A parameter to quantify dynamics of a researcher’s scientific activity

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November 11, 2018

Abstract

I propose the coefficient, \( t_h \), and its modification \( N_t \) which in a simple way reflect dynamics of scientific activity of an individual researcher. I determine \( t_h \) as a time period (from some moment in the past till the present moment) during which papers responsible for \( 1/2 \) of the total citation index were published. Parameter \( N_t \) represents average of the citation index over this period: \( N_t = \text{C.I.}/2t_h \).

1 Introduction

The problem of estimation of an impact of a scientist (or a group of them) is an actual one (see, for example, [1] and references therein). Still, in many countries, for example in Russia, citation index (C.I. hereafter) or its modifications are not widely used. Only now, especially in front of a possible reorganization in the sphere of science, russian scientists and officials start to discuss problems related to quantifying a scientific impact of individual researchers or their groups.

The task to quantify scientific output is non-trivial as many components are involved, and it is impossible to describe fairly quality of a scientist by a single parameter (to prove harmony by algebra\(^1\)). The total impact can be more or less given by the C.I. (we do not discuss here such disadvantages of this parameter as dependence on research topics, influence of promotion of results, personal contacts, etc.). However, the structure of C.I. of a scientist (if it is mainly determined by a single paper with very high C.I., or by several of them with medium C.I., or by numerous papers with very small C.I., etc.) is lost when only one simple parameter is used. Different modifications can be suggested. Recently, Hirsch [2] proposed an interesting coefficient which supplements the standard C.I. This parameter is sensitive to the structure of C.I., i.e. it can describe if the index is dominated by few papers or not. However, all these parameters do not reflect dynamics of scientific activity. Below we propose a simple estimate which can distinguish if the C.I. of a scientist is due to recent or old publications, so in principle it is possible to estimate how it is probable that the scientist produce an important result in near future.
Figure 1: A simple illustration of scientific activity of three scientists with the same total C.I., but with different distribution of important papers over time. On the vertical axis I show the number of citations at the present moment to papers published in a given year.

2 Characteristic time

There were many attempts to include dynamics into bibliometric studies (see, for example, the citation age in [1] which reflects the citation history of a given paper). It is important to determine a characteristic time interval not arbitrary, but individually for each scientist. For example, one can think about a minimum time (min $\Delta t$) in a scientific career of a person, when papers responsible for 1/2 of the total C.I. were published (obviously, for scientists who did the main contribution in one paper or in a set of papers published during a short time $\min \Delta t$ is short, vise versa for those who continuously published papers of the same level $\min \Delta t$ is comparable with the duration of the career). If one adds to this $\min \Delta t$ another parameter - time interval separating the present moment $t_0$ from the end of the period responsible for $\min \Delta t$ - then we have a rough figure of scientific activity of a scientists in time. However, I think that a better parameter can be defined for clearness.

Here I discuss a simple way to estimate a characteristic applicable to individual scientists. Up to my knowledge such a parameter was not discussed before.

The idea is to define some characteristic time which can demonstrate how long ago a scientist published papers which give the main contribution to the C.I. I propose the parameter $t_h$ which is defined as follows. It is the time (from the present moment towards the past) during which papers that are responsible for 1/2 of the total C.I. were published. Let me examplify it.

Imagine three scientists (see Fig.1). All started careers simultaneously. At the present moment all three have the same C.I.=5000. One published in 1965 a paper with C.I.=5000, and nothing after that. For him $t_h = 40$ yrs. The second published a paper with C.I.=2500 in 1965 and another one with the same C.I. in 1975. For him we obtain $t_h = 30$ yrs. The third one also had published in 1965 a top-cited paper with C.I.=1000, and then every year published a papers all of which now have C.I.=100. For him $t_h = 25$ years as 1/2 of his C.I. is due to papers published after 1980.

All these values can be compared with another two limits (again we consider scientists with career started in 1965, and with present-day C.I. equal to 5000). The first limit is the following, consider a scientist with a constant rate of publications all papers of whom now have equal number of citations would have $t_h = 20$ yrs. Note, that such a researcher actually demonstrate a growth of scientific output as his/her later papers quicker gain citations. Another limit (see also below) is a scientist with a constant rate of publications all of which gain citations also with a constant rate. For him/her we obtain $t_h \approx 28.3$ yrs. Clearly, among these five scientists with equal C.I. those who demonstrated more activity recently has shorter $t_h$. 


Let us discuss the fifth case in more details (see Fig. 2.). Consider a scientist who publishes papers with a constant rate during his scientific career, and these papers receive a constant number of citations per year. In this case the number of citations of papers published in a given year is proportional to time. Let us denote the coefficient (i.e. the number of citations in a year per papers published in a given year) $A$ and the durations of a career as $T_{\text{car}}$. So, we have $N_{\text{cit}} = At$. The total number of citations is:

$$\text{C.I.} = \frac{AT_{\text{car}}^2}{2}$$

We want to obtain $t_h$:

$$\frac{1}{2} \text{C.I.} = \frac{At_h^2}{2} = \frac{AT_{\text{car}}^2}{4}$$

So, we obtain:

$$t_h = \frac{T_{\text{car}}}{\sqrt{2}}.$$

The value $T_{\text{car}}/\sqrt{2}$ is in some sense a critical one. One can expect for scientists active in recent time $t_h < T_{\text{car}}/\sqrt{2}$ independent on $T_{\text{car}}$.

The parameter $t_h$ alone is not a very useful thing as it says nothing about the total impact. But it can be useful to distinguish researchers who’s activity is not in the far past. Even for the same total C.I. $t_h$ is shorter for those who published papers with large impact later. Especially, $t_h$ can be useful when both young and more senior scientists are under consideration. It appears indeed capable to ideally complement the standard C.I. or Hirsch’s parameter $h$.

The main disadvantage of $t_h$ is the following: variations of this value are not very large. However, as we propose this quantity as a secondary coefficient (i.e. to compare researchers with similar C.I.) even small differences (a factor $\sim 1.5 - 2$) are important.

It is possible to modify $t_h$ to include information about the total C.I. And in the following section I show a possible way to do it.
3 Average activity over the characteristic time

After we determine $t_h$ we know a characteristic time scale of scientific activity of a researcher. Now what we can do is to average its C.I. (or better 1/2 of C.I. as $t_h$ is related to half of the total index, and letter $h$ comes from half) over $t_h$. We define

$$N_I = \text{C.I.}/2t_h.$$ 

For the five scientists in the example above $N_I = 62.5, 83.3, 100, 125,$ and $88.4$ correspondently. For the same total C.I. values of $N_I$ are different demonstrating the fact that the first one was inactive for a long time, and the periods of activity (and recognition of the results) of the third and the fourth ones are closer to the present moment than for the rest two researchers (the fifth scientist in the example shows the same rate of activity as the fourth, but rates of citation have different time behaviour). For the same C.I. $N_I$ can be different up to a factor of a few (or even by an order of magnitude) if persons have significantly different histories of scientific activity.

The main disadvantage of the approach is the possibility to have relatively high $N_I$ just by self-citation, i.e. by publishing a huge amount of papers referring to own previous publications.

4 Conclusions

I presented a simple estimate $t_h$ of a time scale which demonstrates dynamics of scientific activity of scientists. Also the parameter $N_I = \text{C.I.}/2t_h$ was proposed as a compromise between integral and dynamical characteristics of scientific impact. In my opinion $t_h$ can be a good additional parameter to the standard C.I. value.

Acknowledgments

I want to thank Prof. J. Hirsch for comments on the idea of the coefficient $t_h$, and participants of the projects Elementy.Ru, Scientific.Ru, and astronomy.ru for discussions. The work was supported by the “Dynasty” Foundation (Russia).

References

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[2] Hirsch J.E., 2005, physics/0508025