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THE (FORMAL) RETURN TO OPENNESS: A QUANTITATIVE CONTRIBUTION TO THE HISTORY OF ECONOMIC THOUGHT

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We develop a comprehensive quantitative account of changing practices in economics in the last 122 years. The analysis uses word detection algorithms to partially characterize prevailing practices. We document a shift toward isolation from other disciplines during most of the twentieth century. In sharp contrast, the most recent decades show a strong move towards a more connected discipline. Periods of more connectedness are associated with openness to a broader set of features of economic agents and the economic environment. In parallel, the 1960s and 1970s show a notable acceleration in the move towards a more mathematical approach. This development did not reverse. As a result, the current state of the discipline is characterized by an embrace of mathematical tools together with openness to a wider set of aspects and findings developed in other disciplines. Most of the reported variables show surprisingly high correlations across disciplines and across journals.

JEL classification codes: B1, A12, B4
Key words: history of economic thought, methodology

I. Introduction

Economic events are complex processes. They involve the interaction of agents characterized by countless features in an environment where multiple economic and non-economic processes are jointly in progress. Under limited capacity to incorporate and examine information, a researcher selects which aspects are deemed central for the inquiry and which features are ignored. In this context, the purpose of this study is to describe, in very general terms, the level of attention assigned to different aspects by an evolving community of researchers.

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The study is based on the analysis of the contents of journals published in the English language in the last 122 years. Our approach uses word detection statistics to characterize the contents. The application of quantitative techniques provides an extensive view of developments in the discipline that is hard to generate and convey otherwise. The analysis is focused on general descriptions. We have abstained from focusing on specific contributions, schools or subject areas.

The contributions in this study can be divided into three groups. First, we evaluate extent of the connections of Economics to other disciplines. Second, we analyze evidence on attention levels assigned to specific features of economic agents and specific characteristics of the economic environment. Finally, we provide a novel account of the movement towards a mathematical approach.

With respect to the first set of observations, the word counts statistics suggest a clear pattern in the connections for our sample period. Starting approximately in the 1930s a period of decreasing connectedness is observed. More specifically, the fraction of journal contents that include words that denote other disciplines, such as history, psychology or sociology, show a clear decreasing pattern that starts approximately the 1930s. For the most notable case, in the 1920s, 50% of the articles include the word "history". In the 1970s, the value of the index dropped to 19%. This development is sharply reversed in the last decades of the sample. Staying with our earlier example, by the 2000s, the word "history" is present in 33% of the sample journal contents, showing a major increment from the 1970s value. Section III provides a detailed analysis of the results for a larger sets of disciplines. Among other observations, we report a surprisingly high correlation of the indices across disciplines and across journals. We interpret these observations as compelling indications of profound changes in the prevailing practices and attitudes in a discipline.

The second set of observations focus on attention levels allocated to features of the agents and the environment. Again, counts of selected words are used to ascertain attention levels. For the economic agent, we evaluate the interest in cognitive limitations and more flexible representation of preferences. With respect to the economic environment, we consider features related to: frictions, contracting, politics, social preferences and culture. On top of its intrinsic value, this exercise can be viewed as a robustness test of the findings regarding the connections to other disciplines. With some variations, the observations suggest an across-the-board initial cycle of narrowing focus and a second period of increasing openness to the inclusion of a wider range of issues in economic analysis. The patterns by and large mimic what is observed for the measures on connectedness.

The last set of observations deals with documenting the prevalence of the use of mathematical techniques in the last 122 years. For that purpose, we compute the fraction of journal articles that include mathematics related words in their full-texts. The mainstream economics has, to a large extent, embraced mathematic techniques as a tool for its analyses. While this fact is not controversial, there is value in providing a detailed description of how this processed unraveled. Our measures show a radical shift towards the adoption of mathematical tools that took place during the 1960s and 1970s. The shift is especially noteworthy considering the absence of similarly intense developments in the previous or in the following decades. The correlations in the measures are surprisingly high. According to our knowledge, this is the first attempt to quantify and date the well known shift of the economic discipline towards a more mathematical methodology.

In summary, this study reports quantitative evidence that suggests that the evolution of the prevailing approach in economics experienced two regimes. There was a first regime of decreasing connectedness with other disciplines, a focus on a narrower set of aspects and increasing embrace of mathematical tools. According to our observations, the stage of massive adoption of a more mathematical approach seems to have occurred after an important fraction of the decline in the connections with other disciplines already occurred. The second stage is characterized by a high degree of adherence to a formal approach together with increasing openness toward other disciplines and the consideration of a broader set of aspects.

We would like to emphasize that we consider the traditional approach to the history of ideas to be irreplaceable. The detailed understanding and comparison of complex objects, such as conceptual maps developed to advance the understanding of economic phenomena cannot be replaced by computer algorithms. The use of quantitative techniques most of the time involves reducing the analysis to a low number of dimensions, and disregarding all information that is not captured in the quantification stage. The value of techniques such as the one used in this study is the ability to analyze and summarize large amounts of data. The largest version of our dataset involves approximately 290,000 economic journal contents. In this way, it is possible to have comprehensive descriptions of the literature that would not be available otherwise. These descriptions can be used to corroborate assertions that are based on more traditional and not as comprehensive analyses of the literature. For example, it is possible that some seminal contribution in a particular date can bias the perception of the prevailing practices on that period. For example, the publication of Paul A. Samuelson's *Foundations of Economic Analysis* in 1947 is considered a landmark moment in the application of mathematical techniques

to economics but, according to our measures, this date should not be viewed as a close approximation to the date in which the discipline embraced these techniques. A comprehensive analysis might help substantiate the validity of that perception.[1] In addition, the quantification of observations allows for the use of statistical techniques and facilitates the exchange of information. It is our view, that historic accounts of developments in the discipline can be complemented with comprehensive quantitative observations. For example, we believe that the measures we provide complement works such as the account of the interwar period fight for preeminence by the neoclassical and institutionalist schools reported in Yonay(1998) and the account of the incorporation of contractual and psychological considerations in mainstream economics reported in Bowles et al. (2002).

This study is related to other quantitative analyses of economic literature. For example, Stigler et al. (1995) analyze citation patterns to evaluate influence and specialization across economic journals between 1987 and 1990. Pieters et al. (2002) develop citation analysis to assess intra- and interdisciplinary communication patterns between journals between 1995 and 1997. This study concludes that the citation patterns observed between economics and sister disciplines suggest limited cross fertilization.

This study is also connected to a growing literature in financial economics that use computer algorithms to form statistics of word content of financial documents or news articles. For example, Tetlock (forthcoming) and Engelberg (2008) count words of news articles and financial statements respectively, to evaluate predictability of stock returns.

Our analysis is inspired by the view, prominent since Kuhn (1962), that the practice of science involves the adherence to a set of assumptions that are shared by a scientific community and have a great influence on the practice of research. These assumptions might be sustained even in front of evidence that proves them not completely accurate. Our work intends to partially characterize the evolution of the prevailing practices through the quantitative analysis of a large piece of the literature.

[1] We found that during the 1960s and 1970s approximately 30% of the AER contents include the word "Samuelson" while in the 1950s the figure is 23%. For another last name associated to the diffusion of formal analysis, the word "Nash" appears in less than 5% of the AER contents up until the mid 1970s, by the early 1990s this figure surpasses 30%.

In the next section we describe the data and methodology. Section III describes the statistics on the connections of economics with other disciplines. Section IV deals with the evidence on consideration of specific features in the economic literature. The embrace of quantitative techniques is presented in Section V. Section VI concludes.

II. Data and methodology

Our dataset is based on the contents of economic journals provided by jstor.org, a commercial journal database. The service provides access to 92 journals in the category "economics". The first articles correspond to 1886 while the last ones correspond to 2007. The total number of articles is 289,475. For the purpose of our analysis, each content is an observation. Table 1 provides information about the number of articles by decade.

Table 1. Number of contents in the dataset by journal and decade

	1880	1890	1900	1910	1920	1930	1940	1950
All Economics	197	2180	3015	4834	6105	11117	13813	21274
AER	72	188	344	1692	1617	2286	2721	3133
QJE	125	363	423	434	426	505	486	546
JPE	0	507	883	1385	752	1295	1313	1372
EJ	0	1128	1333	1201	1308	1614	941	1520
REStat	0	0	0	62	380	417	443	898
Economica	0	0	0	0	561	838	780	1110
Econometrica	0	0	0	0	0	323	414	850
RES	0	0	0	0	0	189	194	297

Table 1. (continued) Number of contents in the dataset by journal and decade

	1960	1970	1980	1990	2000	Total
All Economics	30570	47113	54491	58200	36566	289475
AER	3416	2264	2299	1983	1615	23630
QJE	626	626	672	554	254	6040
JPE	1409	1390	956	708	413	12383
EJ	1796	2010	1906	2497	960	18214
REStat	898	886	1113	942	402	6441
Economica	1250	1110	918	669	605	7841
Econometrica	1155	1618	1456	963	794	7573
RES	408	634	638	510	453	3323

For many parts of the analysis we will focus on a smaller fraction of the dataset. The restriction to a smaller number of publications responds to the objective of focusing on a uniform set of publications over long periods of time and is used to focus on what might be called "core of the mainstream". In some cases we will only consider the three oldest American journals: the *Quarterly Journal of Economics* (QJE) founded in 1886, the *Journal of Political Economy* (JPE) founded in 1892 and the *American Economic Review* (AER) founded in 1911.[2] In other analysis we also include: *The Economic Journal* (EJ) founded in 1891, *The Review of Economic and Statistics* (REStat) founded in 1919, *Economica* founded in 1921, *Econometrica* founded in 1933 and *The Review of Economic Studies* (RES) founded in 1933. The above listed publications contain approximately 30% of total number of contents in the full dataset of 92 journals.

The economic literature considered in this study consists of contents published in mainstream English language economic journals. This focus leaves out economic literature in a different language and literature that did not belong to the mainstream in each period of the analysis. At the same time, this includes studies

[2] We have extended the time series of articles corresponding to the American Economic Association through 1886 by taking into consideration the *American Economic Association Quarterly* 1908-1910 and *Publications of the American Economic Association* 1886-1907

whose object has not been traditionally viewed as economic problems but were published in economic journals. The data coverage implies that the observations of our analysis, especially when we consider a reduced number of publications, correspond to the practice of economics by mainstream professionals. In other words, our study is about prevailing practices in a given community, changes in the practices can be due to changes in the views of the members or the inclusion/expulsion of members.

The basic measure in the analysis is an index of word detection. For a specific word/phrase "A", a specific time range and list of publication, the index is equal to the percentage of listed contents that include the word/phrase "A" in its full text.[3] To calculate the index value we use the search algorithm provided by jstor in its website. In some cases we calculate indices for a list of words using the "or" logical condition.

In some cases, to facilitate comparison among different words, we find it convenient to calculate standardized versions of the indices. The standardization is implemented by calculating the mean and the standard deviation for the index corresponding to a given word, and correcting the original index by subtracting the mean and dividing the difference by the standard deviation.

III. Economics and other disciplines

In this section we present a novel account of the extent to which economics has been connected to other disciplines in the last 122 years. Our findings suggest that there is an important degree of correspondence between the connection measures for different disciplines. As anticipated in the introduction, we find clear patterns indicating periods of isolation and connectedness.

Economics can establish a connection to another discipline by using findings and concepts developed by other fields to explain economic phenomena. For example, economics might use insights from psychology to explain investment decisions. Alternatively, a connection might result from the study in economic

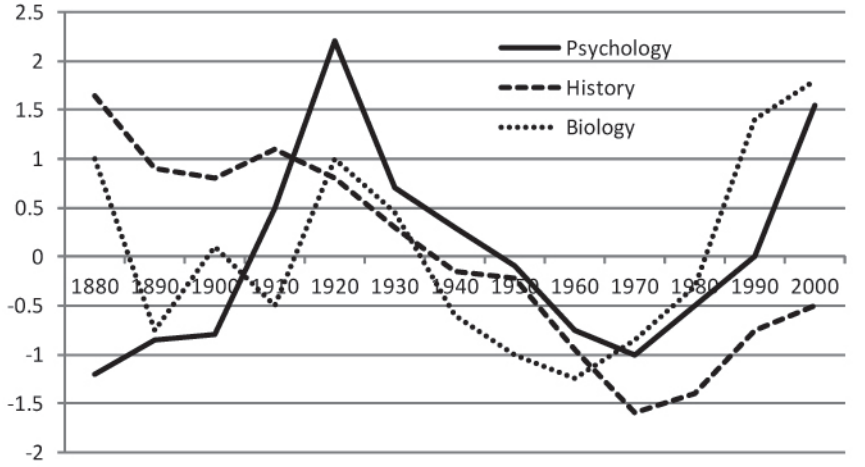
[3] The search algorithm we use includes "all journal contents"; this means that other objects which are not articles, such as reviews or tables of content are included in the search. Our objective is to describe the state of the discipline in a certain point in time. We consider that "all journal contents" defines an adequate sample universe for such analysis.

journals of issues that are traditionally associated with a different discipline. For example, an economic journal might publish an article that studies voting in an election for a public office, a topic typically associated with political science. Our measures capture both types of connections. Our measures are not able to separate these two types of relationship. Nevertheless, in some cases, the type of relationship can be inferred from the nature of the disciplines. For example, we believe that most mentions of Psychology or Biology in economic journals are mainly related to cases in which economist use insights from these disciplines as inputs in an analysis of an issue that is traditionally considered an economic issue.

A first peak of our findings is shown in Figure 1 where the evolution of our measure of connectedness of economics to three selected disciplines (Psychology, History and Biology) is shown. For each discipline, we calculate the fraction of journal contents that include in its full text the word or phrase that denotes each discipline. To facilitate the comparison, the figure reports standardized values of the index.[4] The figure suggests that starting approximately in the 1930s a period of less connectedness begins. This trend is sharply reversed in the last decades of the sample. The indices capture significant changes in word detection in journal articles. For the most notable case, in the 1920s, 50% of the articles include the word "history". In the 1970s, the value of the index dropped to 19%. The latest number for the 2000s is 33%. For Psychology and Biology, the values of the indices are, on average, lower; but the changes in proportional terms are comparable to the case of History as Figure 1 shows. We believe these numbers are indicative of profound changes in the prevailing practices and attitudes in a discipline. In the online appendix we provide data for the original word count indices for nine different disciplines.

[4] The mean value of the index for each discipline can be very different. The standardization is used mainly to a have an index that facilitates comparison across different fields/words at the same time. We calculate the mean and the standard deviation for each word. The standardization consists of subtracting the mean to the index and then dividing the difference by the standard deviation.

Figure 1. Standardized index of word detection — selected disciplines



Before providing a more careful description of evolution through time we find it convenient to observe that our measures are highly correlated across disciplines. Table 2 presents the mean values and the correlation coefficients for the indices of word detection corresponding to 9 different disciplines. The statistics are calculated using information corresponding to the sub-sample of 8 publications indicated in the previous section. The first column reports data on the sample value of the index for each discipline. History is the discipline with the highest mean value for the index. On average, 39.7% of the contents in the journals include the word History. Other five disciplines have average index values that range between 3.8 and 7.7. These five disciplines are: Psychology, Sociology, Political Science, Philosophy and Ethics. Finally, three natural sciences: Physics, Biology and Chemistry, have average index values which are below 1.7. In the online appendix we provide tables with the values of the indices for each discipline and each decade.[5]

The indices exhibit surprisingly high correlations. The values of the correlation coefficients are higher for the calculations that exclude the first decades of the sample, as shown in the second panel of Table 2. The co-movement is especially

[5] See Table A1. Similar observations result when all the journals of the sample are considered. See Table A2 in the online appendix for the values of the indices for that case.

notable for computations among the first six disciplines in the matrices that is, when the natural sciences are excluded. For example, the coefficient of correlation for History calculated for the 1910-2000 period is above 0.89 when the coefficient is calculated using Psychology, Sociology, Political Science or Ethics as the other discipline. These high correlations suggest that the practice of economics, as evidenced by the sampled journals, was characterized by wide raging movements toward more connectedness or openness and equally extensive shifts toward of isolation.

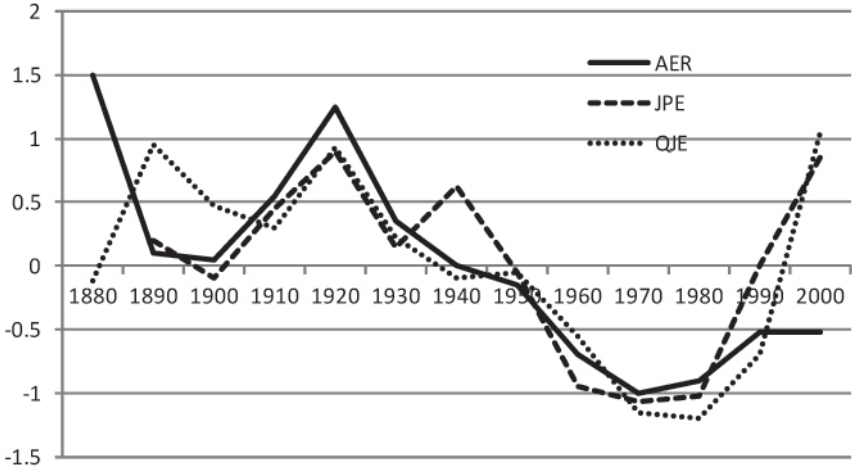
Table 2. Correlations of word detection indices across disciplines

	Mean	Correlation coefficients								Mean.
	index	Psy.	Hist.	Soc.	P.Sc.	Eth.	Phi.	Bio.	Phy.	Che.	corr. coef.
1880-2000											
Psychology	5.33	-	0.92	0.27	-0.16	0.11	0.1	0.53	0.6	-0.14	0.22
History	39.72	0.92	-	0.92	0.76	0.94	0.83	0.27	0.36	0.84	0.73
Sociology	5.91	0.27	0.92	-	0.61	0.87	0.74	0.4	0.5	0.78	0.64
Pol. Science	6.96	-0.16	0.76	0.61	-	0.72	0.69	0.36	0.39	0.94	0.54
Ethics	3.8	0.11	0.94	0.87	0.72	-	0.73	0.31	0.43	0.83	0.62
Philosophy	7.73	0.1	0.83	0.74	0.69	0.73	-	0.08	0.46	0.71	0.54
Biology	1.44	0.53	0.27	0.4	0.36	0.31	0.08	-	0.46	0.36	0.35
Physics	1.69	0.16	0.36	0.5	0.39	0.43	0.46	0.46	-	0.47	0.40
Chemistry	1.17	-0.14	0.84	0.78	0.94	0.83	0.71	0.36	0.47	-	0.60
1910-2000											
Psychology	6.15	-	0.91	0.91	0.84	0.78	0.49	0.73	0.46	0.86	0.75
History	35.66	0.91	-	0.91	0.89	0.9	0.79	0.26	0.19	0.84	0.71
Sociology	5.37	0.91	0.91	-	0.94	0.87	0.74	0.5	0.47	0.96	0.79
Pol. Science	5.69	0.84	0.89	0.94	-	0.75	0.74	0.38	0.3	0.84	0.71
Ethics	3.22	0.78	0.9	0.87	0.75	-	0.64	0.39	0.24	0.87	0.68
Philosophy	7.11	0.49	0.79	0.74	0.74	0.64	-	-0.02	0.34	0.71	0.55
Biology	1.43	0.73	0.26	0.5	0.38	0.39	-0.02	-	0.55	0.4	0.40
Physics	1.63	0.46	0.19	0.49	0.3	0.24	0.34	0.55	-	0.49	0.38
Chemistry	0.9	0.86	0.84	0.96	0.84	0.87	0.71	0.4	0.49	-	0.75

Notes: The indices are calculated using information corresponding to eight selected publications: AER, QJE, JPE, EJ, REStat, Economica, Econometrica and RES.

Given the high correlations found across disciplines, we find it convenient to calculate an index that succinctly describes the state of economics in terms of connectedness to a group of other disciplines. For that purpose, we calculate the equally weighted average of the standardized indices for: Psychology, History, Political Science, Sociology, Philosophy and Ethics. Figure 2 presents this index calculated separately for the three oldest American economic journals. The correlations across journals are extremely high, especially for the last 60 years.[6] The figure shows that in the 1920s the indices for the three journals display a peak. From the 1920s until the 1970s the predominant tendency is towards more isolation. This tendency is reversed, starting in the 1980s.

Figure 2. Standarized word detection index — average values for selected disciplines (Psychology, History, Political Science, Sociology, Philosophy, and Ethics)



The tables of the indices for different disciplines (in the online appendix) show a sharp contrast between the behavior of indices for behavioral sciences versus indices for some natural sciences. For example, the indices for disciplines such as History and Psychology show the reported sharp U-shaped pattern. On the other

[6] Table A3 of the online appendix provides the correlation coefficient across journals for the sub-sample of 8 journals.

hand, disciplines such as Physics and Chemistry are mostly flat. We believe that this contrast favors the interpretation of our results as evidence of a change in the practices of the discipline that goes beyond a simple change in the frequency of words in journal contents.

One concern regarding our measures is given by the alternative uses of words that denote a discipline. While it is safe to assume that "political science" typically refers to the social discipline, words such as "history" or "psychology" can be used to refer either to the discipline or to a different concept. For example, in game theory, the word "history" is used to refer to the actions selected by players' and nature in the previous periods of a dynamic game. This issue weakens the value of the evidence for this second class of words. While still imperfect, one possible robustness check involves computing similar indices for related, but different words such as "historical" and "psychological". The alternative measure serves as a robustness check because by considering closely related terms some undesired uses of the original word might be eliminated. It is imperfect because it is also the case that the newly considered words are used in ways that do not match what the index is designed to capture. Indices for these two words were computed resulting in patterns very similar to those found in the original indices. This evidence lends support to the stance that our measures are not driven by alternative uses of the word.

The findings presented in this section are indicative of profound changes in the prevailing practices in the discipline. We have identified periods, particularly the 1960s and 1970s, in which the low frequency of references to other disciplines suggests increased prevalence of the view that the understanding of economic issues does not involve recurring to concepts and findings developed by other disciplines and that the economic method applies to traditional economic subjects, but not to topics of other disciplines. These trends are all-encompassing, in the sense that it is identified for different journals and different disciplines.

IV. The approach to the economic agent and its environment

Conducting economic research requires making choices about which are the features of the economic agent and its environment that belong to the core of the analysis and which features should be ignored. These choices might not be explicitly stated, but are inevitable given the complexity of economic events and economic actors and the limited tools of the analyst. The selection of specific

features is shaped by the objectives of the study in question, the prevailing practices in the community to which the researcher belongs to and the original insights of the researcher.

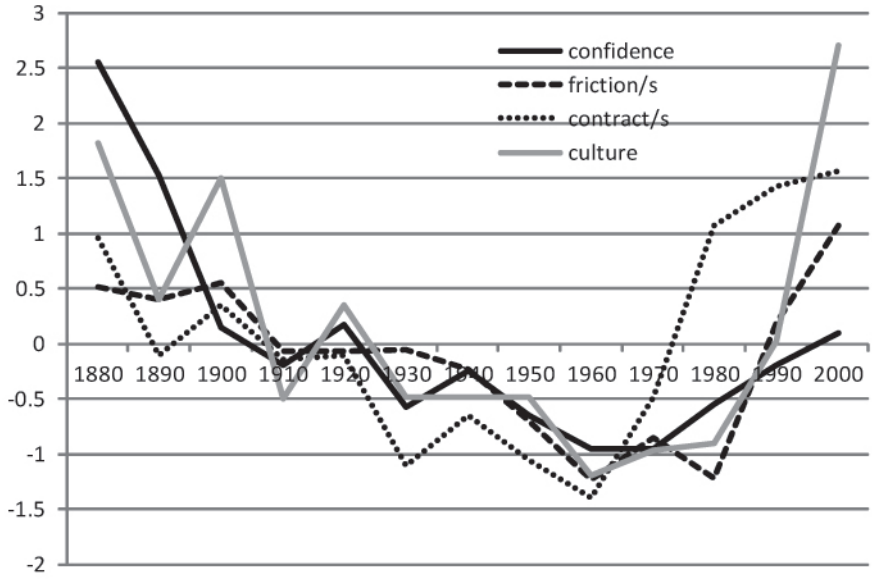
The focus in this section is placed on assessing the attention assigned to specific features of economic events. In contrast to the previous section, where the focus was placed on connections with other disciplines, in this section the focus is placed on the consideration of aspects of economic agents and the economic environment in which agents interact. These aspects sometimes can be linked to specific disciplines, but that is not always the case. For example, characteristics of the economy that generate "frictions" are not necessarily linked to other disciplines.

As in the previous section, our evaluations are based on the presence of specific words in journal contents. The underlying assumption is that words included in the full text of the documents are informative of which features were considered pertinent in economic analyses.

Our observations, detailed below, report patterns which are similar to the evidence reported in the previous section on connectedness of the economic discipline. We believe that in addition to its intrinsic value, this evidence can be interpreted as a robustness check of the inference made in the previous section.

As an opening example, Figure 3 presents standardized indices for the use of four words or pairs of words: "confidence", "friction/s", "contract/s" and "culture". We observe that each word or pair of words can be associated to a feature of the agents or the environment that is beyond what can be considered the core group of features commonly associated with economic analysis. The word "confidence" can be associated with the idea that economic agents form expectations without a complete understanding of their environment through a process that does not necessarily follow formal reasoning. The detection of "friction/s" suggests an interest in the possibility that the environment can present conditions that interfere with the smooth interaction of agents. In turn, the presence of the word "contracts" denotes a focus on the architecture of transactions and relationships. Finally, the detection of the word "culture" signals an interest in the set of beliefs and practices developed and shared by a community.

Figure 3. Standardized index of word detection — selected words



For each of the selected words we find that there is an initial decline in the respective indices. With some variations with respect to the starting date, this trend is reversed towards the end of the sample. For example, the index for "contract/s" exhibits an important increment starting in the 1970s, while the index for "culture" and "friction/s" do not exhibit a notable increase until the 1990s. The reported variations in attention levels are of significance; for example the word "culture" is detected in 7.1% of the contents in the 1920s; this figure drops to 2.9% in the 1980s. The last number for the 2000s is 8.9%. These examples are suggestive of nontrivial changes in the attention allocated to these issues by researchers that published in the sampled publications.

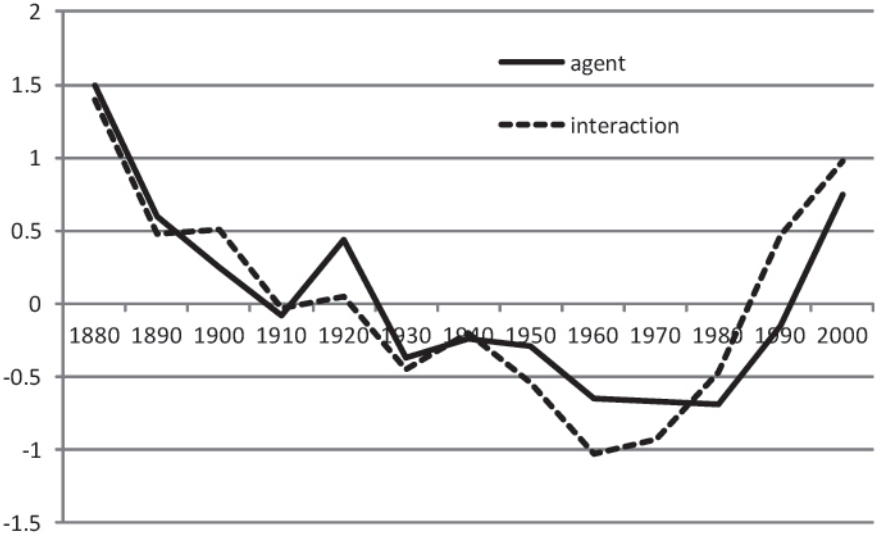
For the rest of this section, we present an extension of this analysis for a broader set of words that are grouped into categories. The words are selected with the objective of covering an ample set of features that are not typically considered to belong to the core of economic concepts but at the same time are important elements of the agents and the environment where they interact. The list of words and its corresponding indices are provided in Table A4 of the online appendix. A subset of words is identified as capturing features of the economic agents while other words are identified as capturing features of the economic environment.

In this way we form two broad categories. In addition, to provide more detailed and structured results, words in each broad category are also classified into subcategories.

Figure 4 presents the evolution of the average indices for the words belonging to the two broad categories. The indices show a very similar pattern for the sample period. With some variations, the U-shaped pattern observed in the previous section is also present in the analysis of this section. Coincidentally with what we found with respect to connections to other disciplines, the last decades in the sample show a clear upward trend in the indices while the intermediary period (1930s-1970s) is characterized by declines in the value of the indices. The main difference with respect to what we observed in the previous section corresponds to the first four decades of the sample (1880s-1910s). While for the case of disciplines we were not able to establish a clear pattern for that period, in the case of attention to features analyzed in this section we detect a clear negative pattern from the 1880s through the 1910s.

Overall we interpret this evidence as consistent with our observations regarding the connectedness to other disciplines. The indices of words associated with features of the agents and the environment portray a process of lessening attention to diverse features followed by a reversal in the trend in the last decades.

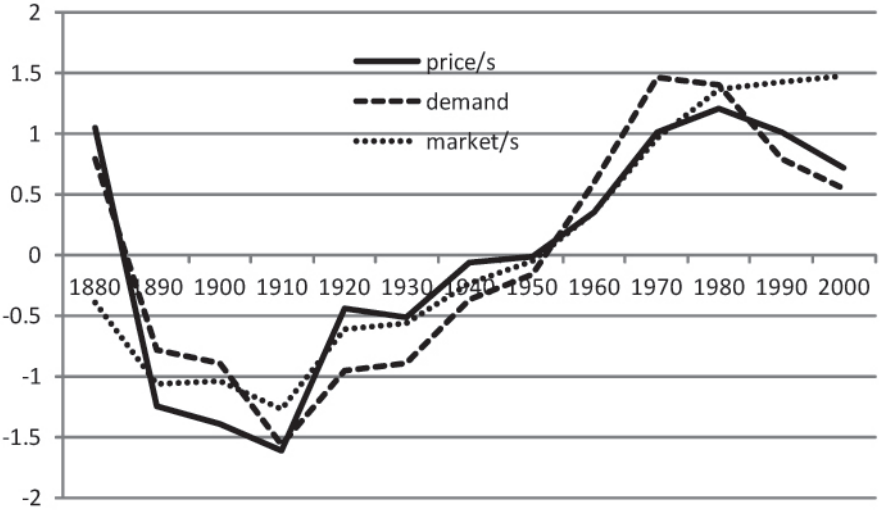
Figure 4. Standardized index of word detection — average values for broad categories



Additional insights can be gained by observing more detailed information. For example, different subcategories show reversals of the downward trend in different periods. While for the subcategory "contracts" and "politics" the index shows a clear upward trend starting in the 1980s, the subcategory "social preferences/culture" shows a clear upward trend only starting in the 1990s. Similarly, the subcategory "cognitive limits" shows an upward trend starting in the 1980s while the subcategory "goals/preferences" shows an upward trend only starting in the 1990s.

One possible robustness test could be provided by a comparison with words that are associated to the core of traditional economic concepts. In Figure 5 we show the indices corresponding to three such words: price, demand and market. This graph presents important contrasts with what we observed in the previous analyses. While in our previous analyses the indices show a clear downward trend for the periods 1930s-1970s, the indices corresponding to core economic concepts show a strong upward trend. In addition for "price/s" and "demand" the last decades of our sample show a downward trend. For "market/s" the upward trend is lower but persists. The distinct evolution of these indices suggests that the previously reported results capture a change in practice of economic research and not simply variations in the probability that any word would appear in journal content.

Figure 5. Standardized index of word detection — core economic concepts

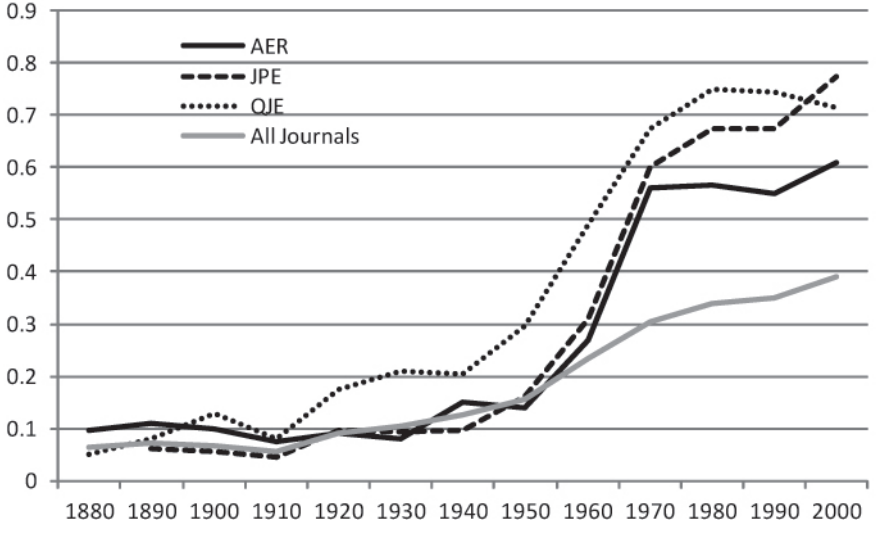


V. The mathematical approach

The economic journals are currently characterized by a heavy use of mathematical techniques in their contents. In this section we provide a novel account of how this process developed. Following the approach of previous analyses detailed in the previous sections, we assess the embrace of mathematical techniques detecting the presence of specific words. In this case we select the words: "mathematics equation theorem axiom'. The index equals the percentage of contents that include at least one of those words in its full text.

Figure 6 shows the indices corresponding to the three oldest journals in the United States of America (QJE, JPE, AER). A dramatic embrace of mathematical techniques is observed during the 1960s and 1970s. For each of the three journals, the variation of the indices during these two decades, adds up to almost to 40. This implies that the percentage of contents that include at least one of the words related with mathematics, jumped from the 17%-30% range in the 1950s to a range of 67%-77% by the 1970s. We consider these developments in premium journals to indicate a violent change in the prevailing practices and views of a community of researchers.

Figure 6. Indices of word detection — mathematics-related words



We also consider a broader set of publications to capture the practices in the discipline beyond the "core mainstream" measured by the three traditional journals. Figure 6 also presents the evolution of the index calculated for the 92 journals included in the full database. The aggregate index indicates a more smooth evolution that is still in progress during the last decades. But, in line with what we observed in the previous case, the 1960s and 1970s are the decades with the largest variation in the index, both in absolute and percentage terms. The change in the index equal 7.1 and 7.6 in the 1960s and 1970s respectively. This represents percentage changes of 45% and 33% respectively.

We would like to note that, for the time range that begins in the the 1960s and ends in the 2000s, the three oldest journals represent between 10% and 20% of the total number of contents for the sample. This means that it is not the case that the variations for the complete sample are mainly explained by developments in those three journals. Also, we would like to note that the second exercise provides an additional robustness check to our findings, since in this case, we are allowing for new journals to enter the calculation of the index. That is, we observe that both, using a constant set of journals and a growing set of journals, the 1960s and 1970s appear as the decades in which mathematical techniques were broadly embraced by the discipline.

VI. Concluding remarks

This is a descriptive contribution. Our objective is to report, in very general terms, comprehensive assessments of changing practices in the profession. The measures we use are novel and informative. As it is the case with any quantification, there is room for further inspection of the results and refinement of the indices. Nevertheless, we do not think that the main message would change significantly. The quantitative measures reported are able to identify significant variations in the way in which economic analyses are developed. The evidence is related to connections with other disciplines, attention to different features of economic events and use of mathematical techniques.

Our observations lead to the identification of three stages in the practice of economic research. A first stage in which a broad set of features is attended to. These features were jointly considered in analyses with heavy use of intuitive judgment and limited use of logical reasoning in the articulation and development of conceptual maps. A second stage, starting approximately in the 1930s, is

characterized by a markedly increased role for mathematical tools. In addition, this second stage is characterized by a focus on a narrow and mostly strictly economic set of features. The evidence in this work is consistent with the view that, in the last decades, the discipline entered a third stage in which the use of mathematics remains strong but the features considered are more diverse.

There are many directions in which this analysis can be extended. First, this analysis could be extended to other social sciences to be able to assess whether similar cycles of isolation and connectedness occurred. In the same spirit, the analysis could be extended to economic journals in other languages. It would be interesting to observe whether the detailed patterns were simultaneously developing in other communities of researchers. The analysis could be extended in time. The main challenge in this case would be identifying, for early dates, a similar sample of scientific writings.

Another possible extension would involve analyzing developments in the way in which specific fields of interest are approached. This is in contrast with the very general perspective taken in the current study. For example, a study could evaluate the fraction of the works on economic growth that have considered institutions or culture as relevant aspects. Similarly, it would be interesting to learn about the evolution of the interest in concepts such as bubbles, fraud, bankruptcy and panic in studies of financial markets. Variations in the frequency of detection of these words can be interpreted as indications of different "eras" in the study of financial markets.

Finally, we believe that similar analyses could be employed to provide insights about the degree of specialization inside of the discipline. Specialization can be a natural consequence of applying additional resources to the study of specific topics. Alternatively, it is possible that beyond the existence of areas of specialization, the discipline changes in a coordinated fashion where changes in methodologies, connections with other disciplines and interest in specific aspects of complex events that are closely related across different areas of specialization. Historic measures could be computed to assess to which degree, studies in different areas appealed to increasingly different inputs from other disciplines or are attentive to different features of the economic agent and the environment in which interactions occur.

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