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Should citations be weighted to assess the influence of an academic article?

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Abstract

Citations are by nature heterogeneous. A citation worth may dramatically vary according to the influence of the citing article or to the journal's reputation from which it is issued. Therefore, while assessing the influence of an academic article, how should we weight citations to take into account their real influence? In order to answer this question, this article suggests various methods of weighting citations in the building of articles quality indicators. These indexes are then used to measure the influence of the articles published in the top five economic journals over the 2000-2010 period and analyses the sensibility of these indicators to the choice of the weighting schemes. Our main result is that whatever the weighting scheme, information carried by the different indicators is not significantly different. From Occam's razor principle, the number of citations provides an efficient and sufficient tool to measure research quality.

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Section 1. Introduction

In the assessment of research, counting of citations is ubiquitous. Articles' influence are valued according to the number of citations they received (Van Noorden, *et al*. 2014, Kim *et al,* 2006). Literature classifies the impact of researchers' work through their number of citations in academic journals (Medoff, 1996, Coupé 2003). Citations influence academic careers and researchers' rewards (Diamond Jr. 1986, Bratsberg *et al*, 2010), contribute to journals reputations (Bollen et al, 2006 , Ritzberger, 2008) and allow the assessment of research departments, universities and countries (Dusansky and Vernon 1998, Braun et al., 1996, Bordons et al., 2002).

However a citation doesn't exhibit the same worth depending on the citing article. In economics, being referenced by an article published in *The Amercican Economic Review* gives a paper a higher visibility than being cited in a second or a third tier journal and, logically, bibliometric indicators take into account the heterogeneity of the pool of citations.

In the literature, the citation worth is assessed according to two major approaches. It is first measured as a function of the number of articles citing the citing article (see for instance Bollen *et al* 2006 and, in economics, Laband and Piette 1994). It may also reflect the quality of the publishing medium in which citing articles are published (the benchmark method here is close to the Eigenfactor approach, see Bergstrom, 2007, Bergstrom *et al,* 2008). Focusing on the pro and con of the two approaches, a vast strand of research considers the most efficient way to measure the value of a given citation. In these settings, this article has two main objectives: first, to suggest alternative ways of introducing the value of a citation in the assessment of articles influence and second, to measure the sensibility of the resulting indicators to the way in which the weight of citations is taken into account.[1]

Our work therefore considers the 3142 articles published in five of the best economic journals *(The American Economic Review, Econometrica, Journal of Political Economy, Reviews of Economic Studies et Quarterly Journal of Economics*)[2] over the period January 2000 - December 2010. Following Hu et al (2011), hereafter, these articles will be referred to as the generation zero. We then identified every article citing these articles and listed in the *Web of Science* (the first generation of citing articles) and each article citing these citing articles (the second generation). With this database, we defined three families of indicators: the first assesses the influence of an article by the raw number of citations it received from the first generation. The second considers that a citation presents a higher value if the citing article in the first generation is itself frequently cited. The third approach pays attention to the journals where the first generation of citing articles were published. Finally, we also computed these indicators considering only citations published in the 600 journals ranked by Combes and Linnemer (2010). This allows us to take into account the influence of the set of journals in which citations are recorded and to build and compare 10 alternative indicators for our benchmark articles.

The main result of our study is that the information conveyed by the different indicators is not significantly different whatever the way citation worth is taken into account.

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1 Note that the purpose of this paper is not to define measures of academic influence. As such, our indicators could easily be criticized.

2 These journals are often considered as the five top journals in economics – see for instance Card and Della Vigna (2013).

When we rank our benchmark articles according to the various indicators, rankings do not appear statistically different (Spearman's rank correlation coefficients are high whatever the rankings considered). More formally, a principal component analysis (PCA) allows us to show that there are only minor differences between the three families of indicators. According to Occam's razor principle, the use of the raw number of citations as a measure of articles influence seems efficient – at least for articles published in the five considered journals.

Section 2: Data

In March 2015, we used the *Web of Science (WOS)* to retrieve the citations received by our benchmark articles (first generation of citing articles) and the citations received by the citing articles (second generation). The Dataset includes 3142 benchmark articles, 57.244 citing articles in the first generation and 191.000 in the second generation.[3] In order to normalize the time period in which citations were recorded, we restricted these citations to the four year window following the publication of the cited articles.

Table 1 presents the mean number of citations by article in the four year window.

Journal	Articles	Citations	Citations / article
AER	1084	19814	18
Eco	668	10992	16
QJE	457	12382	27
RES	480	6461	13
JPE	453	7595	17
Total	3142	57244	18

Table 1: Mean numbers of citations in the four year window

We then built 10 indicators aiming at reflecting the scientific influence of the articles published by the five journals. Following a methodology introduced by Schubert (2009), indicators are built by analogy to the h and g-indexes proposed by Hirsch (2005) and Egghe (2006) to measure researchers' influence.

Basically, our indicators rely on the number of citations; however they differ in the weight accorded to each citation.

The first indicator (*T_C*) only records the number of citations:

- *T_C:* this indicator indicates for each article of the five journals the raw number of citations recorded in WOS.

The two next indicators (P_h and P_g) develop a PageRank approach to assess articles' influence (indicators *P* for PageRank). In these indicators, the worth of a citation is linked to the number of articles citing the citing article. Consequently, a citation is considered only if the citing article itself is influential.

[3] Note that some articles are counted twice when their references include both a benchmark article (they are members of the first generation of citing articles) and one of its citing paper (they are also members of the second generation).

- P_h *:* this indicator extends the h-index to single articles. The P_h of an article is therefore equal to x if x is the highest natural number such as there is at least x citing articles that are cited at least x time.[4]
- P_g*:* this indicator measures an article's influence by reference to the g-index (Egghe 2006). P_g is then equal to z if z is the largest number such as the z more influential citing articles received together at least z^2 citations.

For instance, let us consider an article which is referred to in four articles. Article 1 is cited five times, article 2 three times, article 3 only once and article 4 received no citation. Given these citations, our benchmark article has a P_h equal to 2, only two of the citing articles are cited more than twice, and a Pg of three as the sum of the citations received by the three more influential citing articles is equal to 9 (i.e. the squared value of rank 3).

By construction, the P_g indicator puts a specific emphasize on the influence of the most important citing articles. A benchmark article cited by only a few influential articles will have a high P_g and a low P_h. The two indicators don't capture the same effects.

The next indicators consider that a citation worth is linked to the quality of the journal in which is published the citing article (indicators *J* for Journal). In order to measure journals' quality, we use the quality measures proposed by Combes and Linnemer (2010) in their journals' ranking. In their article, these authors give two measures (CLm and CLh) of the quality of each of the 1202 Econlit Journals. These measures are the result of the same estimation and therefore imply the same ordinal ranking of journals; however, they differ in the relative weights they give to each journal. The CLm indicator (where m stands for medium convexity) exhibits a relatively low difference between the weight assigned to the journals of the top tier and a journal in the middle of the ranking while this difference is higher with the CLh indicator (where h stands for high convexity). With these two quality measures, we defined two alternative sets of indicators.

First, two indicators are computed considering citing articles published in an Econlit Journals with an explicit reference to the h-index.

- J_h^{CLh}: this indicator presents a value x if x is the largest natural number with the following property: the cited article has received at least x citations from articles published in journals with a weight CL_h exceeding or equal to x. For instance, consider an article cited by five articles. If only three of these journals present a weight CL_h exceeding or equal to 3, the article's J_h^{CLh} will be equal to 3.
- J_h^{CLm}: this indicator replicates the previous indicator but uses the CL_m weight system.

The two following indicators are computed considering citing articles published in Econlit journals with an explicit reference to the g-index.

- J_g^{CLh}: for a given article, this indicator takes value x when x is the largest number with the following property : the sum of the CLh score of the best x journals (ranked according to Combes and Linnemer (2010) CLh classification) publishing an article citing the reference article is higher or equal to x^2. For a given article, a J_g^{CLh} Indicator equal to 5 means that the sum of the five best CLh journals' score exceeds 25 (i.e. 5^2).
- J_g^{CLm}: this indicator replicates the previous indicator with the CL_m weight system

- Finally, the last three indicators replicate the previous methodology but restrict the set of citations to citing articles published in one of the 600 influential journals listed in Combes and Linnemer [2010].

[4] This index is formally equivalent to the h-index put forward by Schubert (2009) to assess single publications.

Author(s)	Title	Journal	Issue	Year	LP/SP	Indicators TC		Indicators J				Indicators *P*			
						T_C	T^R_C	J_h^{CLh}	J_g^{CLh}	J_h^{CLm}	J_g^{CLm}	P_h	P_g	P^R_h	P^R_g
Lawrence J. Christiano, Martin Eichenbaum, and Charles L. Evans	Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy	JPE	1	2005	LP	1	1	1	1	3	1	35	17	35	16
Marianne Bertrand, Esther Duflo, and Sendhdl Mullainathan	How Much Should We Trust Differences-In-Differences Estimates?	QJE	1	2004	LP	2	2	2	4	2	3	10	12	10	12
Jeffrey R. Kling, Jeffrey B. Liebman and Lawrence E Katz	Experimental Analysis of Neighborhood Effect	ECO	1	2007	LP	3	18	82	70	75	53	26	25	26	24
Frank Smets and Rafael Wouters	Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach	AER	3	2007	LP	4	3	9	10	4	4	67	105	67	98
Elhanan Helpman, Marc Melitz and Yona Rubinstein	Estimating Trade Flows: Trading Partners and Trading Volumes	QJE	2	2008	LP	5	5	77	107	47	80	176	314	178	281
Marc J. Melitz and Giancarlo I. P. Ottaviano	Market Size, Trade, and Productivity	RES	1	2008	LP	6	4	32	23	8	7	59	127	59	124
Lutz Kilian	Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market	AER	3	2009	SP	7	7	238	430	87	156	83	138	83	135
Gary E Bolton and Axel Ockenfels	ERC: A Theory of Equity, Reciprocity, and Competition	AER	1	2000	LP	8	6	7	9	15	4	1	1	1	1
Urs Fischbacher and Simon Gächter	Social Preferences, Beliefs, and the Dynamics of Free Riding in Public Goods Experiments	AER	1	2010	SP	9	28	238	703	26	136	20	19	20	19
James E. Anderson and Eric Van Wincoop	Gravity with Gravitas: A Solution to the Border Puzzle	AER	1	2003	LP	10	8	25	50	43	36	7	3	7	3

Table 2: The ten most cited articles and their ranking according to the 9 indicators.

These indicators therefore give a more elitist measure of the articles' influence by considering a restricted number of potentially influential citations.

- P^R_h and P^R_g: these indicators use the same methodology that the P_h and the P_g indicators but with the above mentioned restricted set of citations.

T^R_C: gives the raw number of citations coming from articles published in one of the 600 journals listed by Combes and Linnemer (2010).

Table 2 lists the ten articles that received the highest number of citations and their respective rank according to our 9 indicators. Amongst the ten most cited articles, five were published in the AER, two in the QJE, and one article in each of the three other journals (JPE, Econometrica and RES). It clearly appears that the various indicators lead to rather different rankings according to the weighting function used to measure the value of a citation. This heterogeneity illustrates the difficulties raised by the use of citations in the assessment of academic influence.

However, the ranks of the ten most cited articles don't give a correct image of the whole dataset. In order to assess the proximity between the ten rankings arising from our indicators, for each indicator, we built a specific ranking of the benchmark papers and computed the Spearman's coefficient for each couple of rankings. Table 3 gives the mean values of the spearman's rho in our database, the lowest coefficient is equal to 0.7 and the mean value is 0.84. According to this table, there is a strong correlation between the different rankings. Even if the 10 indicators measure the worth of a citation according to rather different criteria, the ranking they induce appears to be weakly sensitive to them.

	P_h	P_g	J_h^{CLh}	J_g^{CLh}	J_h^{CLm}	J_g^{CLm}	P^R_h	P^R_g	T^R_C
T_C	0,967	0,862	0,912	0,952	0,984	0,775	0,874	0,777	0,891
P_h	0,899	0,923	0,982	0,974	0,768	0,858	0,772	0,874	
P_g	0,923	0,917	0,899	0,697	0,775	0,701	0,788		
J_h^{CLh}	0,932	0,952	0,731	0,818	0,735	0,835			
J_g^{CLh}	0,969	0,762	0,850	0,766	0,866				
J_h^{CLm}	0,770	0,869	0,774	0,889					
J_g^{CLm}	0,940	0,998	0,926						
P^R_h	0,940	0,996							
P^R_g	0,927								

Table 3: Spearman's Rank correlation matrix

Section 3. Statistical analysis

In order to focus more precisely on the relationship between our various indicators, we then developed a Principal Components Analysis (PCA) using graphical representations in two dimensions.

One methodological issue in our study is linked to the period over which citations are collected. As our study covers articles published between 2000 and 2010, older articles naturally received a higher mean number of citations than the more recent ones and therefore the value of our indicators is time dependent. In order to avoid this issue, the dataset has been

split in two subsets, a first subset considers articles published during the period 2000-2005 (i.e. 1752 articles) and the second, articles published between 2006 and 2010 (1390 articles). For each subset, we performed a specific Principal Components Analysis.

For period 2000-2005, Kaiser's criterion indicates that 97.16% of the total inertia is explained in the first two axis where the first one (Axis 1) allows explaining 94,33% of the overall information of our PCA. The two first column of Table 4 show that all variables are highly positively correlated with the first axis and weakly correlated with the second. While considering period 2006-2010, results appear to be very similar. 95,31% of the information is captured by the two first axes (84,18% by axis 1 and 11,13% by axis 2) and the different indicators are highly correlated with axis 1 (see the two last column of table 4). Therefore, these indicators are strongly correlated with each other.

	Period : 2000-2005		Period : 2006-2010	
	Axis 1	Axis 2	Axis 1	Axis 2
T_C	0,988	-0,046	0,945	-0,188
P_h	0,956	-0,247	0,874	0,461
P_g	0,989	-0,081	0,91	0,38
J_h^{CLh}	0,92	0,324	0,88	-0,333
J_g^{CLh}	0,959	0,183	0,914	-0,288
J_h^{CLm}	0,979	0,102	0,944	-0,271
J_g^{CLm}	0,99	0,031	0,958	-0,246
P^R_h	0,958	-0,239	0,876	0,458
P^R_g	0,988	-0,066	0,923	0,344
T^R_C	0,983	0,054	0,946	-0,255

Table 4 : Correlations between variables and factors

Furthermore, for period 2000-2005, Table 5 shows that our ten indicators contribute equally, 10% on average, to the formation of the main axis (axis 1). The same result appears for period 2006-2010 with one difference between the two sub periods as Axis 2 seems to introduce a slight difference between the P and the J indicators. We will come back to this point later on.

	Period : 2000-2005		Period : 2006-2010	
	Axis 1	Axis 2	Axis 1	Axis 2
T_C	10,34	0,756	10,619	3,166
P_h	9,698	21,503	9,084	19,073
P_g	10,369	2,306	9,841	12,978
J_h^{CLh}	8,977	37	9,206	9,983
J_g^{CLh}	9,749	11,771	9,923	7,441
J_h^{CLm}	10,163	3,661	10,575	6,616
J_g^{CLm}	10,397	0,334	10,893	5,435
P^R_h	9,726	20,102	9,119	18,832
P^R_g	10,343	1,555	10,114	10,612
T^R_C	10,238	1,012	10,625	5,861

Table 5: Contributions of variables (indicators) expressed in %

Fig. 1. Below presents the various indicators on the correlation circle for the two sub periods. Each indicator is associated with a dot whose coordinates are given by the correlation between the factor and the indicator. The strength of the relationship between two variables is given by the squared cosine of the angle between the radius of the circle passing through the representative dots. The smaller the angle, the stronger is the correlation between the two variables.

Note that, in both circles figures, dots locations are very close to the edge of the circle and are therefore very representative of the variables (indicators) on the plane. The proximity between the vectors – as measured by the angles they form pair wise - allows us to determine whether indicators (or evaluation methods) are similar.

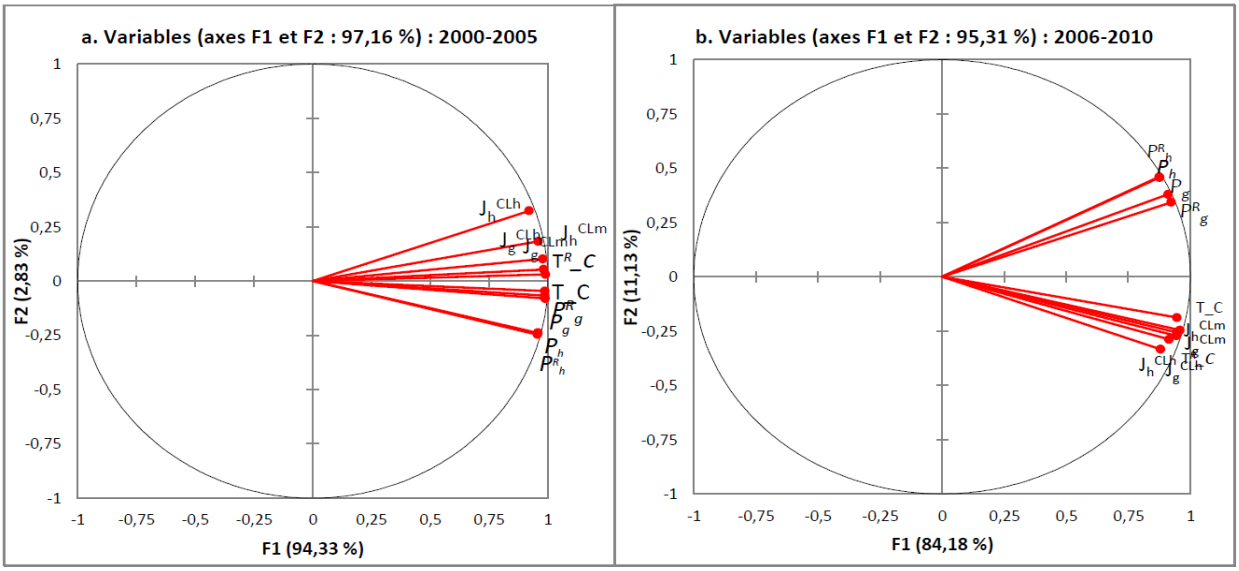

Fig 1: ACP Axis

Figure 1. therefore illustrates the high correlation between the different variables. For articles published during period 2000-2005. We note a slight difference between the J-indicators (J_h^{CLh}, J_g^{CLh}, J_h^{CLm}, J_g^{CLm}), above axis 1, that take into account the quality of the citing journal, and the P-indicators (P_h, P^R_h, P_g, P^R_g) below the same axis and focusing on the influence of the citing article. Both types of indicators seem also highly correlated with the two raw indicators: T_C and T^R_C (respectively the total number of citations received by each article and the number of citations from a journal surveyed in Combes and Linnemer, 2010). Note that the two last indicators present the highest correlation with axis 1 – respectively 0.945 and 0.946 – meaning that this axis is closely related to the raw number of citations.[5]

Equivalent results may be observed while considering period 2006-2010. The two sets of vectors are still distributed on each side of the horizontal axis. However, things seem to be more contrasted as the two blocks of variables exhibits a V shape with a 45 degrees angle. Above axis 1, vectors are representatives of indicators focusing on citing articles (*P*-indicators), below this axis we find the J-indicators (considering the influence of the citing journal). As shown in Fig. 4, indicators T_C and T^R_C are plotted below the horizontal axis, meaning that they are more correlated to the *J*-indicators than to the *P* ones. Like for the period 2000-2005, the indicators grounded on the quality of the citing journal are highly correlated with the raw number of citations – whatever the way these citations are recorded.

[5] Indicator J_g^{CLm} is the is the only one with a stronger correlation.

Things are rather different for the *P*-indicators as time plays a crucial role in the number of citations. Recall that the *P*-indicators measure the worth of a citation according to the number of citations received by the citing article. As writing and publishing articles is a time consuming process, an article may hardly record a significant *P*-indicator before four or five years after its publication. For articles published in the 2006-2010 period, the *P*-indicators computed with citations recorded until 2014 appear to give an imperfect measure of articles influence, an imperfection which is corrected through time as reflected by the correlation between the *P* and the *J*-indicators for the 2000-2005 period.

Finally, the Principal Components Analysis allows emphasizing the strong link between the various indicators. Statistically, the assessment of articles' influence leads to very similar results if one counts only the raw number of citations or if one considers more subtle measures taking into account the influence of the citing articles or the quality of the citing journals.

This result is not surprising. First, the fact that rankings are poorly influenced by the choice of the set of citing journals reflects the specific nature of our indicators. By construction, these indicators consider the most influential citations, i.e. citations coming from highly cited articles or from publications in influential journals. Restricting the set of journals to the best ones only removes citations coming from second tier journals or authors with only little influence. It barely affects our indicators and the resulting ranking.

Moreover, even if they rely on different measures of a citation worth, our indicators are basically grounded on the same benchmark. If the best academic journals were able to attract and publish only the highest quality articles, these articles should receive a high number of citations from very influential authors published in the best journals. Measuring citation quality with a specific focus on the number of citations that the citing article receives or on the journal where this citing article has been published should not make a large difference. In this case, our indicators would lead to the same ranking whatever the way a citation worth is measured. The Matthew effect (Merton, 1968) also contributes to smooth the differences between our measures of a citation worth. While choosing their bibliographical references, researchers present an obvious bias toward recognized authors and prestigious journals. Articles from the first generation of citing articles have a higher probability of being cited if they are published in top tier journals and a high *J*-indicator should induce a high *P*-indicator. Moreover, a citation by an influential article increases the visibility of the cited article and fosters further citations. A high *J*-indicator also implies a high *T_C* value (citation in good journals induces additional citations).

The difference revealed by the PCA between the *J* and the *P*-indicators would not exist if top tier journals were able to publish only the highest quality articles. However, articles' selection is sometime inaccurate and referees may reject good articles or accept articles with little scientific contribution (See for instance Oswald 2007 or Gans and Shepherd 1994). If an influential journal publishes poorly cited articles, a bias could be introduced between our indicators.[6] An article of the first generation of citing articles with low impact published in such a journal may contribute to an increase of the *J* indicators but will have no effect on the *P* indicators. Journal specificities may also induce a difference between the two kinds of indicators. For instance, when a journal publishes literature reviews, articles may be cited by a high number of PhD students but will be ignored by senior researchers (Bollen et al. 2006). Only few citations will be found in the best journals and the indicators will diverge.

[6] This could be specifically the case if an influential journal deals with highly specialized topics that induce only few citations.

Finally, our study tends to demonstrate that these mechanisms have a minor effect on our indicators. If the *J* and the *P*-indicators captures different phenomena, these differences are low and the simple citation count is highly correlated with other indicators. In a nutshell, despite its simplicity, citation count appears efficient.

Section 4. Conclusion

Over the last thirty years, the rise of research assessment procedures induced the search for efficient tools able to give correct measures of research efficiency. Most of the time, researcher performance and journal influence are evaluated through a simple count of the citations they receive. However, citations are intrinsically heterogeneous. The set of journals in which citations are collected and the impact of the citing articles lead to high discrepancies in the measure of researchers or journals' influence.

The aim of this work is to measure the sensibility of impact indicators to the metrics used to assess citation worth. To do so, we considered all articles published by five of the most influential journals in economics over the period 2000-2010 and built several indicators reflecting their influence. Each indicator was grounded on citation count but they differ from each other in the way citations were valued. Despite their differences, our indicators appear to be highly correlated and lead to statistically similar rankings. Following Occam's rule, for a given scientific field, assessing articles' influence by a simple citation count appears to be an efficient procedure.

This result is not exempt from criticism. First, our database only considers a very specific set of benchmark articles. A more general study should check these results with a more important set of articles. In this case, the problem of self-citation would have to be considered. Moreover, our approach let apart the characteristics of the citing authors. A citation coming from a Nobel price would not have the same value than a citation from a PhD student. Citation worth is certainly linked to the characteristics of its author. In turn this raises important methodological problems when a citing article results from collaboration between authors with different level of notoriety. These points deserve an in depth analysis in further research.

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