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Javier E., Contreras-Reyes

Instituto de Fomento Pesquero (IFOP), Universidad Técnica  
Federico Santa María

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# Credit allocation based on journal impact factor and coauthorship contribution

Javier E. Contreras-Reyes<sup>a,b,\*</sup>

<sup>a</sup>*Departamento de Economía y Estadística, División de Investigación Pesquera,  
Instituto de Fomento Pesquero (IFOP), Valparaíso, Chile*

<sup>b</sup>*Departamento de Matemáticas, Universidad Técnica Federico Santa María, Valparaíso, Chile*

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## Abstract

Some research institutions demand researchers to distribute the incomes they earn from publishing papers to their researchers and/or co-authors. In this study, we deal with the Impact Factor-based ranking journal as a criteria for the correct distribution of these incomes. We also include the Authorship Credit factor for distribution of the incomes among authors, using the geometric progression of Cantor's theory and the Harmonic Credit Index. Depending on the ranking of the journal, the proposed model develops a proper publication credit allocation among all authors. Moreover, our tool can be deployed in the evaluation of an institution for a funding program, as well as calculating the amounts necessary to incentivize research among personnel.

*Key words:* co-author credit; impact factor; ranking; Cantor's succession; harmonic credit

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## 1. Introduction

Research institutions like universities or governmental/military institutes require staff to re-distribute the remunerations they receive from publishing in journals among their researchers/employers (Groschen 1991). Thus, one wage type earned for published papers serves as payment to co-authors. This problem is difficult to solve, given the prevalent conflicts of interest in many institutions, where distribution of payments is often unjust due to bad practice or ignorance. Therefore, a quantitative method to deal with distribution issues in relation to co-authorship is necessary.

The impact factor (IF) is a citation-based measure for performance related to prestige and proliferation of journals in which research institutions publish their papers (Mattsson et al. 2011). A journal's IF gives the mean number of citations received by papers that have been published in these journals, and is one of the most popular indexes regarding quantitative methods to evaluate research (Bouyssou and Marchant

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\*Corresponding author, Phone +56 7 9608218. Address: Departamento de Economía y Estadística, División de Investigación Pesquera, Instituto de Fomento Pesquero, Blanco 839, Valparaíso, Chile.

*Email addresses:* `jecontrr@uc.cl`, `javier.contreras@ifop.cl` (Javier E. Contreras-Reyes)

2011). Moreover, the number of citations determines the impact of journals on journal rankings (Tsai 2014). Generally, journals with a high IF contain a lower percentage of uncited articles (Hsu and Huang 2012).

In this paper, we present a model for the distribution of money benefits to an individual or a group of co-authors who published an International Scientific Indexing (ISI) paper. The model is based on two elements:

- (i) the ranking of the journal based on Impact Factor (IF) as a criterion for weighing the distribution of these incomes; and
- (ii) the authorship credit factor for a distribution of the incomes among the authors (Lukovits and Vinkler 1995), useful for multi-authored scientific publications.

Below our authorship factor considers the geometric progression of Cantor's theory (Cantor 1883), which we then compare with the harmonic credit approach of Hagen (2008). Finally, we illustrate our results using three publications with varying numbers of co-authors, and journals with distinct IF and scholarly fields.

## 2. Credit distribution model

Let  $t$  be the total publication credit allocated for one article ( $t > 0$ ), and let  $r$  be the quotient of the journal's rank with respect to the total number of journals ( $0 < r < 1$ ). The journal's rank is based on IF and is associated to the journal's area, as by the Web of Science. Let  $p$  be a proportion arbitrarily assigned to an institution to define the income base from the total  $t$ . Thus, the total publication credit allocated for all authors is obtained by

$$(1) \quad Q_t(p, r) = pt + (1 - p)(1 - r)t, \quad 0 \leq p \leq 1,$$

Function (1) depends only on the variables  $p$  and  $r$ ;  $t$  is known. Evaluating point  $(1, 0)$  in the second derivative we obtain

$$\frac{\partial^2}{\partial p \partial r} Q_t(p, r) = t > 0,$$

i.e.,  $Q_t(p, r)$  reaches a relative maximum at  $(1, 0)$  and is given by the total available amount. Therefore,  $Q_t(p, r) \leq t$  for all  $0 \leq p \leq 1$  and for any  $t > 0$ . We can interpret the model (1) with respect to  $p$  as:

- (i) if  $p = 1$ , the credit  $Q_t(1, r)$  corresponds to the available funding. Even if relative maximum  $t$  is reached with this value, it does not incentivize the publication with respect to the journal quality;
- (ii) if  $0 < p < 1$ , the credit  $Q_t(p, r)$  is the sum of a bonus base,  $pt$ , with an extra bonus,  $(1 - p)(1 - r)t$ , given by the IF of the journal. This is favourable if an institution wishes to incentivize a publication with respect to journal quality;

(iii) if  $p = 0$ , the credit  $Q_t(0, r)$  depends not only on the available funding, but also relates to journal ranking. This is a non-favourable case if an institution wishes to use all available funding to incentivize publication (Figure 1 illustrates the aforementioned cases).

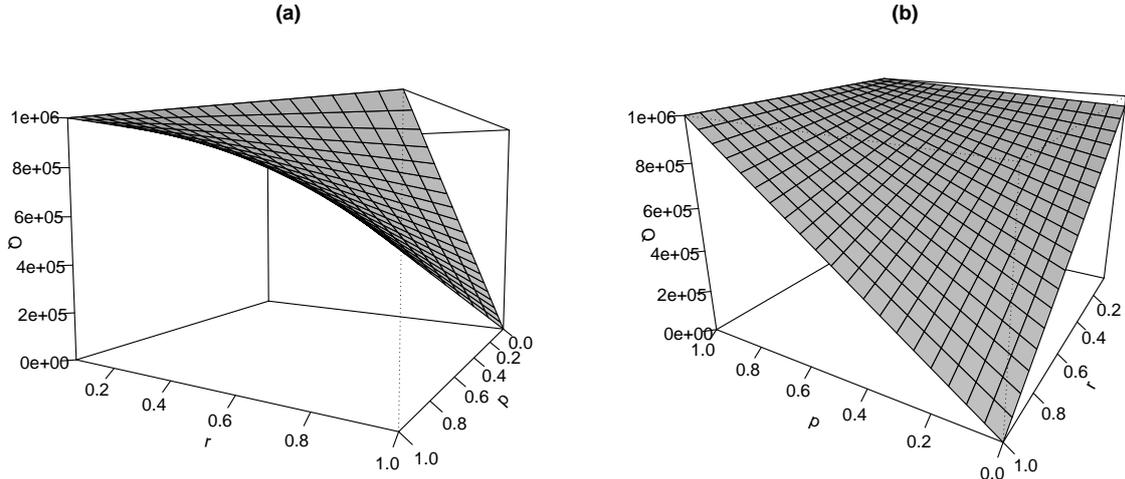


Figure 1: Total publication credit  $Q \equiv Q_t(p, r)$  allocated for all authors, with  $t = 10^6$ ,  $0 \leq p \leq 1$ , and  $0 < r \leq 1$ .

When  $r \approx 0$  and  $p = 1$ , the total amount is maximized, and is minimized when  $r = 1$  and  $p \approx 0$ . For these values, the amount quickly decreases and the value  $p = 0.5$  could be acceptable to differentiate the credit base from the credit related to journal ranking. Values of  $r$  near (and including it) 1 correspond to journals with the lowest impact, and  $Q_t(0, r) = 0$ ,  $Q_t(p, r) = pt$  and  $Q_t(1, r) = t$ . This means that the ranking influences negatively the total publication credit. In a contrary case, values of  $t$  near zero relate to the more prestigious journals. Given the values  $p$ ,  $r$  and  $t$ , model (1) gives the total credit to be allocated for the co-authors. As such, the institutions generally divided the credit equally among all co-authors (Hagen 2008).

In the next section, we consider three authorship credit indexes to distribute the credit  $Q_t(p, r)$  in fractional form to privilege the main authors of a paper.

### 3. Authorship credit indexes

The total credit determined by model (1) is related to the publication; but how could it be assigned to the publication's authors? Authorship credit for multi-authored scientific publications is routinely allocated either by issuing full publication credit repeatedly to all co-authors (Hagen 2008), or by dividing one credit

equally among all of them (Karpov 2014). We consider this latter option. That is, the credit allocated for a specific author is

$$(2) \quad A_t^i(p, r) = P_i Q_t(p, r),$$

where  $P_i$ ,  $0 < P_i < 1$ , corresponds to a succession of proportions or weight of the total credit. From (2) it becomes clear that infinite  $P_i$  functions exist to share the incomes between  $N$  authors. In addition, the condition called *sums of all shares  $P_i$  is equal to 1* is accomplished (Hagen 2008). Among all of these functions proposed in the literature (Egghe et al. 2000; Hagen 2013), we highlight the Harmonic Credit Index in the next subsection.

### 3.1. Harmonic credit index

Hagen (2008) proposed the Harmonic Credit Index (HCI)  $H_i$  for the  $i$ th-author as follows:

$$(3) \quad H_i = \frac{1}{i} \left( \sum_{j=1}^N \frac{1}{j} \right)^{-1}, \quad i = 1, \dots, N,$$

where  $N$  is the number of authors. The d'Alembert's ratio test for succession (3) shows that

$$\lim_{i \rightarrow \infty} |H_{i+1}/H_i| = 1,$$

meaning the test is inconclusive. However, the property (i) of Section 3.1,  $H_1 + \dots + H_N = 1$ , ensures the convergence of this succession (Hagen 2008). HCI ensures that:

- (i) the total publication credit is shared among all coauthors;
- (ii) the main author gets most credit, and the  $(i + 1)$ th author receives more credit than the  $i$ th author;
- (iii) the higher the number of authors, the less credit per author.

In Hagen (2013), HCI is compared with various co-author credit models such as fractional, Liu-Fang, Lukovits-Vinkler, and Trueba-Guerrero. For an empirical dataset including medicine, bibliometric literature, psychology, and chemistry (see more details in Hagen 2010), HCI performs better than its competitors explaining nearly 97% of the variation versus, for example, 40% of fractional credit index.

The amount assigned to co-authors of (2) can be evaluated using (3), yielding

$$(4) \quad A_t^i(p, r) = H_i Q_t(p, r).$$

Following from these properties of HCI, the total sum of  $A_p^i(t, r)$  is equal to the credit  $Q_t(p, r)$  assigned to all co-authors. Thus, formula (4) gives the complete HCI.

### 3.2. Cantor's succession index

A geometric progression can be considered as a co-author credit index. The formula

$$(5) \quad C_i = \frac{2^{i-1}}{3^i}, \quad i = 1, \dots, N,$$

with  $N$  the number of authors, corresponds to the proportion of the unit interval remaining, or Cantor's set (Cantor 1883).

The d'Alembert's ratio test shows that

$$\lim_{i \rightarrow \infty} |C_{i+1}/C_i| = 2/3 < 1,$$

i.e., the series converges absolutely.

Compared with  $H_i$ ,  $C_i$  do not depend on the total number of authors. However, the total sum of the  $C_i$ 's is less than 1; it is 1 only for a large number  $N$  of authors. These series correspond to the total length removed from Cantor's sets. Figure 2 compares both successions (3) and (5) between  $N = 20$  authors. It shows that the first five  $H_i$  proportions differ from each author in a decreasing order. The first five  $C_i$ , however, are about similar to each author, but in decreasing order. Only for  $i = 6$  both successions are about equal and for  $i > 6$ ,  $H_i$  tends to be larger than  $C_i$  but with similar distribution among these authors. This illustrates that Cantor's succession is also a fractional counting, where one credit is divided non-uniformly among all co-authors (Hagen 2008, 2010). Therefore, this succession also corrects for the inflationary bias produced by multi-authored publications.

As in Section 3.1, co-author amount assignment of (2) can be evaluated using (5) to obtain

$$(6) \quad A_t^i(p, r) = C_i Q_t(p, r).$$

Hereafter, we will refer to formula (6) as the Cantor's Succession Index (CSI). We see that the total sum of  $A_p^i(t, r)$  is less than the total credit  $Q_p(t, r)$ . If a large number of co-authors worked on the publication, the total sum of  $A_p^i(t, r)$  tends to be the total credit  $Q_p(t, r)$ . However, for a small number of authors, CSI produces an error in the distribution and a considerable bias, leading to ill-distributed credit. For this reason, and to obtain an index with which this important property is accomplished, it is necessary to implement a correction factor for CSI, as presented in the next subsection.

### 3.3. Adjusted Cantor's succession index

For a finite number of authors  $N$ , we have the publication credit

$$(7) \quad \varepsilon = Q_t(p, r) - \sum_{i=1}^N A_t^i(p, r) = Q_t(p, r) \left( 1 - \sum_{i=1}^N C_i \right)$$

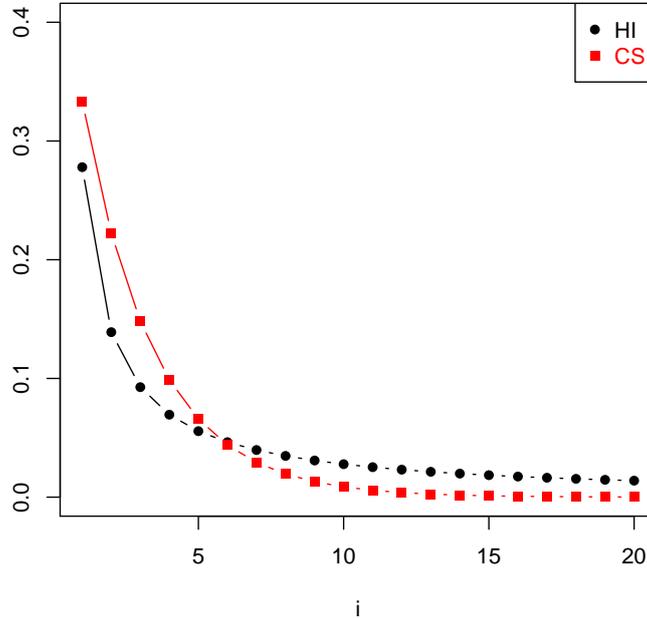


Figure 2: Harmonic credit (HI) and Cantor's succession (CS) for  $N = 20$  authors.

that is always positive and is zero when  $N \rightarrow \infty$ . Using (7), we define a corrected version for  $A_p^i(t, r)$  as

$$(8) \quad \bar{A}_t^i(p, r) = A_t^i(p, r) + \frac{\varepsilon}{N}.$$

Hereafter, we will refer to formula (8) as the Adjusted Cantor's Succession Index (ACSI).

From (8), it is clear that  $\bar{A}_t^i(p, r) = A_t^i(p, r)$  when  $N \rightarrow \infty$ . Considering (7) and (8), we can corroborate that  $\sum_{i=1}^N \bar{A}_t^i(p, r) = Q_t(p, r)$ . Based on ACSI, we obtain a new publication credit allocated for an specific  $i$ th author in (2) given by

$$(9) \quad \bar{A}_t^i(p, r) = C_i Q_t(p, r) + \frac{\varepsilon}{N}.$$

ACSI also preserves the property of fractional counting, where one credit is divided non-uniformly and equally among the main co-authors and the rest, respectively.

#### 4. Examples

We illustrate the performance of each co-author credit from ISI publications, considering formulas (4) and (9) and a bonus base proportion of  $p = 0.5$ , in the following examples:

1. The *Earth and Planetary Science Letters* ISI journal has an impact factor of 4.724 (according to the Web of Science 2013), and ranked 5th out of 80 journals in the field of *Geochemistry & Geophysics*. Considering research by Lange et al. (2012), for the values  $t = 2 \times 10^6$ ,  $r = 0.063$  and  $N = 11$ , the publication credit allocation between the  $N$  authors is  $Q_t(0.5, 0.063) = 1,937,000$  for HCI and ACSI and  $Q_t(0.5, 0.063) = 1,914,606$  for CSI (see Table 1). The total proportion of  $C_i$  is near 1 given the large list of coauthors. This produces CSI near ACSI. However, for the properties mentioned in Section 3.1, HCI distributed the credit to the three main authors in a non-uniform way, whereas ACSI provides more equal credits among them.

Table 1: Credit coauthorship distribution considering the paper Lange et al. (2012).

Author ( $i$ )	$C_i$	CSI	ACSI	$H_i$	HCI
1	0.333	645,666.67	647,702.46	0.331	641,416.78
2	0.222	430,444.44	432,480.23	0.166	320,708.39
3	0.148	286,962.96	288,998.75	0.110	213,805.59
4	0.099	191,308.64	193,344.43	0.083	160,354.19
5	0.066	127,539.10	129,574.89	0.066	128,283.36
6	0.044	85,026.06	87,061.85	0.055	106,902.80
7	0.029	56,684.04	58,719.83	0.047	91,630.97
8	0.020	37,789.36	39,825.15	0.041	80,177.10
9	0.013	25,192.91	27,228.70	0.037	71,268.53
10	0.009	16,795.27	18,831.06	0.033	64,141.68
11	0.006	11,196.85	13,232.64	0.030	58,310.62
Total	0.989	1,914,606.00	1,937,000.00	1	1,937,000.00

2. The *Fisheries Research* ISI journal has an impact factor of 1.843 (according to the Web of Science 2013), and ranked 12 out of 50 journals in the *Fisheries* field. Considering research by Contreras-Reyes et al. (2014), for the values  $t = 1.2 \times 10^6$ ,  $r = 0.24$  and  $N = 3$ , the publication credit allocation between the  $N$  authors is  $Q_t(0.5, 0.24) = 1,056,000$  for HCI and ACSI and  $Q_t(0.5, 0.24) = 743,111.1$  for CSI (see Table 2). In contrast to the first example,  $C_i$  is far from 1, given the short list of coauthors, thus CSI is far from ACSI. In this case, HCI should be more adequate to distribute the total amount between the three authors. However, ACSI preserves the proportion among the authors.

Table 2: Credit coauthorship distribution considering the paper Contreras-Reyes et al. (2014).

Author ( $i$ )	$C_i$	CSI	ACSI	$H_i$	HCI
1	0.333	352,000.0	456,296.3	0.545	576,000
2	0.222	234,666.7	338,963.0	0.273	288,000
3	0.148	156,444.4	260,740.7	0.182	192,000
Total	0.704	743,111.1	1,056,000.0	1	1,056,000

3. Consider now Ausloos (2015). The *Physica A* ISI journal has an impact factor of 1.722 (according to

the Web of Science 2013), and is ranked 25 out of 78 journals in the *Physics Multidisciplinary* field. For the values  $t = 1.2 \times 10^6$ ,  $r = 0.321$  and  $N = 1$ , the publication credit allocation for the author is  $Q_t(0.5, 0.321) = 792,308$  for HCI, CSI and ACSI. Given that we have only one author, obviously CSI does not provide a precise criterion. Using the adjusted version, we obtain the same result for HCI.

## 5. Conclusions

The proposed bonus distribution model gives a publication credit allocation associated to the performance of a journal, given by its IF-based ranking. This approach allows to restrict the credit allocated to each author, and so ranking criteria encourage research activity in an institution and to publish in higher-ranked journals. This tool is also helpful when an institution needs to be evaluated for a funding program as well as to determine where to direct amounts to incentivize research (Egghe et al. 2000).

The proposed model is not restricted to a specific succession index. The most simple index is one that divides the total available amount equally among all co-authors (Hagen 2008). Cantor's index considers authorship rank instead, and the HCI considers these ranks and the number of co-authors. HCI provides different credits among the main authors, where this number depends on the total number of authors. However, the HCI should be employed for three main reasons:

- (i) HCI proportions differ from each author in a decreasing order, allocating the higher amounts of credit to the prime authors, who make larger individual contributions to a paper (Mattsson et al. 2011);
- (ii) Adjusted Cantor's Index is still a fractional counting, and only divides non-uniformly the first fraction of the credit among all co-authors; and
- (iii) HCI's formula is much more tractable and simpler than ACSI.

Since the selection of proportion  $p$  of the proposed model is largely influenced by institution's policies, the model allows for sufficient flexibility to decide how to develop research among co-authors. Actually, several institutions such as universities choose option (i) of Section 2, assuming that an ISI paper deserves recognition only if it has the aforementioned indexation. This looks erroneous, however, because the journal ranking provides a qualification to measure its reputation with respect to an associated field (Bouyssou and Marchant 2011).

Given that  $H$ -index is probably not the best indicator/predictor of the journal quality (Hirsch 2007), the model can be easily adapted to a more effective index to determine the ranking  $r$ . Additionally, further research using a stochastic  $H$ -index (Nair and Turlach 2012) is needed, where the underlying proposed model is dependent on time.

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