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The age at which Noble Prize research is conducted

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Abstract
Nobel Laureates are used as a proxy to study at what age scientists produce their most groundbreaking work. We determine the average age of Nobel Laureates at the time that their Prize-winning research was conducted. This is done using the Advanced Information document with scientific background information published by the Nobel Foundation for every awarded Nobel Prize since 1995 for physics and economics, 2000 for chemistry and 2006 for physiology or medicine. For all Laureates their average age when their Prize-winning research was conducted was 44.1 ± 9.7, with Laureates in physics generally being younger compared to the other fields. It is shown to be statistically significant that Laureates in physics have published their Nobel Prize winning works within a shorter span of years compared to the other fields, whereas Laureates in economics use a longer span of years. The number of papers cited by the Nobel Foundation for each Laureate was found to be 9.6 ± 8.6, with Laureates in physics have significantly fewer papers cited compared to the other fields, 5.4 ± 4.8, while Laureates in economics have significantly more, 17.3 ± 11.5. Finally, we find that Laureates wait an average of 22.3 ± 10.8 years between conducting their prize-winning research and receiving the Nobel Prize.

Keywords Nobel Prize · Age · Highest-impact work · Number of papers · Waiting time · Average age

Introduction

At what age do a scientist produce the most groundbreaking work? This general question remains unanswered although a lot is known about the productivity of scientists in general. What is known it that there is no correlation between a scientists highest-impact publication and its publication time within that scientists career (Sinatra et al. 2016). This is even though other research have shown that most scientists are most productive within the first 8 years after first becoming faculty (Way et al. 2017; Clauset et al. 2017). However, judging a scientific career simply by their most cited works may not be entirely fair, and a more objective evaluation of a scientific career should be found. Fortunately, there exist a well

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known and well respected group of scientists, that have had their most important contribution to science evaluated by an external committee of the highest standard. These are the Nobel Laureates, for whom the Nobel Foundation publishes a detailed evaluation of the work for which they are awarded the Nobel Prize.

It is therefore of interest to ask how old the Lauretes were when they conducted the research for which they were later awarded the Nobel Prize? This simple yet tantalizing question is far from trivial to answer, even through the Nobel Foundation provides a plethora of information regarding Nobel Laureates. For example it is well known that the average age at which the Nobel Prize is awarded is 59 for Laureates in all prize categories, for the period between 1901 and 2016 (https://www.nobelprize.org/nobel_prizes/lists/laureates_ages/all_ages.html). However, this tells us little of when the research, for which the prize was awarded, was actually conducted.

The original wording of Alfred Nobel's will states that

> the capital, invested in safe securities by my executors, shall constitute a fund, the interest on which shall be annually distributed in the form of prizes to those who, during the preceding year, shall have conferred the greatest benefit to mankind.

However the statement regarding "the preceding year" is not followed, and thus the average age of the Laureates says nothing of when they conducted their prize-winning research. This question will be considered in the following.

Literature review

As the Nobel Prize is unarguably the most prestigious award within science, research has also been conducted on how the prize has been awarded. The network of Nobel Laureates in physiology or medicine was investigated by Wagner et al. (2015) in terms of impact, coauthorship and international collaboration patterns. The result was that Laureates produce fewer but more cited papers. Also no difference in international collaboration patterns was found compared to a reference group. However, Chan et al. (2015) investigated if Nobel Laureates change their patterns of collaboration following prize reception. The results indicate less collaboration with new coauthors post award. In a further study Chan et al. (2016) also found that publications of Nobel Laureates with collaborators tended to be cited more if they were work done early in the time span of the collaboration. In another study Schlagberger et al. (2016) looked at the affiliated institutions of Nobel Laureates from physics, chemistry and medicine/physiology. The finding was that as a country USA dominated in the number of affiliated Laureates, and the three institutions that was found to contain a larger number of Laureates at all time, UC Berkeley, Columbia University and the Massachusetts Institute of Technology (MIT), are also located there. Finally, Karazija and Momkauskait (2004) considered the distribution of Nobel Prizes to different subfields in physics, as well as the difference in awards between theoretical and experimental work. The pattern of awards received by Nobel Laureates both before and after being award the Nobel Prize has also been studied by Chan et al. (2014). It was shown that the rate of awards increased up to being awarded the Nobel Prize, after which it drops sharply. Further work by Chan and Torgler (2015) also showed that Nobel Laureates with a theoretical background received more awards compared to Laureates doing empirical research.

With regards to the question of at what age Nobel Prize research is conducted Manniche and Falk (1957) investigated a total of 164 scientists, comprising all Nobel Prize winners in the period 1901–1950, to determine the age at which a Laureate made his or hers Nobel Prize awarded contribution to science. The age was estimated based on the date of publication of the articles specified in the award citation by the Nobel Prize committee. The conclusion was an average age at the time of doing the Nobel Prize award work of 35.4 ± 1.0 for physics, 38.3 ± 1.1 for chemistry and 41.9 ± 0.9 for physiology or medicine. This analysis was subsequently revisited by Stephan and Levin (1993), who determined the relationship between age and productivity for Nobel Prize winners in science during the period 1901–1992. The conclusion was that the odds of winning a nobel prize decrease markedly in mid-life and fall off precipitously after age 50, particularly in chemistry and physics. An investigation by Chan and Torgler (2013) looked at the waiting period between scientific discovery and being awarded the Nobel Prize. Studying 466 Nobel Laureates and using a biographical encyclopedia to identify the year in which laureates produced their Nobel Prize winning work it was found that in physics, the waiting time was just 5 years, whereas in chemistry it was 9 years and in medicine the time was 11 years.

The question of when Nobel Prize research is conducted has also been investigated by Jones and Weinberg (2011), who also analyzed at what age a Laureate has done the awarded Nobel Prize research. The analysis was done for all Laureates up to 2008, and the result was that the mean age of prize-winning work increased by up to 13.4 years (for physics) over the last century. The authors concluded that the frequency of great achievement at young ages is more a function of time than field. Interestingly, specifics events in science, such as the development of quantum mechanics, is directly observable as a decease in prize-winning age. However, it should be noted that the work of Jones and Weinberg (2011) relies on an identification of the single most important contribution of a Laureate, using scientific literature as well as individual biographies. This choice of most important work can be subjective, especially for modern day Laureates, which tend to be awarded the Prize for a large number of publications, as will be discussed subsequently. It should be mentioned that Jones and Weinberg (2011) do estimates the middle year of the research period to define the age at great achievement for some Laureates. Finally, Baffes and Vamvakidis (2011) discusses whether Laureates are selected based on their age. The conclusion is that if there is a preference for older Nobel candidates, this is introduced during the nomination process.

Most works on answering the question of when Nobel Prize research is conducted has relied on the subjective choice of determining which scientific paper was most important for a given Laureate in earning them the Nobel Prize. In this work we determine at what age Nobel Prize research is conducted using only official information from the Nobel Foundation, removing this subjective choice. Furthermore, we also consider the field of economics, which have so far been excluded in all the above analyses.

Method and results

The data material for this research is the document entitled Advanced Information which the Nobel Foundation publishes. This document gives the scientific background, including references to the relevant articles, for which the Prize is awarded. This document has been published since 1995 for physics and economics, since 2000 for chemistry and since 2006 for physiology or medicine. In total data on 178 Laureates have been analyzed and compiled into a database. Of these 61 Laureates was in physics, 46 in chemistry, 30 in physiology or medicine and 41 in economics. In the following we will refer to the award in the field of physiology or medicine as “medicine”.

Using this database of references, we have calculated the average age of the Laureates at the time that the papers cited by the Nobel committee was published. The average number of papers per Laureate cited in the Advanced Information is 9.6, as will be discussed subsequently. The average age of Laureates when their Prize-winning research was conducted is shown in Fig. 1a binned in 5 year intervals, while the probability of the different age categories for the different fields is shown in Fig. 1b. The average age when the Prize-winning research was conducted for all Laureates is 44.1 ± 9.7, but as the numbers of Laureates within each field varies, this number must be taken with caution. For the individual fields the values are 42.0 ± 12.5 for physics, 46.5 ± 7.7 for chemistry, 45.1 ± 8.5 for medicine and 43.9 ± 6.9 for economics. These values are comparable to Jones and Weinberg (2011), who find an average Laureate research age of 39.0 ± 8.54, while their results for the individual fields are 37.2 ± 9.20 for physics, 40.2 ± 8.24 for chemistry, 39.9 ± 7.86 for medicine, for the entire period that the Nobel Prize has been awarded. These ages are all older that the corresponding values found by Manniche and Falk (1957) for the period 1901–1950, clearly illustrating that Nobel Laureates conduct their prize-winning work at a later age today.

In Fig. 1b the probability of the different age groups is shown for the different fields. The distribution between the different fields is seen to be somewhat different. The probability of being awarded the prize in physics for research conducted at an age below 40 is much greater than for the other three fields, where the distribution peaks between ages 40 and 50. A two-sample Kolmogorov–Smirnov test for the null hypothesis is that the age data for when Nobel prize research is conducted as determined by Jones and Weinberg (2011) and as determined in this work are from the same continuous distribution has been conducted for the field of physics, chemistry and medicine, for the same range of years. The p value for the different field are $p_{phys} = 0.87$, $p_{chem} = 0.08$ and $p_{medi} = 0.92$ respectively. Thus the null hypothesis cannot be rejected. The data presented in Jones and Weinberg (2011) was in that work compared with a previous work by Kragh (1999) for physicists and the work of Stephan and Levin (1993) for the field of physics, chemistry and medicine. There was a correlation in the determined year

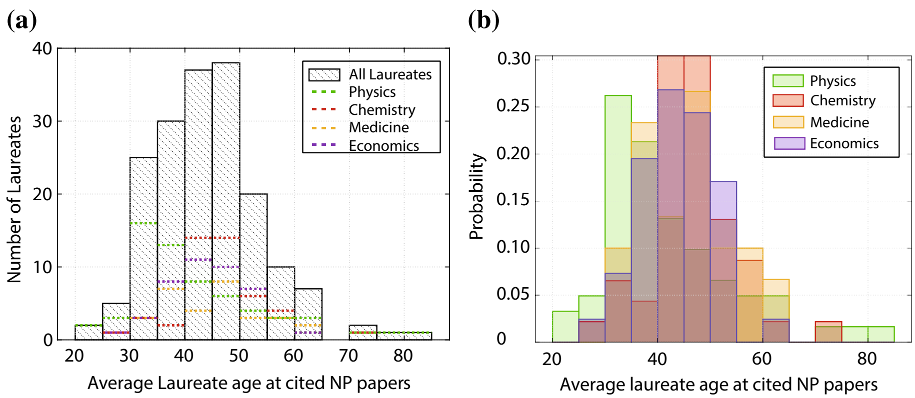

Fig. 1 **a** The average Laureate age at the time that the papers cited by the Nobel Prize (NP) committee was published, **b** the probability of the different age categories for the different fields

Table 1 The p value for the hypothesis is that different age data are from the same continuous distribution using a two-sample Kolmogorov–Smirnov test

p value	Physics	Chemistry	Medicine	Economics
Physics	–	7.1e–06	0.05	0.02
Chemistry		–	0.27	0.12
Medicine			–	0.84
Economics				–

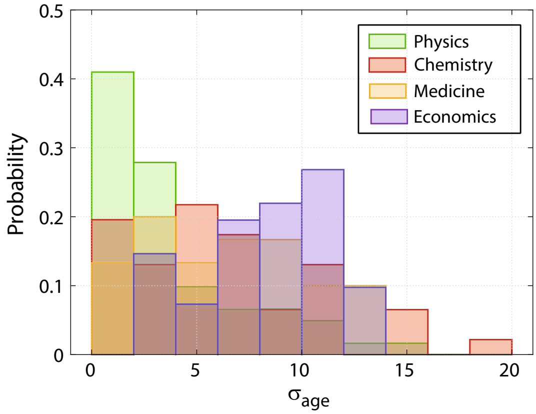

Fig. 2 The standard deviation, σ_{age}, on the average Laureate age shown in Fig. 1 for the different fields

of greatest Nobel Prize awarded work of 0.995 and 0.974, respectively, between these works. These high values of correlation puts trust in the data collection scheme used in this work.

It is of interest to compare the age distribution for the different fields in which the Nobel Prize is awarded. A two-sample Kolmogorov–Smirnov test for the null hypothesis is that different age data are from the same continuous distributions has been conducted. The computed p values are given in Table 1. At the 1% significance level all tests rejects the null hypothesis, except the test on physics/chemistry, where the result is statistically significant.

As previously mentioned each Laureate has a number of papers cited by the Nobel Prize committee. The papers are published in different years, and thus the average age at which the prize-winning research was conducted have a standard deviation, σ_{age}, which is shown in Fig. 2. As can be seen, Laureates in physics have a much smaller standard deviation then the other fields, meaning that Laureates in physics have published their Nobel Prize cited works within a shorter span of years compared to the other fields. It is also of interest to note that Laureates in economics tend to have published their cited Nobel Prize papers over a longer time span compared to the other fields. To determine the statistical significance of these statements, again a two-sample Kolmogorov–Smirnov test for the null hypothesis is that different standard deviation data are from the same continuous distributions has been conducted. The computed p values are given in Table 2. For this test at the 1% significance level, the difference in the standard deviation for physics compared to all other fields is statistically significant, as is the difference for economics with all other fields. Thus Laureates in physics published their Nobel Prize winning work in a much shorter time span than in other fields, whereas in economics the time span is much longer. The reason for this will be discussed subsequently.

Table 2 The p value for the hypothesis is that different σ_{age} data are from the same continuous distribution using a two-sample Kolmogorov–Smirnov test

p value	Physics	Chemistry	Medicine	Economics
Physics	–	0.0049	3.6e−6	5.8e−9
Chemistry		–	0.27	2.0e−6
Medicine			–	6.0e−4
Economics				–

Papers per Laureate

The number of papers cited by the Nobel Prize committee for each Laureate is shown in Fig. 3a for all Laureates and in Fig. 3b the probability for each field is shown. The average number of cited works by the Nobel Prize committee for all Laureates is 9.6 ± 8.6. Laureates in physics are given the Prize based on much fewer number of papers compared to Laureates in other fields, with an average number of papers of 5.4 ± 4.8. For the other fields the values are 8.1 ± 5.5 for chemistry, 9.8 ± 6.5 for medicine and 17.3 ± 11.5 for economics. Thus Laureates in economics have by far the largest number of papers cited by the Nobel Prize committee, resulting in a distribution markedly different from the other fields. Again a two-sample Kolmogorov–Smirnov test for the null hypothesis is that different number of papers data are from the same continuous distributions has been conducted. The computed p values are given in Table 3. For this test at the 1% significance level, the difference number of papers for physics compared to all other fields is statistically significant. Furthermore, the number of papers for economics is statistically different from chemistry.

Waiting for the Prize

Finally, we have also determined the time between conducting the Prize-awarded research and being awarded the Nobel Prize. This data for each individual Laureate is shown in Fig. 4. The distribution of this "waiting time" has been fitted with a normal distribution, with a resulting mean value and standard deviation of 22.3 ± 10.8 years. This is thus the

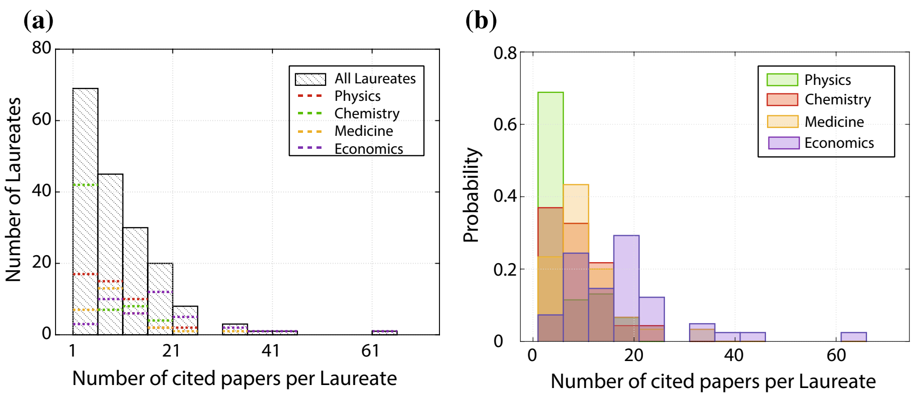

Fig. 3 **a** The number of papers per Laureate cited by the Nobel Prize committee, **b** the probability for the different fields

Table 3 The p value for the hypothesis is that different number of papers data are from the same continuous distribution using a two-sample Kolmogorov–Smirnov test

p value	Physics	Chemistry	Medicine	Economics
Physics	–	2.1e−4	9.6e−4	9.5e−09
Chemistry		–	0.94	0.0040
Medicine			–	0.014
Economics				–

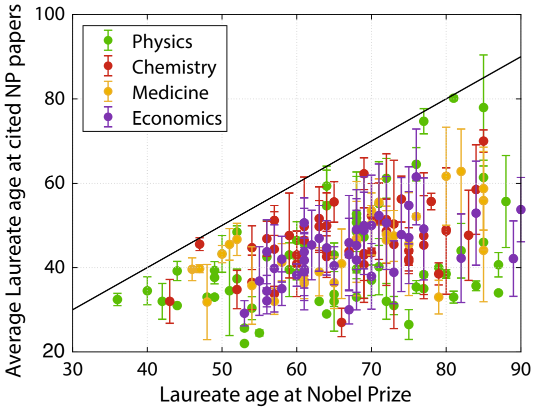

Fig. 4 The average Laureate age at the time that the papers cited by the Nobel Prize (NP) committee was published as function of the age of the Laureate when the Nobel Prize was awarded

mean waiting time for all Laureates consider in this study. For the individual fields, the fitted mean and standard deviation are 23.5 ± 14.0 years for physics, 20.8 ± 9.2 years for chemistry, 21.2 ± 9.4 years for medicine and 23.2 ± 7.5 years for economics. These waiting times are much longer than those determined by Chan and Torgler (2013) as mentioned earlier in the work. However, that study consider the period from 1901 to 2000, where especially during the early period the waiting time was very short.

Discussion

The above analysis showed that the scientific fields can be grouped in three statistically different groups. These are physics in one group, chemistry and medicine in another and economics in the final. While the age distribution between Laureates in physics and the other fields were not statistically significant, it was shown statistically that Laureates in physics have published their Nobel Prize work within a shorter span of years compared to the other fields. The number of papers published by Laureates in physics were also statistically different from the other fields. These two phenomena are likely dependent, i.e. because Laureates in physics needs to publish fewer papers to be awarded a Nobel Prize, they can do so over a shorter time period. The opposite is true for Laureates in economics, where Laureates must publish a larger number of papers, which thus takes a correspondingly longer time. These findings indicates that Laureates in physics are awarded the Prize for a single scientific discovery while Laureates in economics are given the Prize for establishing and promoting a new economic theory over many years. Also, Laureates in physics have a chance of doing their single scientific discovery early in their research career, explaining the tendency for Laureates in physics to be younger than in other fields. The fields of chemistry and medicine are situated in between physics and economics in terms of time span and the number of papers required to be awarded a Nobel Prize.

The present study uses the Advanced Information published by the Nobel Foundation to establish the statistics reported above. In the analysis we assume that all works by a Nobel Laureate cited by the Nobel Foundation are equally important. However, this may not always be the case. On the other hand, as discussed previously selecting or ordering the scientific works of each Laureate remains at best a subjective exercise, so this is no ideal alternative.

For future work, the time dependence of some of the quantities reported in this work, such as the age distribution and the number of papers, would be of interest studying, provided that a source of information for the years before 1995 as trustworthy as the Advanced Information by the Nobel Foundation could be found.

Conclusion

In conclusion, using the Advanced Information document with scientific background published by the Nobel Foundation for each awarded Nobel Prize since 1995 for physics and economics, since 2000 for chemistry and since 2006 for medicine, we have determined the average Laureate age at the time that the papers cited by the Nobel committee was published. For all Laureates the average age was 44.1 ± 9.7. Laureates in physics were shown to be younger when conducting their Nobel prize research as compared to the other fields. It was shown to be statistically significant that Laureates in physics have published their Nobel Prize work within a shorter span of years compared to the other fields, where Laureates in economics take a longer span of years. The number of papers cited by the Nobel Foundation for each Laureate was also investigated and it was shown that Laureates in physics have significantly fewer cited papers while Laureates in economics have more, compared to the other fields. This clearly indicates that Laureates in physics are awarded the Prize for a single scientific discovery while Laureates in economics are given the Prize for establishing and promoting a new economic theory over many years. Finally, we showed that Laureates wait an average of 22.3 ± 10.8 years between conducting their award-winning research and receiving the Nobel Prize.

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