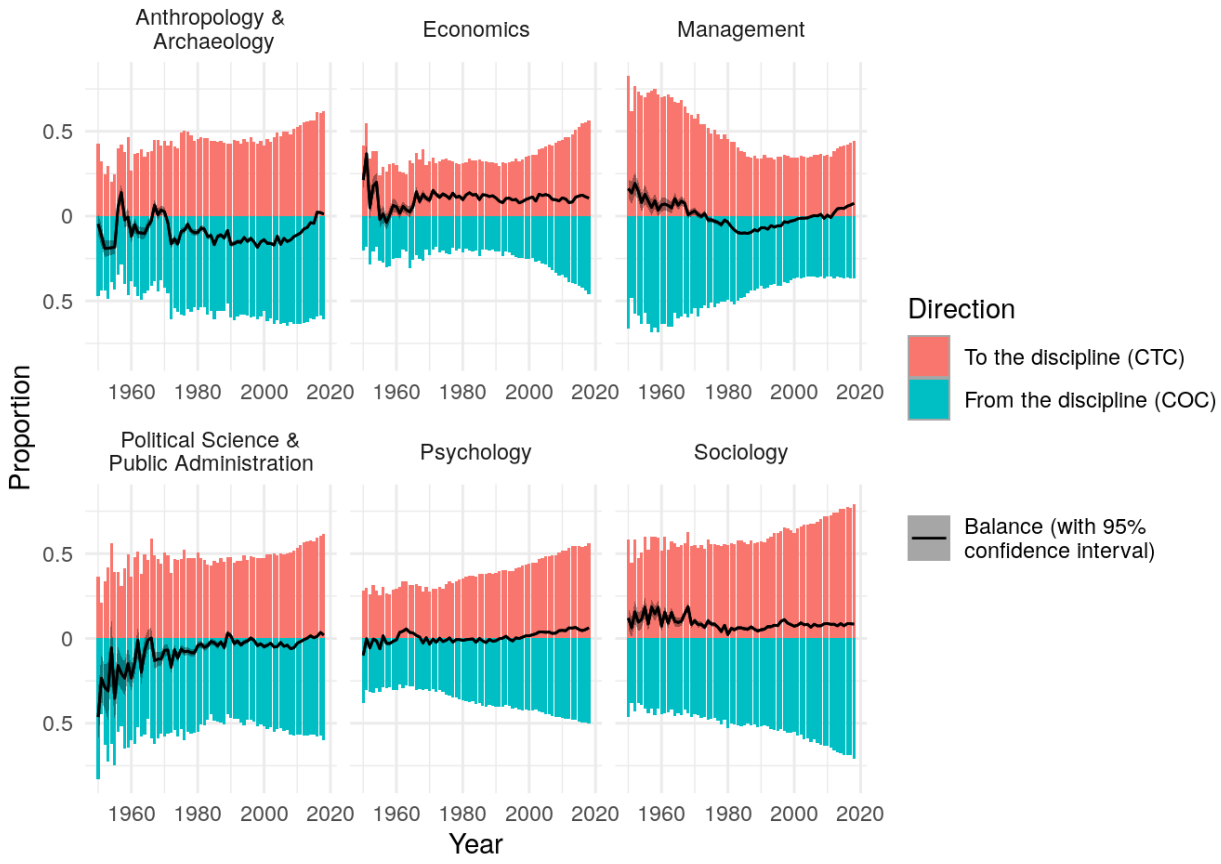


Figure 8: Balance of interdisciplinary citations in the main social sciences. The upper part of the graph shows the ratios for citations toward the discipline (CTC) while the lower part presents the ratios for outward citations (COC). The line is the difference between the two ratios, which gives the kind of openness dominant for each of the six disciplines.

A first conclusion emerges from this comparison:

C9 Economics and sociology are alone among our six main disciplines in being consistently net lenders.

Figure 8 justifies this claim and captures many of our previous results: (1) the overall interdisciplinary shares to and from each discipline, (2) their evolution overtime, and (3) the difference between the two shares, which we call the balance.

A striking property of this balance is that it can tilt toward net lender or borrower irrespective of the overall level of interdisciplinarity. Economics and sociology both have a balance tilted consistently toward influence on other disciplines (net lenders) although economics has been the archetype of a relatively insular discipline while sociology exemplifies a historically well-connected discipline. We also see that a relatively well-connected discipline such as anthropology & archaeology can have a balance tilted consistently toward borrowing. Finally, we also see with management that a discipline can move to being a net lender as it becomes less interdisciplinary.

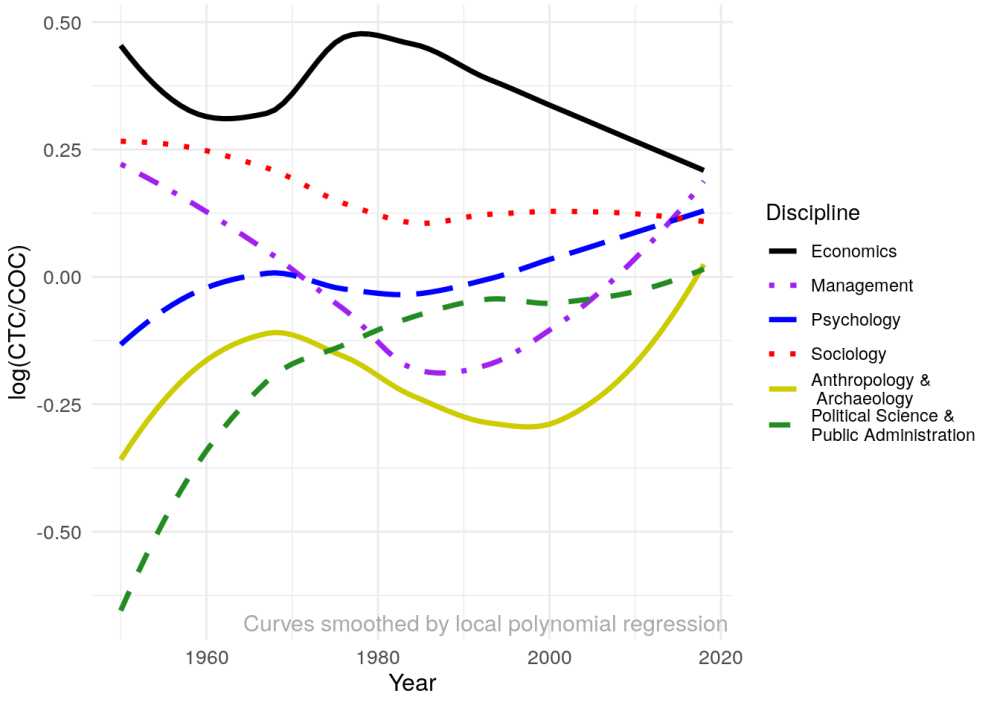


Figure 9: Ratio of lending to borrowing among the main SSH disciplines (in logarithms)

Figure 9, which looks at the log-ratio of CTC to COC, highlights another relevant property:

C10 The position of net lender of economics has been significantly more important than all other disciplines when we take into account the comparatively small magnitude of its interdisciplinary exchanges.

Indeed, the strength of the position of net lender of economics before 2000 is only comparable to the position of net borrower of political science & public administration at the beginning of the studied period, in the mid-1950s. This result is what captures best the asymmetric relationship of economics to the rest of the social sciences up to recently: it is not that other researchers have borrowed intensely from economics (i.e., its CTC has been relatively low), it is rather that the extent of this borrowing is not matched by a propensity of economics to itself borrow from other disciplines.

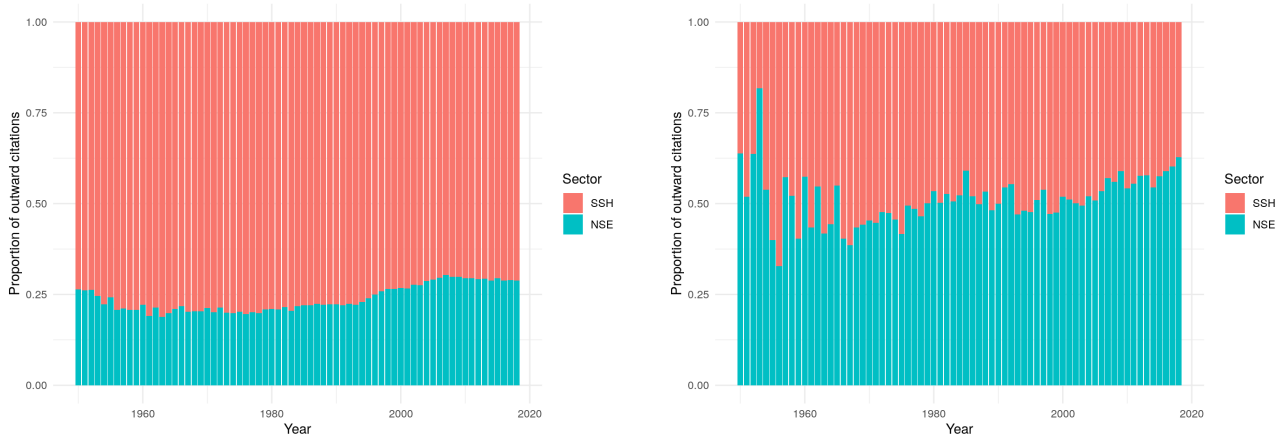
5 Disaggregating the relations of economics

To better understand the interdisciplinarity of economics, and more particularly its increased interdisciplinarity since the late 1990s, we can disaggregate the relations of economics. We first split the citations involving other social sciences and humanities (SSH) from the citations involving the natural sciences, engineering and biomedical sciences (NSE). We then look at the specific disciplines most cited by economics, distinguishing between the strongest ties and weaker, but nevertheless telling, ties.

5.1 Interdisciplinarity from the SSH to the NSE

Most of the literature on the insularity of economics has focused on the relationships among social sciences and has ignored the natural sciences. This approach misses important dynamics at the boundary between the two sectors. We observe two important trends:

C11 Across all SSH, an average of 24% of extradisciplinary citations goes to the NSE, with a slightly upward trend from the 1990s until 2007 (Figure 10a).



(a) From all SSH

(b) From economics only

Figure 10: Shares of the extradisciplinary citations going to NSE publications

C12 In economics, this proportion of extradisciplinary citations going to the NSE is higher at around 51%, with a slightly upward trend since 2000 (Figure 10b).

This result is consistent with research on the citation relations among all sciences. Attempts to map sciences by Moya-Anegón et al. (2004) and by Boyack, Klavans and Börner (2005) indicate that, among the social sciences, economics and psychology have uniquely strong relationships with some NSE: mathematics and computer science for economics; biology and neuroscience for psychology. A recent study of the French disciplinary classification system by Renisio and Zamith (2015) showed that automatic detection of communities puts economics with computer sciences and mathematics rather than with other SSH. Overall, economics and psychology act as bridges between the two sectors (SSH and NSE).

5.2 The strong ties of economics

Figure 11 focuses on the disciplines with the strongest historical ties to economics – i.e., the seven disciplines that have had the highest shares of economics citations over the studied period.

The first important transformation of economics' ties is in its relation to mathematics:

C13 In the 1950s, mathematics was, by far, the most cited discipline by economics, but its

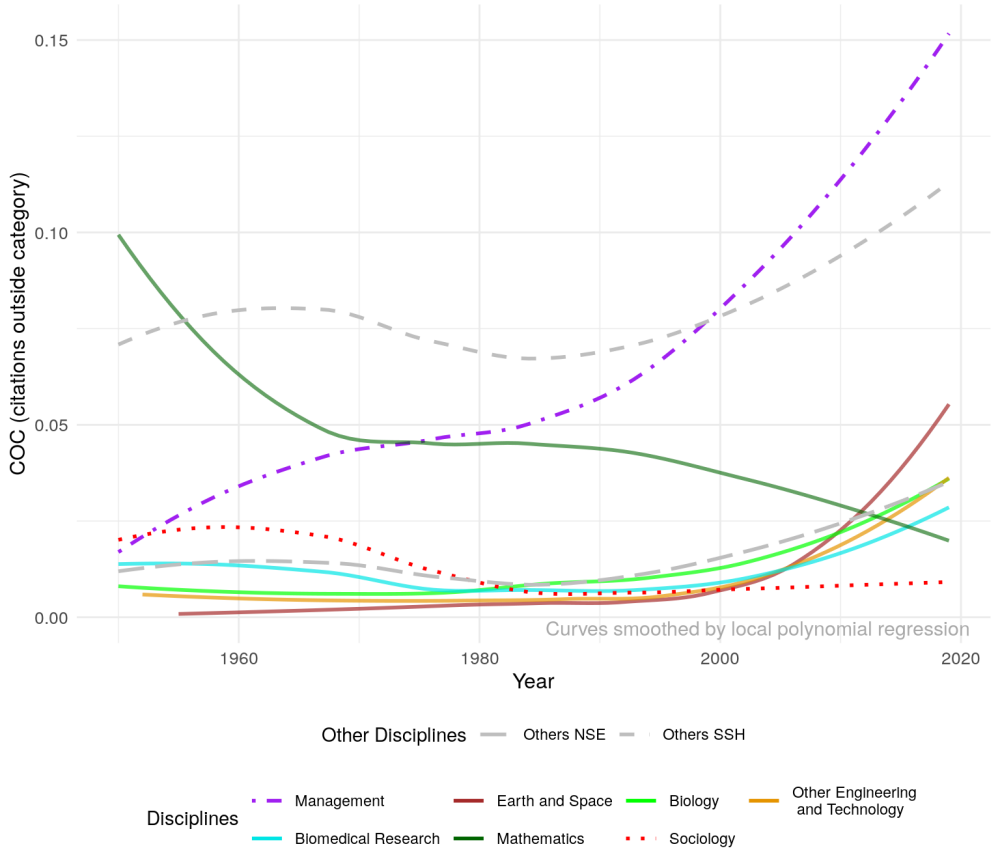


Figure 11: Extradisciplinary citations of economics, with a focus on the seven disciplines with highest overall shares.

influence steadily decreased to the point of being a relatively minor source of reference today.

The high rate of citations to mathematics in the 1950s and 1960s is consistent with the standard history of economics as a discipline that entered a phase of intense mathematization starting in the 1930s (Weintraub, 2002). With respect to the steadily weakening ties, two explanations complement each other.

On the one hand, as suggested by McCain (2014), there is a phenomenon of 'obliteration by incorporation.' While importing mathematical tools, economists developed their own mathematical culture. After some time, it became less relevant to reference explicitly the disciplinary origin of some of the most central tools of economics. According to this

interpretation, economics did not necessarily become less mathematical as it came to cite mathematics less intensively. It has incorporated parts of mathematics in a way that does not necessitate constantly renewed interdisciplinary borrowing.

On the other hand, there is evidence that economics is becoming less mathematical in the sense that economists are less keen today to integrate evermore complex mathematics. Romer (2015) talks about a new equilibrium of 'mathiness' in some areas, and some bibliometric studies with manually assigned codes suggest that, in some specialties like behavioral economics, the use of mathematics is now less prominent (Braesemann, 2019). This change would be related to the shift toward more empirical and less theoretical research (Angrist et al., 2017). In addition, the rising use of big data and simulations in economics might contribute to the decreasing importance of mathematics relatively to computer science (Backhouse and Cherrier, 2017), although we observe no strong substitution of one for the other in our citation data (see Figure 11).

The second notable transformation of economics' ties is with management, which evolved in the opposite direction to mathematics:

C14 The share of economics' citations going to management steadily grew over the period, overtaking mathematics in the 1970s and approaching 15% of all citations most recently.

This interdisciplinary relation is intense: in the last five years of our period (2014 to 2018), management accounted for a third of the extradisciplinary citations of economics. This strong rapprochement is also striking because the two disciplines have radically contrastive bibliometric histories.

As we saw earlier (see Figure 2 and accompanying discussion), their interdisciplinary trends are opposite: economics becoming more interdisciplinary while management became more insular. More importantly, economics and management also had very dissimilar strong ties earlier in the period. A previous study asserted that management had strong ties to sociology and psychology up to the 1990s (Johnson and Podsakoff, 1994). Our own data suggest the following:

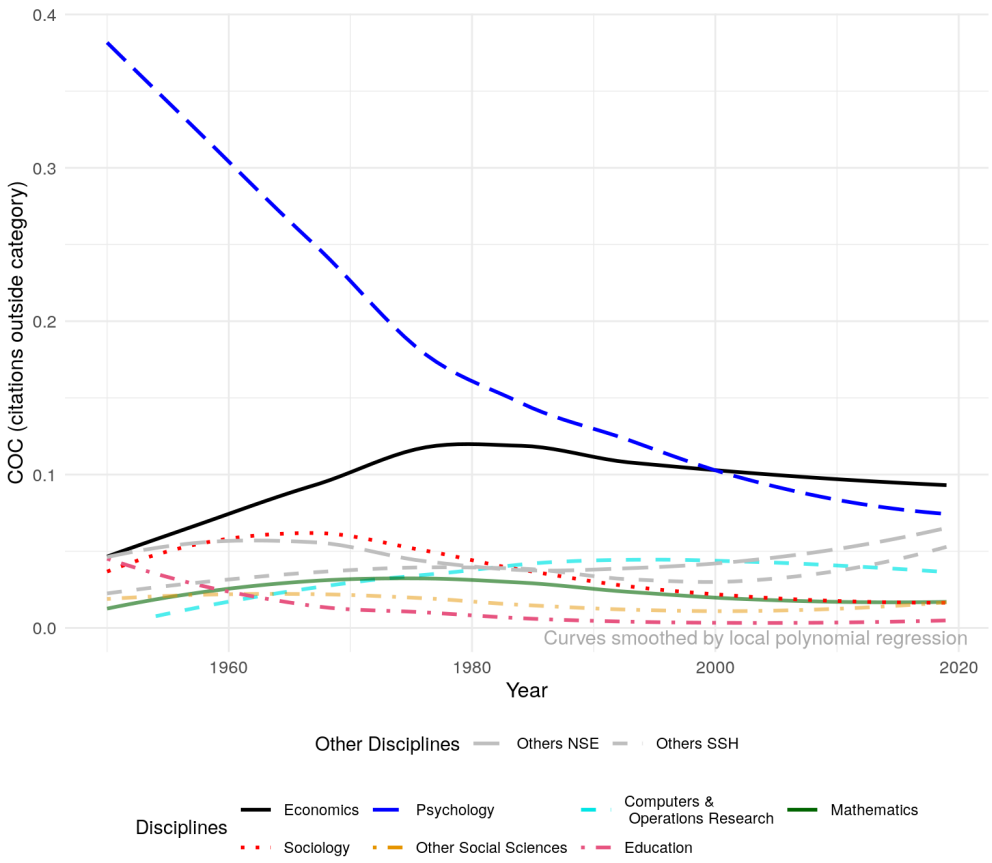


Figure 12: Extradisciplinary citations of management

C15 Early in the period, psychology was, by far, the most cited discipline by management and economics overtook psychology as the main discipline of reference for management only in the 2000s (Figure 12).

The early openness of management to psychology – i.e., in the 1950s, an average of 35% of management's total citations went exclusively to this discipline – contrasts with the scepticism of economists early in the period toward all other social sciences and toward psychology in particular (Guala, 2005). There is ample evidence that a large share of economists considered that psychology was either less scientific than economics or dangerous for the core of economic theory (Hands, 2010). The reliance of management on psychology might have contributed to the separation between management and economics in the 1950s and 1960s, as they embodied different ideals of interdisciplinary practice.

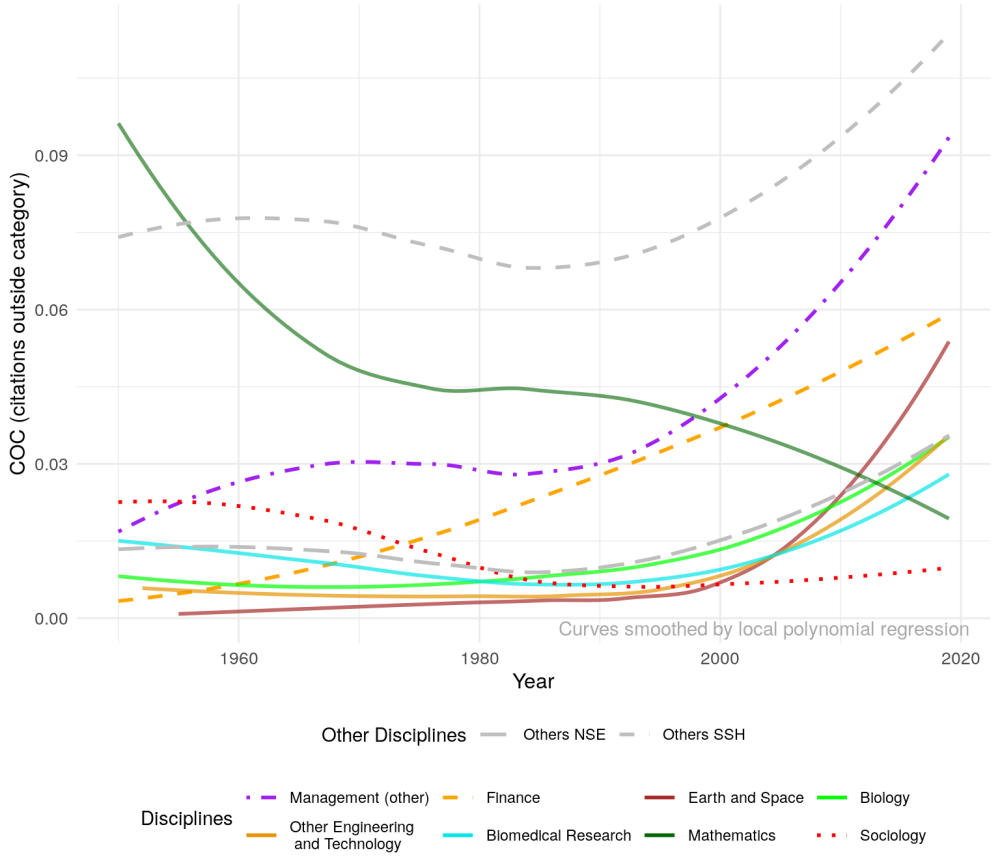


Figure 13: Extradisciplinary citations of economics. This figure reproduces Figure 11 with the exception that management is split between finance and other management.

Now, what can be said about the sharp rise in the citations of economics to management? Following Fourcade, Ollion and Algan (2015), an intuitive explanation is that what we are capturing is mostly the rise of finance. Indeed, the NSF category 'management' bundles together a variety of fields associated to business disciplines such as accounting, finance, general management, marketing and the management of information systems. We know that some journals in finance – most notably the *Journal of Finance* – have become prestigious venues for economists. Perhaps the strong rapprochement of economics is not with management in general, but with finance in particular.

To test this hypothesis, we have designed a procedure to split the journals included in

our management category into finance journals and the others.[9] The results do not confirm the hypothesis (see Figure 13):

C16 From the 1970s to the late 1980s, the increased relation of economics to management was concentrated in finance, but since the 1990s, management journals outside finance are responsible for most of the rise in influence of management on economics.

In short, the rapprochement of economics is with business fields in general. Future work should investigate the connection of this phenomenon with the rising importance of business schools in the social sciences and as employers of economists specifically.

5.3 The weak ties of economics

Besides the strong ties of economics with management and mathematics, weaker ties are worth discussing. Although they do not individually represent a substantial share of citations from economics, they add up. To investigate the weak ties of economics, we exclude mathematics and management and plot in Figure 14 the next 10 disciplines with the highest overall shares of economics' citations.

We can highlight three important transformations of the weak ties of economics:

C17 Since 2000, citations to natural and health sciences have grown rapidly (earth and space, biology, biomedical research, engineering and technology).

C18 Citations to sociology have contracted from the 1960s to the 1980s, and have stabilized to a low level ever since.

C19 Citations to other social sciences (mainly political science, geography and psychology) have been on a mild upward trend for a long time.

The connection of economics with environmental research has been noted in previous research. Vedeld (1994) compared ecological sciences and economics to argue that interdisciplinarity between the two was slow to develop because of important methodological and

[9] See the technical appendix for details and further results.

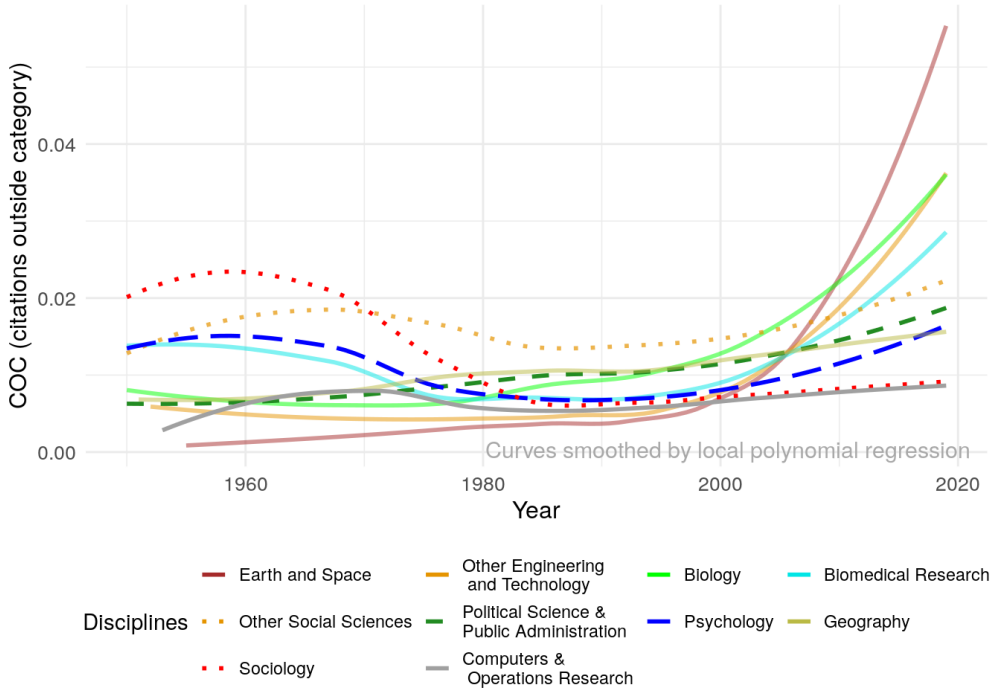


Figure 14: Extradisciplinary citations of economics after excluding management and mathematics.

theoretical differences, but that some common practices (such as a focus on mathematical modeling and quantitative empirical studies) could be a sufficient basis for a stronger relationship in the future. Our data shows that this prediction was realized: in the late 2010s, earth and space (which includes environmental sciences) was the second most cited disciplines by economics (after management) and biology (encompassing ecology) was in third place. The attribution to William Nordhaus of the 2018 Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel is another indicator of the strengthening importance of this connection, since this interdisciplinary trend is closely linked to the emergence and growth of the field of environmental economics (Huet, 2018).

Of course, environmental economics is not the only cause of the rise of citations to natural and health sciences such as biomedical research, engineering and technology, and biology. It reflect specific interests from specialties and applied fields in economics such as health economics, transport economics and industrial economics.

Our last two conclusions on the weak ties of economics concern other social sciences.

The first notable transformation is the contraction of citations to sociology. This pattern is consistent with research that describes the relationship of economics and sociology has shifting from a 'complementary' one to a 'competitive' one after 1945 (Geary, 2010).

The evolution of the relation to psychology is more complex. Like sociology in the 1950s, psychology was a relatively important discipline for economics. While citations to sociology never recovered, we do find a slight increase in the intensity of citations to psychology since the 1990s, which has now reached a level similar to the 1960s. The interaction between economics and psychology has attracted much attention in the last decades as behavioral economics grew in importance, with two Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel (in 2002 and 2017) awarded to some of its key figures. Many historians and philosophers interested in interdisciplinarity have studied this case (e.g., Sent, 2004; Guala, 2005; Davis, 2008). In a scientometric study, Braesemann (2019) found that citation rates to psychology from *behavioral* economics decreased between 1980 and 2010. Our own data indicate that this rate has increased for economics *as a whole*, which is consistent with Braesemann's result to the extent that behavioral economics constitutes a larger share of economics today (see Truc, 2020, for evidence of this composition effect).

We also observe a slow but steady rise of citations to geography. The relation of economics to geography has been a subject of controversy. For instance, Martin (1999, p. 84) criticized the 'new "geographical turn" in economics' of the 1990s for being too focused on 'mathematical-theoretical papers' at the expense of work in regional science. Brakman, Garretsen and van Marrewijk (2011) provided a similar conclusion about the asymmetric relationship between the two disciplines by looking at citations among the publications in the *Journal of Economic Geography*. More recently, Atienza, Ronda-Pupo and Phelps (2019, p. 18) has used bibliographical coupling on publications in 55 journals at the frontiers of the two disciplines and concluded that 'the distance between the core journals of geographers and economists appears to have increased and mutual neglect seems the dominant position' even if there is an 'emerging space of dialogues' at the periphery of the discipline. Our own data do not support the thesis of a growing 'mutual neglect' since we observe a steady

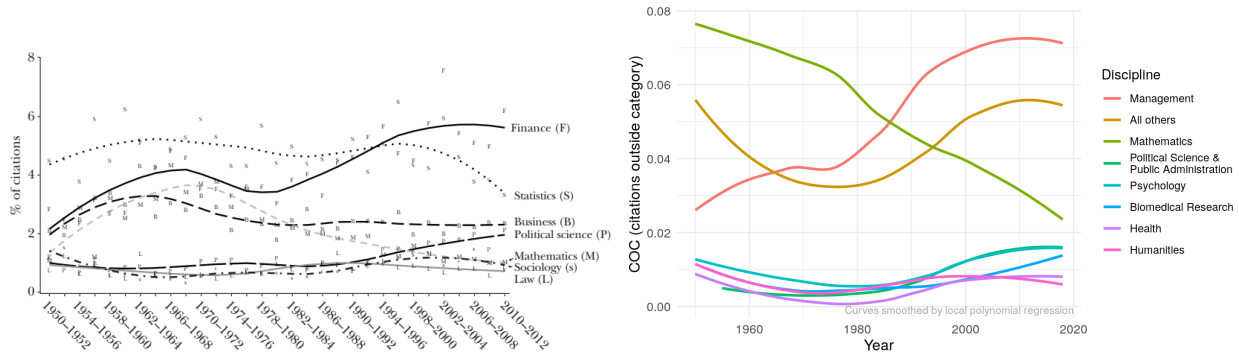
rise of citations from economics to geography. This result echoes other conclusions in the specialized literature: Rebours (2019) shows that, since the 1990s, economic geography has emerged and steadily grown to become a relatively autonomous specialty in economics.

The relation of economics to political science has also been discussed extensively elsewhere. In the 1950s, Black (1950, p. 506) already emphasized the unity of the two disciplines: according to him, they shared language, concepts and methods. Rational choice theory was heavily influential in political science after 1945, in what has been called 'the second revolution' (Goodin and Klingemann, 1998, p. 23). This influence is sometimes described with the metaphor of imperialism: 'the only relative exception to this pattern [...] is political science, in which the dominant economic paradigm has successfully conquered a segment of the discipline.' (Fourcade, Ollion and Algan, 2015, p. 94) The underlying concern is shared by some political scientists who see in this asymmetric relationship 'one of the main threats to the separate identity of political science in recent decades' (Moran, 2006, p. 75). While the relationship between economics and political science might have been one of imperialism in the 1950s and 1960s, the growing citation rate from economics to political science suggests that the relation is increasingly bidirectional.

6 Comparison with the recent literature

With all these results in hand, let us now go back to the two studies discussed in the introduction (Fourcade, Ollion and Algan, 2015; Angrist et al., 2020). This section serves two goals. First, it provides a robustness check on our classification procedure: since the data used by these two studies are subsets of our data, we should be able to reproduce their results by imposing the relevant constraints. Otherwise, it could signal a problem with our classification. Second, the comparison allows us to show that some of the methodological choices made in these previous studies imply an overestimation or an underestimation of the interdisciplinarity of economics.

6.1 Robustness check of our method



(a) The original

(b) Our reproduction

Figure 15: Extradisciplinary citations from economics. Reproduction of Fourcade, Ollion and Algan (2015, Fig. 3) using their selection of journals and our classification.

The method of Fourcade, Ollion and Algan (2015) differs from our own in two major ways: they focus on five top journals in economics instead of 373 journals, and they use finer categories for some disciplines such as distinguishing statistics from mathematics and finance from business. Using our own categories, but focusing on the same top journals, we produce highly similar results (see Figure 15). The overall level of extradisciplinary citations is at a similar level, between 0 and 8% depending on the disciplines. We also find the same general trends with the decreasing importance of mathematics (our mathematics versus their statistics and mathematics), the increasing importance of management (our management versus their business and finance), and a slowly increasing interdisciplinarity with a variety of disciplines that remain at an overall low level. Fourcade, Ollion and Algan (2015, web appendix) hand-coded the 6 million references from their five journals into 26 categories, which gave them high quality bibliographic data to produce their Figure. The fact that we can reproduce their results with our data is strong evidence that our categories are valid.

Turning to Angrist et al. (2020), we can highlight two important methodological differences. The first is that they develop their own procedure to sort journals into categories while we use a predefined and exhaustive list of categories from the NSF with all journals

in the *Web of Science* sorted in one category. In contrast, they began by selecting 17 disciplines of interest to them, thus overlooking many others. They then selected one or two core journals for each discipline using the journal(s) associated with the leading American professional association of the field. Finally, they looked at the top 50 journals most cited by the core journal(s), and considered these 50 journals as constitutive of the discipline. Our second methodological difference with Angrist et al. (2020) is that they weigh citations using their own impact factor. In contrast, our main results count all citations equally, irrespective of the originating journal.[10]

Although our methodological choices differ markedly from Angrist et al. (2020), we can reproduce their results by restricting the journals and disciplines to their list, and by adding a weighing scheme similar to theirs.[11] For instance, their Figure 1 is reprinted and then reproduced in our Figure 16. This exercise shows again that our data are not fundamentally different from theirs.

6.2 Methodological issues in previous studies

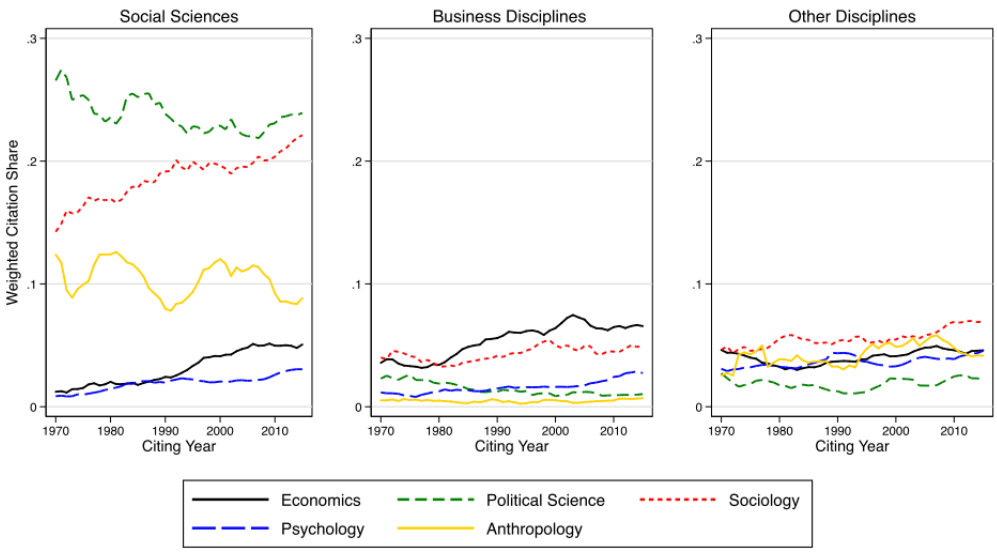
The differences we observe between our results and the literature are easily explained and there are compelling reasons to prefer our methods and conclusions.

In the case of Fourcade, Ollion and Algan (2015), our study can be interpreted as an extension of their own. Rather than focusing on five top journals, we consider all economics journals available in the *Web of Science*. As we have shown in Figure 4, top journals did not participate in the interdisciplinary turn we observed in the 1990s and 2000s. It is, therefore, not surprising to find that Fourcade, Ollion and Algan (2015) *underestimate* interdisciplinarity in economics and conclude that economics was and remains highly insular.

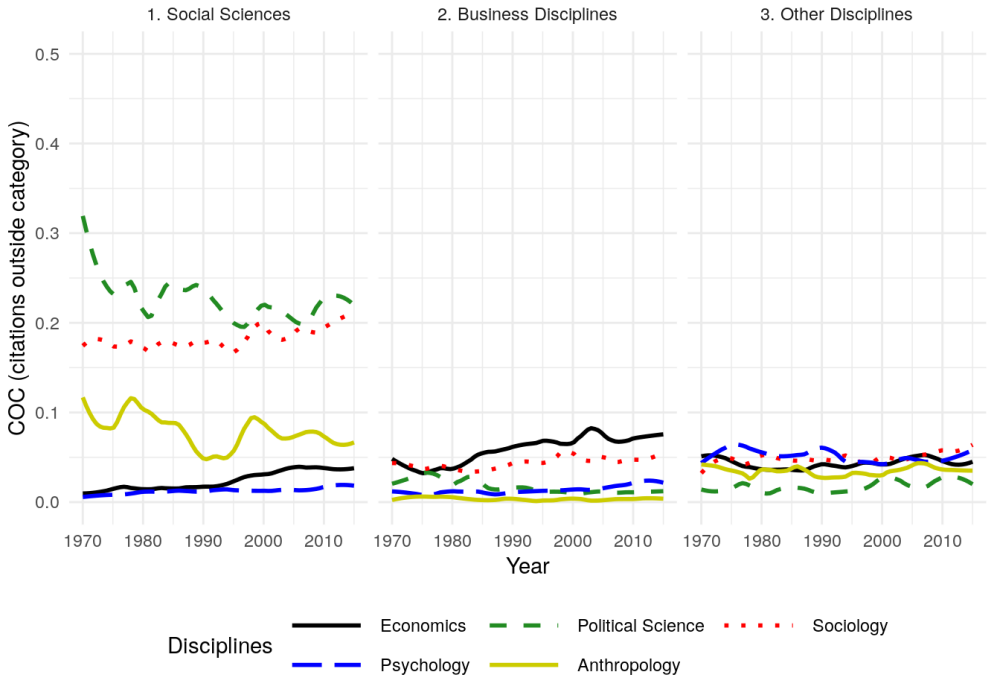
Angrist et al. (2020) also represent an extension of Fourcade, Ollion and Algan (2015).

[10] When we use an impact factor – e.g., to find the most influential journals in each discipline (see Section 4.2), but also as robustness checks in our technical appendix – we do not count citations originating only from a single core journal, but all citations internal to a discipline.

[11] This weighing scheme is different from the one we use elsewhere in this article and in the technical appendix because we tried to mimic their choices. The description of their weighing scheme being incomplete (see their web appendix), we had to be somewhat creative. We conjecture that the minor discrepancies in our reproduction of their Figure 1 is mostly attributable to differences in the weighing scheme.



(a) The original



(b) Our reproduction

Figure 16: Social Science Insularity. Reproduction of Angrist et al. (2020, Fig. 1) using their categories and approximating their weighing scheme.

We share with them the 'clear trend showing economics to be increasingly outward looking' (Angrist et al., 2020, p. 4). However, our results do not support their claim that:

> [E]conomics is not uniquely insular: psychology is less outward-looking than economics, and anthropology looks more like economics than like political science or sociology. (Angrist et al., 2020, p.4)

This conclusion is mainly supported by the figure reproduced in our Figure 16. Indeed, if this figure (and especially the right panel about 'Other Disciplines') was an accurate depiction of interdisciplinary citation flows, economics would not be historically peculiar.

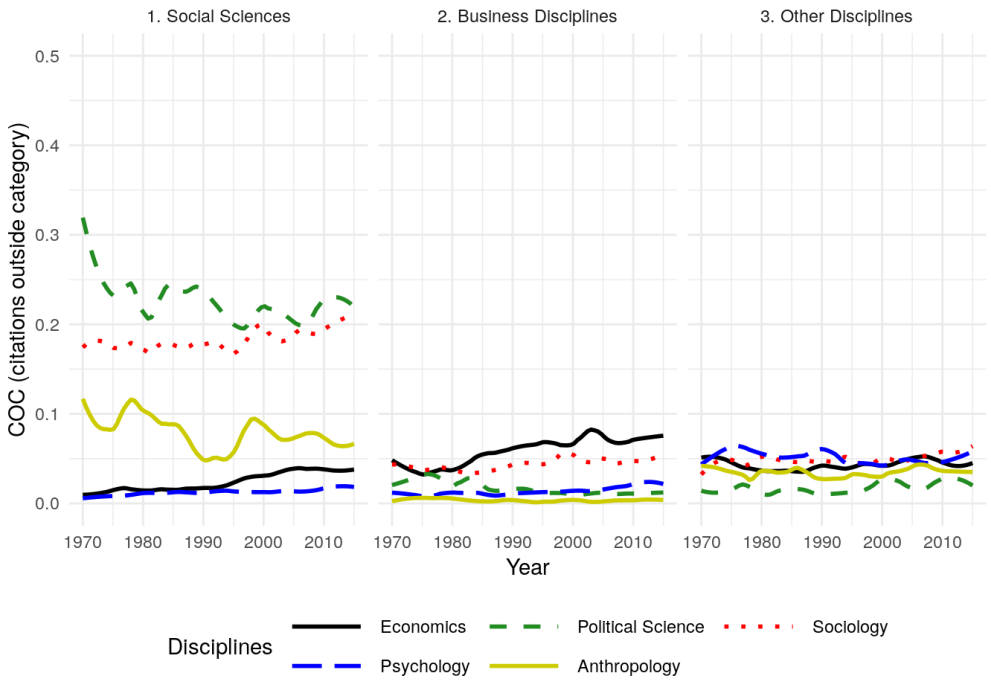
Yet, because they use non-exhaustive categories to identify disciplines, Angrist et al. (2020) significantly *overestimate* the interdisciplinarity of economics relative to other disciplines. The left panel in Figure 16 already shows that political science and sociology have been far more outward looking than economics. Psychology and anthropology are left as disciplines with insularity potentially similar to economics and, indeed, no panel in Figure 16 indicates that they have COC markedly above economics. But psychology and anthropology rely heavily on disciplines outside the social sciences such as biology and neuroscience, disciplines that are not part of the list compiled by Angrist et al. (2020). What does the Figure 16 look like if we take all disciplines as potential recipients of citations? Figure 17b gives the answer. With a better coverage of disciplines, psychology and anthropology stand out as having strong ties in the natural and health sciences. Furthermore, sociology, political science and anthropology have interdisciplinary connections with other social sciences that dwarf those of economics. Hence, economics is left alone as peculiarly inward looking if we take the three (corrected) panels into consideration.[12]

Note that the overturning of Angrist et al.'s conclusion does not hinge on the choice of a weighing scheme for journals, but on the removal of their sampling bias. Indeed, the results in Figure 17b are produced while using their weighing scheme. It might be considered reasonable to impose such a scheme to account for the greater 'importance' of some journals.[13]

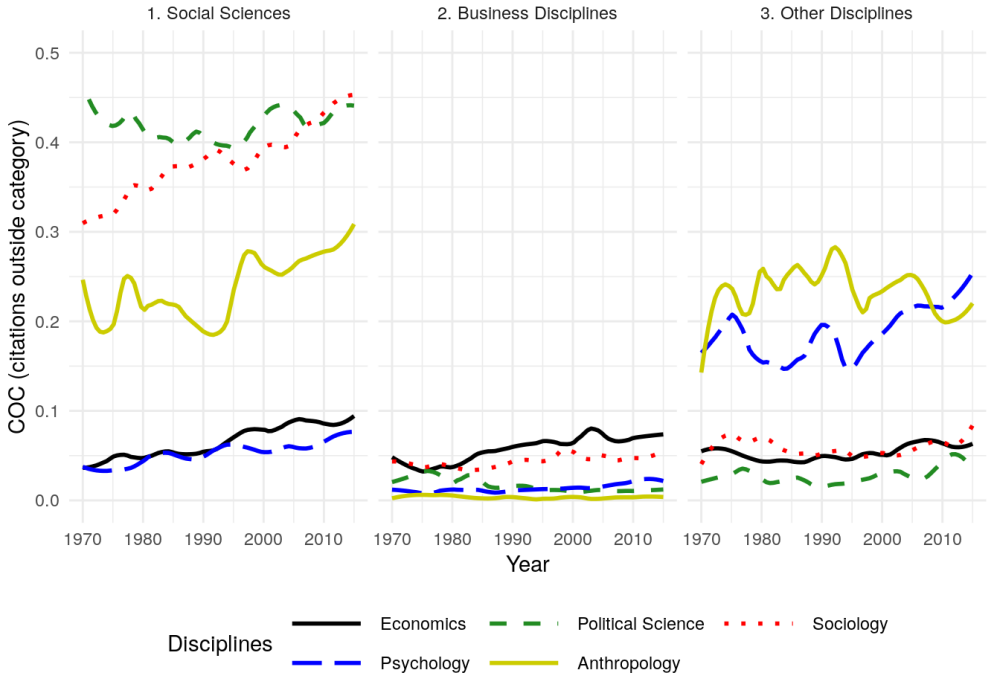
[12] As is also evident from Figure 17b, Angrist et al. (2020, p. 4) gave one important correct answer, but for the wrong reasons. They "document a clear trend showing economics to be increasingly outward looking." Yet, the trend visible in Figure 17 when the list of disciplines is exhaustive is mild, expecially if we compare it to the trend shown in our Figure 2. This discrepancy stems from their weighing scheme: by extremely overweighing the *American Economic Review*, they miss much of the intensity of the recent interdisciplinarity.

[13] Note that 'importance' as measured by citations should not be equated to something akin to overall 'scientific quality.' See (Colussi, 2018) and D'Ippoliti (2020) for the case of economics.

However, we see no way to justify a biased sample of disciplines. What the team has done is akin to surveying people above 55 years old regarding their online habits, and then drawing conclusions for all adults.



(a) First reproduction (same weighing scheme, same disciplines)



(b) Second reproduction (same weighing scheme, but exhaustive disciplines)

Figure 17: Social Science Insularity. Reproduction of Angrist et al. (2020, Fig. 1). Both versions approximate their weighing scheme, but the version below drops their arbitrary restriction to a small list of cited disciplines.

7 Conclusion

Recent citation studies by Fourcade, Ollion and Algan (2015) and Angrist et al. (2020) have reached opposite conclusions. For the former, economics is uniquely insular in comparison to other social sciences. For the latter, economics is growing more open, and was never as inward looking as often alleged. As demonstrated in the previous section, both studies have important methodological limitations.

With our own study, we have corrected and expanded the understanding of the interdisciplinary relations of economics since the 1950s. Historically, economics has been uniquely inward looking. Between 1950 and 2010, economics was the most insular of all social sciences and humanities in terms of its propensity to cite scholarly work outside the discipline. Management won the title in 2010, but economics is still second to management on this metric.

Since the 1990s, economics has become more outward looking surprisingly swiftly. If the current trend continues, it will take only a few years for economics to surpass the average ratio of interdisciplinary citations among all social sciences. Its interdisciplinary relations have also changed. Its orientation toward the discipline of mathematics is long gone. Strong ties with management have developed, accompanied by weaker but diverse connections to other disciplines.

Two characteristics complicate the story of an interdisciplinary turn of economics. First, it is still a discipline that does not perfectly reciprocate the interest other scholars take in it: among the main social sciences, economics has been and is still the discipline with the highest ratio of citations toward itself (CTC) to outward citations (COC).

Second and most importantly, the most influential journals in economics do not participate to the increased rate of outward citations: they remain extremely inward looking while the rest of the discipline diversifies. Since economics is a particularly hierarchical discipline, with influence concentrated among a few institutions (Fourcade, Ollion and Algan, 2015; Colussi, 2018; Hoover and Svorenčík, 2020; Heckman and Moktan, 2020), it is therefore far from having completed a genuine interdisciplinary turn. For this turn to happen, its 'top'

journals must either follow the lead of historically less influential venues or their influence must drop from their current stratospheric level. The internal power dynamics of economics is thus entangled with its openness to external influence.

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