Creative Careers: The Life Cycles of Nobel Laureates in Economics

Bruce A. Weinberg & David W. Galenson

De Economist
Netherlands Economic Review

ISSN 0013-063X
Volume 167
Number 3

De Economist (2019) 167:221-239
DOI 10.1007/s10645-019-09339-9

Springer

De Economist (2019) 167:221–239
https://doi.org/10.1007/s10645-019-09339-9

Creative Careers: The Life Cycles of Nobel Laureates in Economics

Bruce A. Weinberg[1] · **David W. Galenson**[2]

Published online: 26 April 2019

Abstract
We identify two polar life cycles of scholarly creativity among Nobel laureate economists with Tinbergen falling broadly in the middle. Experimental innovators work inductively, accumulating knowledge from experience. Conceptual innovators work deductively, applying abstract principles. Innovators whose work is more conceptual do their most important work earlier in their careers than those whose work is more experimental. Our estimates imply that the probability that the most conceptual laureate publishes his single best work peaks at age 25 compared to the mid-50 s for the most experimental laureate. Thus, while experience benefits experimental innovators, newness to a field benefits conceptual innovators.

Keywords Creativity · Life cycle · Innovation · Nobel laureates · Economics of science

JEL Classification J240 · O300 · B310

Many scholars believe that creativity is the particular domain of the young. One prominent economist, former President Lawrence Summers of Harvard University, vetoed offers of tenured professorships to two 54-year-old scholars out of concern for what the university's Dean of the Faculty called the problem of "extinct volcanoes." In support of Summers, a 35-year-old professor of earth sciences explained that "It's more exciting to be around a place where things are going on now—not a place where people have done important things in the past" (Golden 2002).

The studies on which our understanding of life-cycle creativity rests were done by psychologists, who have aggregated individual creators to the discipline-level, to study differences across disciplines in peak ages of creativity. These studies tend

✉ Bruce A. Weinberg
weinberg.27@osu.edu

[1] Department of Economics, Ohio State University, Columbus, USA

[2] Department of Economics, University of Chicago, Chicago, USA

to find relatively small variations across disciplines in the age of peak creativity, with creativity peaking in the mid or late 30s or early 40s in most disciplines (e.g. Lehman 1953, Chaps. 15–16; Simonton 1988, pp. 66–71). Psychologists have attributed these differences across disciplines to the nature of the disciplines themselves, not to the individuals who are active in those disciplines. The handful of economists who have studied life cycle creativity have also treated disciplines as the unit of analysis (see Lillard and Weiss 1978; Diamond 1986; Levin and Stephan 1991; Stephan and Levin 1993; Hamermesh and Oster 1998; Van Dalen 1999).

There is a systematic relationship between age and scholarly creativity, but it is more complex than the typical view or that in the existing literature. By studying the careers of a group of Nobel laureates in economics, we will show that there is substantial variation in the life cycle of scholarly creativity within a specific discipline. The evidence furthermore reveals that the path a scholar follows is related to the nature of his work and that there are only very slight systematic changes in the nature of a scholar's important works over the life cycle. This understanding of the life cycles of innovative economists constitutes an important step toward a theory of human creativity in general.

In studying differences in the life cycle of scholarly creativity within a single discipline and showing that the life cycle of an individual scholar's work is directly related to the nature of his or her work, we depart markedly from the existing literature. The large variations in the life cycle of creativity within a discipline that we document stand in contrast to the small differences found in previous studies that compare entire disciplines.

It is important to recognize that there are important practitioners spanning the range of types described in this paper within most, if not all, intellectual activities. The differences existing studies have found across disciplines in the central tendency of important contributors' peak achievements by age may be largely a consequence of differences across disciplines in the relative numbers of the types of innovators. Viewing life cycle creativity as an individual and not a disciplinary phenomenon also suggests that there may be systematic changes over time in the mean age of peak creativity within disciplines as the relative numbers of the types of innovators change in response to contributions made in those disciplines (see Jones 2010; Jones and Weinberg 2011).

We also depart from most of the existing literature by focusing on very important innovators under the belief that important individuals are particularly interesting for understanding innovation. Most existing work focuses on less important scholars (exceptions are Stephan and Levin 1993; van Dalen 1999; Jones 2010; and Jones and Weinberg 2011).

At a theoretical level, economists studying life cycle creativity have interpreted their estimates using a human capital framework. Our estimates indicate that the creativity of many of the important economists in our sample peaks well before age 30. Such early peaks are inconsistent with a human capital approach in which productivity peaks as people cut investments as the end of their career approaches. We argue that the investment approach may help understand the results for some of our laureates but provide a radically different interpretation for others.

Even if they do not consider it in any other context, most scholars consider the relationship between age and creativity in evaluating appointments and promotions in their own departments, as they try to assess the likely future path of other scholars' research. For this purpose, existing studies are of remarkably little use in that they shed no light on the factors that are related to individual differences in life cycle creativity within a discipline.

The present paper builds on work on life cycle creativity in the arts that we have done in a number of ways (Galenson and Weinberg 2000, 2001; Galenson 2001, 2006). First, we demonstrate the importance of our conceptual-experimental distinction in the sciences. The present paper is the first to categorize innovators using objective, quantitative characteristics. It is also the first to formally investigate changes in the nature of work over the life cycle.

1 Conceptual and Experimental Innovators

Research on the careers of modern painters, poets, novelists, and natural scientists has revealed that there have been two polar types of innovators in each of these activities (Galenson 2001, 2006; Galenson and Pope 2013). The basic distinction between the two turns on whether the individual innovator works deductively or inductively. Conceptual artists, who are motivated by the desire to communicate specific ideas or emotions, have precise goals for their works. They often plan them carefully in advance, and execute them systematically. Their innovations appear suddenly, as a new idea produces a result quite different not only from other artists' work, but also from the artist's own previous work. In contrast, the goals of important experimental innovators are ambitious but vague, as they seek to present perceptions that are less precise. The imprecision of their goals leads them to work tentatively, by a process of trial and error. They arrive gradually and incrementally at their major contributions, often over an extended period of time.

The long periods of trial and error often required for important experimental innovations make them tend to occur late in an innovator's career. So, for example, Paul Cézanne, Robert Frost, Virginia Woolf, and Charles Darwin all arrived at their greatest accomplishments after many years of work. Conceptual innovations are made more quickly and can occur at any age. Yet the achievement of radical conceptual innovations depends on the ability to perceive and appreciate extreme deviations from existing conventions, and this ability tends to decline with experience, as habits of thought become more firmly established. The most important conceptual innovations consequently tend to occur early in an innovator's career. Thus, for example, Pablo Picasso, T. S. Eliot, Herman Melville, and Albert Einstein all made their greatest contributions early in their long lives.

The distinction between deductive and inductive innovators applies equally to economists. Conceptual economists pose precise problems and solve them deductively. They may do this throughout their careers, but their most general—and consequently most important—innovations tend to come early in their careers, when they are more likely to challenge basic tenets of the discipline that are widely treated as rules by more experienced scholars. In contrast, experimental economists may

pose broader questions, which they solve inductively by accumulating evidence that serves as the basis for new generalizations. The more evidence they can analyze, the more powerful their generalizations, so the most important experimental innovations are often the product of long periods of research.

This paper extends the study of the life cycle of creativity to a select group of innovative economists. Based on the analysis presented above, the hypothesis to be tested is that economists who have made important conceptual innovations tend to make their most important contributions earlier in their careers than their counterparts who have made experimental innovations. We also study the extent to which the nature of a scholar's important contributions is fixed as opposed to changing systematically over the life cycle.

2 Data

We measure the importance of work using citations. Citations were collected from the Web of Science, an on-line database comprising the Social Science Citation Index, the Science Citation Index, and the Arts and Humanities Citation Index.[1]

We collected the number of citations to all works in each year of each laureate's career made between 1980 and 1999 inclusive.[2] These data on citations to the works each laureate published in each year of his career are our units of analysis. For the purpose of the empirical analysis, laureates are included in our sample from the time they received their doctorate or from the time of their first cited publication if it preceded their doctorate or if they never earned a doctorate.

The importance of scholars depends primarily on their most important contributions. We use two methods to identify the years in which the laureates made important contributions. One method is to identify all years in which citations are above a threshold. To do this, we first estimate the mean and standard deviation of each laureate's annual citations. We define years in which a laureate's citations were at least two of his standard deviations above his mean to be his *two standard deviation peaks*. To estimate the year in which each laureate made his single most important

[1] We searched for citations under each Nobel laureate's last name and initials. For laureates who published with their middle initial, we searched for citations with and without the middle initial. To exclude citations to other authors with the same last name and initials, citations were checked against publication lists. The database lists coauthored papers under the lead author's name. Citations to the Modigliani–Miller papers were included in the counts for both laureates.

[2] Collecting citations to individual works would have been prohibitively costly given the number of published works and the number of citations. In virtually all years with high citations, a single work dominates the citations. Citations to important books were assigned to the year the first edition was published. The period 1980–1990 was chosen based on the availability of online data. Citations to works that have been incorporated into the literature will be lower. Works published around 1980 will receive more citations than those published earlier or later. The dates reflect when works were published, which will be after the work was done, because of publication lags. We are not aware of reasons why any of these factors would bias our estimates toward early peaks for conceptual laureates and late peaks for experimental laureates.

contribution, we also consider the single year with the most citations for each laureate. We refer to this year as the laureate's *single best year*.

Most other analyses of Nobel laureates, especially of those in the hard sciences, have sought to identify when people did the work for which they received their Nobel Prizes. Unfortunately, the Nobel Committee does not systematically indicate the publications for which economics prizes were awarded. Consequently, researchers who have sought to use the Nobel Committee's statements to date when economists did their most important work have, in fact, been forced to rely on a wide variety of approaches. (For instance, van Dalen 1999 uses reports of the Nobel Prize committee, but also uses autobiographies, biographies, and citations.) Citations provide a widely accepted, objective method that can be consistently applied to all the laureates.[3]

Our measure identifies scholars' most influential work, which will reflect a combination of the originality of the work and the importance of the question to other scholars.[4] While the receipt of a Nobel Prize may increase an individual's citations (see Merton 1968), we do not use citations to make inter-personal comparisons, only to determine when each laureate did his most important work. We are not aware of evidence that receiving a Nobel Prize increases citations to work from particular ages, nor are we aware of reasons that additional citations would be to the late works of experimental laureates or to the early works of conceptual laureates.

3 Attributes of the Laureates' Work

Our theory distinguishes experimental from conceptual innovators. Experimental innovators work inductively. Their innovations derive from knowledge accumulated with experience. Because empirical research frequently involves generalizing from a body of evidence, empirical innovators are often, but not always, experimental. An example of a conceptual empiricist would be someone whose primary contribution was testing hypotheses formulated a priori.

Conceptual innovators work deductively. Their innovations derive primarily from a priori logic and are often direct responses to existing work. Theorists tend to be conceptual. The most abstract and mathematical theorists tend to be the most conceptual. While our distinction between experimental and conceptual work is different from the distinction between theoretical and empirical work, we are not aware of any systematic classification of the laureates even as theoretical or empirical.[5]

[3] While our understanding of the Nobel citations, when they are sufficiently explicit, indicates that the most cited works and the works for which people received the Nobel Prize frequently coincide, when they do not, it is not clear that the opinion of the Nobel Prize committee is preferable to that of the discipline as a whole.

[4] On citations as a measure of scientific importance, see Simonton (1988, pp. 84–85).

[5] The Nobel Committee, for instance, does not systematically indicate whether the prizes were awarded for empirical or theoretical contributions.

To classify each laureate's work, we have obtained objective characteristics of each laureate's two standard deviation peaks.[6] As indicated, experimental work relies on direct inference from facts. The characteristic that best measures the use of facts with the least processing are references to specific items—places, time periods, and industries or commodities. Conceptual work involves deriving results from assumptions made a priori. The characteristics that are most associated with conceptual work are the use of assumptions and proofs, the use of equations, and the presence of a mathematical appendix or introduction. Economics is appealing for our purposes because of the large observable and objective differences between conceptual and experimental works in economics. While many of the criteria we use to distinguish conceptual and experimental work in economics relate to the use of mathematics, our work on artists shows that the same variations between conceptual and experimental work arise even in fields where mathematics is not used. Table 1 lists these measures, their construction, and their means and standard deviations.

The use of statistical procedures has a non-monotonic relationship to the type of work. It tends to be highest among laureates whose work is neither extremely conceptual nor extremely experimental because the most extreme conceptual laureates rarely perform any empirical work, and the most extreme experimental laureates usually use data, but with less processing. We do not include a measure of the use of statistical procedures because of its non-monotonic relationship to the nature of work.

The increase in the use of statistical procedures through much of the range from the most experimental laureates toward more conceptual laureates is significant in that it indicates that there are large variations in the nature of work even among empirical laureates. Thus, our distinction between conceptual and experimental work captures variations in the nature of work beyond whether it is empirical or theoretical.

As indicated, the distinction between the conceptual and experimental approaches is not qualitative, but quantitative. We use these objective characteristics of each laureate's single most important work to array the laureates along a continuum from most experimental to most conceptual. To do this, we ranked the laureates on each characteristic. We then constructed the sum of the ranking for the number of assumptions and proofs, the number of equations, and the presence of a mathematical appendix or introduction and subtracted from it the rank in the number of specific references. We use rankings to preserve variations in the frequency of each characteristic while ensuring that a laureate's classification is not dominated by an

[6] We examined 19 pages from each piece. When the work contained 20 or more pages, we sampled 19 pages evenly spaced through the work—the pages that were 5%, 10%, 15% and so forth through the work. When a work contained fewer than 19 pages, we inspected all pages. To obtain estimates that would be comparable to works with 19 or more pages, we calculated the number of each item per page and multiplied these per-page figures by 19. When a page was partially or completely blank, we used the following page or, if that page was partially or completely blank, the preceding page. Complete pages of references were replaced by the last page that was not in the references section. Appendix pages and pages of notes were included.

Table 1 Objective characteristics of works

Characteristic	Description	Mean
References to specific items	The sum of: The number of pages with references to specific places The number of pages with references to specific time periods The number of pages with references to industries or commodities	12.461 (15.134)
Assumptions and proofs	The sum of: The number of pages with formal proofs The number of pages with proof structure The number of pages with explicit statements of assumptions, axioms, lemmas, postulates, theorems, formal definitions	1.340 (4.423)
Equations	The number of (whole-line) equations	19.877 (22.867)
Mathematical appendix	A binary variable equal to 1 if the work has a technical appendix or introduction	.218 (.416)

Standard deviations in parentheses

extreme value for any single characteristic. The conceptual laureates have the highest values on this index, while experimental laureates have low values.

Our data cover Nobel laureates in economics born in or before 1926 who published primarily in English.[7] Because the youngest laureate who was clearly experimental was born in 1926, this cutoff ensures that our laureates span the full range of types in a common cohort.

4 The Nature of Work: Fixed or Changing

Thus far, we have discussed the nature of a laureates' work as a time-invariant characteristic. In principle the nature of a laureate's work may change over the life cycle. We are able to assess the extent to which the nature of the laureates' important contributions changes over their lives because we have on average 2.5 two standard deviation peaks per laureate.

Let Age_{ij} give the age at which laureate i published his jth two standard deviation peak; $Index_i$ denotes our index of the nature of laureate i's jth two standard deviation peak; and $Laureate_i$ denotes a dummy variable equal to 1 for laureate i and 0 otherwise. Formally, we estimate,

$$Index_i = \pi Age_{ij} + \sum\nolimits_i \delta_i Laureate_i + \varepsilon_{ij}. \tag{1}$$

Here the δ_i are the coefficients on the laureate fixed effects, which capture time-invariant differences in the nature of work across the laureates, and π gives the relationship between age and the nature of a laureate's work.

We estimate $\hat{\pi} = -.611$, with a standard error of .350, implying a p value of .085. The mean difference in age between a laureate's first and last two standard deviation peaks is 14.9 years. Over this length of time, a laureate's work shifts by 9.1 points, 4.5% of the range of 201. Thus, there is some tendency for any given laureate to become more experimental as he ages, but this tendency is quite weak both statistically and economically.

Another way to assess the importance of changes that are related to age relative to time-invariant factors is to decompose the variance in the index. We do this by estimating the partial R^2 of the age variable and the partial R^2 of the laureate fixed effects in regression (1). The laureate fixed effects account for 71.6% of the variance in the index, while age accounts for only 1.1% of the variance. Thus, the vast majority of the variation in the index is due to time-invariant, individual differences with very small systematic variations due to aging.

[7] Maurice Allais, Leonid Kantorovich, Tjalling Koopmans, and Reinhardt Selten were excluded because of language of publication. (Koopmans' began his career as a physicist and his most cited publication, *Über die Zuordnung von Wellenfunktionen und Eigenwerten zu den einzelnen Elektronen eines Atoms*, is in Physics in German. Tinbergen, who is the focus of this volume, is included even though his work on cobweb models was published in German.

Table 2 Classification of laureates

Name	Index fixed effect
North	−75.500
Fogel	−75.000
Myrdal	−73.833
Lewis	−70.500
Kuznets	−68.500
Schultz	−62.500
Friedman	−46.000
Hayek	−37.500
Coase	−33.000
Ohlin	−23.000
Tinbergen	−10.000
Meade	−7.750
Buchanan	−7.500
Simon	−7.167
Leontief	−5.200
Miller	0.250
Solow	8.333
Frisch	15.833
Stigler	16.500
Klein	19.750
Hicks	21.500
Tobin	27.333
Stone	31.000
Modigliani	34.750
Haavelmo	53.750
Samuelson	55.800
Harsanyi	62.500
Vickrey	63.000
Arrow	69.750
Debreu	76.500
Markowitz	114.750

The index is the time-invariant component of the index estimated from Eq. (1) for each laureate, which adjusts for age, and is normalized to have a mean of zero

To the best of our knowledge, these are first estimates of the stability or fluidity of the nature of innovators' work over the life cycle and they show remarkable stability. In the empirical work that follows, we exploit both the time-varying and time-invariant components of the variation in the nature of the laureates' works. Table 2 shows the time-invariant estimates of the nature of the laureates' works based on the fixed effects estimated in (1).

5 Classification of the Laureates

A discussion of how our index of conceptual versus experimental work applies to each individual in our sample would be prohibitive. Nevertheless, some discussion of individual laureates will clarify the experimental-conceptual distinction and how it is captured by our index.

Paul Samuelson is one of the most conceptual laureates. Samuelson's most cited work is his *Foundations of Economic Analysis* of 1947, which was based on his dissertation. He begins it by describing how he was inspired to write it by the classes he took in graduate school:

> *The existence of analogies between central features of various theories implies the existence of a general theory which underlies the particular theories and unifies them with respect to these central features.* This fundamental principle of generalization by abstraction was enunciated by the eminent American mathematician E. H. Moore more than 30 years ago. It is the purpose of the pages that follow to work out its implications for theoretical and applied economics (Samuelson 1947, p. 3).

Samuelson explicitly states that his contribution is to provide a rigorous, unified methodological foundation for a range existing work, making his work conceptual.

The econometrician Trygve Haavelmo is also among the most conceptual of the laureates. Econometrics is important for empirical analysis and some econometricians make empirical contributions as well as contributions to econometric theory. How econometricians will be classified depends on whether their most important contribution is empirical (or arises from empirical work), which tends to be experimental, or in econometric theory, which tends to be conceptual. Haavelmo's most cited work, the essay "The Probability Approach to Econometrics" of 1944, is "an attempt to supply a theoretical foundation for the analysis of interrelations between economic variables (p. iii)." He motivates it stating:

> If we want to apply statistical inference to testing the hypotheses of economic theory, it *implies* such a formulation of economic theories that they represent *statistical* hypotheses, i.e., statements - perhaps very broad ones - regarding certain probability distributions. The belief that we can make use of statistical inference without this link can only be based upon a lack of precision in formulating the problems (Haavelmo 1944, p. iv).

The empirical implications of his work notwithstanding, Haavelmo's contribution, like Samuelson's, is to provide a rigorous, unified methodological foundation for existing work. His work is also conceptual even though its subject is estimation.

Robert Fogel is among the most experimental laureates. Fogel concludes his most cited work, *Without Consent or Contract* of 1989, by discussing how his understanding of slavery evolved based on his empirical studies of it. He explains how his findings contradicted the traditional view of slavery he held when his research began, stating:

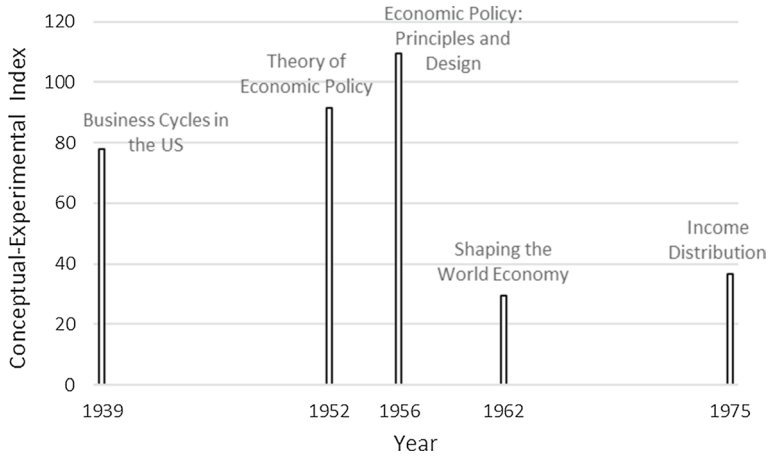

Fig. 1 Values of the conceptual-experimental index for the Jan Tinbergen's two standard deviation peaks. *Note* The index takes on higher values for more conceptual works and lower values for more experimental works

> Engerman and I delayed publication of our preliminary findings for nearly 2 years as we investigated these possibilities and searched for new data that might reverse the computation. The results of these searches did not relieve me of the dilemma. Quite to the contrary, the new evidence further eroded my confidence in conventional views of the moral problems of slavery (Fogel 1989, p. 391).

That the accumulation of evidence, which in Fogel's case took decades, would cause his conclusions to contradict his expectations so thoroughly indicates that Fogel is an experimental researcher.

Tinbergen, whose receipt of the first Nobel Prize is recognized by this volume, also illustrates our approach (see Hansen 1969; Klein 2004). His contributions to econometrics and macroeconomics were motivated by empirical facts and concerns. For instance, his work on cobweb models was an attempt to understand comovements of prices and quantities in agricultural markets. His work on macro models, which influenced subsequent Nobel Laureates (e.g. Lawrence Klein), was not a purely theoretical exercise either—it was an attempt to understand the Great Depression. Similarly, his work on development was heavily focused on providing recommendations for policy. Consequently, Tinbergen is closer to the center of our conceptual-experimental continuum.

Figure 1 plots the value of our index for Tinbergen's five two-standard deviation peaks. While Tinbergen's first three two-standard deviation peaks are relatively conceptual, he illustrates the tendency to become somewhat more experimental over time.

Table 3 Regressions of age of two standard deviation peaks and single best years on the conceptual-experimental index for individual works

	Two standard deviation peaks	Single best years	Two standard deviation peaks other than single best
Index	−0.102	−0.113	−0.091
	(0.024)	(0.030)	(0.035)
Intercept	48.218	44.917	50.418
	(1.314)	(1.705)	(1.824)
Observations	78	31	47
R^2	0.187	0.329	0.129
Age for most experimental	56.378	53.957	57.698
Age for most conceptual	35.876	31.244	39.407
Difference	20.502	22.713	18.291

Standard errors reported in parentheses. The index is for the main work published in each year and is normalized to have a mean of zero across laureates so that the intercept gives the mean age for the mean laureate. The ages and difference in bottom panel are estimates based on the models

6 Estimates

We perform a variety of analyses to estimate the relationship between the nature of a laureate's work and the age at which he makes his important contributions. We begin with regressions of the age at which each Nobel laureate has his two standard deviation peaks, single best year, or two standard deviation peaks other than his single best on our index. To illustrate this procedure, let Age_{ij} give the age at which laureate i had his jth important year. Let $Index_{ij}$ denote our measure of the nature of laureate i's jth important work. Formally, we estimate,

$$Age_{ij} = \gamma_0 + \gamma_1 Index_{ij} + \varepsilon_{ij}.$$

We normalize $Index_{ij}$ to have a mean of zero across the laureates, so that γ_0 gives the mean age of two standard deviation peaks for the average laureate. Given that higher values of the index correspond to more conceptual laureates, we hypothesize that $\gamma_1 < 0$.

The estimates are shown in the top panel of Table 3. The bottom panel shows the estimated age for the most experimental and most conceptual work as well as the difference between them. The first column shows that a 1 point increase in the index corresponds to a .1 year reduction in the mean age of two standard deviation peaks. Given the range of our index of 201, the implied difference in mean age of important contributions between the most experimental and most conceptual laureates is 20.5 years.

The second column shows analogous results for the single best years. Here each laureate appears exactly one time and Age_{ij} denotes the age at which laureate i had his single best year. For the single best years, a 1 point increase in the index corresponds to a .113 year reduction in the mean age. Given the range of our index, the implied difference in mean ages of the single best years between the most experimental and most conceptual laureates, is 22.7 years.

The third column of the table shows results using the two standard deviation peaks other than the single best. For this analysis, the sample is restricted to laureates with two or more two standard deviation peaks, because the single best year is excluded. The estimates are smaller than for the single best years, but remain negative and statistically significant. As indicated by the intercepts, the single best years occur at earlier ages than the other two standard deviation peaks.

We next perform a similar analysis, replacing the index for each work with the time-invariant fixed effect for the nature of each laureate's work. The preceding estimates account for the effect of changes in the nature of a laureate's work over the life, which affect when they do their important work, although these variations are potentially endogenous. Insofar as there are random variations across works in the characteristics we study for a given nature of work, using fixed effects will reduce attenuation bias.

Let $Index_i^{FE}$ denote the fixed effect estimated for laureate i from Eq. (1) and Age_{ij} again give the age at which laureate i had his jth important year. We estimate

$$Age_{ij} = \gamma_0 + \gamma_1 Index_i^{FE} + \varepsilon_{ij}.$$

Here too, $Index_i^{FE}$ is normalized to have a mean of zero across the laureates, so that γ_0 gives the mean age of two standard deviation peaks for the average laureate. As above, we hypothesize that $\gamma_1 < 0$.

The estimates reported in the first three columns of Table 4, are broadly comparable to those reported in Table 3. Using the fixed effects for the nature of work instead of a work-specific measure slightly increases the estimated relationship between the nature of a laureate's work and the age of his two standard deviation peaks other than the single best (and all two standard deviation peaks). Thus, eliminating attenuation bias has a greater effect than eliminating endogeneity, which is not too surprising, given the very weak relationship between age and the nature of work reported above.

As discussed, we estimate the age at which the laureates did their important works using citations. While citations are a widely accepted method for determining the importance of work, and the only objective method of which we are aware, we consider whether our results depend on our use of citations. The most thorough attempts to measure the age at which the Nobel laureate economists did their most important work using autobiographical and biographical sources are van Dalen (1999) and Jones (2010). Columns 4 and 5 reproduce our analysis using Jones's midpoint years and then van Dalen's "motherlode years," which are closest to our single best years. The estimates remain large and statistically significant using both of these measures.

6.1 Life-Cycle Profiles

To provide further information about the life-cycle pattern in the importance of work, we estimate the probability that a laureate had an important year on polynomials in age interacted with our index for the nature of a laureate's work and interactions between age and the index. Let i index laureates and t index the calendar year. Let Age_{it} denote laureate i's age in year t. As above, $Index_i^{FE}$ denotes our measure of the nature of laureate i's work based on the fixed effects estimated in Eq. (1). Our dependent variables, *Two Standard Deviation Peak*$_{it}$ and *Single*

Table 4 Regressions of age of two standard deviation peaks and single best years on the conceptual-experimental index fixed effects

	Two standard deviation peaks	Single best years	Two standard deviation peaks other than single best	Jones's midpoint years	Van Dalen's motherlode years
Index	−0.117	−0.109	−0.121	−0.068	−0.055
	(0.029)	(0.035)	(0.043)	(0.022)	(0.025)
Intercept	48.218	44.982	50.335	36.893	38.960
	(1.322)	(1.819)	(1.801)	(1.105)	(1.252)
Observations	78	31	47	31	31
R^2	0.177	0.237	0.151	0.249	0.144
Age for most experimental	57.052	53.212	59.471	42.027	43.113
Age for most conceptual	34.792	32.474	36.450	29.090	32.649
Difference	22.259	20.737	23.020	12.937	10.464

Standard errors reported in parentheses. The index is the time-invariant component of the index for each individual reported in Table 2, which adjusts for age and is normalized to have a mean of zero across laureates so that the intercept gives the mean age for the mean laureate. The ages and difference in bottom panel are estimates based on the models

Table 5 Probit models of age and the probability of two standard deviation peaks and single best years

	Two standard deviation peaks		Single best years	
Age	0.1036	(0.0295)	0.1244	(0.0516)
Age^2	−0.0011	(0.0003)	−0.0015	(0.0005)
Index	0.0159	(0.0048)	0.0205	(0.0075)
Age × Index	−0.0003	(0.0001)	−0.0005	(0.0002)
Intercept	−3.8359	(0.7214)	−4.4916	(1.1940)
Observations	1771		1771	

Standard errors reported in parentheses. The index is the time-invariant component of the index for each individual reported in Table 2, which adjusts for age and is normalized to have a mean of zero across laureates so that the coefficients on Age and Age^2 give the profile of the mean laureate

Best Year$_{it}$ are dichotomous variables equal to 1 if laureate *i* had citations two of his standard deviations above his mean or his maximum citations in year *t* and zero otherwise. Our specification for *Two Standard Deviation Peak*$_{it}$ is

$$\begin{array}{c}\text{Two Standard}\\ \text{Deviation Peak}_{it}\end{array} = \begin{cases} 0 \; if \; \beta_0 + \beta_1 Age_{it} + \beta_2 Age_{it}^2 + \beta_3 Index_i^{FE} + \beta_4 Index_i^{FE} \cdot Age_{it} + \varepsilon_{it} \leq 0 \\ 1 \; if \; \beta_0 + \beta_1 Age_{it} + \beta_2 Age_{it}^2 + \beta_3 Index_i^{FE} + \beta_4 Index_i^{FE} \cdot Age_{it} + \varepsilon_{it} > 0 \end{cases}.$$

The specification for *Single Best Year*$_{it}$ is analogous. Assuming that ε_{it} is normally distributed implies a probit structure. Each laureate contributes an observation for each year of his career.

We normalize the index to have a mean of zero, so the coefficients β_1 and β_2 give the relationship between age and the probability of having an important year for a laureate with the mean nature in the sample. The coefficient β_4 governs how the peak of the profiles change with the nature of a laureate's work. The profile for a laureate with a value of the index of $Index_i^{FE}$ peaks at $Age_i^* = -\frac{\beta_1 + \beta_4 Index_i^{FE}}{\beta_2}$, where a hump-shaped profile requires $\beta_2 < 0$. Because higher values of the index correspond to more conceptual work, our hypothesis that conceptual laureates do their best work earlier in their careers implies that $\beta_4 < 0$. Both β_3 and β_4 control how the height of the profile changes with the nature of work. Our model contains a quadratic in Age_{it}; a first-order interaction between Age_{it} and $Index_i^{FE}$; and a linear direct effect of $Index_i^{FE}$ because all higher order terms are statistically insignificant in one or both regressions.

Table 5 presents the estimates. The estimates show the expected hump-shaped relationship between age and the probability of an important work or a single best year. The negative estimates of β_4 on the interaction between the index for the nature of a laureate's work and his age, which are statistically significant at any conventional level, show that conceptual laureates do their important work earlier than experimental laureates.

Figure 2 plots the probability of a two standard deviation peak and a single best year implied by the models for the most conceptual and experimental laureates. The profiles

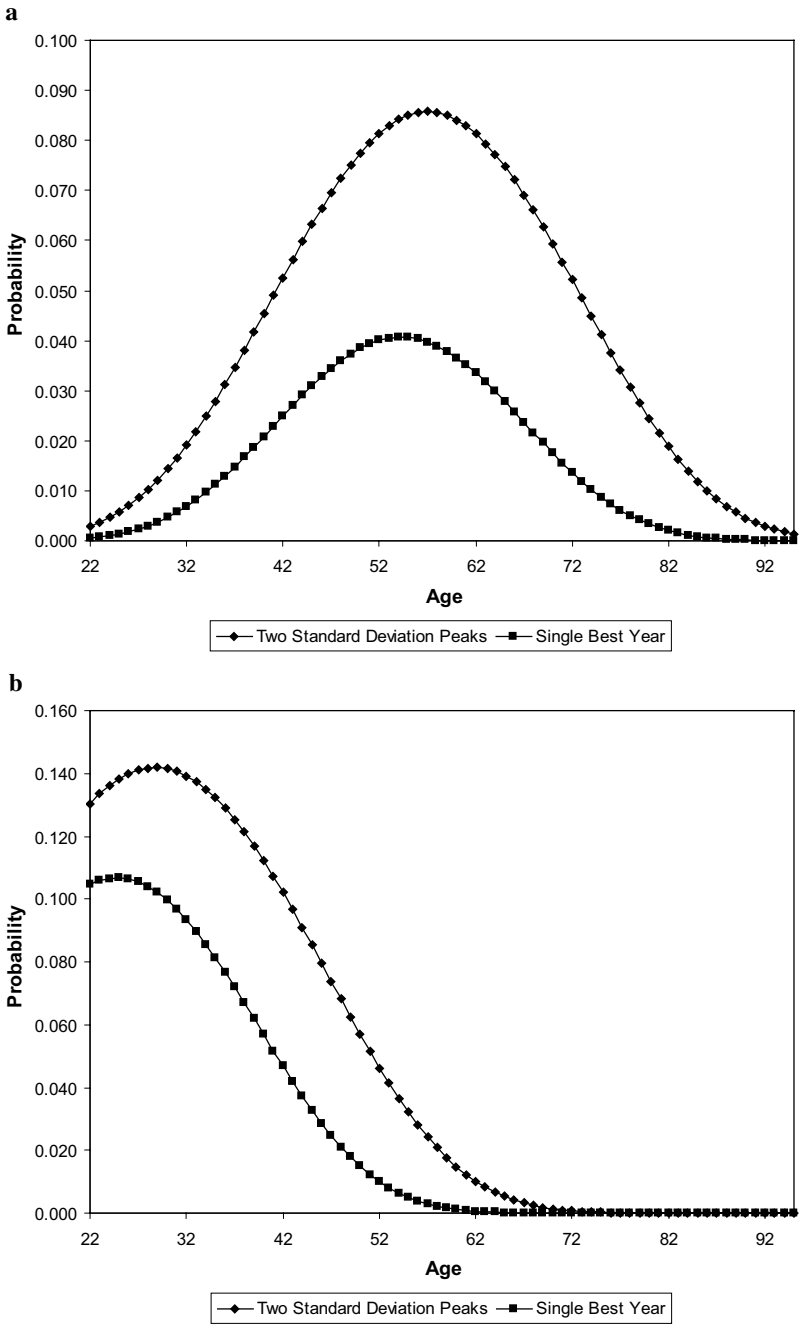

Fig. 2 Age and the probability of a two standard deviation peak and single best year, by nature of work. **a** Most experimental laureate **b** Most conceptual laureate. *Note* Curves give the probabilities predicted from the probit models in Table 5

for the conceptual and experimental laureates differ markedly. The most conceptual laureate's probability of a two standard deviation peak is 15% in the first year of the career, and it reaches a peak at age 28.8 years. For the most experimental laureate, the probability of two standard deviation peak is less than half of a percent at the beginning of the career, reaching a peak at age 56.9, close to double the age of the most conceptual laureate. By comparison, the mean laureate's profile peaks at age 47.1.

The profiles for the single best years are beneath those for the two standard deviation peaks because there are fewer single best years than two standard deviation peaks. There is little difference in the shape of the profiles between the two standard deviation peaks and single best years for the most experimental laureates—both peak in the mid-50s. For the most conceptual laureate the probability of a single best year is close to that of an important year at the beginning of the career, but increases less before dropping. For the most conceptual laureate, the probability of a single best year peaks at age at age 24.8.

7 Conclusion

The empirical analysis of this paper provides strong support for the proposition that the life cycles of important scholars in economics vary continuously between two very different poles. As in the arts, more conceptual innovators in economics have tended to produce their most important contributions considerably earlier in their careers than their more experimental counterparts. It appears that the ability to formulate and solve problems deductively declines earlier in the career than the ability to innovate inductively. As scholars age, they accumulate knowledge related to their fields of study and become increasingly accustomed to particular habits of thought about their disciplines. Both of these effects may increase the creativity of inductive scholars, since the power of their generalizations will tend to be greater as the evidence on which they are based increases. As experimental scholars age, their efficiency in analyzing and accumulating useful information may increase, and the empirical base for their research may consequently grow at an increasing rate over extended periods. In contrast, at a relatively early stage both the accumulation of knowledge and the establishment of fixed habits of thought may begin to reduce the ability to create radical new abstract ideations, which is key to important conceptual innovations. This difference in the impact of experience on the two different types of innovator may explain why some great scholars are most creative early in their careers, and others late.

Although some academics believe that creativity is exclusively associated with youth, others understand that there are two different life cycles of creativity, and that which cycle a scholar follows is related to his approach to his discipline. When Harvard's president vetoed job offers to two 54-year-old scholars, government professor Michael Sandel observed that "a prejudice for younger over older candidates amounts to a prejudice for mathematical and statistical approaches—such as those reflected by Mr. Summers's own economics background—over historical or philosophical approaches, where people often do their best work in their fifties, sixties or beyond" (Golden 2002).

Acknowledgements We thank Jeff Rosen, Alicia Lee, and Gwen Jacobs for excellent research assistance and Andrew Abel, Daron Acemoglu, David Blau, Aya Chacar, Dan Hamermesh, David Hirschliefer, and Howard Marvel and seminar participants at New York University; Ohio State University; the Society of Labor Economists; Maastricht University; Dartmouth College; the University of Connecticut; and the NBER Productivity Lunch for comments. Galenson gratefully acknowledges support from NSF SES 0099105. Weinberg is grateful for support from R24 AG048059, R24 HD058484, UL1 TR000090, the National Institute on Aging and the Office of Behavioral and Social Science Research via P01AG039347 (on which Weinberg and his work were supported directly by the National Bureau of Economic Research and indirectly by Ohio State); NSF SES 0095776, NSF DGE 1760544, 1535399, 1348691, and SciSIP 1064220; and the Ewing Marion Kauffman and Alfred P. Sloan Foundations.

References

Diamond, A. M., Jr. (1986). The life-cycle research productivity of mathematicians and scientists. *Journal of Gerontology, 41*(4), 520–525.

Fogel, R. W. (1989). *Without consent or contract: The rise and fall of american slavery*. New York: W.W. Norton and Company.

Galenson, D. W. (2001). *Painting outside the lines*. Cambridge: Harvard University Press.

Galenson, D. W. (2006). *Old masters and young geniuses: The two life cycles of artistic creativity*. Princeton: Princeton University Press.

Galenson, D. W., & Pope, C. L. (2013). Experimental and conceptual innovators in the sciences: The cases of Darwin and Einstein. *Historical Methods: A Journal of Quantitative and Interdisciplinary History, 46*(2), 102–112.

Galenson, D. W., & Weinberg, B. A. (2000). Age and the quality of work: The case of modern American painters. *Journal of Political Economy, 108*(4), 761–777.

Galenson, D. W., & Weinberg, B. A. (2001). Creating modern art: The changing careers of painters in France from impressionism to cubism. *American Economic Review, 91*(4), 1063–1071.

Golden, D. (2002). Course correction. *Wall Street Journal*, 11.

Haavelmo, T. (1944). The probability approach in econometrics. *Econometrica, 12*((Supplement): iii–vi), 1–115.

Hansen, B. (1969). Jan Tinbergen: An appraisal of his contributions to economics. *Swedish Journal of Economics, 71*(4), 325–336.

Jones, B. F. (2010). Age and great invention. *Review of Economics and Statistics, 92*(1), 1–14.

Jones, B. F., & Weinberg, B. A. (2011). Age dynamics in scientific creativity. with Ben Jones. In *Proceedings of the national academy of the sciences,* (November 22), (Vol. 108(18), pp. 910–914).

Klein, L. R. (2004). The contributions of Jan Tinbergen to economic science. *De Economist, 152*(2), 155–157.

Lehman, Harvey C. (1953). *Age and achievement*. Princeton: Princeton University Press.

Levin, S., & Stephan, P. (1991). Research productivity over the life cycle: Evidence from American scientists. *American Economic Review, 81*(1), 114–132.

Lillard, L. A., & Weiss, Y. (1978). Experience, vintage, and time effects in the growth of earnings: American scientists 1960–1970. *Journal of Political Economy, 86,* 427–448.

Merton, R. K. (1968). The Matthew effect in science. *Science, 159*(5), 56–63.

Oster, S. M., & Hamermesh, D. S. (1998). The research productivity of economists. *Review of Economics and Statistics, 53*(1), 154–156.

Samuelson, P. A. (1947). *Foundations of economic analysis*. Cambridge, MA and London: Harvard University Press.

Simonton, D. K. (1988). *Scientific genius*. Cambridge: Cambridge University Press.

Stephan, P., & Levin, S. (1993). Age and the nobel prize revisited. *Scientometrics, 28*(3), 387–399.

Van Dalen, H. P. (1999). The golden age of nobel economists. *American Economist, 43*(2), 19–35.