The Ranking of Researchers by Publications and Citations

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Abstract

Researcher-level metrics assess a researcher's publications and number of citations for each publication. This paper tests empirically 28 two-variable metrics, 26 of which are new in this paper, determined as geometric means from eight one-variable metrics. The 54 highest ranked researchers in RePEc are considered, 13 of whom are Nobel prize winners. One new one-variable metric, the number of citations for the 10^{th} most cited publication, is introduced. Characteristics of the eight one-variable metrics are considered, illustrating why two-variable metrics are needed. The 54 researchers are ranked for all 36 metrics. The lowest sum of ranks for the 13 Nobel prize winners occurs for metric c_1, the number of citations for the highest cited publication. The 13 Nobel prize winners have on average 5.3 higher rank on w than on h, suggesting a need for being widely cited, not captured by the h -index. The metric $\sqrt{nc}$, the square root of the product of the number of publications and the citation count, proposed as an interesting metric, correlates best with the RePEc scores. Correlations between the 36 metrics are determined. The 28 two-variable metrics are tentatively ranked according to how they capture characteristics apparently not captured by the one-variable metrics.

1 Introduction

A plethora of researcher-level metrics have been introduced in recent years. The best metric or combination of metrics have been sought, realizing that a researcher's entire dataset of citations for each publication is overwhelming and not easily rankable. Two dimensions are essential, i.e. publication rank (counting the number of publications) and number of citations for each publication.

This paper has four objectives. First, we identify one-variable metrics along these two dimensions. Second, we propose two-variable metrics by determining all possible geometric means of the one-variable metrics. Third, we determine the correlation between all single- and two-variable metrics, and the RePEc scores for the 54 highest ranked researchers, applying the harmonic mean of ranks across 29 criteria.[1] Thirteen of the 54 are Nobel prize winners, i.e. earned the Nobel Memorial Prize in Economic Sciences. Fourth, we compare and attempt to rank the metrics.

Seven known one-variable metrics are the number n of publications, the number c of citations, w (Wu, 2010), h (Hirsch, 2005), i_{10} (Google Scholar, 2011) g (Egghe, 2006), and c_1 which is the number of citations for the highest cited publication. Observing the popularity of i_{10} along the publication rank dimension, we identify the counterpart c_{10} along the number of citations dimension, defined as the number of citations for the researcher's publication with the 10th highest number of citations. We propose c_{10} as a new one-variable metric.

The binomial coefficient $\binom{8}{2} = 28$ identifies all possible two-variable combinations, expressed as geometric means, of the eight one-variable metrics, proposed as metrics in this paper. Two of these 28 metrics have been determined earlier (Alonso, Cabrerizo, Herrera-Viedma, & Herrera, 2010; Dorogovtsev & Mendes, 2015), and 26 are new. We consider the

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[1] https://ideas.repec.org/top/top.person.all.html , retrieved October 31, 2016. Seiler and Wohlrabe (2012) apply principal component analysis to RePEc data, assign "weights to each indicator prior to aggregation," and "provide some cautionary remarks concerning the interpretation of some provided bibliometric measures in RePEc."

geometric means[2] since these two have been analyzed earlier and are mathematically simple. Future research may consider e.g. the harmonic or arithmetic means.

Section 2 presents various researcher-level metrics. Section 3 determines the correlation between the metrics and the RePEc scores. Section 4 assesses the metrics for the 13 Nobel prize winners. Section 5 considers characteristics of seven interesting researchers. Section 6 examines the eight one-variable metrics. Section 7 examines the 28 two-variable metrics. Section 8 presents some limitations of citations. Section 10 suggests future research. Section 10 discusses and concludes.

2 Various researcher-level metrics

Asymmetries exist between publications and citations. Citations presuppose publications, but not vice versa. Publications can generate future citations, but citations cannot generate future publications. Citations may bolster existing publications so that they earn more citations. Citations may draw researchers' attention to publications that are cited, which may induce these researchers to also cite the same publications. For publications with few citations, new and old publications differ. New publications with few citations are usually more likely to earn future citations.

Figure 1 plots an accurate depiction of a researcher, which is the citation numbers as functions of the publication rank, where the most cited publications are ranked towards the left, and successively less cited publications are ranked towards the right. Although plotting is done as a smooth function without loss of generality, the citation numbers are discrete.

[2] The geometric mean discourages poor rankings and encourages good rankings. For example, the geometric, harmonic and arithmetic means of 10 and 30 are $\sqrt{10 \cdot 30} \approx 17.3$, 15 and 20, respectively.

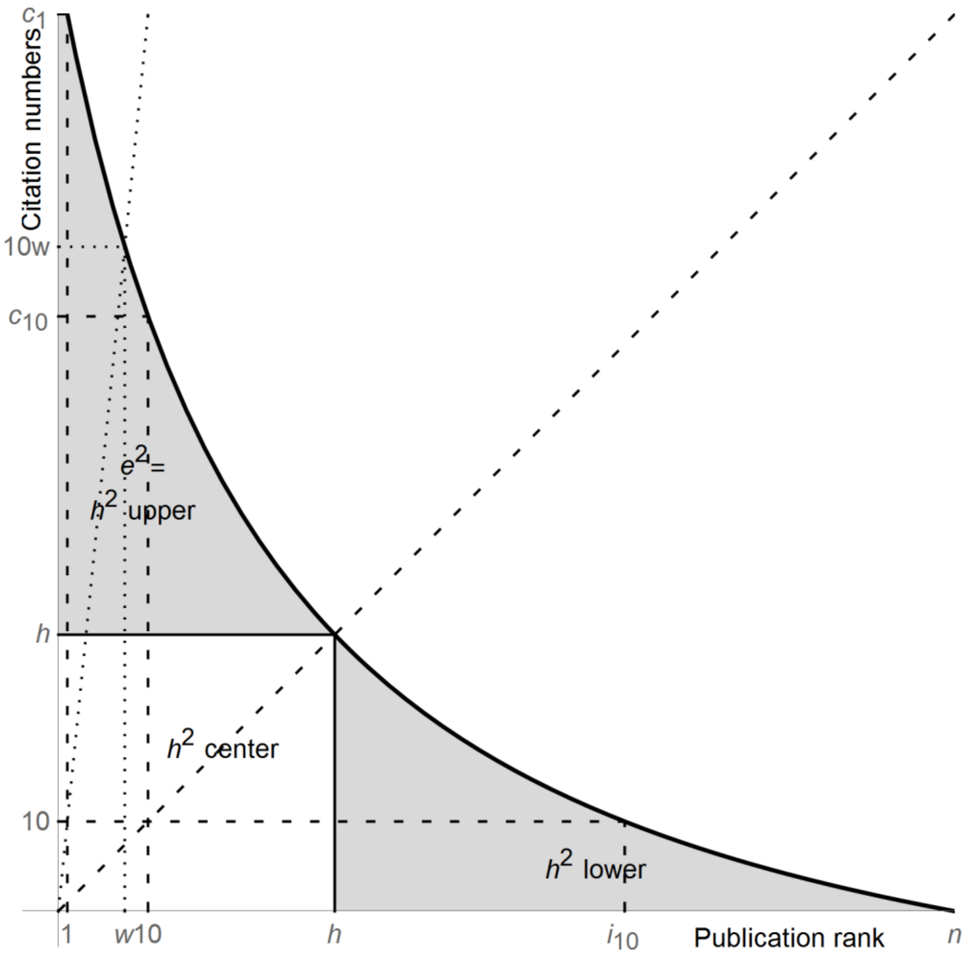

Figure 1: Citation numbers as functions of publication rank, plotted without loss of generality as a smooth function.

The area under the curve in Figure 1 is expressed discretely as

$$c = \sum_{j=1}^{n} c_j \tag{1}$$

where c_j is the number of citations for publication $j, j = 1, \ldots, n$, ranked so that c_1 is the highest cited publication, $c_{j+1} \leq c_j, j = 1, \ldots, n-1$, and c_n is the least cited publication.

Since Figure 1 contains n ranked data points, where n is often large, especially for productive researchers, the literature presents a plethora of suggestions to compress the insight in Figure 1 to one or a few numbers. This paper assesses most of these, proposes additional compressed numbers, and determines the correlations between these numbers and the RePEc scores for the 54 highest ranked researchers in RePEc.

Theoretically a researcher can have a large number n of publications, but no citations, i.e. $c = 0$. The curve in Figure 1 then coincides with the horizontal axis. The hypothetical opposite, since publications are needed for citations, is a researcher with one publication $n = 1$ having earned a large number of citations, i.e. $c = c_1$. The curve in Figure 1 then simplifies to one point at position $(1, c_1)$. Most researchers are between these two extremes.

Figure 1 presents six numbers along the horizontal axis, i.e. publication rank 1, w which is the highest number of publications having each received at least $10w$ citations, publication rank 10, h which is the largest number such that h publications have at least h citations, i_{10} which is the number of publications with at least 10 citations, and n which is the least cited publication.[3]

Figure 1 presents five numbers along the vertical axis, i.e. the number 10 of citations marked with a horizontal dashed line hitting the downward sloping curve at i_{10} measured horizontally, h marked with a horizontal line hitting the downward sloping curve at h to form a square, and c_{10} which is the number of citations for the researcher's publication with the 10th highest number of citations, marked with a horizontal dashed line hitting the downward sloping curve at 10 horizontally. We define c_{10}=0 when n≤9. Fifth comes c_1 marked with a horizontal line hitting the downward sloping curve at 1 horizontally.

Figure 1 also contains three areas identified by Bornmann, Mutz, and Daniel (2010). The first is h^2 center, which is the square captured by the h-index. The second marked in light grey is h^2 upper, which captures the researcher's most cited publications. The area is referred to by e^2 by Zhang (2009). The third area, also marked in light grey, is h^2 lower, which captures the researcher's least cited publications.

If the metrics i_{10} and n are substantially larger than h, that's indicative of a large area h^2 lower. Similarly, if the metrics c_{10} and c_1 are substantially larger than h, that's indicative of a large area h^2 and thus large e^2.

Generally $i_{10} \leq n$ and $c_{10} \leq c_1$. For highly cited researchers, and especially recognized researchers ceasing production, i_{10} may be large and close to n. In contrast, researchers with

[3] Figure 1 plots $1 < w < 10 < h < i_{10}$ and $h < c_{10} < 10w$, but most other rankings are possible.

few citations, and especially productive researchers early in their careers, may have i_{10} substantially below n. That c_{10} is close to c_1 may occur both for highly and lowly cited researchers. It means that the researcher's 10 most cited publications are similarly recognized through citations. In contrast, c_{10} substantially below c_1 means that the researcher has at least one highly cited publication ("a lucky winner"), while the downward sloping curve in Figure 1 thereafter falls off rapidly.

Table 1 presents the 54 highest ranked researchers in RePEc in column 1 (from the left), their initials (Init) in column 2, their rank R from 1 to 54 in column 3, their RePEc score S in column 4, and the 36 metrics in the subsequent columns. We refer to a researcher with rank i as researcher Ri, i=1,…,54. The 13 Nobel prize winners are shown in bold. The bottom row shows the correlation between the metric in the given column and the RePEc score in column 4 for all researchers.

Columns 5-11 show the seven metrics also presented in Figure 1, i.e. n, i_{10}, h, w, c_{10}, c_1, c. Column 12 presents the g-index which is the largest number of publications for which the average number of citations is at least g. Highly cited publications thus boost lowly cited publications in meeting the threshold. The g-index, not plotted in Figure 1 since the average number of citations is required along the vertical axis, thus accounts for some of the features of e^2 and h^2 upper, which the h-index does not capture.

All 28 metrics expressed as geometric means from column 13 and towards the right in Table 1 are new, to the author's knowledge, except two. First, Alonso et al. (2010) propose $\sqrt{hg}$ which they argue is superior to h and g considered separately. For example, $\sqrt{hg}$ is closer to h than to g, which prevents the high impact of a highly cited publication which occurs in the g-index. Second, Dorogovtsev and Mendes (2015) "find that the h-index actually favours modestly performing researchers and propose" $\sqrt{hc_1}$, where c_1 "accounts for the great result, and h accounts for persistence and diligence." Testing 208 scientists within physics and complex systems, they show "how many successful researchers, deeply hidden in the h-based ranking, become well visible if we apply the $\sqrt{hc_1}$-index." This controversial statement assumes that success flows from c_1 and h, where the most cited publication is essential and constitutes performance. An alternative to $\sqrt{hc_1}$ is $\sqrt{hc}$ which measures not only the "great result", but citations c overall. It can equally well be argued that success and performance flow from any other mean in Table 1. The most plausible mirrors of $\sqrt{hc_1}$ and $\sqrt{hc}$, which emphasize citations, are $\sqrt{ni_{10}}$, $\sqrt{nh}$, and $\sqrt{i_{10}h}$ which for productive researchers with $i_{10} > h$ in decreasing order emphasize publications.

In Figure 1 geometric means determined by multiplying numbers high on the horizontal axis, ranked as n, i_{10}, h, w, express the importance of publications. In contrast, means determined by multiplying numbers high on the vertical axis, ranked as c (summing all vertical columns under the curve), c_1, c_{10}, h for highly cited researchers, express the importance of citations.

3 Determining the correlation between the metrics and the RePEc scores

No gold standard exists for determining the best metric. For the RePEc[4] score we use the harmonic mean of ranks, which "rewards those who are particularly good in some category" (Zimmermann, 2012, p. 19), for 31 criteria, excluding the best and the worst. We define n as the number of distinct works, which is a RePEc criterion counting different works only once. We ignore citations to edited books.

The metric best reflecting the RePEc scores in terms of correlation, identified as the correlation closest to -1, is $\sqrt{nc}$, with a correlation of -0.55. That is, multiplying the number n of publications with the number c of citations and taking the square root gives the best match. A complete match cannot be expected since some of the 31 RePEc criteria, e.g. RePEc downloads, are not reflected in the 36 metrics. The ranking of the match from best to worse between the 36 metrics and the RePEc scores in terms of correlation is $\sqrt{nc}$,$\sqrt{nc_{10}}$,$\sqrt{i_{10}c}$,c,$\sqrt{i_{10}c_{10}}$,$\sqrt{hc}$,$\sqrt{cg}$,$\sqrt{c_{10}c}$,$\sqrt{wc}$,$\sqrt{ng}$,$\sqrt{i_{10}g}$,$\sqrt{hc_{10}}$,$\sqrt{i_{10}w}$,$\sqrt{nw}$,$\sqrt{nc_1}$, $\sqrt{i_{10}c_1}$,$\sqrt{c_1c}$,$\sqrt{c_{10}g}$,c_{10},$\sqrt{hg}$,g,$\sqrt{wc_{10}}$,$\sqrt{wg}$,$\sqrt{hw}$,$\sqrt{i_{10}h}$,$\sqrt{c_{10}c_1}$,$\sqrt{nh}$,h,$\sqrt{hc_1}$,w,i_{10},$\sqrt{wc_1}$, $\sqrt{c_1g}$,$\sqrt{ni_{10}}$,c_1,n. That n gives the worst match (correlation -0.22) with the RePEc scores in terms of correlation is perhaps understandable since RePEc's objective is not to capture prolificness. That c_1 gives the second worst match (correlation -0.27) with the RePEc scores in terms of correlation is remarkable since the sum of ranks according to c_1 is lowest for the 13 Nobel prize winners, as shown in the next section.

4 Assessing the metrics for the 13 Nobel prize winners

[4] https://ideas.repec.org/top/top.person.all.html , retrieved October 31, 2016.

Table 2 ranks the 54 researchers according to each of the 36 metrics. The bottom row shows the sum of the ranks of the 13 Nobel prize winners (in bold). The three rightmost columns show the harmonic mean HM of ranks, the arithmetic mean AM of ranks, and the geometric mean GM of ranks, respectively. The lowest sum of ranks for the 13 Nobel prize winners, 219, occurs for metric c_1, i.e. the number of citations for the most cited publication. The seven lowest sums of ranks involve c_1. The 13th lowest occurs for $\sqrt{nc_1}$, and the highest sum, 93% above 219 at 422, occurs for n, to underscore that prolificness n is uncommon for Nobel prize winners. The 11 highest sums involve n or i_{10}. A hypothetical explanation for this result may be that Nobel prize winners are rewarded for outstanding results, which may potentially be reported in one outstanding publication. Potentially, high c_1 may be an indicator of future Nobel prizes. Future research may determine the percentage of citations for the highest cited publication earned before the Nobel prize was awarded. One example, illustrating that mass production is not necessarily the trait characterizing Nobel prize winners, is the 1991 Nobel prize winner Ronald Coase (1910–2013), researcher R1953, S =1860.16, $n = 49$, $i_{10} = 19$, $h = 15$, $w = 4$, $c_{10} = 22$, $c_1 = 325$, $c = 1021$, $g = 31$, providing a seminal publication in 1937 (Coase, 1937). However, this does not prevent some Nobel prize winners from engaging in mass production (before or after earning the Nobel prize). Thus researcher R3 (Joseph E. Stiglitz, Nobel prize 2001 shared with George A. Akerlof and A. Michael Spence) is ranked first on i_{10} and fourth on n, and researcher R7 (Jean Tirole, Nobel prize 2014) is ranked fourth on i_{10}. The ranking of the sum of ranks for the 13 Nobel prize winners, from lowest to highest, for the 36 metrics is c_1,$\sqrt{wc_1}$,$\sqrt{c_1g}$,$\sqrt{c_1c}$,$\sqrt{hc_1}$,$\sqrt{c_{10}c_1}$,$\sqrt{i_{10}c_1}$,g,$c \mathrel{\widehat{=}} \sqrt{cg}$,$\sqrt{wc}$,$\sqrt{c_{10}c}$,$\sqrt{nc_1}$, $\sqrt{c_{10}g}$,$w \mathrel{\widehat{=}} \sqrt{wg}$,$c_{10}$,$\sqrt{wc_{10}}$,$\sqrt{hc}$,$\sqrt{hc_{10}}$,$\sqrt{hg}$,$\sqrt{i_{10}c_{10}}$,$\sqrt{i_{10}c} \mathrel{\widehat{=}} \sqrt{hw}$,$h \mathrel{\widehat{=}} \sqrt{nc_{10}}$,$\sqrt{i_{10}g}$, $\sqrt{i_{10}w} \mathrel{\widehat{=}} \sqrt{nc}$,$\sqrt{i_{10}h} \mathrel{\widehat{=}} \sqrt{ng}$,$i_{10}$,$\sqrt{nw}$,$\sqrt{nh}$,$\sqrt{ni_{10}}$,$n$. The sign $\widehat{=}$ instead of comma four places means equal rank.

5 Characteristics of seven researchers R1,R2,R3,R13,R17,R18,R42

Let us consider some interesting characteristics of Table 2 for seven researchers. First, the highest ranked researcher R1 (Andrei Shleifer) is highest ranked for 23 of the 36 metrics, i.e. all metrics except n,i_{10},c_1,$\sqrt{ni_{10}}$,$\sqrt{nh}$,$\sqrt{nw}$,$\sqrt{nc_1}$,$\sqrt{nc}$,$\sqrt{ng}$,$\sqrt{i_{10}h}$,$\sqrt{i_{10}c_1}$, $\sqrt{hc_1}$,$\sqrt{c_1g}$. The lowest rank 23 occurs for the number n of publications, which also impacts some of the other metrics. Researcher R1 is thus not the most prolific (in terms of number of publications), but compensates in most other metrics. Researcher R1 also does not have the highest citation count

c_1 for the most cited publication (rank 8), which is a prominent trait of Nobel prize winners, but is ranked highest on the number c of citations and on c_{10}.

Second, the second highest ranked researcher R2 (James J. Heckman) is highest ranked on five metrics, i.e. $\sqrt{nc_1}$,$\sqrt{i_{10}h}$,$\sqrt{i_{10}c_1}$,$\sqrt{hc_1}$,$\sqrt{c_1 g}$. Four of these metrics involve c_1 multiplicatively (R2 is ranked third on c_1 individually), and the fifth involves i_{10} and h (R2 is ranked second on i_{10} and h individually). Researcher R2 is more prolific (rank 8 on n) than researcher R1, has more citations c_1 for the highest cited publication, but has lower c_{10} (rank 8) and lower c (rank 2). On 17 of the metrics where researcher R1 is ranked first, researcher R2 is ranked second.

Third, the third highest ranked researcher R3 (Joseph E. Stiglitz) is highest ranked on six metrics, i.e. i_{10},$\sqrt{ni_{10}}$,$\sqrt{nh}$,$\sqrt{nw}$,$\sqrt{nc}$,$\sqrt{ng}$. All these involve i_{10} or n. Researcher R3's strength relative to researchers R1 and R2 is to be prolific, expressed with rank 4 on n, where researchers R1 and R2 are ranked as 23 and 8. Being prolific may lay the groundwork for citations. Researcher R3 thus has earned a high i_{10} and high c (rank 5), but c_1 is modest (rank 12), w is more modest (rank 26), and c_{10} is even more modest (rank 31).

The three highest ranked researchers R1,R2,R3 are thus ranked first on 23+5+6=34 of the 36 metrics. For six of the 36 metrics R1,R2,R3 occupy ranks 1,2 or 3. The ranking of R1,R2,R3 does not change if the geometric mean is used instead of the harmonic mean. But for the arithmetic the ranking is R2,R1,R3. Let us consider the two researchers ranked highest for the two remaining metrics.

Fourth, the 13th highest ranked researcher R13 (Peter Nijkamp) is ranked highest on the number n of publications. Researcher R13 is unusually prolific, which impacts all metrics where n is involved. Researcher R13 is ranked at 42 for i_{10}, at 51 for h, w, c_{10}, c, and at 52 for c_1 and g.

Fifth, the 17th highest ranked researcher R17 (Richard Blundell) is ranked highest on the number c_1 of citations for the highest cited publication. Although R17 has not earned the Nobel prize, this publication is certainly worth a thorough look (Blundell & Bond, 1998). Researcher R17 thus ranks high on all two-variable metrics involving c_1. Researcher R17 ranks between 15 and 29 for the seven one-variable metrics n, i_{10}, h, w, c_{10}, c, g.

The five researchers R1,R2,R3,R13,R17, occupying at least one highest rank, all have harmonic means which are lower than their arithmetic means and geometric means, meaning that they have certain metrics where they excel.

Sixth, the 18th highest ranked researcher R18 (Nicholas Cox) is distinguished by rank 2 on n, and the lowest rank 54 on all other metrics. This is explained by R18 scoring high on the RePEc criteria number of works, number of journal pages, number of abstract views over the past 12 months, and the number of downloads over the past 12 months, scoring second or third in the RePEc database on some of these.

Seventh, the 41th highest ranked researcher R41 (Ilhan Ozturk) is distinguished by rank 50 on c_1, and 51-53 on all other metrics. This is explained especially by R41 ranking highest in the RePEc database on the number of abstract views over the past 12 months.

6 The eight one-variable metrics

Table 3 shows the correlations between the 36 metrics for the 54 highest ranked researchers in RePEc. The 36×36 matrix is symmetric across the diagonal from upper left to lower right; hence the correlations below the diagonal are omitted. Aside from c_{10}, the one-variable metrics are known from the literature. The metric n measures an author's prolificness. Aside from researchers R13,R18,R3 discussed above, researchers R16 (Barry J. Eichengreen, rank 3), R6 (Peter C.B. Phillips, rank 5), R51 (Bruno S. Frey, rank 6), and R50 (Richard B. Freeman, rank 7), are also prolific. They all have harmonic means lower than their arithmetic and geometric means. In contrast, researchers R32 (Robert W. Vishny, rank 54), R22 (Eugene F Fama Sr., rank 53), R41 (Ilhan Ozturk, rank 52), R33 (James H. Stock, rank 51), and R9 (Robert E. Lucas Jr., rank 50) are least prolific. These also have harmonic means lower than their arithmetic and geometric means. Researcher R32 compensates with high c_{10} (rank 3), R22 with high c_{10} (rank 5), R41 compensates with RePEc abstract views (rank 1), R33 compensates with high w (rank 4), and R9 compensates with high c_1 (rank 2). The metric n captures something unique about a researcher in that it correlates positively with only nine metrics, i.e. the seven involving n, plus $\sqrt{i_{10}h}$ at 0.06 and i_{10} at 0.23.

The metric i_{10} also measures prolificness. However, i_{10} requires that at least ten citations are ensured. This latter requirement has a substantial impact. Researchers R1,R2,R3 are confined to the top three ranks also for i_{10}, R7 has rank 4, and R5 has rank 5. However, researcher R16 has rank 6, as a highly prolific researcher also sustaining a high i_{10}. Researcher R16 does not sustain the citation count substantially beyond 10, and is ranked 21 on h and 41 or lower on the remaining five one-variable metrics w, c_{10}, c_1, c, g. In contrast, researcher R25 (Christopher F. Baum), has low i_{10} (rank 52) and compensates with substantial RePEc downloads and abstract views (ranks 1,2,3). Researcher R22 also has low i_{10} (rank 50) and compensates with substantial citations, e.g. high c_{10} (rank 5).

The metric h dampens the need for prolificness since citations are needed. Thus the correlation with n is -0.15, but the correlation with i_{10} is 0.80. The simplicity of the metric h has made it attractive. But prolificness beyond h is not needed, and citations beyond h for any publication is not needed. Researcher R46 (Alberto Alesina) utilizes this feature fully. Researcher R46 is highly ranked at 7 on h, but is not prolific (rank 41 on n), and is not most cited (rank 35 on c_1, rank 22 on c, rank 19 on c_{10}, rank 14 on w). Researcher R21 (Carmen M. Reinhart) also utilizes this feature to some extent. Researcher R21 is highly ranked at 5 on h, but is only moderately prolific (rank 28 on n), and is not most cited (rank 20 on c_1, rank 10 on c, rank 16 on c_{10}, rank 14 on w). The highest ranked researchers usually score high on h, but exceptions exist. The highly prolific researcher R6 (Peter C.B. Phillips) is ranked 35 on h. Although R6 has a reasonably high c_1 (rank 14), citation numbers thereafter fall off quickly constraining h. Researcher R9 (Robert E Lucas Jr.) is ranked 39 on h, compensating not by being prolific (rank 50 on n), but by high c_1 (rank 2), potentially justifying the Nobel prize. Researcher R12 (Gary S. Becker) is ranked 32 on h, compensating not by being prolific (rank 46 on n), and also not by high c_1 (rank 22), but by high w (rank 3) and high c_{10} (rank 6). This illustrates that earning the Nobel prize may not correlate with high c_1, but can be correlated with being substantially cited across a broad number of publications, expressed with high w and high c_{10}.

The metric w "plays close attention to the more widely cited papers" (Wu, 2010), compared with the metric h, with correlation 0.80. Wu (2010) illustrates these differences "by comparing the ranks of 20 astrophysicists, a few famous physical scientists, and 16 Price medalists," who fare better on w than on h. Consistently with this finding, Table 2 shows the sum of ranks 269 for w and 338 for h for the 13 Nobel prize winners, i.e. an average of 5.3 higher rank (standard deviation 16.6) for each Nobel prize winner. The most prominent difference occurs for researcher R12 (Gary S. Becker) earning rank 3 on w and only rank 32 on h. Second comes researcher R22 (Eugene F Fama Sr., rank 14 on w , rank 47 on h). Third comes researcher R9

(Robert E Lucas Jr., rank 14 on w, rank 39 on h). The most prominent exception is researcher R3 (Joseph E. Stiglitz, rank 26 on w, rank 4 on h), who compensates by being highly prolific (rank 4 on n, rank 1 on i_{10}, rank 5 on c). Two non-Nobel prize researchers improving substantially from rank 35 on h to rank 4 on w are R20 (Mark L. Gertler) and R33 (James H. Stock). Similarly, researcher R33 (Kenneth S. Rogoff) improves from rank 11 on h to rank 2 on w. These three researchers are characterized by being cited widely on some key publications. Two exceptions are researchers R21 (rank 14 on w, rank 5 on h) and R46 (rank 14 on w, rank 7 on h) discussed in the previous paragraph. The metric w correlates only 0.37 with i_{10}, and -0.43 with n.

The metric c_{10} correlates highly at 0.91 with w and c, at 0.90 with g, at 0.62 with h, at 0.57 with c_1, at 0.19 with i_{10}, and at -0.42 with n. Both c_{10} and w "plays close attention to the more widely cited papers." The difference is that c_{10} fixes "the more widely cited papers" to be exactly 10 publications, while w scales the number of publications that are accounted for among "the more widely cited papers" to depend on the number of citations earned by these "more widely cited papers." The metric c_{10} applies the same logic as i_{10} which fixes the required number of citations to be at least 10. In contrast, the metric w applies the same logic as h which scales the number of publications that are accounted for to determine h to depend on the number of citations earned by these h publications, namely at least h citations. The highest commonality between c_{10} and w can be expected for researchers with w=10, i.e. at least 100 citations for the 10 most cited publications. Then c_{10} and w are measured at around the same number of citations for the various researchers. Four researchers have w=10, i.e. R15 with c_{10}=111, R31 with c_{10}=130, R47 with c_{10}=105, and R50 with c_{10}=106. These four all have equal rank 46 on w (since w is an integer), and they have ranks 47, 46, 49, 48, respectively, on c_{10}. The one researcher R48 with w=11, and the three researchers R16, R36, and R51 with w=12 are also similarly ranked on c_{10} and w. The metric c_{10} pays no attention to the number of citations for the 11th, 12th, etc. publication. The average w across the 54 researchers is 16.96, which is substantially above 10 for the sample of 54 researchers, with standard deviation 5.99, and researcher R1 has w=34 causing rank 1. The most substantial decrease in rank from w to c_{10} occurs for researcher R7 (Jean Tirole), from rank 10 to rank 22. This researcher certainly has many widely cited publications, sustained all the way up to w=22 and beyond, but the 10th most cited publication is moderately cited at 357. Second comes researcher R10 (John Y. Campbell), decreasing from rank 4 on w to rank 15 on c_{10}. Third comes researcher R17 (Richard Blundell), decreasing from rank 20 on w to rank 29 on c_{10}. Fourth come researchers R5 (Daron Acemoglu) and R8 (Kenneth S. Rogoff), decreasing from rank 4 on w to rank 12 on c_{10}, and from rank 2 on w to rank 10 on c_{10}, respectively. These five researchers have in common that they are widely cited across many publications earning w of at least 19 (R17), but the 10th most cited publication is only moderately cited. In contrast, the most substantial increase in rank from w to c_{10} occurs for researcher R22 (Eugene F. Fama Sr.), from rank 14 on w to rank 5 on c_{10}. Second comes researcher R32 (Robert W. Vishny), from rank 10 on w to rank 3 on c_{10}. Common for these two researchers is that they are widely cited up to the 10th publication, while citations thereafter fall off rapidly.

The metric c_1 correlates only modestly at 0.57 with c_{10}, at 0.52 with w, at 0.36 with h, at 0.14 with i_{10}, and with n at -0.31. The metric c_1, commonly high for Nobel prize winners as discussed in section 4, emphasizes the one unique result, i.e. the one publication with the highest number of citations. The standard deviation of the rank difference between c_1 and c_{10} is 13.22. Eleven researchers have rank changes of at least 17. The most substantial decreases in rank from c_{10} to c_1, in decreasing order, occur for R34 (from 18 to 42), R10 (from 15 to 37), and R11 (from 11 to 28). Common for these is a modest c_1 and a comparably substantial c_{10}, i.e. the most similar citation numbers across the 10 most cited publications. In contrast, the most substantial increases in rank from c_{10} to c_1, in decreasing order, occur for R17 (from 29 to 1), R42 (33 to 6), R36 (from 41 to 15), R27 (from 35 to 10), R6 (from 37 to 14), R3 (from 31 to 12), R31 (from 46 to 27), and R47 (from 49 to 30). Common for these is a substantial c_1 and a comparably low c_{10}, i.e. the most dissimilar citation numbers across the 10 most cited publications.

The metric c correlates substantially with c_{10} and w at 0.91, with h at 0.79, with c_1 at 0.67, with i_{10} at 0.45, and with n at -0.29. The standard deviation of the rank difference between c and c_1 is 10.93. The metric c counts all citations, regardless of whether they come from highly or lowly cited publications. Thus for 10 of the 11 researchers in the previous paragraph, a rank change in one direction from c_{10} to c_1 is associated with a rank change in the other direction from c_1 to c. For the three researchers experiencing rank decreases from c_{10} to c_1, all experience rank increases from c_1 to c, i.e. R34 (from 42 to 30), R10 (from 37 to 21), and R11 (from 28 to 14). For the eight researchers experiencing rank increases from c_{10} to c_1, seven experience rank decreases from c_1 to c, i.e. R17 (from 1 to 19), R42 (6 to 26), R36 (from 15 to 39), R27 (from 10 to 18), R6 (from 14 to 32), R31 (from 27 to 48), and R47 (from 30 to 44). The exception is R3, with rank 31 on c_{10}, rank 12 on c_1, and rank 5 on c. The unique feature of R3 is that although c_{10} is comparably low, and c_1 is not exceptional, the prolificness expressed with ranks 4 and 1 on n and i_{10} generates an overall large citation count c. Three additional researchers experience substantial rank changes from c_1 to c. Researcher R54 experiences decreased rank from 17 to 34, caused by a comparably high c_1 and rapidly falling citation numbers associated with unprolificness, i.e. low ranks 49, 48, 46 on n, i_{10}, h. In contrast, R7 experiences increased rank from 31 to 9, caused by a comparably low c_1, slowly falling citation numbers, and prolificness expressed with reasonably high ranks 17, 4, 3 on n, i_{10}, h. Researcher R8 also experiences increased rank, from 24 to 5, caused by a comparably low c_1, extremely slowly falling citation numbers expressed with the high ranks 2 and 10 on w and c_{10}, and unprolificness expressed with relatively low ranks 25, 25, 11 on n, i_{10}, h. These two latter researchers illustrate that high c and comparably low c_1 can be caused by both prolificness and unprolificness as it does not matter where the citations c are earned.

The metric g correlates substantially with c at 0.96, with w at 0.95, with c_{10} at 0.90, with h at 0.81, with c_1 at 0.69, with i_{10} at 0.44, and with n at -0.41. The standard deviation of the rank difference between g and c is 1.14. The high correlation between g and c is consistent with De Visscher's (2011, p. 2290) finding that although "the g -index is a measure of a researcher's specific impact" "for the productive 'core' of publications," "the g -index does not differ from the square root of the total number of citations in a bibliometrically meaningful way when the entire publication list is considered." From c to g no researchers have rank changes above 3. Only the extremely prolific researchers R3 (Joseph E. Stiglitz, ranks 4 and 1 on n and i_{10}) and R16 (Barry J. Eichengreen, ranks 3 and 6 on n and i_{10}) have a rank decrease of 3 from c to g. This occurs since the extremely many publications with very low citations numbers causes c to increase, but does not cause g to increase beyond a certain level. This finding for R3 and R16 is also consistent with De Visscher's (2011, p. 2293) finding that c and g may deviate for "researchers who combine a large publication output with high consistency." In contrast, only the unprolific researchers R31 (Jeffrey M. Wooldridge, ranks 31 and 51 on n and i_{10}, and substantial RePEc downloads at ranks 1 and 2) and R47 (Donald W. K. Andrews, rank 47 on n and i_{10}) have rank increases of 3 from c to g. This occurs since very few publications have very low citations numbers. This causes g to be high, while c does not increase beyond a certain level. Stated in a simplified manner, R31 and R47 prefer either to write successful publications earning many citations, or prefer not to publish at all.

7 The 28 two-variable metrics

Aside from $\sqrt{hc_1}$ and $\sqrt{hg}$, the two-variable metrics are not known from the literature, to the authors' knowledge. Evidently, ranking highly on both one-variable metrics constituting a two-variable metric causes high ranking also on the latter, and otherwise a balance is struck. Since n is unique in that it has low, and for h, w, c_{10}, c_1, c, g negative, correlations with the other one-variable metrics, the first seven two-variable metrics involving n are also unique.

The metric $\sqrt{ni_{10}}$ expresses the second highest prolificness, after n and before i_{10}. The correlation with n and i_{10} is high, at 0.66 and 0.85, respectively. Multiplying n with i_{10} causes $\sqrt{ni_{10}}$=0 when i_{10}=0, which may occur for young or rarely cited researchers who have not earned at least 10 citations on at least publication. Researcher R16=BJE has high ranks 3 and 6 on n and i_{10}, due to prolificness while sustaining at least 10 citations across a broad number of publications, which combines to cause rank 3 on $\sqrt{ni_{10}}$. In contrast, R13=PN has different ranks 1 and 42 on n with i_{10}, due to prolificness while not sustaining at least 10 citations across a broad number of publications, which combines to cause rank 2 on $\sqrt{ni_{10}}$. The metric $\sqrt{ni_{10}}$ dampens the high ranks of prolific researchers not sustaining high i_{10}, dampens the high ranks of researchers with high i_{10} not being prolific, and reinforces the ranks of researchers highly ranked on both n and i_{10}.

The metric $\sqrt{nh}$ correlates at 0.86 with i_{10} and combines prolificness n with h. For the unprolific researcher R46=AA highly ranked at 7 on h, this causes rank 29 on $\sqrt{nh}$. In contrast, the highly prolific researcher R6=PP with rank 5 on n, and low rank 35 on h due to quickly falling citation numbers, has rank 6 on $\sqrt{nh}$. Similarly, the highly prolific researcher R51=BSF with rank 6 on n, and low rank 39 on h due to quickly falling citation numbers, earns the high rank 9 on $\sqrt{nh}$. The metric $\sqrt{nh}$ is in one sense a mirror image of $\sqrt{hc_1}$ proposed by Dorogovtsev and Mendes (2015). Whereas $\sqrt{hc_1}$ combines persistence and diligence from h with the one great result in terms of citations from c_1, $\sqrt{nh}$ combines persistence and diligence from h with the one great result in terms of prolificness from n.

The metric $\sqrt{nw}$ correlates at 0.83 with i_{10} and is interesting since w plays close attention to the more widely cited publications compared with h. The metrics n and w combine quite disparate characteristics, i.e. prolificness and being widely cited. The prolific researcher R3=JES with rank 4 on n, earning high total citation count c, but not being widely cited expressed with low rank 28 on w, earns the highest rank 1 on $\sqrt{nw}$. This follows since R3's n is so high. Similarly, the prolific R16=BJE, with high rank 3 on n, and low rank 42 on w, is ranked quite high at 9 on $\sqrt{nw}$. In contrast, the unprolific R9=REL with rank 50 on n is not helped much by rank 14 on w, and is ranked 46 on $\sqrt{nw}$. Similarly, R22=EFF has low rank 53 on n, intermediate rank 14 on w, but still low rank 50 on $\sqrt{nw}$. The unprolific R12=GSB, with low rank 46 on n, and high rank 3 on w, has relatively low rank 37 on $\sqrt{nw}$.

The metric $\sqrt{nc_{10}}$ correlates at 0.82 with h, and with $\sqrt{nw}$ at 0.88, reflecting that c_{10} correlates with w at 0.91. The difference is that c_{10} fixes being "widely cited" to exactly 10 publications. The prolific R13=PN with rank 1 on n, and low c_{10}=50 causing rank 51, decreases his rank from 4 on $\sqrt{nw}$ to rank 28 on $\sqrt{nc_{10}}$. In contrast, the unprolific R22=EFF increasing his rank from 14 on w to rank 5 on c_{10}, increases his rank from 50 on $\sqrt{nw}$ to rank 44 on $\sqrt{nc_{10}}$, due to citations falling off rapidly after the 10th publication.

The metric $\sqrt{nc_1}$ is remarkable since it combines being prolific (high n) with obtaining at least one highly cited publication. These are opposite characteristics of a researcher. The metric $\sqrt{nc_1}$ correlates better with c_1 at 0.77 than with n at 0.07. Researcher R17=RB obtains high rank 3 on $\sqrt{nc_1}$, caused by high rank 1 on c_1 and moderate prolificness expressed with rank 22 on n. Similarly, R53=CWG obtains high rank 6 on $\sqrt{nc_1}$, caused by high rank 4 on c_1 and moderate prolificness expressed with rank 31 on n. Researcher R3=JES obtains high rank 2 on $\sqrt{nc_1}$ through opposite means, i.e. moderate rank 12 on c_1 and high prolificness expressed with rank 4 on n. In contrast, R9=REL earns not the highest rank 11 on $\sqrt{nc_1}$, despite earning the high rank 2 on c_1, due to the low rank 50 on n.

The metric $\sqrt{nc}$, found in section 3 to reflect the RePEc scores best in terms of correlation, correlates at 0.85 with i_{10} and at 0.80 with h, and reflects $\sqrt{nc_1}$ partly in that both prolificness and citations are needed. But $\sqrt{nc}$ is less extreme in that the one highly cited publication is not all that matters. Instead the overall citation count matters. Hence it is irrelevant whether citations are earned by highly or lowly cited publications. The metric $\sqrt{nc}$ correlates with c at

0.70 and with n at 0.29. The metric $\sqrt{nc}$ may encourage prolificness since researchers may reason that citations may be earned somehow, without knowing in advance exactly how. One example is the prolific R16=BJE, with high rank 3 on n and low rank 49 on c_1 causing low rank 37 on $\sqrt{nc_1}$, boosting his overall citation count to rank 41 on c which causes the high rank 11 on $\sqrt{nc}$. In contrast, the unprolific R36=REH with low rank 36 on n and high rank 15 on c_1 causing high rank 17 on $\sqrt{nc_1}$, has a low overall citation count at rank 39 on c which causes the low rank 44 on $\sqrt{nc}$.

The metric $\sqrt{ng}$ correlates at 0.83 with i_{10}, and at 0.94 with $\sqrt{nc}$. The difference between c and g discussed in the previous section impacts $\sqrt{ng}$ and $\sqrt{nc}$, and gets amplified if n is large, but also when n is small since then c and g impact more, where c typically has two orders of magnitude higher than g. The prolific R13=PN with rank 1 on n and low c=2822 increases his rank from 17 on $\sqrt{nc}$ to 4 on $\sqrt{ng}$. Similarly, R50=RBF with rank 7 on n increases his rank from 33 on $\sqrt{nc}$ to 23 on $\sqrt{ng}$, and R51=BSF with rank 6 on n increases his rank from 22 on $\sqrt{nc}$ to 12 on $\sqrt{ng}$. These improvements are only possible when the productive core of the researcher's publications, as expressed by g, contribute more than the overall citation impact c. In contrast, R20=MLG with the low rank 48 on n and high c=20526 decreases his rank from 28 on $\sqrt{nc}$ to 40 on $\sqrt{ng}$, with similar ranks 7 and 6 on c and g. Similarly, R9=REL with the low rank 50 on n decreases his rank from 41 on $\sqrt{nc}$ to 46 on $\sqrt{ng}$, also with similar ranks 16 and 15 on c and g. Similarly, R28=RL with the low rank 37 on n decreases his rank from 19 on $\sqrt{nc}$ to 27 on $\sqrt{ng}$, also with similar ranks 13 and 12 on c and g. These three benefit more from the overall citation impact of c than from g to determine $\sqrt{ng}$.

The metric $\sqrt{i_{10}h}$ correlates at 0.96 with i_{10} and combines prolificness provided that at least 10 citations are obtained, while more than 10 citations are not needed, with h where neither prolificness nor citations beyond h are needed. This hurts the unprolific R4=RJB who has comparably low rank 13 on $\sqrt{i_{10}h}$ due to low rank 19 on i_{10}, though somewhat higher rank 6 on h . Researcher R4 does not benefit from his many citations. In contrast, the more prolific R44=JAF has high rank 7 on $\sqrt{i_{10}h}$ due to high rank 7 on i_{10}, and somewhat lower rank 18 on h. Researcher R44 is not hurt by comparably fewer citations.

The metric $\sqrt{i_{10}w}$ correlates at 0.97 with h, correlates at 0.78 with $\sqrt{nw}$ and combines i_{10}, where more than 10 citations are not needed, with w where being more widely cited is indeed needed. This hurts the prolific R6=PP who has comparably low rank 27 on $\sqrt{i_{10}w}$ despite reasonably high rank 10 on i_{10}, caused by low rank 41 on w due to not being widely cited. In contrast, the unprolific R46=AA has comparably high rank 10 on $\sqrt{i_{10}w}$ caused by reasonably high ranks 18 and 14 on i_{10} and w.

The metric $\sqrt{i_{10}c_{10}}$ correlates at 0.92 with h and c, correlates at 0.94 with $\sqrt{i_{10}w}$ and exhibits the nice symmetry where at least 10 citations are needed for i_{10} while the tenth most cited publication counts for the new c_{10}. This benefits the unprolific R32=RWV who increases his rank from 44 on $\sqrt{i_{10}w}$ to 26 on $\sqrt{i_{10}c_{10}}$ due to high rank 3 on w, compared to high rank 10 on c_{10}, despite low rank 49 on i_{10}. In contrast, the prolific R23=JL with high rank 13 on i_{10} decreases his rank from 23 on $\sqrt{i_{10}w}$ to 41 on $\sqrt{i_{10}c_{10}}$ due to the low rank decreasing from 40 on w to 42 on c_{10}.

The metric $\sqrt{i_{10}c_1}$ correlates at 0.86 with c_1, at 0.93 with $\sqrt{nc_1}$ and combines the requirement of at least 10 citations on many publications with one highly cited publication. Researchers with high ranks on c_1, e.g. R17=RB (rank 1), R42=NGM (rank 9), R53=CWG (6), obviously benefit from this, earning high ranks 2, 9, 6 on $\sqrt{i_{10}c_1}$, despite low ranks 10, 37, 35, respectively, on i_{10}. In contrast, the prolific R7 uses high rank 10 on i_{10} to compensate for his low rank 31 on c_1 to earn the intermediate rank 15 on $\sqrt{i_{10}c_1}$.

The metric $\sqrt{i_{10}c}$ correlates at 0.94 with h, and at 0.89 with $\sqrt{nc}$. The metrics i_{10} and c can combine in multifarious ways to cause high $\sqrt{i_{10}c}$. Researcher R21=CMR with intermediate rank 19 on i_{10} and high rank 10 on c earns the high rank 9 on $\sqrt{i_{10}c}$. Researcher R27=MHP with high rank 8 on i_{10} and intermediate rank 18 on c earns the high rank 8 on $\sqrt{i_{10}c}$. The prolific R6=PP with high rank 10 on i_{10} and low rank 32 on c earns the intermediate rank 16 on $\sqrt{i_{10}c}$. Highly ranked researchers can also earn low rank on $\sqrt{i_{10}c}$ for several reasons. The unprolific R9=REL and R12=GSB with low ranks 47 and 43 on i_{10} and intermediate ranks 16 and 15 on c earn the low ranks 33 and 29 on $\sqrt{i_{10}c}$. Differently, R14=TJS with intermediate rank 19 on i_{10} and low rank 42 on c earns the low rank 36 on $\sqrt{i_{10}c}$. More extremely, R15=MSF with high rank 11 on i_{10} and low rank 46 on c earns the low rank 37 on $\sqrt{i_{10}c}$.

The metric $\sqrt{i_{10}g}$ correlates at 0.95 with h, and correlates at 0.98 with $\sqrt{i_{10}c}$. Researchers R1-R7 retain their ranks from $\sqrt{i_{10}g}$ to $\sqrt{i_{10}c}$. The prolific R48=JP with rank 14 on i_{10} increases his rank from 40 on $\sqrt{i_{10}c}$ to 30 on $\sqrt{i_{10}g}$, with similar ranks 45 and 46 on c and g, preferring the impact by g of the productive core of publications. In contrast, the unprolific R20=MLG with rank 45 on i_{10} decreases his rank from 27 on $\sqrt{i_{10}c}$ to 39 on $\sqrt{i_{10}g}$, with similar ranks 7 and 6 on c and g. Similarly, R32=RWV with rank 49 on i_{10} decreases his rank from 35 on $\sqrt{i_{10}c}$ to 45 on $\sqrt{i_{10}g}$, with similar ranks 8 and 6 on c and g. Similarly, R9=REL with rank 47 on i_{10} decreases his rank from 33 on $\sqrt{i_{10}c}$ to 42 on $\sqrt{i_{10}g}$, with similar ranks 16 and 15 on c and g. Similarly, R12=GSB with rank 43 on i_{10} decreases his rank from 29 on $\sqrt{i_{10}c}$ to 38 on $\sqrt{i_{10}g}$, with similar ranks 15 and 15 on c and g. These four unprolific researchers prefer the overall citation impact c on $\sqrt{i_{10}c}$ rather than $\sqrt{i_{10}g}$.

The metric $\sqrt{hw}$ correlates at 0.95 with w, and consists of the related metrics h requiring being at least modestly cited, and w requiring being more widely cited. Three highly ranked researchers earn low or intermediate ranks on $\sqrt{hw}$ for different reasons. The prolific R6=PP earns the low rank 41 on $\sqrt{hw}$ due to low ranks 35 and 41 on h and w. The prolific R3=JES has intermediate rank 12 on $\sqrt{hw}$ as a compromise between high rank 4 on h and low rank 26 on w due to not being widely cited. The unprolific R9=REL has low rank 30 on $\sqrt{hw}$ due to low rank 39 on h and higher rank 14 on w, not counting the high rank 2 on c_1. In contrast, three researchers with lower ranking have high ranks on $\sqrt{hw}$ due to being well cited up to a certain point. The intermediately prolific R21=CMR has high rank 8 on $\sqrt{hw}$ due to ranks 5 and 14 on h and w. The unprolific R28=RL has high rank 10 on $\sqrt{hw}$ due to high ranks 10 and 12 on h and w. The unprolific R46=AA has high rank 11 on $\sqrt{hw}$ due to high ranks 7 and 14 on h and w.

The metric $\sqrt{hc_{10}}$ correlates at 0.96 with w, c, and g, and correlates at 0.96 with $\sqrt{hw}$. Since on average w=16.96 across the 54 researchers, most prefer $\sqrt{hc_{10}}$ if c_{10} is high, and $\sqrt{hw}$ if more widely cited. Researchers R22=EFF, R32=RWV, R53=CWG prefer the former and increase their ranks from 38, 28, 36 on $\sqrt{hw}$ to 18, 9, 24 on $\sqrt{hc_{10}}$ due to ranks 14, 10, 33 on w and higher ranks 5, 3, 20, respectively, on c_{10}. In contrast, R43=MW, R42=NGM, R19=DEC decrease their ranks from 15, 21, 21 on $\sqrt{hw}$ to 32, 31, 30 on $\sqrt{hc_{10}}$ due to ranks 20, 26, 26 on w and lower ranks 34, 33, 32, respectively, on c_{10}.

The metric $\sqrt{hc_1}$ proposed by Dorogovtsev and Mendes (2015) correlates at 0.93 with c_1, and combines “persistence and diligence” from h with “the great result” from c_1. The metric $\sqrt{hc_1}$ correlates at 0.67 with h and at 0.93 with c_1. Researcher R17=RB with top rank 1 on c_1 earns lower rank 3 on $\sqrt{hc_1}$ due to low rank 18 on h. Researchers R31=JMW, R36=REH, R22=EFF decrease their ranks from 27, 15, 9 on c_1 to 42, 28, 19 on $\sqrt{hc_1}$ due to low ranks 50, 49, 47 on h. In contrast, R7=JT, R28=RL, R21=CMR increase their ranks from 31, 25, 20 on c_1 to 21, 16, 12 on $\sqrt{hc_1}$ due to high ranks 3, 10, 5 on h.

The metric $\sqrt{hc}$ correlates at 0.97 with c, correlates at 0.83 with $\sqrt{hc_1}$ and dampens the need of the one great result c_1 since overall citations c are generated from all publications. Researchers R6=PP, R9=REL, R36=REH, R54=CS decrease their ranks from 15, 7, 28, 26 on $\sqrt{hc_1}$ to 36, 23, 44, 42 on $\sqrt{hc}$ due to higher ranks 14, 2, 15, 17 on c_1 than ranks 32, 16, 39, 38 on c. In contrast, R19=DEC, R10=JYC, R7=JT increase their ranks from 43, 30, 21 on $\sqrt{hc_1}$ to 25, 13, 5 on $\sqrt{hc}$ due to lower ranks 44, 37, 31 on c_1 than ranks 34, 21, 9 on c.

The metric $\sqrt{hg}$ proposed by Alonso et al. (2010) correlates at 0.95 with h and g, correlates at 0.98 with $\sqrt{hc}$, influenced by the high correlation 0.96 between g and c, and correlates at 0.95 with both h and g, recalling correlation 0.81 between h and g. Alonso et al. (2010) argue that $\sqrt{hg}$ is closer to h than to g, which prevents the high impact of a highly cited publication which occurs in the g-index. Thus $\sqrt{hg}$ accounts for related characteristics, preventing the deficiency of h which ignores citations beyond h from any single publication, and prevents too high emphasis of one or a few highly cited publications. Researchers R9=REL, R22=EFF, R32=RWV benefit from the overall citation impact of c and decrease their ranks from 23, 28, 17 on $\sqrt{hc}$ to 32, 37, 26 on $\sqrt{hg}$, observing similar ranks 16, 12, 8 on c and ranks 15, 12, 6 on g. In contrast, R43=MW benefits from his productive core of publications expressed by g, and increases his rank from 34 on $\sqrt{hc}$ to 24 on $\sqrt{hg}$, observing similar ranks 36 and 35 on c and g.

The metric $\sqrt{wc_{10}}$ correlates at 0.99 with c_{10}, at 0.97 with w, and involves the closely related metrics w and c_{10} which correlate at 0.91. Researcher R7=JT is widely cited beyond the 10th publication expressed with high rank 10 on w and increases his rank from 22 on c_{10} to rank 18 on $\sqrt{wc_{10}}$. In contrast, R54=CS is not widely cited beyond the 10th publication expressed with low rank 33 on w and decreases his rank from 26 on c_{10} to rank 31 on $\sqrt{wc_{10}}$.

The metric $\sqrt{wc_1}$ correlates at 0.93 with c_1, at 0.79 with w, and combines being widely cited expressed with w, with being exceptionally cited on one publication expressed with c_1. Researcher R1=AS is not superbly cited expressed with rank 8 on c_1 for the most cited publication, but is ranked 1 on w due to being widely cited beyond the 10th publication expressed with rank 1 on w, thus obtaining rank 1 also on $\sqrt{wc_1}$. In contrast, R36=REH has high rank 15 on c_1, low rank 42 on w, causing the intermediate rank 27 on $\sqrt{wc_1}$.

The metric $\sqrt{wc}$ correlates at 0.98 with c, at 0.97 with w, and involves the closely related metrics w and c which correlate at 0.91. The metric $\sqrt{wc}$ combines being widely cited expressed with w, with being overall well cited as expressed with c. Researcher R33=JHS is superbly widely cited expressed with high rank 4 on w. But citation numbers thereafter fall off quickly causing comparably low rank 17 on c. The compromise is intermediate rank 11 on $\sqrt{wc}$. In contrast, the prolific R3=JES is not widely cited expressed with low rank 26 on w. But the overall citation count is excellent causing high rank 5 on c. The compromise is intermediate rank 13 also on $\sqrt{wc}$.

The metric $\sqrt{wg}$ correlates at 0.99 with w, g and $\sqrt{wc}$. Twenty five researchers have the same rank on the two metrics. Nineteen researchers change their rank 1 up or down. Researcher R10=JYC increases his rank from 17 on $\sqrt{wc}$ to 12 on $\sqrt{wg}$, with equal rank 21 on c and g, preferring the impact by g of the productive core of publications. In contrast, R27=MHP decreases his rank from 23 on $\sqrt{wc}$ to 28 on $\sqrt{wg}$ with similar ranks 6 and 5 on c and g, preferring the overall citation impact c on $\sqrt{wc}$ rather than $\sqrt{wg}$.

The metric $\sqrt{c_{10}c_1}$ correlates at 0.89 with c_1, c, g, and correlates at 0.98 with $\sqrt{wc_1}$. Researcher R28=RL increases his rank from 22 on $\sqrt{wc_1}$ to 16 on $\sqrt{c_{10}c_1}$, due to lower rank 12 on w than rank 9 on c_{10}, caused by not being widely cited beyond the 10th publication, and rank 25 on c_1. In contrast, R3=JES decreases his rank from 13 on $\sqrt{wc_1}$ to 19 on $\sqrt{c_{10}c_1}$, due to higher rank 26 on w than rank 31 on c_{10}, caused by not being widely cited beyond the 10th publication, and rank 12 on c_1.

The metric $\sqrt{c_{10}c}$ correlates at 0.98 with c_{10} and at 0.97 with c. In addition to R3 and R7 negatively affected by comparably low c_{10}, R27=MHP is ranked low at 35 on c_{10} which decreases his rank from 18 on c to rank 27 on $\sqrt{c_{10}c}$. In contrast, R34=ABK is ranked comparably high at 18 on c_{10} which increases his rank from 30 on c to rank 22 on $\sqrt{c_{10}c}$.

The metric $\sqrt{c_{10}g}$ correlates at 0.99 with c_{10} and $\sqrt{c_{10}c}$. Researcher R3=JES prefers the overall citation impact c which decreases his rank from 19 on $\sqrt{c_{10}c}$ to rank 25 on $\sqrt{c_{10}g}$. In contrast, R35=MO prefers the productive core of publications expressed by g, which increases his rank from 26 on $\sqrt{c_{10}c}$ to rank 22 on $\sqrt{c_{10}g}$.

The metric $\sqrt{c_1c}$ correlates at 0.93 with c_1 and at 0.89 with c. Researcher R8=KSR prefers the overall citation impact c with rank 4 which increases his rank from 24 on c_1 to rank 15 on $\sqrt{c_1c}$. In contrast, R31=JMW does not prefer the overall citation impact c with rank 48, which decreases his rank from 27 on c_1 to rank 40 on $\sqrt{c_1c}$.

The metric $\sqrt{c_1g}$ correlates at 0.96 with c_1, and at 0.99 with $\sqrt{c_1c}$. Researcher R7=JT with rank 31 on c_1 prefers the overall citation impact c with rank 9 rather than the citation impact g at rank 10 of the productive core of publications, as his rank decreases from 24 on $\sqrt{c_1c}$ to rank 28 on $\sqrt{c_1g}$. In contrast, R47=DWA with rank 30 on c_1 prefers the citation impact g at rank 41 of the productive core of publications rather than the overall citation impact c with rank 44, as his rank increases from 38 on $\sqrt{c_1c}$ to rank 33 on $\sqrt{c_1g}$.

The metric $\sqrt{cg}$ correlates at 0.99 with c, g, and $\sqrt{wc}$. These high correlations, and the high correlation 0.96 between c and g suggest that $\sqrt{cg}$ is not particularly useful. Forty five researchers keep their same ranks on c and$\sqrt{cg}$. Seven researchers change their ranks by one.

Researcher R16=BJE decreases his rank from 41 on c to 44 on $\sqrt{cg}$ due to lower rank 44 on g. In contrast, R47=DWA 2 increases his rank from 44 on c to 42 on $\sqrt{cg}$ due to the higher rank 41 on g.

8 Some limitations of citations

Publications measure production which may be valuable but sometimes goes unnoticed. Citations measure consumers' interest which should neither be discounted nor be given too much weight. A justified view should be developed for the relative weighting of publications and citations. Determining that weighting is beyond the scope of this paper, but it impacts which of the 36 metrics should be applied. Citations are generally believed to be important. A balanced view is needed. Consider five reasons for valuing publications with few or no citations. First, new publications initially have no citations and may be highly valuable, which may take years to determine. Second, some publications may be genial but may not gain many citations initially due to low accessibility, difficulty understanding, may open up a new field where few researchers operate, may be written incomprehensibly, or may be written by unknown outsiders. Three examples are Hume's (1740) Treatise which "fell dead from the press", Coase's (1937) paper which took substantial time to understand but eventually contributed to a Nobel Memorial Prize, and Harsanyi's (1967) so-called "type theory" which took some 10-15 years to become extensively cited e.g. within bargaining theory and principal-agent theory with incomplete information. Third, due to a requirement to position one's work within the literature, some publications cite earlier work superficially by mentioning them in a list together with others. Such citation may be arbitrary and based on what the researcher happens to know, or superficially finds out by observing who others cite, without assessing the citations' qualities. Fourth, some publications cite earlier publications not because of their qualities, but as a matter of duty since some journals expect or require a reasonable number of citations, and hence citations may become name-dropping. Fifth, some publications may quickly reorient a scientific field and become received theory to the extent that they are neither questioned nor acknowledged since the majority accepts the reorientation. Such reorientation may occur within years, decades, or centuries, varying across disciplines. A related point is that some old scholars, such as Aristotle and Plato, and even more recent scholars such as Newton, Adam Smith, Darwin, and Einstein are often referred to in scientific work without citing their actual publications.

9 Future research

RePEc considers the 37 criteria NbWorks, DNbWorks, ScWorks, WScWorks, ANbWorks, AScWorks, AWScWorks, NbCites, DCites, ScCites, DScCites, WScCites, WDScCites, ANbCites, ADCites, AScCites, ADScCites, AWScCites, AWDScCites, HIndex, NCAuthors, RCAuthors, NbPages, ScPages, WScPages, ANbPages, AScPages, AWScPages, AbsViews, Downloads, AAbsViews, ADownloads, Students, Closeness, Betweenness, NEPCites, excluding NbWorks and the Wu-index for the ranking (Zimmermann, 2012, p. 21). These 37 cover four of the eight considered in this paper, i.e. DNbWorks= n, HIndex= h, NbCites= c, Wu-index= w. Adding i_{10}, c_{10}, c_1, g gives 41 criteria. Additional criteria are easily added. Future research may test these 41 one-variable metrics, leading to $\sum_{j=1}^{40} j$=820 geometric means. Harmonic and arithmetic means, and other combinations, of multi-variable metrics may also be considered. Further, more than two one-variable metrics may be multiplied by, divided by, added to, or subtracted from each other, each raised to different powers, applying combinations of addition, multiplication, exponentiation, etc.

Factor analysis may be used, where each indicator is a linear combination of at least two factors plus noise. Then standard methods are applicable to calculate the two- or multi-dimensional plane of factors. One thereafter proceeds to identify the factors: for the first, one chooses that vector in that two- or multi-dimensional plane that is as highly correlated as possible with a very prominent ranking criterion. One insists that the second vector is orthogonal to the first, and analogously for the subsequent vectors. Thereafter a variance decomposition is conducted to determine how much each vector explains each criterion, how any two vectors explain each criterion, etc., up to how all vectors jointly explain each criterion. The researchers are ranked on each factor alone. The study can be conducted for the 500 highest ranked researchers, or for all 48,266 researchers.

Applying historic RePEc data, the method may be used to predict Nobel Prize winners, i.e. ranking researchers on their probability of receiving the prize e.g. in the next ten years.[5]

10 Discussion and conclusion

[5] I thank Harald Uhlig for suggesting the factor analysis and Nobel prize prediction method sketched in this section.

The paper presents 28 two-variable researcher-level metrics as all possible geometric means from eight one-variable metrics. Twenty six of the two-variable metrics and one of the one-variable metrics are new in this paper, to the author's knowledge. The 26 metrics are assessed empirically for the 54 highest ranked researchers in the RePEc database comprising 48,266 researchers, applying the harmonic mean of ranks across 29 criteria. The 36 metrics account in varying degrees for the two dimensions publication rank and number of citations for each publication.

The eight one-variable metrics differ as follows, and have limitations we point out. The number n of publications and number number c of citations are especially different, emphasizing prolificness and consumer interest, respectively, correlating at -0.29. Boosting n can partly be done with limited focus on quality, which is its limitation. Boosting c can be done in many ways, which limits what it captures. The number c_1 of citations for the highest cited publication is distinguished by identifying consumer interest in one particular publication, and has the lowest sum of ranks for the 13 Nobel prize winners across the 36 metrics. Its limitation is that merely one successful publication says nothing about other publications. The commonly used metric h jointly encourages both publication and citation up to, but not beyond, h, which is its limitation. The metric w encourages being widely cited beyond h. Its limitations are that it ignores publications beyond w, and ignores citations beyond 10w. Consistently with Wu's (2010) finding that prominent researchers score higher on w than on h, the 13 Nobel prize winners have on average 5.3 higher rank on w than on h. The metric i_{10} measures prolificness provided that at least 10 citations are ensured for each publication, but correlates only at 0.23 with n, and at 0.45 with c. It actually correlates better with h at 0.80. Limitations are that it ignores publications with fewer than 10 citations, and being cited more than 10 times does not count. The new metric c_{10}, the number of citations for the 10^{th} highest cited publication, is inspired by i_{10} with which it correlates only at 0.19. The metric c_{10} correlates at 0.91 with w and c, and at -0.42 with n. It differs from w in that it is easier to determine and fixes being "widely cited" to exactly the 10^{th} most cited publication. Limitations are that it ignores publications beyond the 10^{th} most cited publication, and being cited more than the 10^{th} most cited publication on the nine most cited publications does not count. The metric g correlates with c at 0.96, which is possibly a limitation, consistently with De Visscher's (2011, p. 2290) finding that g measures the impact of the "productive core of publications," while c is bibliometrically similar and measures total citation impact. The metric g correlates at 0.95

with w and at 0.90 with c_{10}. Limitations are, analogously as for e.g. h and w, that it ignores publications and citations of publications beyond g.

Since all the one-variable metrics have limitations, we proceed to discuss whether the two-variable metrics remedy the limitations. Since no gold standard exists for ranking metrics, we rank the 28 two-variable metrics tentatively and impressionistically in the order in which they look interesting. We focus especially on whether they capture different characteristics not captured by the one-variable metrics. Future research may develop systematic methodology for ranking these and other metrics. The first five metrics combine prolificness n with being cited in various ways. None of them correlate above 0.85 with any one-variable metric.

1. The metric $\sqrt{nc}$ correlates at 0.85 with i_{10} and at 0.80 with h and reflects the RePEc scores best, combining prolificness with overall citation impact, where n and c correlate at -0.29.
2. The metric $\sqrt{nc_{10}}$ correlates at 0.82 with h and combines prolificness with being widely cited to 10 publications. It reflects the RePEc scores second best, where n and c_{10} correlate at -0.42.
3. The metric $\sqrt{nw}$ correlates at 0.83 with i_{10} and combines prolificness with being widely cited, where n and w correlate at -0.43.
4. The metric $\sqrt{ng}$ correlates at 0.83 with i_{10}, where n and g correlate at -0.41.
5. The metric $\sqrt{nc_1}$ correlates at 0.77 with c_1 and is remarkable since it combines being prolific with obtaining at least one highly cited publication, where n and c_1 correlate at -0.31.

The next three metrics combine prolificness i_{10} given that at least 10 citations are obtained on each publication, with being cited in various ways.

6. The metric $\sqrt{i_{10}c_{10}}$ correlates at 0.92 with h and c, and exhibits the nice symmetry where at least 10 citations are needed for i_{10} while the tenth most cited publication counts for the new c_{10}.
7. The metric $\sqrt{i_{10}c_1}$ correlates at 0.86 with c_1 and combines the requirement of at least 10 citations on many publications with one highly cited publication.
8. The metric $\sqrt{i_{10}c}$ correlates at 0.94 with h and combines the requirement of at least 10 citations on many publications with overall citation impact. It reflects the RePEc scores third best.

The next three metrics combine interestingly the common metric h with three other one-variable metrics.

9. The metric $\sqrt{hc_1}$ proposed by Dorogovtsev and Mendes (2015) correlates at 0.93 with c_1 and at 0.67 with h and combines “persistence and diligence” from h with “the great result” from c_1.
10. The metric $\sqrt{nh}$ correlates at 0.86 with i_{10} and is in one sense a mirror image of $\sqrt{hc_1}$. Whereas $\sqrt{hc_1}$ combines persistence and diligence from h with the one great result in terms of citations from c_1, $\sqrt{nh}$ combines persistence and diligence from h with the one great result in terms of prolificness from n.
11. The metric $\sqrt{hg}$ proposed by Alonso et al. (2010) correlates at 0.95 with h and g, at 0.92 with w and c, and is closer to h than to g, which prevents the high impact of a highly cited publication which occurs in the g-index.

The next four metrics combine one-variable metrics with insufficiently different characteristics.

12. The metric $\sqrt{ni_{10}}$ correlates at 0.85 with i_{10}. Although it does not correlate above 0.85 with any other one-variable metric, n measures prolificness while i_{10} measures prolificness to a certain degree.
13. The metric $\sqrt{c_{10}c_1}$ correlates at 0.89 with c_1, c, g, and at 0.88 with c_{10}. It is in a sense mirror image of $\sqrt{ni_{10}}$ where the great result c_1 corresponds to n, and being cited at c_{10} corresponds to publishing with at least 10 citations. Although $\sqrt{c_{10}c_1}$ does not correlate above 0.89 with any other one-variable metric, c_1 measures being exceptionally cited while c_{10} measures degree of citations for the 10th highest cited publication.
14. The metric $\sqrt{wc_1}$ correlates at 0.93 with c_1, and at 0.89 with g, and combines being widely cited with being exceptionally cited.
15. The metric $\sqrt{c_1c}$ correlates at 0.93 with c_1 and at 0.89 with c, and combines being overall well cited with being exceptionally cited.

The remaining 13 metrics correlate at least 0.95 with at least one other one-variable metrics and are ranked in increasing order of this correlation, from 0.95 to 0.99.

16. The metric $\sqrt{i_{10}g}$ correlates at 0.95 with h, where i_{10} and g correlate at 0.44.

17. The metric $\sqrt{hw}$ correlates at 0.95 with w, at 0.94 with h, and at 0.93 with g, and combines being at least modestly cited with being more widely cited.

18. The metric $\sqrt{c_1 g}$ correlates at 0.96 with c_1.

19. The metric $\sqrt{i_{10}h}$ correlates at 0.96 with i_{10} and at 0.94 with h, and combines prolificness provided that at least 10 citations are obtained.

20. The metric $\sqrt{hc_{10}}$ correlates at 0.96 with w, c, and g, and at 0.94 with c_{10}.

21. The metric $\sqrt{i_{10}w}$ remarkably correlates at 0.97 with h and combines i_{10}, where more than 10 citations are not needed, with w where being more widely cited is indeed needed.

22. The metric $\sqrt{hc}$ correlates at 0.97 with c, at 0.95 with g, at 0.92 with h, and at 0.91 with w.

23. The metric $\sqrt{wc}$ correlates at 0.98 with c, at 0.97 with w, and involves the closely related metrics w and c which correlate at 0.91.

24. The metric $\sqrt{c_{10}c}$ correlates at 0.98 with c_{10}, at 0.97 with c, at 0.95 with g, and at 0.93 with w.

25. The metric $\sqrt{c_{10}g}$ correlates at 0.99 with c_{10}, at 0.96 with g, and at 0.95 with w and c.

26. The metric $\sqrt{wc_{10}}$ correlates at 0.99 with c_{10}, at 0.97 with w, at 0.94 with g, at 0.93 with c, and involves the closely related metrics w and c_{10} which correlate at 0.91.

27. The metric $\sqrt{wg}$ correlates at 0.99 with the closely related w and g, at 0.94 with c, and at 0.92 with c_{10}.

28. The metric $\sqrt{cg}$ correlates at 0.99 with c and g, and at 0.93 with w.

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Table 1: The 54 highest ranked researchers in RePEc, name initials Init, rank R, RePEc score S, the eight metrics n, i_{10}, h, w, c_{10}, c_1, c, g, and the 28 geometric means. The 13 Nobel prize winners are shown in bold. The bottom row shows the correlation between the metric in the given column and the RePEc score in column 4 for all researchers. † means deceased.

Name	Init	R	S	n	i_{10}	h	w	c_{10}	c_1	c	g	$\sqrt{ni_{10}}$	$\sqrt{nh}$
Andrei Shleifer	AS	1	3.04	215	159	90	34	887	3363	40519	201	184.9	139.1
James J Heckman	**JJH**	2	3.61	320	186	78	23	522	4761	27826	164	244.0	158.0
Joseph E Stiglitz	**JES**	3	4.88	457	190	66	18	283	2755	21672	142	294.7	173.7
Robert J Barro	RJB	4	4.98	183	107	61	23	751	2883	26421	162	139.9	105.7
Daron Acemoglu	DA	5	5.58	286	149	59	23	466	2415	19215	137	206.4	129.9
Peter CB Phillips	PP	6	8.48	430	125	44	13	248	2477	12460	107	231.8	137.5
Jean Tirole	**JT**	7	10.57	251	151	72	22	357	1298	19365	137	194.7	134.4
Kenneth S Rogoff	KSR	8	11.98	199	98	57	25	493	1817	22537	150	139.6	106.5
Robert E Lucas Jr.	**REL**	9	12.44	96	56	41	20	454	4936	17269	131	73.3	62.7
John Y Campbell	JYC	10	15.29	139	92	56	23	450	1167	15992	126	113.1	88.2
Olivier J Blanchard	OJB	11	17.05	202	114	59	21	491	1529	17905	133	151.7	109.2
Gary S Becker †	**GSB**	12	18.55	115	63	45	24	565	1952	17271	131	85.1	71.9
Peter Nijkamp	PN	13	22.22	1106	66	25	6	50	128	2822	41	270.2	166.3
Thomas J Sargent	**TJS**	14	22.66	242	107	48	15	202	513	8588	89	160.9	107.8
Martin S Feldstein	MSF	15	23.53	319	124	41	10	111	1264	7402	78	198.9	114.4
Barry J Eichengreen	BJE	16	24.95	459	148	51	12	149	404	8784	82	260.6	153.0
Richard Blundell	RB	17	25.01	218	114	52	19	301	4963	16583	128	157.6	106.5
Nicholas Cox	NC	18	25.2	466	0	3	0	1	4	37	3	0.0	37.4
David E Card	DEC	19	26.09	241	124	54	18	280	704	12286	108	172.9	114.1
Mark L Gertler	MLG	20	26.29	107	57	44	23	577	2340	20526	143	78.1	68.6
Carmen M Reinhart	CMR	21	26.89	182	107	64	20	446	2115	19347	139	139.5	107.9
Eugene F Fama Sr.	**EFF**	22	27.32	61	45	34	20	567	2982	18677	136	52.4	45.5
John List	JL	23	30.06	277	120	45	14	157	818	8475	86	182.3	111.6
Paul R Krugman	**PRK**	24	30.48	165	95	48	19	335	2519	14783	121	125.2	89.0
Christopher F Baum	CFB	25	32.3	267	29	18	6	42	546	2166	44	88.0	69.3
Robert F Engle III	**RFE**	26	32.67	162	97	53	20	465	4559	21275	145	125.4	92.7
M Hashem Pesaran	MHP	27	32.95	282	129	51	16	261	2959	16897	128	190.7	119.9
Ross Levine	RL	28	32.96	158	102	58	21	500	1795	18648	136	126.9	95.7
Edward C Prescott	**ECP**	29	33.31	136	74	43	18	303	2229	14335	119	100.3	76.5
Lawrence H Summers	LHS	30	33.56	198	104	55	18	323	1119	12501	110	143.5	104.4
Jeffrey M Wooldridge	JMW	31	34.35	173	39	26	10	130	1532	6593	81	82.1	67.1
Robert W Vishny	RWV	32	37.14	50	46	39	22	674	3398	20456	143	48.0	44.2
James H Stock	JHS	33	37.56	94	70	44	23	554	2033	17257	131	81.1	64.3
Alan B Krueger	ABK	34	38.22	226	112	49	18	399	943	12674	111	159.1	105.2
Maurice Obstfeld	MO	35	39.03	157	92	49	18	362	1864	12815	113	120.2	87.7
Robert E Hall	REH	36	39.26	161	68	32	12	183	2462	9762	98	104.6	71.8
Ben S Bernanke	BSB	37	39.74	314	59	39	20	402	1467	14256	119	136.1	110.7
Raghuram G Rajan	RGR	38	41.72	124	68	48	19	355	1718	13372	115	91.8	77.1
Stephen J Turnovsky	SJT	39	41.94	291	92	33	7	66	106	3326	46	163.6	98.0
Elhanan Helpman	EH	40	42.16	157	87	49	19	314	1280	12931	113	116.9	87.7
Ilhan Ozturk	IO	41	43.23	80	27	18	5	35	353	1419	36	46.5	37.9
N Gregory Mankiw	NGM	42	43.42	113	78	54	18	277	4022	13948	118	93.9	78.1
Michael Woodford	MW	43	44.88	178	87	55	19	264	952	11089	105	124.4	98.9
Jeffrey A Frankel	JAF	44	45.86	310	134	52	16	250	1170	11947	105	203.8	127.0
Angus S Deaton	**ASD**	45	47.49	163	85	48	16	239	1231	10384	101	117.7	88.5
Alberto Alesina	AA	46	50.46	146	109	60	20	387	1176	14838	121	126.2	93.6
Donald W K Andrews	DWA	47	53.59	120	57	37	10	105	1418	8232	90	82.7	66.6
James Poterba	JP	48	53.6	251	119	47	11	154	606	7415	80	172.8	108.6
Edward L Glaeser	ELG	49	58.41	158	97	52	19	296	1009	12418	110	123.8	90.6
Richard B Freeman	RBF	50	58.88	333	126	39	10	106	343	6036	67	204.8	114.0
Bruno S Frey	BSF	51	59.31	397	100	41	12	145	1040	7033	78	199.2	127.6
Timothy J Besley	TJB	52	59.84	175	93	48	16	219	609	8887	93	127.6	91.7
Clive W J Granger †	**CWG**	53	64.59	173	86	45	16	378	4579	16455	128	122.0	88.2
Christopher Sims	**CS**	54	65.67	106	50	35	16	315	2385	10179	100	72.8	60.9
Correlation				-0.22	-0.37	-0.38	-0.37	-0.41	-0.27	-0.52	-0.41	-0.32	-0.38

Init	$\sqrt{nw}$	$\sqrt{nc_{10}}$	$\sqrt{nc_1}$	$\sqrt{nc}$	$\sqrt{ng}$	$\sqrt{i_{10}h}$	$\sqrt{i_{10}w}$	$\sqrt{i_{10}c_{10}}$	$\sqrt{i_{10}c_1}$	$\sqrt{i_{10}c}$	$\sqrt{i_{10}g}$	$\sqrt{hw}$	$\sqrt{hc_{10}}$
AS	85.5	436.7	850.3	2951.5	207.9	119.6	73.5	375.5	731.2	2538.2	178.8	55.3	282.5
JJH	85.8	408.7	1234.3	2984.0	229.1	120.4	65.4	311.6	941.0	2275.0	174.7	42.4	201.8
JES	90.7	359.6	1122.1	3147.1	254.7	112.0	58.5	231.9	723.5	2029.2	164.3	34.5	136.7
RJB	64.9	370.7	726.4	2198.9	172.2	80.8	49.6	283.5	555.4	1681.4	131.7	37.5	214.0
DA	81.1	365.1	831.1	2344.2	197.9	93.8	58.5	263.5	599.9	1692.1	142.9	36.8	165.8
PP	74.8	326.6	1032.0	2314.7	214.5	74.2	40.3	176.1	556.4	1248.0	115.7	23.9	104.5
JT	74.3	299.3	570.8	2204.7	185.4	104.3	57.6	232.2	442.7	1710.0	143.8	39.8	160.3
KSR	70.5	313.2	601.3	2117.7	172.8	74.7	49.5	219.8	422.0	1486.1	121.2	37.7	167.6
REL	43.8	208.8	688.4	1287.6	112.1	47.9	33.5	159.4	525.8	983.4	85.7	28.6	136.4
JYC	56.5	250.1	402.8	1490.9	132.3	71.8	46.0	203.5	327.7	1213.0	107.7	35.9	158.7
OJB	65.1	314.9	555.7	1901.8	163.9	82.0	48.9	236.6	417.5	1428.7	123.1	35.2	170.2
GSB	52.5	254.9	473.8	1409.3	122.7	53.2	38.9	188.7	350.7	1043.1	90.8	32.9	159.5
PN	81.5	235.2	376.3	1766.7	212.9	40.6	19.9	57.4	91.9	431.6	52.0	12.2	35.4
TJS	60.2	221.1	352.3	1441.6	146.8	71.7	40.1	147.0	234.3	958.6	97.6	26.8	98.5
MSF	56.5	188.2	635.0	1536.6	157.7	71.3	35.2	117.3	395.9	958.0	98.3	20.2	67.5
BJE	74.2	261.5	430.6	2007.9	194.0	86.9	42.1	148.5	244.5	1140.2	110.2	24.7	87.2
RB	64.4	256.2	1040.2	1901.3	167.0	77.0	46.5	185.2	752.2	1374.9	120.8	31.4	125.1
NC	0.0	21.6	43.2	131.3	37.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
DEC	65.9	259.8	411.9	1720.7	161.3	81.8	47.2	186.3	295.5	1234.3	115.7	31.2	123.0
MLG	49.6	248.5	500.4	1482.0	123.7	50.1	36.2	181.4	365.2	1081.7	90.3	31.8	159.3
CMR	60.3	284.9	620.4	1876.5	159.1	82.8	46.3	218.5	475.7	1438.8	122.0	35.8	168.9
EFF	34.9	186.0	426.5	1067.4	91.1	39.1	30.0	159.7	366.3	916.8	78.2	26.1	138.8
JL	62.3	208.5	476.0	1532.2	154.3	73.5	41.0	137.3	313.3	1008.5	101.6	25.1	84.1
PRK	56.0	235.1	644.7	1561.8	141.3	67.5	42.5	178.4	489.2	1185.1	107.2	30.2	126.8
CFB	40.0	105.9	381.8	760.5	108.4	22.8	13.2	34.9	125.8	250.6	35.7	10.4	27.5
RFE	56.9	274.5	859.4	1856.5	153.3	71.7	44.0	212.4	665.0	1436.5	118.6	32.6	157.0
MHP	67.2	271.3	913.5	2182.9	190.0	81.1	45.4	183.5	617.8	1476.4	128.5	28.6	115.4
RL	57.6	281.1	532.6	1716.5	146.6	76.9	46.3	225.8	427.9	1379.2	117.8	34.9	170.3
ECP	49.5	203.0	550.6	1396.3	127.2	56.4	36.5	149.7	406.1	1029.9	93.8	27.8	114.1
LHS	59.7	252.9	470.7	1573.3	147.6	75.6	43.3	183.3	341.1	1140.2	107.0	31.5	133.3
JMW	41.6	150.0	514.8	1068.0	118.4	31.8	19.7	71.2	244.4	507.1	56.2	16.1	58.1
RWV	33.2	183.6	412.2	1011.3	84.6	42.4	31.8	176.1	395.4	970.0	81.1	29.3	162.1
JHS	46.5	228.2	437.2	1273.6	111.0	55.5	40.1	196.9	377.2	1099.1	95.8	31.8	156.1
ABK	63.8	300.3	461.6	1692.4	158.4	74.1	44.9	211.4	325.0	1191.4	111.5	29.7	139.8
MO	53.2	238.4	541.0	1418.4	133.2	67.1	40.7	182.5	414.1	1085.8	102.0	29.7	133.2
REH	44.0	171.6	629.6	1253.7	125.6	46.6	28.6	111.6	409.2	814.7	81.6	19.6	76.5
BSB	79.2	355.3	678.7	2115.7	193.3	48.0	34.4	154.0	294.2	917.1	83.8	27.9	125.2
RGR	48.5	209.8	461.6	1287.7	119.4	57.1	35.9	155.4	341.8	953.6	88.4	30.2	130.5
SJT	45.1	138.6	175.6	983.8	115.7	55.1	25.4	77.9	98.8	553.2	65.1	15.2	46.7
EH	54.6	222.0	448.3	1424.8	133.2	65.3	40.7	165.3	333.7	1060.7	99.2	30.5	124.0
IO	20.0	52.9	168.0	336.9	53.7	22.0	11.6	30.7	97.6	195.7	31.2	9.5	25.1
NGM	45.1	176.9	674.2	1255.4	115.5	64.9	37.5	147.0	560.1	1043.0	95.9	31.2	122.3
MW	58.2	216.8	411.7	1404.9	136.7	69.2	40.7	151.6	287.8	982.2	95.6	32.3	120.5
JAF	70.4	278.4	602.2	1924.5	180.4	83.5	46.3	183.0	396.0	1265.3	118.6	28.8	114.0
ASD	51.1	197.4	447.9	1301.0	128.3	63.9	36.9	142.5	323.5	939.5	92.7	27.7	107.1
AA	54.0	237.7	414.4	1471.9	132.9	80.9	46.7	205.4	358.0	1271.7	114.8	34.6	152.4
DWA	34.6	112.2	412.5	993.9	103.9	45.9	23.9	77.4	284.3	685.0	71.6	19.2	62.3
JP	52.5	196.6	390.0	1364.2	141.7	74.8	36.2	135.4	268.5	939.4	97.6	22.7	85.1
ELG	54.8	216.3	399.3	1400.7	131.8	71.0	42.9	169.4	312.8	1097.5	103.3	31.4	124.1
RBF	57.7	187.9	338.0	1417.7	149.4	70.1	35.5	115.6	207.9	872.1	91.9	19.7	64.3
BSF	69.0	239.9	642.6	1671.0	176.0	64.0	34.6	120.4	322.5	838.6	88.3	22.2	77.1
TJB	52.9	195.8	326.5	1247.1	127.6	66.8	38.6	142.7	238.0	909.1	93.0	27.7	102.5
CWG	52.6	255.7	890.0	1687.2	148.8	62.2	37.1	180.3	627.5	1189.6	104.9	26.8	130.4
CS	41.2	182.7	502.8	1038.7	103.0	41.8	28.3	125.5	345.3	713.4	70.7	23.7	105.0
Corr	-0.43	-0.53	-0.42	-0.55	-0.46	-0.39	-0.43	-0.49	-0.42	-0.52	-0.44	-0.39	-0.44

Init	$\sqrt{hc_1}$	$\sqrt{hc}$	$\sqrt{hg}$	$\sqrt{wc_{10}}$	$\sqrt{wc_1}$	$\sqrt{wc}$	$\sqrt{wg}$	$\sqrt{c_{10}c_1}$	$\sqrt{c_{10}c}$	$\sqrt{c_{10}g}$	$\sqrt{c_1c}$	$\sqrt{c_1g}$	$\sqrt{cg}$
AS	550.2	1909.6	134.5	173.7	338.1	1173.7	82.7	1727.1	5995.0	422.2	11673.3	822.2	2853.8
JJH	609.4	1473.2	113.1	109.6	330.9	800.0	61.4	1576.5	3811.2	292.6	11510.0	883.6	2136.2
JES	426.4	1196.0	96.8	71.4	222.7	624.6	50.6	883.0	2476.5	200.5	7727.0	625.5	1754.3
RJB	419.4	1269.5	99.4	131.4	257.5	779.5	61.0	1471.4	4454.5	348.8	8727.6	683.4	2068.9
DA	377.5	1064.7	89.9	103.5	235.7	664.8	56.1	1060.8	2992.4	252.7	6812.1	575.2	1622.5
PP	330.1	740.4	68.6	56.8	179.4	402.5	37.3	783.8	1757.9	162.9	5555.5	514.8	1154.7
JT	305.7	1180.8	99.3	88.6	169.0	652.7	54.9	680.7	2629.3	221.2	5013.6	421.7	1628.8
KSR	321.8	1133.4	92.5	111.0	213.1	750.6	61.2	946.5	3333.3	271.9	6399.2	522.1	1838.6
REL	449.9	841.4	73.3	95.3	314.2	587.7	51.2	1497.0	2800.0	243.9	9232.5	804.1	1504.1
JYC	255.6	946.3	84.0	101.7	163.8	606.5	53.8	724.7	2682.6	238.1	4320.0	383.5	1419.5
OJB	300.4	1027.8	88.6	101.5	179.2	613.2	52.8	866.5	2965.0	255.5	5232.3	451.0	1543.2
GSB	296.4	881.6	76.8	116.4	216.4	643.8	56.1	1050.2	3123.8	272.1	5806.3	505.7	1504.2
PN	56.6	265.6	32.0	17.3	27.7	130.1	15.7	80.0	375.6	45.3	601.0	72.4	340.1
TJS	156.9	642.0	65.4	55.0	87.7	358.9	36.5	321.9	1317.1	134.1	2099.0	213.7	874.3
MSF	227.6	550.9	56.6	33.3	112.4	272.1	27.9	374.6	906.4	93.0	3058.8	314.0	759.8
BJE	143.5	669.3	64.7	42.3	69.6	324.7	31.4	245.3	1144.0	110.5	1883.8	182.0	848.7
RB	508.0	928.6	81.6	75.6	307.1	561.3	49.3	1222.2	2234.2	196.3	9072.0	797.0	1456.9
NC	3.5	10.5	3.0	0.0	0.0	0.0	0.0	2.0	6.1	1.7	12.2	3.5	10.5
DEC	195.0	814.5	76.4	71.0	112.6	470.3	44.1	444.0	1854.7	173.9	2941.0	275.7	1151.9
MLG	320.9	950.3	79.3	115.2	232.0	687.1	57.3	1162.0	3441.4	287.2	6930.4	578.5	1713.2
CMR	367.9	1112.7	94.3	94.4	205.7	622.0	52.7	971.2	2937.5	249.0	6396.8	542.2	1639.9
EFF	318.4	796.9	68.0	106.5	244.2	611.2	52.2	1300.3	3254.2	277.7	7462.9	636.8	1593.8
JL	191.9	617.6	62.2	46.9	107.0	344.5	34.7	358.4	1153.5	116.2	2633.0	265.2	853.7
PRK	347.7	842.4	76.2	79.8	218.8	530.0	47.9	918.6	2225.4	201.3	6102.3	552.1	1337.4
CFB	99.1	197.5	28.1	15.9	57.2	114.0	16.2	151.4	301.6	43.0	1087.5	155.0	308.7
RFE	491.6	1061.9	87.7	96.4	302.0	652.3	53.9	1456.0	3145.3	259.7	9848.5	813.1	1756.4
MHP	388.5	928.3	80.8	64.6	217.6	520.0	45.3	878.8	2100.0	182.8	7070.9	615.4	1470.7
RL	322.7	1040.0	88.8	102.5	194.2	625.8	53.4	947.4	3053.5	260.8	5785.6	494.1	1592.5
ECP	309.6	785.1	71.5	73.9	200.3	508.0	46.3	821.8	2084.1	189.9	5652.7	515.0	1306.1
LHS	248.1	829.2	77.8	76.2	141.9	474.4	44.5	601.2	2009.4	188.5	3740.1	350.8	1172.7
JMW	199.6	414.0	45.9	36.1	123.8	256.8	28.5	446.3	925.8	102.6	3178.1	352.3	730.8
RWV	364.0	893.2	74.7	121.8	273.4	670.8	56.1	1513.4	3713.1	310.5	8337.2	697.1	1710.3
JHS	299.1	871.4	75.9	112.9	216.2	630.0	54.9	1061.3	3092.0	269.4	5923.1	516.1	1503.6
ABK	215.0	788.1	73.7	84.7	130.3	477.6	44.7	613.4	2248.8	210.4	3457.1	323.5	1186.1
MO	302.2	792.4	74.4	80.7	183.2	480.3	45.1	821.4	2153.8	202.3	4887.4	458.9	1203.4
REH	280.7	558.9	56.0	46.9	171.9	342.3	34.3	671.2	1336.6	133.9	4902.5	491.2	978.1
BSB	239.2	745.6	68.1	89.7	171.3	534.0	48.8	767.9	2393.9	218.7	4573.1	417.8	1302.5
RGR	287.2	801.2	74.3	82.1	180.7	504.1	46.7	781.0	2178.8	202.1	4793.0	444.5	1240.1
SJT	59.1	331.3	39.0	21.5	27.2	152.6	17.9	83.6	468.5	55.1	593.8	69.8	391.1
EH	250.4	796.0	74.4	77.2	155.9	495.7	46.3	634.0	2015.0	188.4	4068.4	380.3	1208.8
IO	79.7	159.8	25.5	13.2	42.0	84.2	13.4	111.2	222.9	35.5	707.7	112.7	226.0
NGM	466.0	867.9	79.8	70.6	269.1	501.1	46.1	1055.5	1965.6	180.8	7489.9	688.9	1282.9
MW	228.8	781.0	76.0	70.8	134.5	459.0	44.7	501.3	1711.0	166.5	3249.1	316.2	1079.0
JAF	246.7	788.2	73.9	63.2	136.8	437.2	41.0	540.8	1728.2	162.0	3738.7	350.5	1120.0
ASD	243.1	706.0	69.6	61.8	140.3	407.6	40.2	542.4	1575.4	155.4	3575.3	352.6	1024.1
AA	265.6	943.5	85.2	88.0	153.4	544.8	49.2	674.6	2396.3	216.4	4177.3	377.2	1339.9
DWA	229.1	551.9	57.7	32.4	119.1	286.9	30.0	385.9	929.7	97.2	3416.6	357.2	860.7
JP	168.8	590.3	61.3	41.2	81.6	285.6	29.7	305.5	1068.6	111.0	2119.8	220.2	770.2
ELG	229.1	803.6	75.6	75.0	138.5	485.7	45.7	546.5	1917.2	180.4	3539.7	333.2	1168.8
RBF	115.7	485.2	51.1	32.6	58.6	245.7	25.9	190.7	799.9	84.3	1438.9	151.6	635.9
BSF	206.5	537.0	56.6	41.7	111.7	290.5	30.6	388.3	1009.8	106.3	2704.5	284.8	740.7
TJB	171.0	653.1	66.8	59.2	98.7	377.1	38.6	365.2	1395.1	142.7	2326.4	238.0	909.1
CWG	453.9	860.5	75.9	77.8	270.7	513.1	45.3	1315.6	2494.0	220.0	8680.3	765.6	1451.3
CS	288.9	596.9	59.2	71.0	195.3	403.6	40.0	866.8	1790.6	177.5	4927.2	488.4	1008.9
Corr	-0.37	-0.49	-0.41	-0.41	-0.36	-0.47	-0.39	-0.38	-0.47	-0.42	-0.42	-0.35	-0.48

Table 2: Ranking of the 54 researchers according to each of the 36 metrics. The bottom row shows the sum of the ranks of the 13 Nobel prize winners (in bold). The three rightmost columns show the harmonic mean HM of ranks, the arithmetic mean AM of ranks, and the geometric mean of ranks GM, respectively.

Init	n	i_{10}	h	w	c_{10}	c_1	c	g	$\sqrt{ni_{10}}$	$\sqrt{nh}$	$\sqrt{nw}$	$\sqrt{nc_{10}}$	$\sqrt{nc_1}$
AS	23	3	1	1	1	8	1	1	13	5	3	1	8
JJH	8	2	2	4	8	3	2	2	4	3	2	2	1
JES	4	1	4	26	31	12	5	8	1	1	1	5	2
RJB	27	19	6	4	2	11	3	3	23	23	16	3	10
DA	13	5	8	4	12	16	11	10	6	8	5	4	9
PP	5	10	35	41	37	14	32	34	5	6	7	7	4
JT	17	4	3	10	22	31	9	10	11	7	8	11	21
KSR	25	25	11	2	10	24	4	4	24	21	10	9	20
REL	50	47	39	14	14	2	16	15	49	49	46	36	11
JYC	42	30	12	4	15	37	21	21	38	36	27	23	44
OJB	24	15	8	12	11	28	14	14	21	17	15	8	22
GSB	46	43	32	3	6	22	15	15	44	42	37	21	30
PN	1	42	51	51	51	52	51	52	2	2	4	28	48
TJS	19	19	26	39	40	48	42	42	18	20	21	32	49
MSF	9	11	39	46	47	33	46	47	10	12	28	42	16
BJE	3	6	21	42	44	49	41	44	3	4	9	17	37
RB	22	15	18	20	29	1	19	18	20	22	17	19	3
NC	2	54	54	54	54	54	54	54	54	54	54	54	54
DEC	20	11	15	26	32	44	34	33	15	13	14	18	42
MLG	48	45	35	4	4	18	7	6	48	45	39	24	28
CMR	28	19	5	14	16	20	10	9	25	19	20	12	18
EFF	53	50	47	14	5	9	12	12	51	51	50	44	38
JL	15	13	32	40	42	43	43	43	14	15	19	37	29
PRK	33	28	26	20	24	13	23	22	31	33	29	29	14
CFB	16	52	52	51	52	47	52	51	43	44	49	52	47
RFE	35	26	17	14	13	5	6	5	30	30	26	15	7
MHP	14	8	21	33	35	10	18	18	12	11	13	16	5
RL	37	23	10	12	9	25	13	12	28	28	25	13	25
ECP	43	38	38	26	28	19	24	24	40	41	40	38	23
LHS	26	22	13	26	25	38	31	31	22	25	22	22	31
JMW	31	51	50	46	46	27	48	45	46	46	47	49	26
RWV	54	49	42	10	3	7	8	6	52	52	52	45	41
JHS	51	39	35	4	7	21	17	15	47	48	42	30	36
ABK	21	17	23	26	18	42	30	30	19	24	18	10	32
MO	39	30	23	26	21	23	29	28	35	37	33	26	24
REH	36	40	49	42	41	15	39	39	39	43	45	48	17
BSB	10	44	42	14	17	29	25	24	26	16	6	6	12
RGR	44	40	26	20	23	26	27	27	42	40	41	35	33
SJT	12	30	48	50	50	53	50	50	17	27	43	50	52
EH	39	33	23	20	27	32	28	28	37	37	31	31	34
IO	52	53	52	53	53	50	53	53	53	53	53	53	53
NGM	47	37	15	26	33	6	26	26	41	39	44	47	13
MW	29	33	13	20	34	41	36	35	32	26	23	33	43
JAF	11	7	18	33	36	36	35	35	8	10	11	14	19
ASD	34	36	26	33	38	34	37	37	36	34	38	39	35
AA	41	18	7	14	19	35	22	22	29	29	32	27	39
DWA	45	45	45	46	49	30	44	41	45	47	51	51	40
JP	17	14	31	45	43	46	45	46	16	18	36	40	46
ELG	37	26	18	20	30	40	33	31	33	32	30	34	45
RBF	7	9	42	46	48	51	49	49	7	14	24	43	50
BSF	6	24	39	42	45	39	47	47	9	9	12	25	15
TJB	30	29	26	33	39	45	40	40	27	31	34	41	51
CWG	31	35	32	33	20	4	20	18	34	35	35	20	6
CS	49	48	46	33	26	17	38	38	50	50	48	46	27
Sum	422	377	338	269	275	219	249	248	399	396	381	338	264

Init	$\sqrt{nc}$	$\sqrt{ng}$	$\sqrt{i_{10}h}$	$\sqrt{i_{10}w}$	$\sqrt{i_{10}c_{10}}$	$\sqrt{i_{10}c_1}$	$\sqrt{i_{10}c}$	$\sqrt{i_{10}g}$	$\sqrt{hw}$	$\sqrt{hc_{10}}$	$\sqrt{hc_1}$	$\sqrt{hc}$	$\sqrt{hg}$
AS	3	5	2	1	1	3	1	1	1	1	2	1	1
JJH	2	2	1	2	2	1	2	2	2	3	1	2	2
JES	1	1	3	4	7	4	3	3	12	19	8	4	5
RJB	7	14	13	6	3	11	6	6	5	2	9	3	3
DA	4	6	5	3	4	8	5	5	6	8	11	8	8
PP	5	3	19	27	27	10	16	16	41	38	15	36	35
JT	6	10	4	5	6	15	4	4	3	10	21	5	4
KSR	9	13	18	7	9	17	7	10	4	7	17	6	7
REL	41	46	44	43	31	12	33	42	30	20	7	23	32
JYC	27	34	22	15	14	34	18	20	7	13	30	13	13
OJB	13	16	9	8	5	18	11	8	9	5	23	11	10
GSB	34	41	41	30	16	29	29	38	13	11	25	18	19
PN	17	4	49	50	51	53	51	51	51	51	53	51	51
TJS	30	26	24	29	37	48	36	29	36	40	47	40	39
MSF	25	20	25	40	45	23	37	28	45	46	39	46	45
BJE	11	7	6	22	36	45	23	19	40	41	48	38	40
RB	14	15	14	11	18	2	13	11	19	27	3	15	14
NC	54	54	54	54	54	54	54	54	54	54	54	54	54
DEC	18	17	10	9	17	40	17	15	21	30	43	25	20
MLG	28	40	42	36	23	27	27	39	16	12	18	12	17
CMR	15	18	8	14	10	14	9	9	8	6	12	7	6
EFF	47	51	50	45	30	26	42	46	38	18	19	28	37
JL	26	21	21	23	41	38	32	26	39	43	44	41	41
PRK	24	29	29	21	25	13	21	21	24	25	14	22	21
CFB	52	48	52	52	52	50	52	52	52	52	50	52	52
RFE	16	22	23	18	11	5	10	13	14	14	4	9	11
MHP	8	9	11	16	19	7	8	7	31	33	10	16	15
RL	19	27	15	13	8	16	12	14	10	4	16	10	9
ECP	37	38	38	35	35	21	31	34	33	34	20	33	33
LHS	23	25	16	19	20	32	22	22	18	21	32	24	18
JMW	46	43	51	51	50	46	50	50	49	49	42	49	49
RWV	49	52	47	44	26	24	35	45	28	9	13	17	26
JHS	42	47	39	28	15	25	24	32	16	15	24	19	23
ABK	20	19	20	17	12	35	19	18	26	17	40	32	31
MO	32	31	30	24	22	19	26	25	26	22	22	30	27
REH	44	39	45	46	47	20	46	44	47	45	28	44	47
BSB	10	8	43	42	33	41	41	43	32	26	35	35	36
RGR	40	42	37	38	32	31	38	40	24	23	27	27	29
SJT	51	44	40	48	48	51	49	49	50	50	52	50	50
EH	31	31	32	25	29	33	28	27	23	29	31	29	27
IO	53	53	53	53	53	52	53	53	53	53	51	53	53
NGM	43	45	33	32	38	9	30	31	21	31	5	20	16
MW	35	30	28	25	34	42	34	33	15	32	38	34	22
JAF	12	11	7	12	21	22	15	12	29	35	33	31	30
ASD	39	36	35	34	40	36	39	36	34	36	34	37	34
AA	29	33	12	10	13	28	14	17	11	16	29	14	12
DWA	50	49	46	49	49	43	48	47	48	48	37	45	44
JP	38	28	17	37	42	44	40	30	43	42	46	43	42
ELG	36	35	26	20	28	39	25	24	19	28	36	26	25
RBF	33	23	27	39	46	49	44	37	46	47	49	48	48
BSF	22	12	34	41	44	37	45	41	44	44	41	47	45
TJB	45	37	31	31	39	47	43	35	34	39	45	39	38
CWG	21	24	36	33	24	6	20	23	36	24	6	21	24
CS	48	50	48	47	43	30	47	48	42	37	26	42	43
Sum	346	376	376	346	307	246	317	339	317	291	232	284	304

Init	$\sqrt{wc_{10}}$	$\sqrt{wc_1}$	$\sqrt{wc}$	$\sqrt{wg}$	$\sqrt{c_{10}c_1}$	$\sqrt{c_{10}c}$	$\sqrt{c_{10}g}$	$\sqrt{c_1c}$	$\sqrt{c_1g}$	$\sqrt{cg}$	HM	AM	GM
AS	1	1	1	1	1	1	1	1	2	1	1.35	2.86	1.72
JJH	8	2	2	2	2	3	4	2	1	2	2.00	2.64	2.26
JES	30	13	13	18	19	19	25	9	11	6	3.34	9.39	5.82
RJB	2	9	3	4	5	2	2	6	9	3	4.47	7.86	5.81
DA	10	11	7	6	12	12	13	14	14	11	6.95	8.39	7.66
PP	39	25	38	39	25	35	36	22	20	33	12.80	23.25	18.23
JT	18	29	8	9	29	17	17	24	28	10	7.89	12.50	9.95
KSR	7	18	4	3	17	6	8	15	17	4	7.61	11.64	9.55
REL	15	3	18	17	4	15	15	4	4	16	11.83	25.08	18.76
JYC	12	30	17	12	28	16	16	30	30	21	17.45	22.83	20.37
OJB	13	26	15	14	22	13	12	23	26	14	12.27	14.81	13.54
GSB	4	16	10	8	14	9	7	19	21	15	14.26	22.86	18.77
PN	51	52	51	52	53	51	51	52	52	51	11.37	42.61	31.56
TJS	40	46	40	40	46	41	40	47	47	41	33.17	36.22	34.80
MSF	47	42	47	48	43	48	48	41	41	46	28.37	36.14	32.89
BJE	43	48	43	43	48	43	44	48	48	44	15.14	31.89	24.65
RB	27	4	19	19	9	23	26	5	5	19	7.96	15.42	12.45
NC	54	54	54	54	54	54	54	54	54	54	31.35	52.56	49.28
DEC	31	41	33	34	40	33	34	42	43	34	21.68	26.78	24.25
MLG	5	12	5	5	10	5	5	13	13	7	11.39	21.33	15.90
CMR	16	19	14	15	15	14	14	16	16	9	11.76	13.86	12.83
EFF	9	10	16	16	8	7	6	11	10	12	16.67	28.28	22.16
JL	41	44	41	41	45	42	42	44	44	43	30.05	34.67	32.61
PRK	23	14	22	22	18	24	24	17	15	23	21.24	22.67	21.98
CFB	52	50	52	51	50	52	52	50	49	52	47.61	49.61	48.93
RFE	14	5	9	11	6	8	11	3	3	5	8.68	13.17	10.76
MHP	35	15	23	28	20	27	30	12	12	18	13.39	17.33	15.25
RL	11	22	12	13	16	11	10	20	22	13	13.26	16.19	14.71
ECP	29	20	25	25	23	28	27	21	19	24	28.36	30.14	29.25
LHS	26	33	32	33	34	30	28	33	36	31	24.65	26.17	25.43
JMW	46	39	48	47	39	47	46	40	35	48	43.74	44.94	44.40
RWV	3	6	6	7	3	4	3	8	7	8	9.76	24.75	16.08
JHS	6	17	11	10	11	10	9	18	18	17	16.30	24.11	20.22
ABK	20	38	31	31	33	22	21	37	39	30	22.74	25.50	24.14
MO	22	23	30	30	24	26	22	27	25	29	26.17	26.89	26.52
REH	42	27	42	42	31	40	41	26	23	39	35.33	38.56	37.17
BSB	17	28	21	21	27	21	19	29	29	25	19.19	25.92	22.85
RGR	21	24	26	23	26	25	23	28	27	27	29.08	30.61	29.82
SJT	50	53	50	50	52	50	50	53	53	50	41.90	46.53	44.86
EH	25	31	28	24	32	29	29	32	31	28	29.00	29.56	29.28
IO	53	51	53	53	51	53	53	51	51	53	52.54	52.56	52.55
NGM	34	8	27	26	13	31	31	10	8	26	18.60	26.89	23.14
MW	33	37	34	32	38	37	35	39	40	36	30.09	32.25	31.31
JAF	36	36	35	35	37	36	37	34	37	35	18.42	25.03	21.86
ASD	37	34	36	36	36	38	38	35	34	37	35.59	35.78	35.69
AA	19	32	20	20	30	20	20	31	32	22	19.06	22.72	20.94
DWA	49	40	45	45	42	46	47	38	33	42	44.11	44.69	44.42
JP	45	47	46	46	47	44	43	46	46	45	34.13	38.61	36.73
ELG	28	35	29	27	35	32	32	36	38	32	29.19	30.56	29.90
RBF	48	49	49	49	49	49	49	49	50	49	29.57	40.69	36.67
BSF	44	43	44	44	41	45	45	43	42	47	26.06	35.94	32.04
TJB	38	45	39	38	44	39	39	45	45	40	37.39	38.36	37.89
CWG	24	7	24	28	7	18	18	7	6	20	14.51	21.67	18.44
CS	31	21	37	37	21	34	33	25	24	38	34.95	38.00	36.57
Sum	282	220	260	269	233	261	265	224	223	249	287.75	298.39	292.95

Table 3: Correlations between the 36 metrics for the 54 highest ranked researchers in RePEc.

	n	i_{10}	h	w	c_{10}	c_1	c	g	$\sqrt{ni_{10}}$	$\sqrt{nh}$	$\sqrt{nw}$	$\sqrt{nc_{10}}$
n	1.00	0.23	-0.15	-0.43	-0.42	-0.31	-0.29	-0.41	0.66	0.65	0.43	0.13
i_{10}		1.00	0.80	0.37	0.19	0.14	0.45	0.44	0.85	0.86	0.83	0.74
h			1.00	0.80	0.62	0.36	0.79	0.81	0.48	0.58	0.71	0.82
w				1.00	0.91	0.52	0.91	0.95	0.03	0.14	0.45	0.73
c_{10}					1.00	0.57	0.91	0.90	-0.12	-0.01	0.27	0.66
c_1						1.00	0.67	0.69	-0.07	-0.03	0.14	0.39
c							1.00	0.96	0.13	0.24	0.48	0.78
g								1.00	0.10	0.20	0.48	0.77
$\sqrt{ni_{10}}$									1.00	0.98	0.87	0.61
$\sqrt{nh}$										1.00	0.92	0.70
$\sqrt{nw}$											1.00	0.88
$\sqrt{nc_{10}}$												1.00

	$\sqrt{nc_1}$	$\sqrt{nc}$	$\sqrt{ng}$	$\sqrt{i_{10}h}$	$\sqrt{i_{10}w}$	$\sqrt{i_{10}c_{10}}$	$\sqrt{i_{10}c_1}$	$\sqrt{i_{10}c}$	$\sqrt{i_{10}g}$	$\sqrt{hw}$	$\sqrt{hc_{10}}$	$\sqrt{hc_1}$
n	0.07	0.29	0.52	0.06	-0.10	-0.21	-0.17	-0.09	-0.06	-0.32	-0.36	-0.33
i_{10}	0.58	0.85	0.83	0.96	0.85	0.68	0.59	0.81	0.88	0.61	0.46	0.40
h	0.56	0.80	0.64	0.94	0.97	0.92	0.71	0.94	0.95	0.94	0.84	0.67
w	0.44	0.57	0.33	0.59	0.80	0.89	0.64	0.79	0.74	0.95	0.96	0.73
c_{10}	0.38	0.45	0.19	0.40	0.63	0.83	0.59	0.68	0.58	0.81	0.94	0.71
c_1	0.77	0.38	0.18	0.25	0.38	0.51	0.86	0.52	0.44	0.47	0.55	0.93
c	0.63	0.70	0.43	0.63	0.80	0.92	0.80	0.88	0.79	0.90	0.96	0.85
g	0.64	0.67	0.42	0.63	0.81	0.92	0.80	0.86	0.80	0.93	0.96	0.87
$\sqrt{ni_{10}}$	0.48	0.77	0.91	0.72	0.55	0.35	0.32	0.51	0.60	0.25	0.10	0.10
$\sqrt{nh}$	0.52	0.84	0.95	0.77	0.63	0.45	0.37	0.59	0.67	0.37	0.22	0.17
$\sqrt{nw}$	0.63	0.93	0.97	0.82	0.78	0.65	0.52	0.74	0.79	0.61	0.48	0.38
$\sqrt{nc_{10}}$	0.71	0.94	0.84	0.82	0.88	0.89	0.71	0.89	0.89	0.82	0.80	0.64
$\sqrt{nc_1}$	1.00	0.79	0.70	0.60	0.62	0.62	0.93	0.73	0.72	0.53	0.51	0.84
$\sqrt{nc}$		1.00	0.94	0.87	0.86	0.80	0.74	0.89	0.90	0.72	0.64	0.61
$\sqrt{ng}$			1.00	0.79	0.71	0.59	0.56	0.71	0.76	0.50	0.39	0.39
$\sqrt{i_{10}h}$				1.00	0.95	0.83	0.67	0.91	0.96	0.80	0.66	0.54
$\sqrt{i_{10}w}$					1.00	0.94	0.74	0.96	0.98	0.93	0.84	0.67
$\sqrt{i_{10}c_{10}}$						1.00	0.77	0.96	0.92	0.96	0.96	0.77
$\sqrt{i_{10}c_1}$							1.00	0.84	0.80	0.71	0.70	0.96
$\sqrt{i_{10}c}$								1.00	0.98	0.91	0.86	0.78
$\sqrt{i_{10}g}$									1.00	0.88	0.80	0.71
$\sqrt{hw}$										1.00	0.96	0.74
$\sqrt{hc_{10}}$											1.00	0.78
$\sqrt{hc_1}$												1.00

	$\sqrt{hc}$	$\sqrt{hg}$	$\sqrt{wc_{10}}$	$\sqrt{wc_1}$	$\sqrt{wc}$	$\sqrt{wg}$	$\sqrt{c_{10}c_1}$	$\sqrt{c_{10}c}$	$\sqrt{c_{10}g}$	$\sqrt{c_1c}$	$\sqrt{c_1g}$	$\sqrt{cg}$
n	-0.26	-0.29	-0.43	-0.41	-0.36	-0.42	-0.41	-0.37	-0.42	-0.33	-0.38	-0.34
i_{10}	0.62	0.65	0.27	0.24	0.43	0.41	0.18	0.32	0.29	0.30	0.25	0.45
h	0.92	0.95	0.71	0.58	0.81	0.81	0.54	0.72	0.71	0.60	0.54	0.81
w	0.91	0.92	0.97	0.79	0.97	0.99	0.80	0.93	0.95	0.76	0.72	0.93
c_{10}	0.84	0.80	0.99	0.80	0.94	0.92	0.88	0.98	0.99	0.79	0.75	0.92
c_1	0.59	0.55	0.56	0.93	0.62	0.61	0.89	0.63	0.63	0.93	0.96	0.68
c	0.97	0.92	0.93	0.86	0.98	0.94	0.89	0.97	0.95	0.89	0.83	0.99
g	0.95	0.95	0.94	0.89	0.98	0.99	0.89	0.95	0.96	0.88	0.86	0.99
$\sqrt{ni_{10}}$	0.27	0.30	-0.06	-0.06	0.09	0.07	-0.11	0.00	-0.04	0.02	-0.03	0.12
$\sqrt{nh}$	0.39	0.41	0.05	0.02	0.20	0.17	-0.03	0.11	0.07	0.09	0.03	0.23
$\sqrt{nw}$	0.60	0.63	0.35	0.27	0.48	0.47	0.23	0.38	0.36	0.31	0.27	0.48
$\sqrt{nc_{10}}$	0.84	0.84	0.70	0.58	0.78	0.76	0.58	0.73	0.72	0.62	0.56	0.79
$\sqrt{nc_1}$	0.64	0.63	0.42	0.74	0.56	0.54	0.65	0.51	0.49	0.77	0.78	0.64
$\sqrt{nc}$	0.78	0.77	0.51	0.50	0.66	0.62	0.47	0.58	0.54	0.57	0.51	0.69
$\sqrt{ng}$	0.54	0.56	0.25	0.25	0.40	0.37	0.20	0.31	0.28	0.32	0.27	0.43
$\sqrt{i_{10}h}$	0.79	0.83	0.49	0.41	0.63	0.62	0.36	0.52	0.50	0.45	0.40	0.64
$\sqrt{i_{10}w}$	0.91	0.94	0.71	0.59	0.82	0.82	0.56	0.72	0.72	0.61	0.56	0.81
$\sqrt{i_{10}c_{10}}$	0.97	0.97	0.88	0.73	0.93	0.92	0.75	0.90	0.89	0.76	0.70	0.93
$\sqrt{i_{10}c_1}$	0.81	0.80	0.62	0.88	0.75	0.73	0.82	0.70	0.68	0.91	0.90	0.81
$\sqrt{i_{10}c}$	0.95	0.95	0.74	0.69	0.86	0.83	0.67	0.79	0.77	0.74	0.68	0.88
$\sqrt{i_{10}g}$	0.90	0.92	0.66	0.61	0.78	0.78	0.57	0.69	0.68	0.65	0.60	0.80
$\sqrt{hw}$	0.96	0.98	0.89	0.72	0.94	0.95	0.71	0.87	0.88	0.72	0.67	0.92
$\sqrt{hc_{10}}$	0.96	0.95	0.97	0.80	0.98	0.97	0.83	0.97	0.97	0.80	0.75	0.97
$\sqrt{hc_1}$	0.83	0.81	0.74	0.97	0.82	0.81	0.93	0.80	0.79	0.98	0.98	0.87
$\sqrt{hc}$	1.00	0.98	0.89	0.80	0.97	0.94	0.80	0.92	0.90	0.83	0.77	0.97
$\sqrt{hg}$		1.00	0.86	0.77	0.94	0.94	0.75	0.87	0.88	0.78	0.74	0.94
$\sqrt{wc_{10}}$			1.00	0.81	0.97	0.97	0.86	0.98	0.99	0.80	0.75	0.94
$\sqrt{wc_1}$				1.00	0.85	0.84	0.98	0.85	0.85	0.99	0.99	0.88
$\sqrt{wc}$					1.00	0.99	0.87	0.98	0.98	0.86	0.81	0.99
$\sqrt{wg}$						1.00	0.85	0.95	0.97	0.83	0.80	0.97
$\sqrt{c_{10}c_1}$							1.00	0.90	0.90	0.98	0.96	0.90
$\sqrt{c_{10}c}$								1.00	0.99	0.86	0.80	0.97
$\sqrt{c_{10}g}$									1.00	0.85	0.81	0.97
$\sqrt{c_1c}$										1.00	0.99	0.90
$\sqrt{c_1g}$											1.00	0.85
$\sqrt{cg}$												1.00