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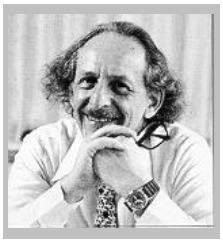

Current Comments®

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'Of Nobel Class': Part 1. An Overview of ISI Studies on Highly Cited Authors and Nobel Laureates

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Since 1980, we have published one or more essays each year on the annual Nobel prizes. These essays have included a citation analysis of each prizewinner's work. Many of these laureates have previously written *Citation Classics*®, which also are identified. Other essays have discussed the close relationship between high citation frequency and authors we've identified as "of Nobel class." Perhaps the most comprehensive study was our series of six essays on the 1,000 most-cited authors for 1965-1978.[1] This and other similar lists include many who have either won the prize already, or go on to win in the future. Indeed, several writers have used citation data to forecast the Nobel awards. For example, in a 1989 article in *The Scientist*,[2] David Pendlebury identified 20 likely candidates for the Nobel prize for medicine. The list included J. Michael Bishop and Harold E. Varmus of the University of California. Both won the prize that year. Subsequently, Angela Martello used the same technique to forecast the chemistry winner, Elias J. Corey of Harvard, in 1990.[3]

Recently, we—myself and Alfred Welljams-Dorof, my scientific assistant at the Institute for Scientific Information® (ISI®)—were invited to review these studies and to discuss methodological problems in using data on citation frequency for a special issue of *Theoretical Medicine*, published quarterly by Kluwer Academic Publishers in The Netherlands. Our article—"*Of Nobel Class*: A Citation Perspective on High Impact Research Authors"[4]—is reprinted below. Because of its length, we have divided it into two parts. A separate but related essay will follow by the editor of *Theoretical Medicine*, B. Ingemar B. Lindahl, describing the other articles in the issue.

Alfred Welljams-Dorof

Effect on Science Discussed

Entitled "Discovery, Theory Change, and the Nobel Prize: On the Mechanisms of Scientific Evolution,"[5] this special issue deals with the problems of evaluating scientific discoveries in the selection of Nobel prize winners as well as with the effect on science of the Nobel prize—now in its 91st year. Lindahl, an associate professor of the theory of medical science at the Karolinska Institute, Stockholm, points out in the introduction to the issue that "disciplines like information science, history of science and ideas, and sociology of science provide opportunities for a fuller

philosophical understanding of the evolution of scientific knowledge."[6]

Not unfamiliar to readers of *Current Contents®* is the work of Harriet Zuckerman of the Andrew W. Mellon Foundation and Columbia University. We often have quoted from her classic book *Scientific Elite*.[7] Her contribution to the issue is a paper on "The Proliferation of Prizes: Nobel Complements and Nobel Surrogates in the Reward System of Science"[8] It calls attention to the increasing number of major scientific awards in general beyond the Nobel prizes, five times in North America alone in the last 20 years.[9] She discusses the implications of this phenomenon in terms of whether the new prizes have effected an important change in the reward system of science. She also addresses the important issue of the effect a Nobel prize has on the behavior of scientists and on the evolution of scientific knowledge as a whole.

Other authors in the issue include Kenneth F. Schaffner of the Department of History and Philosophy of Science, University of Pittsburgh, and Franz Luttenberger of the Department of History of Science and Ideas, University of Uppsala, Sweden. Schaffner has written a two-part article on theory change in immunology. Luttenberger's work examines the election process for the Nobel prizes for physiology or medicine at the Karolinska Institute.[10-12] Interestingly, the process has three components: 1) an international nominating system, 2) a Nobel Assembly, consisting of 50 of 141 professors at the institute, and 3) an award committee, consisting of six professors, also from the institute.

The Question of Impact

As Lindahl states, the concept of scientific impact (that is, influence on the theory change in science), and how this should be distinguished from citation frequency in general, is an important issue to address in the philosophical study of the "science of science." He correctly adds that this philosophical question is beyond the scope of our paper reprinted below.

However, our paper does discuss citation frequency as one indicator of a researcher's impact on science. Previous studies of most-cited authors are reviewed, along with methodological problems associated with using data on citation frequency. Finally, we comment on the possibility of forecasting Nobel prize winners based on citation data or in combination with other indicators. Both Pendlebury[2] and Martello[3] included other "predictor awards" in their forecasts.

A. Welljams-Dorof

Al Dorof has been with ISI for about 10 years and has specialized in citation-based analyses. He formerly served as director of Editorial Services. We have coauthored several articles on science fraud, language trends in science, the uses and misuses of citation analyses, and so on. He also has made presentations at various international congresses in Spain, Germany, and Czechoslovakia. Al has a BA in history and philosophy from the University of Pennsylvania, and has completed work toward a master's degree at Penn's Annenberg School of Communications.

B.I.B. Lindahl

Lindahl was born in Stockholm in 1949. He received his BA in theoretical philosophy from Stockholm University. In 1985, he received his doctor of medical science degree from the Karolinska Institute. That same year, he joined the editorial board of *Theoretical Medicine,* and was appointed editor of the 13-year-old journal in 1989. He is presently researching theoretical problems in diagnosing Alzheimer's disease.

We will discuss Lindahl's background in more detail later.

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My thanks to Paul R. Ryan and Eric Thurschwell for their help in the preparation of this introduction.

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OF NOBEL CLASS: A CITATION PERSPECTIVE ON HIGH IMPACT RESEARCH AUTHORS

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ABSTRACT. The purpose of this paper was to determine if quantitative rankings of highly cited research authors confirm Nobel prize awards. Six studies covering different time periods and author sample sizes were reviewed. The number of Nobel laureates at the time each study was published was tabulated, as was the number of high impact authors who later became laureates. The Nobelists and laureates-to-be were also compared with non-Nobelists to see if they differed in terms of impact and productivity. The results indicate that high rankings by citation frequency identify researchers *of Nobel class*—that is, a small set of authors that includes a high proportion of actual Nobelists and laureates-to-be. Also, the average impact (citations per author) of Nobelists and laureates-to-be is sufficiently high to distinguish them from non-Nobelists in these rankings. In conclusion, a simple, quantitative, and objective algorithm based on citation data can effectively corroborate—*and even forecast*—a complex, qualitative, and subjective selection process based on human judgement.

Key words: citation analysis, citation impact, Nobel prize, Science Citation Index, scientometrics

1. INTRODUCTION

The Nobel prize is unique among all the awards in science. Since 1901 when the first laureates were named, the Nobels have become the universally recognized symbol of research excellence both by the scientific community and the general public. The public perception of an award's prestige is influenced by many factors. Among these, according

to Harriet Zuckerman, Columbia University, are the age of the prize, the amount of its honorarium, the reputation of its sponsoring organization, and the stature of its recipients.[1]

The Nobel Committee's power to confer so coveted and prestigious a prize on a small, elite group of scientists and the secrecy that shrouds its selection process also add to the prize's mystique and visibility. For a few weeks every October, the scientific community holds its breath in anticipation of the Nobel Committee's pronouncements on the new laureates in medicine, physics, and chemistry. And for several months after, the science and popular press profile the winners and try to intuit the Nobel Committee's subjective deliberations.

For 25 years now, the Institute for Scientific Information® (ISI®) has published analyses of citation patterns in the research literature to determine whether or not they confirm—*and even anticipate*—the Nobel awards. The idea is straightforward. Presumably, the Nobel prize is awarded to researchers who have made breakthrough discoveries in science. The papers they publish ought to be seminal and more influential than the average, and thereby become important or significant.

One means of characterizing the impact of researchers, both Nobelists and non-Nobelists, is to count their papers and the number of times they are cited. The researchers can then be compared on the basis of *productivity* (articles per author), *author impact* (citations per author), and *article impact* (citations per paper).

The purpose of this study is to review six major ISI rankings of high impact authors to determine how many already were Nobel laureates at the time each ranking was published and how many authors later went on to win the prize. The Nobelists and laureates-to-be were also compared with non-Nobelists to see if they differed in terms of impact and productivity.

The results indicate that high rankings by citation frequency are strongly correlated with Nobel class authors. In the highest percentile, e.g. the top 0.1% of authors, a significant percentage have won the Nobel prize or go on to win the prize in later years. Also, the author impact of Nobelists is sufficiently high to distinguish them from non-Nobelists. But in terms of author productivity, the margin of difference between Nobelists and non-Nobelists is slight.

Out of the million scientists in the world, it is remarkable that any system can identify a small set of authors that includes a high proportion of both present and future Nobelists. It is even more remarkable because the citation-based system is a quantitative and objective algorithm that does not rely on subjective or qualitative enhancement.

2. REVIEW OF SIX MAJOR ISI STUDIES OF MOST-CITED AUTHORS

The ISI database includes more than 14 million source articles published in thousands of journals since 1945, and more than 200 million references they cited. Over the years, we have published literally scores of studies examining, directly or indirectly, the relationship between citedness and Nobel awards. The studies vary widely in the number of most-cited authors or articles considered, ranging from the top 50 to 1,000. They also vary by time span, some covering annual data files while others are based on multiyear cumulations of the *Science Citation Index®* (*SCI®*), *Social Sciences Citation Index®* (*SSCI®*), and *Arts & Humanities Citation Index®* (*A&HCI®*).

Instead of detailing the particulars of each study, we offer a summary of six major multipart studies of most-cited authors.[2-18] Table I provides data on total numbers of

Table I
Summary information on most-cited author studies based on *Science Citation Index* (*SCI*) data.

	1967[a]	1972[b]	1961-72[b]	1961-75[c]	1961-76[d]	1965-78[e]
PRE Nobel						
Authors	8	5	5	13	15	26
Citations	6,274	4,859	40,376	94,586	99,468	120,248
Impact	784	972	8075	7276	6631	4625
POST Nobel						
Authors	6	7	13	38	22	35
Citations	5,107	6,966	100,923	279,472	146,652	174,252
Impact	851	995	7763	7355	6666	4979
ALL Nobel						
Authors	14	12	18	51	37	61
Citations	11,381	11,825	141,299	374,058	246,120	294,500
Impact	813	985	7850	7334	6652	4828
NON Nobel						
Authors	36	38	32	198	263	939
Citations	29,287	34,091	259,613	1,194,775	1,402,326	3,515,504
Impact	813	897	8113	6034	5332	3744
*Authors	35	37	31	197		
*Citations	26,366	28,166	224,415	1,136,471	NA	NA
*Impact	753	761	7239	5769		
Total						
Authors	50	50	50	249	300	1,000
Citations	40,668	45,916	400,912	1,568,833	1,648,446	3,810,004

[a] Based on [2]
[b] Based on [3]
[c] Based on [4-6]
[d] Based on [7-11]
[e] Based on [12-17]
*Excluding citations to O.H. Lowry.

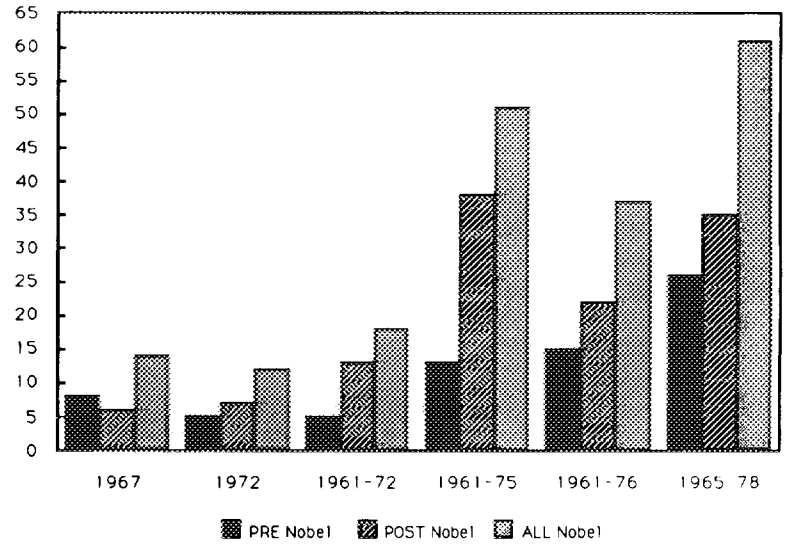
authors, time spans, and other statistical details for these studies. Readers may refer to the original papers[2-18] to examine the lists of authors and papers—far too extensive to reproduce here.

In each of these studies, we determined which and how many authors already were Nobel laureates (post-Nobel) or went on to win the prize later (pre-Nobel). We then compared them with non-Nobelists in terms of impact and productivity.

As this review will show, most-cited author rankings effectively identify groups or sets of authors *of Nobel class*,[18] including actual Nobelists. This is not surprising, since citation data have been shown to correlate highly with other indicators of "prestige" or "eminence," such as peer ratings, academy memberships, etc.[19-22]

But ISI's system also effectively *forecasts* future laureates—that is, identifies a group of most-likely candidates. This is remarkable because a simple, quantitative, and objective algorithm can consistently anticipate a highly subjective and qualitative selection process.

Of course, not every most-cited author will go on to win the Nobel prize, although virtually all Nobelists are highly cited within their specialties. Some may rank high on the basis of just a few high impact papers. Others may be listed because of widely cited



N = 50, 50, 50, 249, 300, and 1,000

Fig. 1. Number of Nobelists appearing in six ISI studies of most-cited research authors. "PRE Nobel" refers to researchers who become laureates *after* each study was published. "POST Nobel" refers to those who already were laureates. See Table I for detailed data on each study.

methods. But even the highest impact authors who have made major theoretical contributions are not assured of Nobel recognition—while many may be deserving, only a few are honored. Zuckerman refers to this group as occupants of the "41st chair" who are not included in the French Academy's limited membership of 40—they are "peers of prize-winners in every sense except that of having the award."[1] (p. 42)

2.1. Nobelists Versus Average Authors

The six studies to be reviewed were initiated by a report presented in 1965.[22] This was the earliest ISI study related to citedness and Nobel prize winners. It was based on a list of about 256,000 *primary* authors cited in the 1961 *SCI*. That is, only the *first* author of a cited paper was identified, credited with all citations, and ranked. Co-authors were excluded. The names of the 1962 and 1963 Nobel prize winners in physics, chemistry, and medicine were checked against the ranked list. Their publication and citation statistics were compared against those for the average author in the same file.

The results showed striking differences: the average Nobel author received 169 citations, 30 times more than the average author (5.5). In addition, Nobelists were far more productive than the average. They published 58.1 cited papers, 17 times more than the average (3.37). But as a result, the average Nobelist-authored paper was cited 2.9 times, "only" about double the average article (1.6). These results—higher author impact, productivity, and paper impact—were characteristic throughout the later studies.

2.2. Nobelists Versus Most-Cited Authors

The results led us to ask early on whether lists of most-cited authors could be used to forecast Nobel prize winners. In a 1970 *Nature* paper,[2] the 50 most-cited primary authors

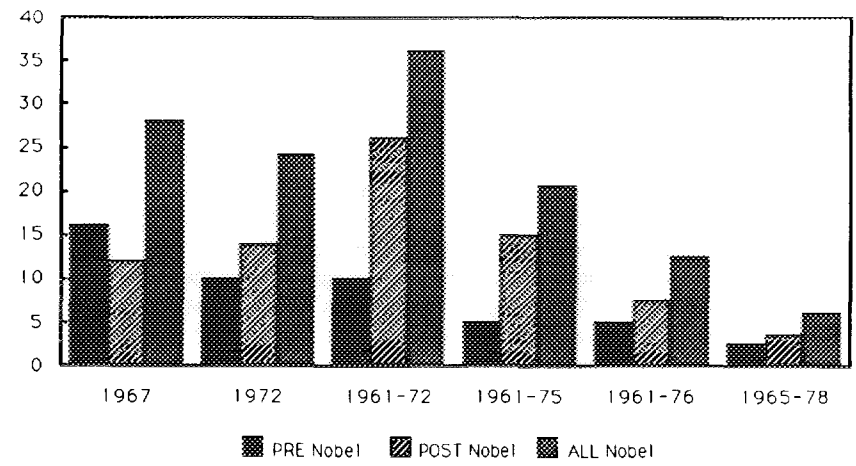
in the 1967 *SCI* were identified. The list included six scientists (12.0%) who had already won the Nobel prize through 1967. Even more interesting, eight others listed (16.0%) went on to become laureates after 1967. Out of that list, derived from a single annual file of 1967 data, 14 Nobelists (28.0%) have been identified through 1990.

Subsequent lists have identified authors most-cited in later years with increasing time frames and numbers of authors: 1972 (50 authors),[3] 1961-72 (50),[3] 1961-75 (249),[4-6] 1961-76 (300),[7-11] and 1965-78 (1,000).[12-17] The first three were based on primary author data. But the last two were "all author" rankings, which included high impact *co*-authors for the first time.

Figure 1 summarizes the number of Nobel laureates that appeared in these studies. The first bar indicates the number of *pre*-Nobel authors listed—that is, laureates-to-be who went on to win the prize after the concluding year in each study. The middle bar shows *post*-Nobel authors—those who had already won the prize. The last bar represents the *total* number of Nobelists.

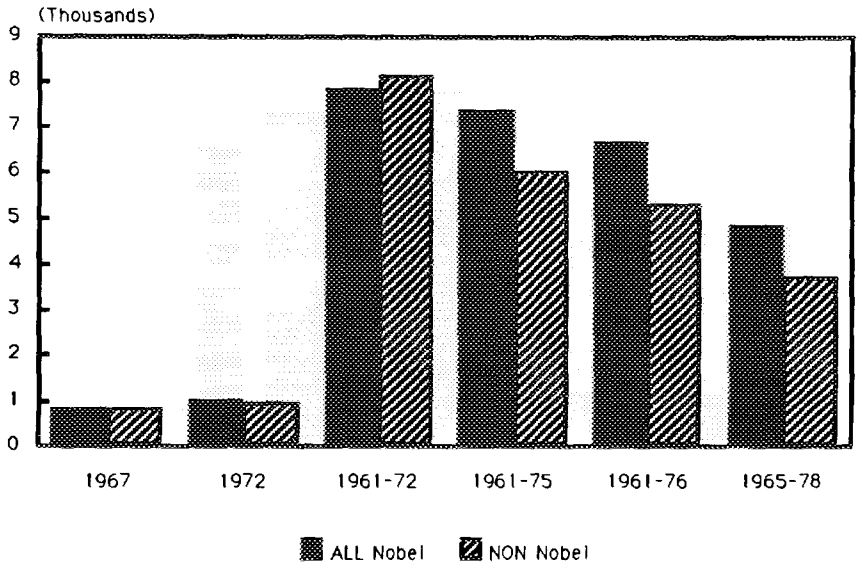
In general, more Nobelists are identified as the studies increase in time frame and numbers of authors (Table I). The exception is the 1961-76 list of 300 most-cited authors. It listed 37 Nobelists, including those who had already won the prize by 1976 and laureates-to-be through 1990, compared with 51 in the 1961-75 list of 249 authors. Keep in mind that the 1961-76 study was the first to restrict the publication years of cited papers. It identified most-cited authors based on papers published from 1961 through 1978. Thus, Nobelists who were highly cited for work prior to 1961 were not included. Also, this was the first "all-author" list and included high impact *co-authors*. Adding co-authors increases the number of non-Nobel authors in the pool because Nobelists only occasionally write papers with other laureates.

The data also show that, in general, most-cited author rankings identify more Nobelists who have already won the prize than laureates-to-be. Whatever the number of authors or time frame for citation and/or publication, the method both *corroborates* existing Nobelists



N = 50, 50, 50, 249, 300, and 1,000

Fig. 2. Percentage of Nobelists appearing in six ISI studies of most-cited research authors. "PRE Nobel" refers to researchers who became laureates *after* each study was published. "POST Nobel" refers to those who already were laureates. See Table I for detailed data on each study.



N = 50, 50, 50, 239, 300, and 1,000

Fig. 3. Author impact (average number of citations per author) of Nobelists and NON Nobelists researchers appearing in six ISI studies of most-cited research authors. See Table I for detailed data on each study.

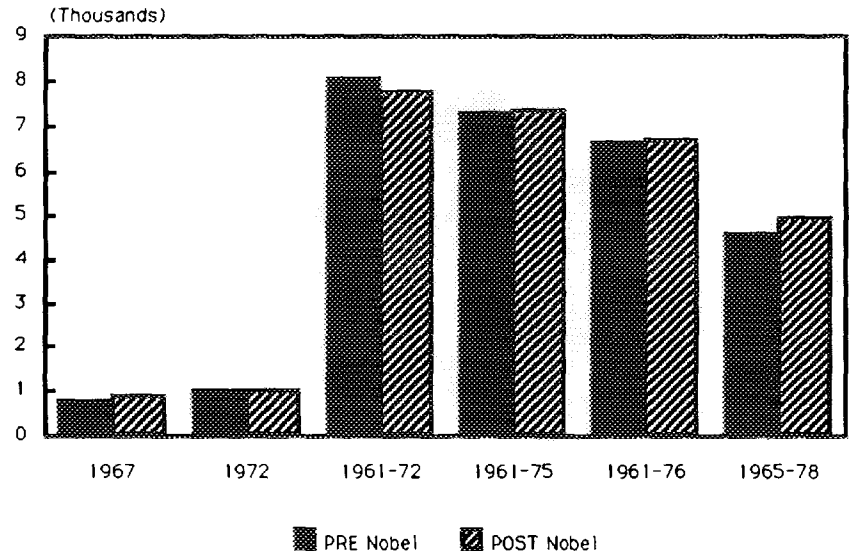
and *anticipates* a significant number. The forecasting power of the citation analyses we have conducted is remarkable in that 26 future laureates were identified.[12-17]

On a percentage basis, however, the highest yields of Nobelists come in the smaller studies involving fewer authors, as shown in Figure 2. In the first three studies covering different years but including the top 50 authors, Nobelists on average represented 29.3%—17.3% who already won the prize and 12.0% laureates-to-be. In the next two larger studies involving 249 and 300 authors, Nobelists averaged 16.0—10.9% post-Nobelists and 5.1% laureates-to-be. In the 1,000 author study, the Nobelist average drops to 6.1%—3.5% post-Nobels and 2.6% pre-Nobels.

These data show that most Nobelists rank high on most-cited lists, because of their greater impact and productivity as authors. Extending lists beyond the top 50-100 names yields greater absolute numbers of Nobelists, but they inevitably account for a smaller proportion of the total.

2.3. Nobel Authors Have Higher Impact

Figure 3 compares the average number of citations per author for Nobelists and non-Nobelists. In general, the impact of Nobelists is comparable to non-Nobelists but increases appreciably in larger studies covering more recent years. The difference is greatest in the 1,000 author study—the average Nobelist author impact (4828) is 28.9% higher than for the non-Nobelist (3744). When Nobelists who had already won the prize are compared with laureates-to-be, there is virtually no difference across the studies, as is shown in Figure 4.



N = 50, 50, 50, 239, 300, and 1,000

Fig. 4. Author impact (average number of citations per author) of Nobelists appearing in six ISI studies of most-cited research authors. "PRE Nobel" refers to researchers who became laureates *after* each study was published. "POST Nobel" refers to those who already were laureates. See Table I for detailed data on each study.

Thus, the impact of Nobelists, both present and future, is sufficiently high to distinguish them from non-Nobelists. The difference is not as great as in the study discussed earlier, which compared Nobelists with the average author in the *SCI* file.[22] Of course, the basis for comparison here is the *most*-cited authors, a very select group representing less than 1% of all scientists. In other words, these authors might be considered to be *of Nobel class*. The fact that several go on to win the prize merely reinforces this point. But, as stated earlier, not everyone listed will eventually win the Nobel prize. While virtually all Nobelists are highly cited, not every high impact author is a laureate-to-be.

2.4. Nobel Papers Have Higher Impact, Too

Two of the most-cited article studies included data on papers—the 1961-76 and 1965-78 all-author lists. They allow comparisons on the basis of paper impact (average citations per paper) and productivity (average papers per author) as well. The data are presented in Table II.

The average paper by a Nobel author was cited about 25% more than a non-Nobel paper. Papers by Nobelists who had already won the prize were cited about 38% more than papers by laureates-to-be. And the impact of papers by laureates-to-be is only slightly higher (about 15%) than that of non-Nobelists in the top group.

In terms of productivity, *non*-Nobelists show the higher overall averages, accounting for 152.2 and 121.5 papers per author, compared to 136.3 and 118.4 for Nobelists. However, laureates-to-be have the edge—they produced 169.7 and 127.1 papers per author. But, again, the margin of difference is slight.

Table II
Article impact and author productivity in two most-cited author studies based on *Science Citation Index* (*SCI*) data.

	1961-76[a]	1965-78[b]
PRE Nobel		
Authors	15	26
Papers	2,546	3,304
Citations	99,468	120,248
Impact	39.1	36.4
Productivity	169.7	127.1
POST Nobel		
Authors	22	35
Papers	2,496	3,919
Citations	146,652	174,252
Impact	58.8	44.5
Productivity	113.4	112.0
ALL Nobel		
Authors	37	61
Papers	5,042	7,223
Citations	246,120	294,500
Impact	48.8	40.8
Productivity	136.3	118.4
NON Nobel		
Authors	263	939
Papers	40,016	114,119
Citations	1,402,326	3,515,504
Impact	35.0	30.8
Productivity	152.1	121.5
Total		
Authors	300	1,000
Papers	45,058	121,342
Citations	246,120	294,500
Impact	5.5	2.4
Productivity	150.2	121.3

[a] Based on [7-11]
[b] Based on [12-17].

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