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The Fragmentation of the Mainstream and Communication in Economics: A View from the Top

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The Fragmentation of the Mainstream and Communication in Economics: A View from the Top

Magda Fontana* and Martina Iori†

The decline of Neoclassical dominance has paved the way to a more fragmented Mainstream. In this article, we empirically explore the Mainstream's thematic structure and its fragmentation's effects on within-discipline communication. For this purpose, we exploit a dataset containing 10,064 articles published in economics in seven Blue Ribbon Eight journals between 1985 and 2006 and their citations. Articles are assigned to 18 topics created via Latent Dirichlet Allocation to represent specialities within economics. Results show that the economic Mainstream has yet to experience a dramatic increase in fragmentation in the observed period, and the prevailing topics are related to market equilibrium and econometrics. Moreover, the Mainstream's thematic structure does not include any heterodox approach. Regarding communication, economists increasingly tap into diverse sources of information, and such diversity positively impacts the citational patterns of articles. The same result holds for the articles written by Nobel Prize winners and the most cited articles in the discipline, which exhibit a higher diversity than the whole sample.

Keywords: communication, mainstream economics, citations

La fragmentation du courant dominant et la communication en économie : une perspective depuis le sommet

Le déclin de la dominance néoclassique a ouvert la voie à un courant dominant plus fragmenté. Dans cet article, nous explorons empiriquement la structure thématique du courant dominant et les effets de la fragmentation sur la communication au sein de la discipline. À cette

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fin, nous exploitons un ensemble de données contenant 10 064 articles publiés en économie dans sept revues issues du Blue Ribbon Eight entre 1985 et 2006, ainsi que leurs citations. Les articles sont classés en 18 sujets créés grâce à la méthode de l'allocation de Dirichlet latente pour représenter les spécialités au sein de l'économie. Les résultats montrent que le courant économique dominant n'a pas encore connu une augmentation significative de la fragmentation pendant la période observée, et les sujets prédominants sont liés à l'équilibre du marché et à l'économétrie. De plus, la structure thématique du courant dominant ne comprend aucune approche hétérodoxe. En ce qui concerne la communication, les économistes font de plus en plus appel à diverses sources d'information, et cette diversité a un impact positif sur les citations des articles. Le même résultat s'applique aux articles écrits par les lauréats du prix Nobel et aux articles les plus cités dans la discipline, qui présentent une plus grande diversité que l'échantillon total.

Mots-clés: communication, économie mainstream, citations

JEL: B20, B40, C01

In the last three decades, economics has taken a more multifaceted profile characterised by a diversity of research programs with distinct theoretical and methodological approaches pursued by different communities of researchers (Davis, 2006; 2008). The increasing diversity of approaches has extended to the once very cohesive Mainstream (Davis, 2006; Fontana, 2010a) up to the point that the current state of the Mainstream is often referred to as one of fragmentation (Cedrini and Fontana, 2018).

The prospective outcome of this process has spurred a thriving debate among scholars that discuss whether such fragmentation could hamper communication among scholars and, eventually, the growth of the discipline itself (Pencavel, 1991; Dow, 2008; Fine and Milonakis, 2009; Cedrini and Fontana, 2018).

In this article, we attempt to tackle this issue through an empirical investigation of communication within the economics Mainstream. We ask whether economists, when publishing their research, tap into different sources of information (namely, economic journals in articles' references) and if there is a correlation between the intensity of such difference and the diffusion of a publication (citations accrued by articles).

The topic is indeed very complex, since the very definition of Mainstream is controversial (see section 1), and approximating information with references and citations implies a radical simplification of the actual process of conducting research. Nevertheless, we rely on and build upon an ever-growing body of literature that applies similar methods to investigate the methodological and historical issues in economics (see, for instance, Cherrier, 2015a; Claveau and Gingras, 2016; see also section 1).

Following the definition of Mainstream by Dequech (2007)—approaches taught at the most prestigious universities, published in the top journals and receiving financial support from the most important institutions—we proxy the Mainstream with the articles published in influential venues in economics: the Blue Ribbon Eight (Conroy and Dusansky, 1995)—the *American Economic Review*, *Econometrica*, the *International Economic Review*, the *Journal of Political Economy*, the *Quarterly Journal of Economics*, the *Review of Economics and Statistics*, the *Review of Economic Studies*, and the *Journal of Economic Theory*. Choosing the most influential outlets in a discipline is an undertaking in itself. In order to avoid a subjective choice and to be able to align our results with the extant literature, we have opted for the Blue Ribbon Eight journals, which are commonly recognised as such (Conroy and Dusansky, 1995; Dusansky and Vernon, 1998; Heck and Zaleski, 2006; Lo et al., 2008, Heck et al., 2009; Cardoso and Teixeira, 2020).

Our Mainstream dataset contains 10,064 articles from the JSTOR database published in economics in seven Blue Ribbon Eight journals between 1985 and 2006. Fragmentation is modelled by assigning each article to a community of articles identified by a shared language. This method is in line with the late Kuhnian characterisation of research communities identified with their distinctive lexicon (Wray, 2011, 97). Topics are generated via Latent Dirichlet Allocation (Blei et al., 2003). The algorithm leverages the co-occurrence of words across documents to come up with the topics. A topic consists of a series of words meaning that several articles tend to use some of these words together repeatedly. This tendency, which is unlikely to happen by coincidence, suggests that those articles have something in common, i.e. a specific topic that is commonly dealt with by using these words in a relevant way. By conducting several sensitivity tests, we eventually identified 18 topics representing the Mainstream's fragments.

Finally, the relationship between the difference in information sources and the diffusion of articles is assessed with an ordinary least squares (OLS) regression. To corroborate our findings, we also study the same effect in two subsets of articles: those written by Nobel Prize winners and the top-cited articles in our sample.

Results show that the economic Mainstream has not experienced a dramatic increase in fragmentation in the observed period, and the prevailing topics are related to market equilibrium and econometrics. Moreover, the Mainstream's thematic structure does not include any heterodox approach. Regarding communication, we find that economists increasingly tap into diverse sources of information and that such diversity positively impacts the citational patterns of articles. The same result holds for the articles written by Nobel Prize winners and the most cited articles in the discipline, which exhibit a higher diversity than the whole sample.

The article is organised as follows: section 1 introduces the theoretical and interpretative background; section 2 presents the dataset and the measures adopted in the empirical analyses; section 3 expounds the results, while section 4 concludes.

1. Theoretical and Methodological Background: Mainstream, Communication and Circulation of Knowledge in Economics

The idea that the decline of neoclassical dominance has paved the way to a more multifaceted discipline and Mainstream has been discussed extensively in the literature.

The 1991's symposium of the *Economic Journal* on "The Next Hundred Years" of the discipline revolves around this theme. It presciently introduces many of the issues that are currently animating the economists' self-reflection debate.

Hahn (1991, 50) expects a future narrower scope of research and anticipates a sort of reverse imperialism: "not only will our successors have to be far less concerned with general laws than we have been, they will have to bring to the particular problems they will study particular histories and methods capable of dealing with the complexity of particular, such as computer simulation. Not for them... the pleasure of theorems and proofs. Instead, the uncertain embrace of history, sociology and biology". Pencavel (1991, 85) pushes the argument further by pointing out that as economics grows in size and diversity, the unity that was once granted by the mathematical language will be lost in favour of a much-fragmented discipline: "Economists will be an increasingly heterogeneous assortment of scholars. Indeed, it will become difficult to identify exactly what common elements bind us all". Economics will, in fact, become "a fragmented world of specialisation" (*ibid.*), with the resulting problem for its practitioners of keeping abreast of developments "in more than a few narrow fields of the subject" (*ibid.*).

As for the nature of fragmentation, Backhouse and Cherrier (2017) highlight the rise, starting from the 1970s, of applied economics to side with the once prevalent theoretically-inclined Mainstream. Davis (2008) maintains that fragmentation would result from the import of ideas from—mainly—heterodox economic approaches (e.g. game theory, experimental economics, evolutionary economics, behavioural economics, complexity economics) and from other disciplines with the result that the Mainstream of economics could no longer be identified as a single theoretical system, not even that of the rationality-maximisation framework.¹

The theoretical and methodological variety that follows the fragmenta-

1 Contrary, see Giocoli (2003), who claims that the discipline would be unified by the attempt at finding a general systematisation of agents' rational behaviour under certainty and uncertainty conditions. In a similar vein, Fine and Milonakis (2009, chapter 7) argue that, even at the edge of a possible dissolution as a discipline, economics is still unified by methodological individualism and universalism. A more nuanced opinion is expressed by D'Ippoliti (2020), who acknowledges the pluralism but recognises a resemblance across Mainstream approaches. A similar position is expressed by Coats (2014, 383), who argues that, even if the prevailing method is still that of mathematical formalisation, a variety of approaches have gained prestige and recognition within the academic and scientific arena.

tion is welcomed by scholars who see such diversity as a possible resource for knowledge creation (Cedrini and Fontana, 2018) or acknowledged as a necessary feature of the discipline (Dow, 2008). Dow sees methodological pluralism as necessary since there are diverse ways of constructing knowledge and no way of unifying them. Dow also considers that variety is essential to the resilience of the discipline and, finally, that a variety of methodological approaches is required as economics covers disparate topics. A different line of research perceives pluralism as a peril for the discipline's future. Roncaglia (2020) depicts economics as a field where fundamental disagreement over methodology and policy prescription abounds. Roncaglia expresses his concerns through Schumpeter's words (1954): excessive pluralism would instil into the discipline "a sense of lacking direction and meaning" (Roncaglia, 2020, 4). Indeed, if "each specialty develops its lexicon or taxonomy, one that is incompatible ('incommensurable') with the established tradition: specialisation implies isolation" (Wray, 2011, 97). The consequences of fragmentation would be that of hampering, possibly stopping, the evolution of economics as a whole: "A large collection of (new) specialties can gravitate around the same set of scientific puzzles, but at the same time, due to fragmentation, a kind of topic-incommensurability (Wray, 2011) is likely to emerge, making a rational resolution of the disputes de facto impossible" (Cedrini and Fontana, 2018, 439).

Similarly, Ritzberger (2008, 402) expresses concern for the hyper specialisation of the discipline: "While half a century ago a well-trained economist may have comprehended all key developments in economics at large, today it is difficult to follow even the pace of subfields. Thus, the judgement by an individual academic is accurate only in so far as it concerns her or his field of specialisation".

Numerous studies have presented evidence that fragmentation is taking place and, therefore, is worth investigating in detail. As early as 1995, Stigler et al. (1995, 334) denounce the increase in the number of academic journals and the specialisation of scholars. Accordingly, prestigious generalist journals—such as the *Review of Economics and Statistics*, *Economica* and the *Economic Journal*—have experienced decreasing importance in rankings, and only a few of them—*American Economic Review*, the *Journal of Political Economy* and *Econometrica*—have conserved their positioning. Specialized economic associations have followed the same dynamics: their growth accelerated in the 1970s and became very sustained during the 1980s. The same process is mirrored in the history of JEL codes that, starting from the 1960s, have given labels to the new niches that were created within economics (Cherrier, 2015a).

In this article, we contribute to the debate on the effects of fragmentation in economics by focusing on communication between disparate areas of the Mainstream. We take an empirical perspective trying to quantify and describe communication. Therefore, this work also contributes to the thriving literature that applies quantitative and statistical methods to

economists' self-reflection. In 1997, Backhouse et al., while highlighting a mounting interest in economists' quantitative self-reflection, made a case for a quantitative history of economic thought based on the advantages of the increasingly available database resources and the refinements in computing techniques. First, "the use of databases makes it possible to focus on the average economist rather than on exceptional individuals" (Backhouse et al., 1997, 20). Second, "historians make generalisations that are quantitative but without testing this statistically" (ibid.). Third, "statistical data can point to puzzles that need explanation, factors that might otherwise be forgotten or suggest areas where new explanations are needed" (ibid.)

Since then, quantitative studies on economics have flourished, covering an ever-growing span of themes among which, unfortunately, history of economic thought makes a rare appearance.² However, Cherrier notes that, recently, there has been a "rise of quantitative analysis in the history of economics working papers" (Cherrier, 2015b). The increasing availability of data on the economic profession, together with the widening set of techniques and their relative accessibility, seems to allow historians to take up Backhouse et al.'s challenge. An essential acknowledgement of the importance of a quantitative history of economic thought is the article published in 2011 by Geoffrey Hodgson in the *Journal of Economic Issues* (Hodgson, 2011). Hodgson commented on the Knight-Keynes uncertainty concept in Mainstream economics by drawing data on word occurrences from JSTOR. This digital library collects digitised documents from academic journals, books and other sources. Other relevant studies have provided scholars with interesting insights into the evolution of the discipline. Claveau and Gingras (2016) combined bibliographic coupling, automated community detection in dynamic networks and text mining to build a history of specialties in economics since the fifties, using a corpus of documents (articles, notes and reviews with references) drawn from the Web of Science. They confirmed, for instance, the decline in the late 1970s of the specialty dedicated to the development of the general economic theory and the transition of econometrics from being a specialty to becoming a widespread tool for many other specialties. From a different perspective, Fourcade et al. (2015) relied on citation counts to describe the status of economics in social sciences showing its insularity and hierarchical structure.

Despite the growing empirical literature, the quantitative approach to studying economics remains a difficult task. Some concepts are hard to quantify, and the scholars researching the topic have yet to reach a consensus on what data should be used to represent their objects of investigation. A typical example would be that of quantitatively expressing economic Mainstream. As expounded above, there has yet to be an agree-

2 Cropper (2000); Fuchs (2002); Pardey and Smith (2004); Sen (2008); Kelly and Bruestle (2011); Hamermesh (2013). A related line of research studies academic departments (Colander, 1989), academic journals (Laband et al., 2002; Card and DellaVigna, 2013; Stern, 2013), co-authorship rates (Laband and Tollison, 2000; Goyal et al., 2006; Hamermesh, 2015), and other measures of collaboration, dissemination and influence in the field (Durden and Ellis, 1993; Kim et al., 2006).

ment on what ideas and methods could accurately describe it. In addition, more general descriptions only overlap partially. For instance, Colander adopts a sociological definition (Dequech, 2007) of Mainstream economics, which revolves around the ideas that leading economists “find acceptable” (Colander et al., 2004, 490). Whereas Dequech’s definition (Dequech, 2007) pivots on prestige and influence in terms of approaches taught at the most prestigious universities, published in the top journals and receiving financial support from the most important institutions.

In the article, we adopt Dequech’s view focusing on topics that are published in prestigious economic journals. Our interest in the circulation of knowledge within the discipline dictates our choice. Moreover, articles embed the information that scholars use to corroborate their research in the form of references and allow us to study, through citations, how their informational content spreads in the discipline. By using the Rao-Stirling diversity index (Stirling, 2007), see section 2, we can account for the variety and disparity of information referenced by articles, therefore indirectly measuring communication within the disciplines. A further challenge is identifying the specialties that make up the Mainstream. We have tackled the issue by adopting topic modelling. Since topic modelling leverages the co-occurrence of words, i.e. groups articles that consistently use the same set of words, to describe the thematic structure of a corpus of documents (in our case, articles), we believe that it constitutes an efficient way to identify the language used within a specialty and, therefore, identifying the fragment of the Mainstream.³ Finally, we quantify the diffusion of ideas in the discipline using the citations of articles.

2. Data and Measures

We conduct our investigation of the Mainstream on a sample of articles published in prestigious economic journals, the so-called Blue Ribbon Eight: the *American Economic Review*, *Econometrica*, the *International Economic Review*, the *Journal of Political Economy*, the *Quarterly Journal of Economics*, the *Review of Economics and Statistics*, the *Review of Economic Studies*, and the *Journal of Economic Theory* (see Fontana et al., 2019). The choice of the list of journals is, to a certain degree, arbitrary. Other options would have included, for instance, rankings—which actually disagree on the ordering—based on impact factor or download of articles,⁴ or creating lists based on our perception. We settled on the Blue Ribbon Eight considering that the list has been widely used in similar studies for a relatively long period (Conroy and Dusansky, 1995; Dusansky and Vernon, 1998; Heck and Zaleski, 2006; Lo et al., 2008; Heck et al., 2009; Cardoso and Teixeira, 2020). Using a stable and acknowledged list of journals will allow us to compare our study

3 For a more detailed explanation on the methodology, see section 2 and Appendix 1.

4 For instance, IDEAS/RePEc (ideas.repec.org/top/top.journals.all.html) or Scimago (www.scimagojr.com/journalrank.php?category=2002).

with the extant literature and escape the danger of preconceptions and subjectivity. Our dataset is composed of the article metadata (title, journal, publication date, authors, etc.), information about references and article full-texts as extracted from the JSTOR database. Due to data availability in JSTOR, the sample is reduced from eight to seven journals, excluding the *Journal of Economic Theory*. We integrate this information with an indicator of the circulation of knowledge based on the number of citations accrued by articles, as obtained from the Web of Science. In order to compare the impact of articles published in different years and to collect the number of citations received in a fixed window of time from publication—in this case, 10 years—the selected sample is composed of articles published between 1985 and 2006.⁵

The original sample counts 14,308 articles, that become 10,583 once removed non-research contributions (i.e. conferences announcements, prefaces, obituaries, minutes of associations' meetings⁶) and articles without references to journals. Among the articles in this sample, 10,064 have complete information about authors and article text. We use articles' references to identify the degree of recombination of information taken from different sources in each article. The analysis of references focuses only on journals since they are easier to attribute to disciplines and excludes references to books, working papers or non-scientific outlets. The number of identified references is 234,162, which corresponds to an average of 23.27 references to journals for each article. We identified 1,746 journals in references, unevenly represented in the sample. We restrict our analysis to journals that occur at least ten times in the sample (454 journals). Dropping journals with few occurrences allows a more accurate measurement of their proximity and a more precise definition of the economics knowledge space (see Figure 1). Since the proximity tells us how frequently two journals co-occur in an article's references (more details below), excluding items that are under-represented in the sample makes the links among journals less noisy. Results, however, are robust to the choice of different minimum thresholds of journal occurrence.⁷

As expected, the distribution of citations over 10 years from publication is skewed and follows a power law distribution, with a maximum of 1,208 citations. The total number of citations is 311,470, corresponding to an average of 30.95 citations per article. More detailed descriptive statistics are reported in Table 1.

The fragmentation of the discipline is measured via machine learning through topic modelling. It is widely acknowledged that the amount of articles produced in economics is rapidly increasing: Claveau and Gingras

5 Articles published in the *Journal of Political Economy* are available until 1997.

6 It is worth noting that, due to its particular character, the Paper and Proceeding issue of the *American Economic Review* is not included in the sample.

7 The correlation among the values of the diversity index—our main independent variable—computed on our sample (minimum occurrence 10 times) with the same index computed on a sample with minimum occurrence equal to 2 and 5 is 80% and 85%, respectively. The correlation when the threshold is 15 is 76%.

Table 1. Descriptive Statistics by Journal

Journal	Number of articles	Average number of references	Average number of citations in 10 years
<i>American Economic Review</i>	3473	19.42	30.16
<i>Econometrica</i>	1323	26.17	42.86
<i>International Economic Review</i>	1139	23.11	11.38
<i>Journal of Political Economy</i>	674	24.77	38.41
<i>Quarterly Journal of Economics</i>	886	28.51	58.75
<i>Review of Economic Studies</i>	893	27.64	30.01
<i>Review of Economics and Statistics</i>	1676	23.34	19.28

(2016) noticed that the number of economic articles indexed in Web of Science has risen from about a thousand per year in 1956 to nearly twenty thousand in recent years. This rate of growth makes the scholars' endeavours harder, thereby making more stringent the need to gather, organise and analyse the literature in a fast and intuitive way. Data mining and, in particular, text mining and machine learning techniques provide tools that allow researchers to perform *distant reading* (Hayles, 2013; Moretti, 2013) on a selection of documents to possibly simplify and accelerate the subsequent process of research and discovery. Although machine learning cannot substitute for human skills, it is also plausible that it might constitute a powerful tool for recognising patterns that would otherwise escape human attention due to cognitive limitations or framing effects. For instance, Aromí (2013), in his quantitative analysis of the JSTOR database of economic articles, suggested that the relevance of a seminal work might alter the perception of the period in which that work produced its effects on that discipline. He observed, in this regard, a substantial lag between the publication of P.A. Samuelson's *Foundations of Economic Analysis* and the diffusion in economics of mathematical techniques adopted in that book. The main goal in topic modelling is to represent the thematic structure embedded in a collection of documents.⁸ Since it is not observable, one has to make assumptions about those documents: once it is assumed that they are generated from an ideal process that involves a variety of topics according to given probabilistic rules, it is possible to proceed backwards, i.e. to infer topics from the actual documents, and then to represent documents in terms of those topics. In particular, Latent Dirichlet Allocation (Blei et al., 2003)—LDA—has become a standard tool in topic modelling by several good properties (DiMaggio et al., 2013), among which the ability to discriminate among different meanings of the same word in diverse contexts and to detect multiple topics in a single document. This technique is particularly interesting concerning the evolution of a discipline (see for instance Ambrosino et al., 2018).

8 A more technical treatment is given in Appendix 1.

In LDA, a topic is defined as a probability distribution over words: for instance, a topic about fruit will likely assign high probabilities to words such as *banana*, *orange*, *strawberry*, *branch* and low or null probabilities to *chimney* or *banker*. On the other hand, each document is represented as the set of the words that compose it—technically, in *bag of words* format. The algorithm leverages the co-occurrence of words across documents to come up with topics. Co-occurrence means that several articles repeatedly use given words together, i.e. it has its lexicon. This tendency, which is unlikely to happen by coincidence, suggests that those articles have something in common, a specific topic that is commonly dealt with by using these words in a relevant way. These words are the first insight into the thematic structure of the database. In short, LDA provides the researcher with a *many-to-many* correspondence between a set of documents and a set of topics. Given a topic, we observe the articles dealing with it and the relevance of the topic in the article. Conversely, given a document, it is possible to sort the topics it deals with according to their weights.

Table 2 reports the thematic structure of the Mainstream as identified by the algorithm. We assign to each article the main topic (i.e. the topic with the highest probability) resulting from the algorithm. The number of topics was decided by considering a series of indicators assessing the modelling performance. Firstly, we used perplexity, a widespread measure in language model evaluation. This indicator allows assessing how well the model describes the set of articles in terms of goodness-of-fit. Secondly, we considered topic coherence, which measures the degree of semantic similarity among the most important words in each topic. Finally, we also evaluated the interpretability of topics by examining the articles associated with each topic and the coherence with the set of words that describe the topic. Table 2 shows the most common words corresponding to each topic.

Finally, we measure communication through the Rao-Stirling diversity, a widely used (Porter and Rafols, 2009; Fontana, 2010a; Yang et al., 2022) compound indicator of information recombination at the article level (Stirling, 2007). It summarises three qualities of recombination: variety, balance, and disparity. In our study, variety relates to the number of different journals referenced by an article, balance refers to the relative distribution of these journals in the article's references, and disparity measures the relative distance in terms of knowledge space (see Figure 3), of these journals. The Rao-Stirling diversity summarises these three components in a single index and is defined as:

$$Diversity = \sum_{i,j \in C, i \neq j} (1 - p_{ij}) f_i f_j \quad (1)$$

where C is the set of journals in article references, p_{ij} is the relative proximity between journals i and j , and f_i is the normalised frequency of journal i in article references. The index is bounded between 0 and 1. A high value of diversity implies strong communication between diverse areas of economics and vice versa.

Table 2. List of the 10 Most Relevant Words that Define each Topic

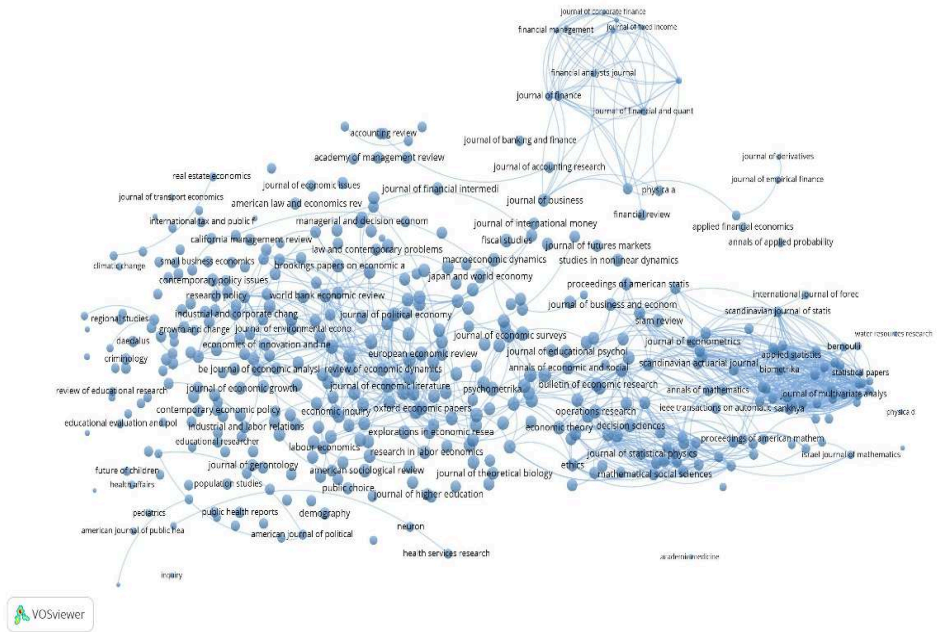
Topics	Words (stemmed)
Business Cycles and Monetary Policy	Shock, money, inflat, monetari, forecast, cycl, output, adjust, seri, nomin
Technological Development	Bank, debt, credit, borrow, patent, loan, project, entrepreneur, liquid, invest
Consumer Economics	Percent, consum, predict, day, group, advertis, sale, car, purchase, retail
Corporate Governance	Firm, industri, plant, manag, coeffici, crime, regul, sale, regress, compani
Econometrics	Asymptot, matrix, vector, linear, varianc, normal, regress, approxim, likelihood, econometr
Econometrics: Treatment Effect Models	Treatment, match, panel, identif, heterogen, out-com, bia
Urban and Regional Economics	Region, popul, citi, land, locat, area, local, network, hous, migrat
Education	School, educ, student, women, age, colleg, children, group, black, parent
Game Theory	Game, player, strategi, payoff, action, belief, play, signal, learn, outcome
Growth	Capit, growth, invest, output, sector, labor, industri, input, countri, elast
Household Choice, Health, Insurance	Household, age, consumpt, health, insur, wealth, famili, save, care, children
Market Equilibrium	Firm, contract, profit, consum, competit, buyer, seller, incent, proposit, offer
International (Monetary) Economics	Countri, exchang, foreign, domest, currenc, trade, world, govern, home, bank
Labor	Wage, worker, labor, job, unemploy, skill, earn, match, hour, search
Public Economics and Public Finance	Tax, govern, welfar, consumpt, privat, subsidi, expenditur, elast, revenu, budget
Portfolio Choice	Risk, asset, stock, consumpt, trade, portfolio, invest, avers, investor
Market Design and Auction Theory	Agent, proof, theorem, satisfi, lemma, proposit, alloc, bid, auction, mechan
Trade, Institution, Politics	Trade, tariff, export, countri, vote, voter, parti, govern, elect, candid

By following previous literature on the science of science and economics of science (see, for instance, Fontana et al., 2020), we apply the cosine similarity to the matrix of journal co-occurrences in article references to compute the knowledge space and the proximity among those journals:

$$p_{ij} = \frac{\sum_{k \in C} c_{ik} c_{jk}}{\sqrt{\sum_{k \in C} c_{ik}^2} \sqrt{\sum_{k \in C} c_{jk}^2}} \quad (2)$$

where c_{ik} is the total number of co-occurrences in article references of journals i and k . This definition of proximity implies that the higher the number of co-occurrences between two disciplines, the higher the proximity be-

Figure 1. Knowledge Space of Economic Journals



The journal (node) location is based on the proximity among those journals. Journals that frequently co-occur together are connected through network links. The plot is made with VOSviewer.

tween them. The resulting proximity is bounded between 0 and 1; therefore, $(1 - p_{ij})$ can be considered the distance between disciplines i and j .

Figure 1 displays the knowledge space in economics based on the proximity among economic journals. Closely-located journals frequently co-occur in article references and usually belong to the same sub-field of economics. The links in the network connect journals with high co-occurrence. In the figure, we can quickly identify communities of sub-fields. For instance, on the right, we can observe journals in the statistical, econometric, and mathematical domains. On the top, there are journals in finance and, on the top left, those in management and business. The latter are close to innovation, industrial dynamics, and geography journals. The network's core is instead made of generalist journals such as the *American Economic Review*, the *Quarterly Journal of Economics*, the *Journal of Economic Literature*, and the *European Economic Review*. Journals related to labour and education are at the bottom of the figure. In the periphery of the network, we can finally observe journals belonging to other disciplines (e.g., medicine and criminology).

3. Mainstream Economics: A View From the Top

In this section, we observe economics from the perspective of the Blue Ribbon Eight. Topics, in turn, allow us to investigate the thematic structure of the Mainstream. By looking at the combination of journals, topics, and within-discipline communication, we expound some evidence on the fragmentation of the Mainstream and its impacts on communication and circulation of knowledge in economics.

3.1. The Fragmentation of the Mainstream and the Insularity of Economics

Table 3. Distribution of Articles by Main Topic

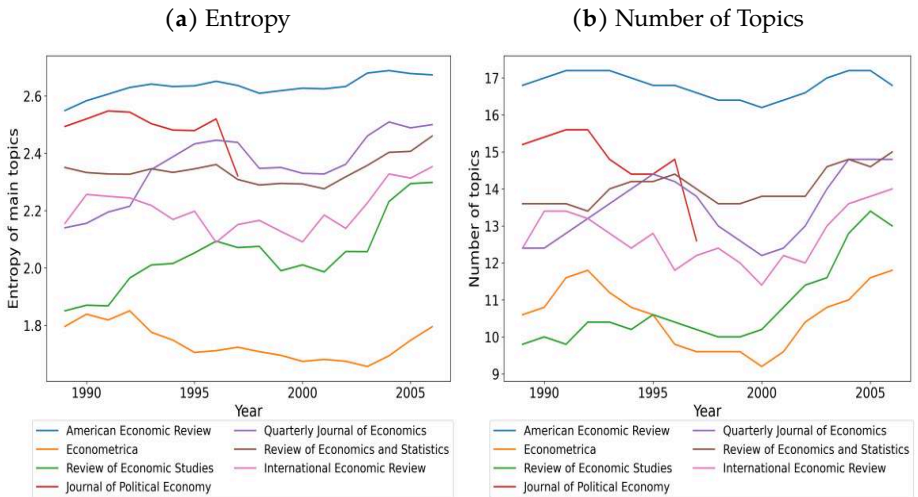
Topic	Number of articles
Market Equilibrium	1091
Econometrics	1016
Market Design and Auction Theory	962
Business Cycles and Monetary Policy	876
Growth	735
Labor	643
Consumer Economics	613
Household Choice, Health, Insurance	571
Corporate Governance	558
Game Theory	556
Education	553
Public Economics and Public Finance	415
Trade, Institution, Politics	365
Portfolio Choice	316
Urban and Regional Economics	289
International (Monetary) Economics	241
Technology Development	220
Econometrics - Treatment Effect Models	44

The structure of the Mainstream, as approximated by topics covered in top journals, reveals some interesting insights. First, the topic that recalls the language of Market equilibrium still prevails in the Mainstream (see Table 3 for the distribution of articles in topics). This seems to bring some evidence that the Mainstream is still very much in line with a traditional concept of economics. Second, the turn toward a more applied discipline highlighted by Backhouse and Cherrier (2017) seems confirmed by the importance of Econometrics. Notice that summing up the two topics that deal with econometrics brings the topic reaching the top of the ranking of the distribution of articles in topics (see Table 3). Third, the idea that fragmentation would result from the import of heterodox economic approaches (experimental economics, evolutionary economics, behavioural economics, complexity economic) highlighted by Davis (2008), is not corroborated by

our data, since none of the topics contains that jargon,⁹ except for Game Theory, that ranks in the middle of the distribution of articles by topics.

For what concerns the dynamic of the fragmentation, by looking at the entropy of the frequency of topics by journal¹⁰ (Figure 2a), we notice that there is no strong evidence of a rapid fragmentation of the Mainstream in the period 1985-2006. However, Figure 2b also shows that, at the journal level and, especially for the *Review of Economics and Statistics*, there is a slight increase in the number of covered topics showing that, indeed, generalist journals are willing to accept a broader set of topics.

Figure 2. Entropy of the Distribution of Topics by Journal (Left Panel) and Average Number of Topics in Journals (Right Panel)



Plots are created by considering 5-year moving averages of the indicators.

Most interestingly to our endeavour, Figure 3 shows that the diversity index computed on the articles of our sample tends to increase over time, witnessing a slight increase in communication, through referencing, among different economic journals. This suggests that the current state of the Mainstream intensifies the exchange of ideas rather than impairing it. This finding corroborates the idea that the diversification of approaches might, in practice, be fruitful for advancing the discipline (Dow, 2008; Cedrini and Fontana, 2018).

9 This does not imply that their contributions are not published in top journals, rather, it means that their lexicon does not occur often enough to result in one of our 18 topics. Nevertheless, we can state that their importance in the Mainstream is not yet as consolidated as is the one of more traditional specialties.

10 To capture the dynamic fragmentation, we use the Shannon entropy as a measure of average level of variation in the main topic: $entropy = - \sum_{t \in T} f_t \log f_t$, where t are the topics in the set of all topics T and f_t is their frequency in the journal.

3.2. Focus on Communication in Journals and Topics

After seeing that Mainstream economics as a whole has exhibited an increase in communication among different areas of discipline, we detail the evidence by looking at journals and topics. Table 4 and Figure 3 show that the diversity of information sources referenced by the articles has been rising in all the top journals. However, in a rather heterogeneous way, i.e. the Mainstream is not equally open to integrating knowledge among different outlets (see Appendix 2 for the evolution in the periods 1985-1995 and 1996-2006). Rather interestingly, the *American Economic Review* features articles that tap into less diverse sources of knowledge. At the same time, the *Quarterly Journal of Economics* is more open to articles that rely on a more innovative combination of sources.

Figure 3. Within-Discipline Communication

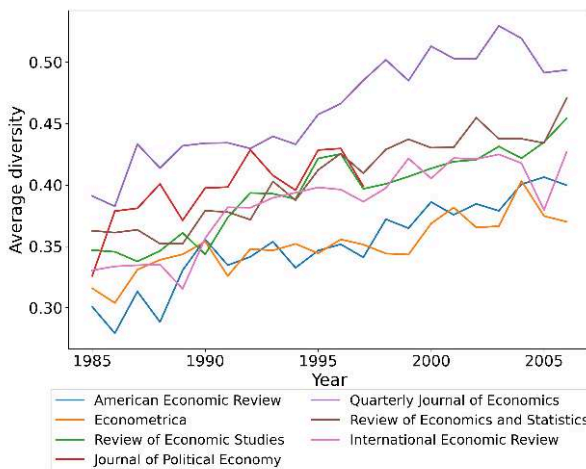


Table 4. Average Cross-Referencing by Journal

Ranking	Journal	Communication
1	<i>Quarterly Journal of Economics</i>	0.457
2	<i>Review of Economics and Statistics</i>	0.403
3	<i>Journal of Political Economy</i>	0.392
4	<i>Review of Economic Studies</i>	0.392
5	<i>International Economic Review</i>	0.382
6	<i>American Economic Review</i>	0.353
7	<i>Econometrica</i>	0.350

Journals are ranked by Rao-Stirling diversity score.

The same pattern is detected in topics, where differentiation in terms of cross-referencing is less pronounced.

Table 5. Average Diversity by Topic in Different Periods (1985-1995 and 1996-2006)

(a) 1985-1995

Ranking	Topic	Diversity
1	Business Cycles and Monetary Policy	0.386
2	Market Equilibrium	0.383
3	Labor	0.383
4	Growth	0.380
5	Household Choice, Health, Insurance	0.368
6	Corporate Governance	0.364
7	Technology Development	0.356
8	Portfolio Choice	0.355
9	Public Economics and Public Finance	0.350
10	Urban and Regional Economics	0.349
11	Consumer Economics	0.345
12	Trade, Institution, Politics	0.344
13	Game Theory	0.342
14	Econometrics	0.340
15	Education	0.330
16	Market Design and Auction Theory	0.327
17	International (Monetary) Economics	0.318
18	Econometrics - Treatment Effect Models	0.237

(b) 1996-2006

Ranking	Topic	Diversity
1	Growth	0.443
2	Labor	0.443
3	Corporate Governance	0.430
4	Business Cycles and Monetary Policy	0.425
5	Trade, Institution, Politics	0.416
6	Urban and Regional Economics	0.413
7	Education	0.413
8	Market Equilibrium	0.413
9	Technology Development	0.410
10	Game Theory	0.403
11	Consumer Economics	0.402
12	Portfolio Choice	0.398
13	Household Choice, Health, Insurance	0.386
14	Econometrics - Treatment Effect Models	0.386
15	Econometrics	0.378
16	Public Economics and Public Finance	0.378
17	Market Design and Auction Theory	0.366
18	International (Monetary) Economics	0.362

Topics are ranked by diversity score.

3.3. Within Discipline Communication and the Circulation of Knowledge

In the face of such an increase in communication within different areas of the economic Mainstream, we investigate the scientific community's response regarding the circulation of knowledge. We ask if referencing more distant and disparate journals in an article impacts its diffusion, i.e. impacts its citations. This investigation aims to discriminate between two equally plausible hypotheses: articles that reference more diverse journals—tap into more disparate sources of knowledge—are less attributable to a single specialty and, therefore, might be read by a broader span of specialties. At the same time, the difficulty of fitting an article into an approach can make it less recognisable by a specialty and, therefore, might result in fewer citations. Empirical evidence on the effect of the features of references on the impact of articles is vast and variegated but, generally, the literature agrees on the existence of an inverted U-shaped relationship between diversity and the number of citation of an article.¹¹

To study the effect of diversity on the circulation of knowledge in economics, measured as the number of citations received by articles within 10 years from the publication date, we perform an econometric analysis on the entire sample of articles. Specifically, we estimate through ordinary least square (OLS) regressions the following model:

$$\log(\text{Number of citations} + 1)_i = \beta_0 + \beta_1 \cdot \text{Diversity}_i + \gamma_i + \delta_t + \phi_j + \lambda_d + \epsilon_{itjd} \quad (3)$$

where i refers to articles, the Number of citations $_i$ considers the number of citations received by article i in 10 years from the publication date, Diversity $_i$ measures the breadth of communication between specialty in the article i through the Rao-Stirling diversity index, γ_i are the controls at the article level that might affect the number of citations (number of references and number of authors), δ_t , ϕ_j , and λ_d are, respectively, time (year), journal, and topic fixed effects. Since the distribution of the number of citations is very skewed, we consider the logarithm transformation of this indicator.

Table 6 reports the results and shows that independently of the fixed effects included in the analysis, tapping into different sources of knowledge has a positive and significant effect on the number of citations received by articles published in the Blue Ribbon Eight journals. It is worth noting that this relationship is confirmed when we control for the number of authors and references in each article.

To better understand this relationship, we also consider the quadratic term of diversity. Specification (4) shows that the effect of diversity is positive. However, it lowers when the diversity of journals referenced by articles grows, i.e. we observe an inverted U-shaped relationship between diversity and the number of citations (Fontana et al., 2020).

11 For a survey see Wagner et al. (2011) and Zeng et al. (2017, section 6.1.1).

Table 6. Impact of Diversity on the Number of Citations Received by Articles in 10 Years from the Publication Date

	<i>log(Number of citations+1)</i>			
	(1)	(2)	(3)	(4)
Diversity	1.409*** (0.116)	1.524*** (0.111)	1.518*** (0.110)	2.181*** (0.283)
Diversity ²				-1.075** (0.425)
Number of references	0.025*** (0.002)	0.023*** (0.002)	0.022*** (0.002)	0.022*** (0.002)
Number of authors	0.200*** (0.016)	0.195*** (0.015)	0.193*** (0.015)	0.193*** (0.015)
Intercept	1.028*** (0.058)	1.343*** (0.071)	1.510*** (0.083)	1.445*** (0.086)
Year FE	Yes	Yes	Yes	Yes
Journal FE		Yes	Yes	Yes
Topic FE			Yes	Yes
Observations	10,064	10,064	10,064	10,064
R ²	0.244	0.337	0.347	0.348
Adjusted R ²	0.242	0.335	0.344	0.345
Residual Std. Error	1.122	1.050	1.043	1.043
F Statistic	107.829***	155.596***	105.687***	103.538***

Note:

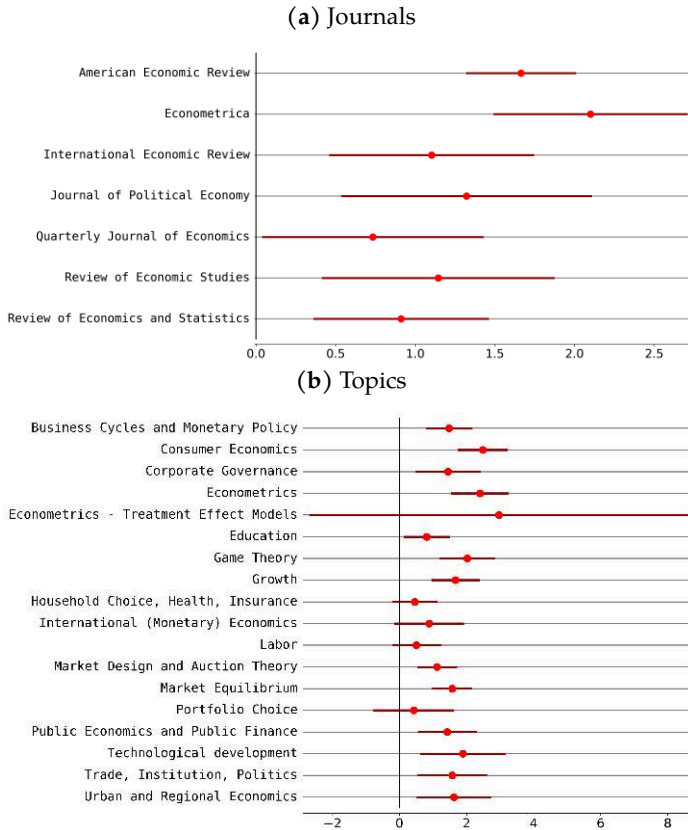
All the models are estimated using OLS.
Robust standard error in parentheses.
Significance: *p<0.1; **p<0.05; ***p<0.01

We also perform the same analysis by separately considering the different journals and topics. Figure 4 reports the coefficients and 95% confidential intervals of diversity for journals and topics. The figure in the top panel shows that the effect of diversity is positive and significant in all journals. While we do not observe large differences in the magnitude of this effect in different journals, we can conclude that the impact of diversity is particularly relevant in *Econometrica*. The coefficient estimated for articles published in this journal is significantly higher than the same coefficient estimated on articles published in the *Quarterly Journal of Economics* or the *Review of Economics and Statistics*.¹² Complete results of regressions on articles published in different journals are reported in Table 7.

Let us move, instead, to the analysis of the impact of diversity on the number of citations in different topics (as reported in the bottom panel of the Figure 4). While diversity’s effect is always positive, it is not significant for articles published in some topics. Specifically, articles belonging to Econometrics - Treatment Effect Models, Household Choice, Health, Insurance, International (Monetary) Economics, Labor, and Portfolio Choice do not benefit from the presence of diversity for what concerns their circulation (number of citations). This result is independent of the average value of diversity of topics (as reported in Table 5). While Labor is one of the

¹² The result is confirmed if we consider a regression in which we introduce interaction terms between diversity and journal dummy variables: the interaction term between diversity and *Econometrica* is positive and significant when we consider the *Quarterly Journal of Economics* or the *Review of Economics and Statistics* as baseline.

Figure 4. Effect of Diversity on the Number of Citations in 10 Years for Articles in Different Journals (Top Panel) and Different Topics (Bottom Panel)



most diverse topics, Econometrics - Treatment Effect Models and International (Monetary) Economics are very conservative ones. Full results are reported in Tables 8, 9, and 10.

Overall, results offer evidence of a positive effect of diversity (up to a certain level) on the circulation of knowledge showing that the discipline is open to citing articles that tap into non-specialised sets of references. In other words, economics is not an insular endeavour: communication between different topics and journals takes place both in referencing and citing articles.

Table 7. Effect of Diversity on the Number of Citations in Articles Published in Different Journals

	<i>log(Number of citations+1)</i>						
	<i>American Economic Review</i>	<i>Econometrica</i>	<i>International Economic Review</i>	<i>Journal of Political Economy</i>	<i>Quarterly Journal of Economics</i>	<i>Review of Economic Studies</i>	<i>Review of Economics and Statistics</i>
Diversity	1.664*** (0.173)	2.100*** (0.308)	1.103*** (0.325)	1.322*** (0.398)	0.734** (0.352)	1.144*** (0.370)	0.911*** (0.278)
Nb. of references	0.021*** (0.003)	0.021*** (0.002)	0.019*** (0.004)	0.022*** (0.004)	0.018*** (0.003)	0.022*** (0.003)	0.025*** (0.002)
Nb. of authors	0.203*** (0.025)	0.147*** (0.039)	0.179*** (0.042)	0.221*** (0.055)	0.216*** (0.050)	0.290*** (0.045)	0.143*** (0.032)
Intercept	1.287*** (0.121)	1.666*** (0.296)	0.802*** (0.210)	1.703*** (0.256)	1.731*** (0.268)	1.362*** (0.235)	0.714*** (0.163)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,473	1,323	1,139	674	886	893	1,676
R ²	0.313	0.341	0.230	0.225	0.430	0.302	0.346
Adjusted R ²	0.305	0.320	0.202	0.188	0.403	0.268	0.330
Res Std. Error	1.078	0.990	0.966	1.007	1.065	0.948	0.979
F Statistic	33.671***	17.069***	8.243***	6.387***	22.643***	9.772***	23.864***

Note: All the models are estimated using OLS. Robust standard error in parentheses. Significance: *p<0.1; **p<0.05; ***p<0.01

Table 8. Effect of Diversity on the Number of Citations in Articles Published in Different Topics

	<i>log(Number of citations+1)</i>					
	Business Cycles and Monetary Policy	Technological Development	Corporate Governance	Growth	Market Equilibrium	Labor
Diversity	1.485*** (0.339)	1.890*** (0.633)	2.485*** (0.365)	1.446*** (0.478)	2.398*** (0.420)	2.963 (2.869)
Nb. of references	0.023*** (0.003)	0.023*** (0.005)	0.010*** (0.004)	0.026*** (0.005)	0.023*** (0.003)	0.018 (0.016)
Nb. of authors	0.180*** (0.058)	0.384*** (0.118)	0.230*** (0.046)	0.225*** (0.061)	0.141*** (0.051)	0.675* (0.410)
Intercept	1.073*** (0.229)	1.146*** (0.427)	0.723*** (0.237)	1.648*** (0.323)	0.849* (0.491)	-1.756 (2.366)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	876	220	613	558	1,016	44
R ²	0.330	0.454	0.427	0.388	0.354	0.591
Adjusted R ²	0.307	0.367	0.397	0.353	0.335	0.297
Res Std. Error	1.105	1.038	1.061	1.091	1.098	1.164
F Statistic	15.430***	7.656***	18.157***	15.183***	20.126***	6.554***

Note: All the models are estimated using OLS. Robust standard error in parentheses. Significance: *p<0.1; **p<0.05; ***p<0.01

Table 9. Effect of Diversity on the Number of Citations in Articles Published in Different Topics

	<i>log(Number of citations+1)</i>					
	Econometrics Treatment Effect Models	Urban and Regional Economics	Education	Household Choice, Health, Insurance	Portfolio Choice	Trade, Institution, Politics
Diversity	1.626*** (0.552)	0.816** (0.337)	2.019*** (0.407)	1.675*** (0.355)	0.458 (0.327)	1.572*** (0.290)
Nb. of references	0.013*** (0.004)	0.026*** (0.004)	0.020*** (0.003)	0.032*** (0.003)	0.029*** (0.003)	0.018*** (0.005)
Nb. of authors	0.131 (0.093)	0.101** (0.049)	0.250*** (0.055)	0.244*** (0.058)	0.085* (0.048)	0.231*** (0.047)
Intercept	2.238*** (0.556)	1.696*** (0.278)	1.657*** (0.311)	0.819*** (0.254)	1.761*** (0.297)	1.135*** (0.212)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	289	553	556	735	571	1,091
R ²	0.405	0.444	0.417	0.460	0.371	0.312
Adjusted R ²	0.336	0.412	0.383	0.437	0.336	0.293
Res Std. Error	1.077	0.975	0.894	1.047	0.932	1.012
F Statistic	6.085***	18.054***	12.978***	27.270***	11.101***	15.315***

Note: All the models are estimated using OLS. Robust standard error in parentheses. Significance: *p<0.1; **p<0.05; ***p<0.01

Table 10. Effect of Diversity on the Number of Citations in Articles Published in Different Topics

	<i>log(Number of citations+1)</i>					
	Consumer Economics	Econometrics	Game Theory	International (Monetary) Economics	Public Economics and Public Finance	Market Design and Auction Theory
Diversity	0.883* (0.514)	0.507 (0.358)	0.425 (0.598)	1.425*** (0.432)	1.121*** (0.291)	1.574*** (0.512)
Nb. of references	0.037*** (0.007)	0.028*** (0.005)	0.023*** (0.004)	0.027*** (0.005)	0.021*** (0.003)	0.025*** (0.005)
Nb. of authors	0.283** (0.121)	0.094 (0.060)	0.361*** (0.087)	0.070 (0.065)	0.231*** (0.043)	0.089 (0.072)
Intercept	1.357*** (0.452)	2.031*** (0.287)	1.649*** (0.404)	1.471*** (0.361)	1.173*** (0.270)	1.735*** (0.475)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	241	643	316	415	962	365
R ²	0.493	0.381	0.443	0.358	0.358	0.444
Adjusted R ²	0.421	0.351	0.385	0.308	0.337	0.394
Res Std. Error	1.033	0.962	1.045	1.008	0.952	0.989
F Statistic	14.116***	14.249***	7.376***	9.498***	19.278***	11.608***

Note: All the models are estimated using OLS. Robust standard error in parentheses. Significance: *p<0.1; **p<0.05; ***p<0.01

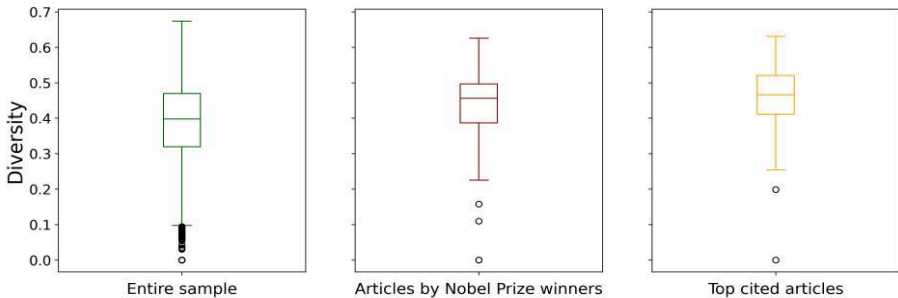
3.4. Nobel Prize Winners and Top Cited Articles

A further refinement of our results considers a very specific sub-set of articles: articles authored by Nobel Prize winners and top-cited articles (Chen et al., 2015). Namely, we aim at exploring whether articles that are particularly appreciated by the discipline are built upon communication across different specialties.

We select the articles published prior to the award by Nobel Prize winners in economics in the last ten years (2009-2018)¹³ and the 150 top cited articles, as listed in IDEAS,¹⁴ that are present in our database.

Figure 5 shows the distribution of diversity in articles belonging to the entire sample (left panel), articles authored by Nobel Prize winners (center), and top-cited articles (right panel). While these distributions largely overlap, the median values of diversity in the two sub-samples are higher than in the entire sample of articles, signalling that the most important and appreciated contributions to the discipline rest on information drawn from different communities.

Figure 5. Distribution of Diversity Among Articles in the Entire Sample (Left Panel), Articles Written by Nobel Prize Winners (Center), and Top Cited Articles (Right Panel)



To better understand this relationship, we use OLS regressions to compute the correlation between diversity and, on the one hand, the presence of Nobel Prize winners as article authors or, on the other, belonging to the top-cited article sample. As in the previous section, we control for the number of references and the number of authors, and we consider the year, journal, and topic fixed effects. Table 11 shows that the correlation between the variables of interest is positive and significant, confirming the insights resulting from the analysis of Figure 5.

This evidence confirms that the essential articles in economics tap into more diverse sources of knowledge and that their diffusion benefits from

¹³ We consider all their articles since the prize is assigned to the scholar and not to a specific publication.

¹⁴ Top 1% economics research items by number of citations: <https://ideas.repec.org/top/top.item.nbcites.html>.

Table 11. Correlation Between Diversity and the Presence of Nobel Prize Winner as Co-Author or Belonging to the List of Top-Cited Articles

	<i>Nobel Prize winners</i>	<i>Top Cited</i>
	(1)	(2)
Diversity	0.015* (0.008)	0.026*** (0.008)
Number of references	0.000 (0.000)	0.001*** (0.000)
Number of authors	0.003** (0.001)	0.007*** (0.002)
Intercept	-0.013*** (0.005)	-0.031*** (0.005)
Year FE	Yes	Yes
Journal FE	Yes	Yes
Topic FE	Yes	Yes
Observations	10,064	10,064
R^2	0.020	0.041
Adjusted R^2	0.015	0.036
Residual Std. Error	0.093	0.117
F Statistic	1.951***	3.150***

Note:

All models are estimated using OLS.
Robust standard error in parentheses.
Significance: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

it. The top scholars' recognition of the importance of diversity corroborates the hypothesis that the core of economics is becoming less cohesive and more open.

4. Discussion and Conclusions

The current debate on the current state of the economic Mainstream raises interesting questions on communication within the discipline. Will the increasing fragmentation of the Mainstream lead to a progressive insularity of research areas? Or will the richness of approaches help sustain the discipline's future development? Our investigation contributes to the discussion by providing some compelling evidence. The observed period (1986-2006) corresponds to a period in which the Neoclassical approach is increasingly put under attack. For example, experimental economics criticises the rationality postulate, while complexity economics criticises the assumption of agents' homogeneity and insists on the importance of adaptation and interaction (Fontana, 2010b). The pressure on the Neoclassical Mainstream is so high that scholars even write of the dissolution of the paradigm (Fontana, 2010a) and of a more composite, fragmented Mainstream (Cedrina and Fontana, 2018).

In spite of this perception, our data reveal that there is no sign of rapid fragmentation going on between 1985 and 2006. Moreover, the thematic structure of the Mainstream provides several insights. First, the lexicon

of market equilibrium still prevails in the Mainstream (see Table 3 for the distribution of articles in topics). This shows that the Mainstream is in line with the pre-fragmentation era. Second, the language of the traditional economic approach is sided by the jargon of Econometrics. Thus confirming the turn toward a more applied discipline highlighted by Backhouse and Cherrier (2017). Third, the idea that fragmentation would result from the import of heterodox economic approaches (experimental economics, evolutionary economics, behavioural economics, complexity economics) highlighted by Davis (2008) is not corroborated by our data: none of the topics contains their jargon, except for Game Theory. The major change that has occurred in the Mainstream is not a significant fragmentation and the reception of—previously—heterodox approaches; instead, it is the rise of applied economics.

Regarding communication, our results show that the diversity index computed on the articles of our sample tends to increase over time, witnessing a slight increase in communication through referencing among different economic journals. A cautious interpretation of this result suggests that the current state of the Mainstream intensifies the exchange of ideas rather than impairing it. This finding corroborates the idea that the diversification of approaches might be fruitful for the advancement of the discipline (Dow, 2008; Cedrini and Fontana, 2018). We also show that the diversity of information sources referenced by the articles is increasing in all the top journals but in a rather heterogeneous way, showing that the Mainstream is not equally open to integrating knowledge among different outlets. Rather interestingly, the *American Economic Review* features articles that tap into less diverse sources of knowledge. At the same time, the *Quarterly Journal of Economics* is more open to articles that rely on a more innovative combination of sources.

Finally, articles that tap into less conventional information sources receive a positive reaction from the scientific community. Diversity is generally found to impact the citations accrued by articles positively. This finding is confirmed by the analysis conducted on articles that highly impact the discipline: articles by Nobel Prize winners and top-cited articles. First, they display a median value of diversity higher than the rest of the sample. Second, diversity has a positive effect on their diffusion.

Further investigations in this line of research could improve the robustness of our findings by using a different definition and operationalisation of the concept of Mainstream and by using a different list of journals and scholars.

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Appendix 1. Latent Dirichlet Allocation

Latent Dirichlet Allocation (Blei et al., 2003) is a statistical model of document collections. It assumes that documents are produced according to an ideal generative random process and result in mixtures of latent topics. LDA proceeds backwards from the documents to the topics through Bayesian inference.

In LDA a topic is defined as a probability distribution over a vocabulary; in particular, one assumes that documents have been generated from K topics and that every document can contain more than one topic with different proportions.

Specifically, topics are distributions over the V words of the vocabulary: they are drawn from a uniform Dirichlet distribution $\beta_t \sim \text{Dirichlet}[\eta]$, $t = 1 \dots K$.¹⁵

The generating process leading to each document $d = 1 \dots D$ can be expressed as follows:

- draw the topic distribution of the document, $\theta_d \sim \text{Dirichlet}[\alpha]$, where α has length K ;
- for the n -th word in the document, $n = 1 \dots N_d$ (N_d is the number of words in document d):
 1. draw the corresponding topic assignment $z_{d,n} \sim \text{Multinomial}[\theta_d]$: $z_{d,n}$ is a K -vector whose ν -th element $z_{d,n}^\nu$ is equal to 1 if the ν -th topic has been drawn, and is equal to 0 otherwise;
 2. draw a word from the distribution of the corresponding topic over the vocabulary: with a slight abuse of notation, $w_{d,n} \sim \text{Multinomial}[\beta_{z_{d,n}}]$ ¹⁶; $w_{d,n}$ is a unit V -vector such that its ν -th component $w_{d,n}^\nu = 1$ if the ν -th word has been drawn, and is equal to 0 otherwise.

In what follows, \mathbf{w} indicates the list of words $[w_{d,1} \dots w_{d,N_d}]$ of a generic document d , \mathbf{z} indicates the list of topics of the same words $[z_{d,1} \dots z_{d,N_d}]$ and $\beta_{ij} = p(w^j = 1 | z^i = 1)$.

While we suggest to refer to Blei et al. (2003) and Blei and Lafferty (2009) for a complete treatment of the inferential problem, we briefly report here some conceptual steps. The key problem is to compute the posterior distribution of the latent variables given a document:

$$p(\theta, \mathbf{z} | \mathbf{w}, \alpha, \beta) = \frac{p(\theta, \mathbf{z}, \mathbf{w} | \alpha, \beta)}{p(\mathbf{w} | \alpha, \beta)} \quad (4)$$

¹⁵ The density of the Dirichlet distribution is $f(x_1, \dots, x_{K-1}; \alpha) = \frac{\Gamma(\sum_{i=1}^K \alpha_i)}{\prod_{i=1}^K \Gamma(\alpha_i)} \prod_{i=1}^K x_i^{\alpha_i - 1}$, where α is a K -vector such that $\alpha_i > 0$, $i = 1 \dots K$. If $\alpha_i = \alpha \ \forall i = 1 \dots K$, it is called symmetric Dirichlet with parameter α .

¹⁶ Indeed, in β_i , i should be an integer and indicate the i -th topic. However, given that the i -th topic is unequivocally identified by a $z_{d,n}$ whose i -th component $z_{d,n}^i = 1$, this abuse of notation does not generate confusion.

As Blei et al. (2003) notice, the coupling between θ and β in the denominator

$$p(\mathbf{w}|\alpha, \beta) = \frac{\Gamma(\sum_i \alpha_i)}{\prod_i \Gamma(\alpha_i)} \int \left(\prod_{i=1}^K \theta_i^{\alpha_i - 1} \right) \left(\prod_{n=1}^N \sum_{i=1}^K \prod_{j=1}^V (\theta_i \beta_{ij})^{w_n^j} \right) d\theta \quad (5)$$

makes the posterior intractable for exact inference. Therefore, approximation techniques must be adopted to deal with the likelihood function.

The algorithms which have been proposed are generally based either on Markov Chain Monte Carlo sampling, such as Gibbs sampling (Griffiths and Steyvers, 2004), or on variational inference. The variational Expectation-Maximisation algorithm proposed by Blei et al. (2003) falls in the latter category. The basic intuition behind this method is to introduce a family of distributions, depending on variational parameters, and to use the closest one to the true posterior to perform the optimisation. Iteratively, for each document the optimal values of the variational parameters are computed (E-step), and then the resulting approximate posterior is used to maximise the log-likelihood with respect to the relevant parameters of the original model (M-step). The algorithm we used in this work belongs to the second category as well and performs an online variational Bayes inference. This algorithm, implemented in Python library Gensim, has been shown to provide a good approximation of the posterior and to be rather fast also with large databases (Hoffman et al., 2010).

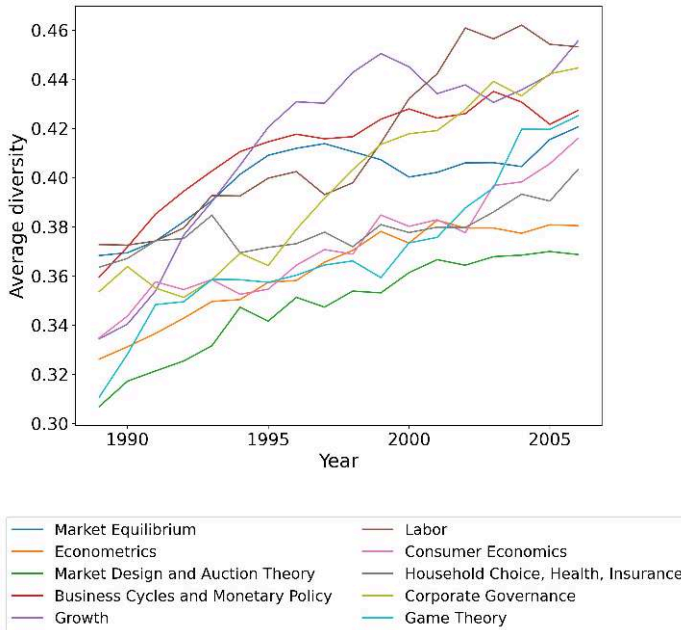
Appendix 2. Additional Results

Table 12 reports the average diversity degree by journal in two periods (1985-1995 and 1996-2006), while Figure 6 shows the average diversity by topic in time. The figure includes only the top 10 topics by the number of articles. Table 13, instead, ranks topics by their average diversity.

Table 12. Average Diversity by Journals in the First and Second Half of the Observed Period

(a) 1985-1995	
Journal	Diversity
<i>Quarterly Journal of Economics</i>	0.425
<i>Journal of Political Economy</i>	0.390
<i>Review of Economics and Statistics</i>	0.376
<i>Review of Economic Studies</i>	0.366
<i>International Economic Review</i>	0.359
<i>Econometrica</i>	0.335
<i>American Economic Review</i>	0.326
(b) 1996-2006	
Journal	Diversity
<i>Quarterly Journal of Economics</i>	0.499
<i>Review of Economics and Statistics</i>	0.435
<i>Journal of Political Economy</i>	0.425
<i>Review of Economic Studies</i>	0.421
<i>International Economic Review</i>	0.408
<i>American Economic Review</i>	0.379
<i>Econometrica</i>	0.367

Figure 6. Average Diversity by Topic in Time



To ease the interpretation of results, the figure includes only the top 10 topics by the number of articles (see Table 3) and has been obtained by considering the moving average of diversity by topic over 5 years.

Table 13. Average Diversity by Topic

Ranking	Topic	Diversity
1	Growth	0.409
2	Labor	0.407
3	Business Cycles And Monetary Policy	0.400
4	Corporate Governance	0.395
5	Market Equilibrium	0.393
6	Technology Development	0.388
7	Urban and Regional Economics	0.383
8	Trade, Institution, Politics	0.383
9	Education	0.380
10	Econometrics - Treatment Effect Models	0.380
11	Household Choice, Health, Insurance	0.378
12	Portfolio Choice	0.376
13	Game Theory	0.374
14	Consumer Economics	0.371
15	Public Economics And Public Finance	0.360
16	Econometrics	0.357
17	Market Design and Auction Theory	0.344
18	International (Monetary) Economics	0.341

Topics are ranked by diversity score.