Which Labor Economists Invested in Human Capital? Geography, Vintage, and Participation in Scientific Revolutions

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We study how proximity and vintage are related to innovation using evidence from the human capital revolution in labor economics. We find a strong effect of geography on the probability of making a contribution and the nature of the contribution. Contributors to the human capital paradigm are significantly more likely to have studied at the University of Chicago or Columbia University and to have been in graduate school in the early years of the human capital revolution, earning their doctorates during the mid-1960s. Our results also indicate that a small numbers of contributors played a large role in the development of human capital, especially at the beginning.

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I. Introduction

This paper studies the effects of geography and vintage on contributions to a scientific revolution. There is substantial interest in the role of local knowledge spillovers on the development of innovations and a presumption that geography is particularly important as an innovation emerges (Zucker, Darby, and Brewer [1998]). The effect of vintage on contributions to a scientific revolution relates to work on sunk costs, business stealing, organizational behavior, and cognition. Participation in scientific revolutions provides a valuable laboratory for studying both of these effects. Our results also shed light on the role played by individuals in scientific revolutions.

Our data are on the development of the human capital paradigm in labor economics.[1] Prior to the 1960s labor economics was largely institutional. The essence of the human capital approach to labor economics is that people make conscious investments in themselves in the form of education, on-the-job training, health, and migration. The human capital revolution was also linked to a shift to large-scale econometric analysis in labor economics. Gary S. Becker, Jacob Mincer, and Theodore W. Schultz are often regarded as having done the seminal work on human capital at the University of Chicago and Columbia University in the late 1950s and early 1960s.

We construct a sample of people who published papers that are later regarded as significant contributions to the human capital paradigm. We find that human capital developed in a series of phases. For the first 10 years after Mincer's publication of "Investment in Human Capital and Personal Income Distribution" in 1958, 70% of important publications on human capital were made by Mincer himself, Becker and

[1] Human capital was chosen because it was the large, recent paradigm shift in labor economics, the area of the author's training. It was the only episode analyzed. The human capital revolution is well timed for our

Schultz. In the next phase, contributions to human capital began to spread, but they were disproportionately made by people who studied at the Chicago or Columbia and by people who earned their doctorates in the mid-1960s. In the final phase, many contributions considered alternatives to human capital, such as signaling or screening. These contributions tended to be made by people who graduated from schools other than Chicago or Columbia. Thus, our paper provides strong evidence for an effect of experience and geography both on participation in the human capital revolution and the nature of contributions. It also shows a central role for the small group of people who initiated human capital research.

There is a growing literature on the effect of geography on innovation. Jaffe, Trajtenberg, and Henderson [1993] and Thompson and Fox-Kean [2005] find evidence for local knowledge spillovers using patent citations. Glaeser, Kallal, Scheinkman, and Schleifer [1992] and Glaeser and Ellison [1997] infer spillovers from data on cities. Gould [2005] infers spillovers from the urban wage premium. Zucker, Darby, and Brewer [1998] study knowledge transfers to industry. Mairesse and Turner [2006] find that immediate proximity increases the probability of collaborating using data on scientists. To the best of our knowledge, we are the first to measure spillovers using individual productivity and we do so in a context where spillovers are likely to be most important.

The idea that vintage affects the acceptance of new scientific paradigms has become known as "Planck's Principle." The physicist Max Planck wrote that "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it (Planck [1949], pp.33-34)."

Taking some liberty with Planck's statement, we refer to the idea that vintage affects the probability of accepting new paradigms as the weak form of Planck's principle

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purposes in that Econlit coverage begins in 1969 shortly after the development of human capital.

and the idea that vintage affects contributions to emerging paradigms as its strong form. Given that most interest is in the development of innovations, the strong form of Planck's principle is of greater interest than the weak form. To the best of our knowledge, there are no tests of the strong form of Planck's principle, and only two tests of the weak form, both of which find only weak support for it.[2]

There are a number of micro-explanations for Planck's principle. Galenson and Weinberg [2000, 2001] and Weinberg and Galenson [2005] argue that at a cognitive level, it becomes more difficult to assimilate and appreciate radical departures from an existing paradigm as one becomes more familiar with that paradigm (also see Brynjolfsson, Renshaw, and Alstyne [1997]).[3] Vintage human capital means that people who have invested in a particular paradigm face a cost of shifting to a new paradigm if skills are imperfectly transferable across paradigms (see Chari and Hopenhayn [1991]; Jovanovic and Nyarko [1996]; Weinberg [2004]). Lastly, a Schumpeterian view of innovation suggests that people or organizations who hold property rights in a currently dominant innovation have less incentive to contribute to a new one (see, for instance, Aghion, Harris, Howitt, and Vickers [2001]).

Our work also has implications for the effect of radical innovations on firms. The management literature has devoted considerable attention to organizational barriers to successful participation in industrial revolutions (see Katz and Allen [2004] and Henderson [1993]). Insofar as the young dominate revolutions and play a smaller role in

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[2] Hull, Tessner, and Diamond [1978] study the acceptance of Darwin's theory of evolution; Diamond [1980] studies the acceptance of cliometrics by economic historians. Both of these studies relate age (and Ph.D. vintage in the case of cliometrics) to measures of acceptance. Our results for contributions indicate that the effects of vintage are non-linear, with the key factor being whether the person's graduate education occurred during the development of the paradigm. These studies find a linear relationship between age and acceptance, but that age explains only a small portion of the variance in acceptance.

[3] This idea is well stated by Sigmund Freud [1929], who at age 73 wrote, "The conceptions that I have summarized here I first put forward only tentatively, but in the course of time they have won such a hold over me that I can no longer think in any other way (p. 790)." Although our approach is different, our approach bears on the literature on life-cycle creativity (see, for instance, Lehman [1953]; Weiss and Lillard [1978]; McDowell [1982]; Simonton [1990]; Levin and Stephan [1991]; Hamermesh and Oster

the management of established firms, the disadvantage experienced by established firms in the face of industrial revolutions may be due to the vintage of their key personnel.

Our result that many of the important contributions to human capital, especially at the beginning of its development, were concentrated among a small number of individuals and our evidence of geographic concentration relate to a debate on the role of small numbers of exceptional individuals versus larger numbers of less eminent individuals in innovation. In the former case, idiosyncratic, individual factors may dominate innovation, while market forces are more likely to be important in the later. (See Mokyr [1990] and Khan and Sokoloff [1993] for these views.)

II. Data

Two datasets were constructed for this project. The first sample is of important contributions in the development of the human capital paradigm, which we refer to as human capital contributions. This sample is constructed in two steps. In the first step, we assemble a list of all the papers that either (1) were published in the 1962, 1972, 1974, 1976, or 1979 supplements to the *Journal of Political Economy* on human capital or (2) were referenced in the reviews of human capital by Mincer [1970]; Schultz [1975]; or Blaug [1976]. Of these papers, the ones that were cited in the papers on human capital in the first volume of the *Handbook of Labor Economics* are taken to be important contributions from a historical perspective.[4]

Screening and signaling models developed as the primary alternative to human capital as an explanation for the returns to school. A number of papers in this literature appeared in our human capital sample.[5] Below, we analyze how these papers differ from

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[1998]; and Jones [2005]).

[4] These pieces are Freeman [1986]; Weiss [1986]; and Willis [1986]. We use the first sample to screen out the publications in the second sample that are not directly related to human capital.

[5] Papers that mentioned screening, signaling, or filtering in their titles were classified as part of this literature.

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the other papers in our human capital sample.

We also develop a comparison sample of papers published in labor economics in top, general-interest journals during the same period.[6] Data from 1969 on was drawn from Econlit, an on-line database of publications in economics. Data for the years before 1969 were drawn from the lists of publications in the *American Economic Review* and the *Journal of Economic Literature*. Publications that were listed as being in labor economics according to the American Economic Association's classification were included. We include notes, but exclude comments, replies, and their equivalents. Publications in the May Papers and Proceedings volume of the *American Economic Review* were excluded. We refer to these publications as all labor contributions. Insofar as some of the contributions in this control sample contribute to or draw on the human capital paradigm, comparisons of our human capital and control samples will understate the difference between human capital contributions and all other labor contributions.

Data on the schools from which the two sets of contributors graduated and the years in which they earned their Ph.D.s were obtained from the UMI ProQuest Dissertation and Theses database. These data contain information on the graduation year and school for more than 2 million people earning doctorates in the United States since 1861.[7]

III. Analysis

III. A. Time Distribution of Contributions

Figure 1 plots the time-distribution of the important contributions to human capital. The units of observation in this graph are publications, with co-authored pieces

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[6] The journals included are the *American Economic Review, Econometrica, International Economic Review, Journal of Economic Theory, Journal of Political Economy, Quarterly Journal of Economics, Review of Economics and Statistics,* and *Review of Economics and Statistics.*

[7] For the human capital contributors, we have supplemented the UMI data with web searches. A few of the human capital contributors did not earn a doctorate. In these cases, we used the year they received their highest degree. In the few cases where no data was available on the year of the highest earned degree, we used the year of the first scholarly publication.

appearing only once. The earliest contribution is Milton Friedman and Simon Kuznet's *Income from Independent Professional Practice*, which laid out the idea of educational decisions as determined by future income flows and is widely regarded as a precursor to the human capital revolution.

The human capital revolution began in 1958 with the publication of Jacob Mincer's "Investment in Human Capital and Personal Income Distribution." The number of human capital contributions rose steadily in each of the succeeding 5-year periods, peaking at 14 in 1973-1977 before declining to 1978-1979, when the last pieces that met our criteria were published.

Gary Becker, Jacob Mincer, and Theodore W. Schultz are generally regarded as having done the seminal work on human capital. They solely authored or co-authored a quarter (9 of 38) of the publications. Strikingly, they solely authored or co-authored 70% (7 of the 10) publications in the first decade of the revolution from 1958 to 1967. Of the 27 publications in or after 1968, Becker, Mincer, and Schultz were authors on only 2 or 7.4%.

Historians of science have debated the role played by small numbers of individuals versus large groups in scientific revolutions. While 31 people ultimately made important contributions to human capital, our estimates indicate that the three founders played a large role in its overall development and dominated the early phase. While one can only speculate as to how human capital would have developed without some or all of its 3 founders, given their share of early contributions, it is plausible that the development would have been significantly altered or retarded.

The nature of contributions also changed over the course of the revolution. Screening or signaling models are a primary alternative to the human capital model as an explanation for the relationship between schooling and earnings. Figure 2 and Table 1 show the number of screening and signaling contributions and the number of other

contributions. The first screening contributions were made in the 1973-1977 period, 25 years after the original human capital contribution. Over the last two periods, 39% of contributions are screening contributions. A χ^2-test rejects the hypothesis that the time-distribution of screening and other contributions is the same at the 10% level of significance.

Our analysis indicates three phases of the revolution. The first was dominated by the three leaders of human capital research, Becker, Mincer, and Schultz. In the second, contributions expanded to a wider range of scholars. In the last phase many contributions shifted to alternatives to the human capital agenda.

III. B. Vintage and Contributions

We next investigate how vintage is related to the probability of making an important contribution to human capital. We are interested in people who contributed to the new paradigm after the initial work, so we eliminate Becker, Mincer, and Schultz and Friedman and Kuznets. Because this analysis and those that follow study the characteristics of individuals contributing to the human capital paradigm, the unit of observation is a publication-author. Thus, a publication with *n* authors will appear *n* times – once for each author. A person who publishes *n* contributions is included *n* times, so people who make more contributions receive more weight.

We begin by estimating the mean level of experience at which the human capital contributors made their contributions to human capital. On average they published their contributions 8.216 years after receiving their Ph.D.s, with a standard deviation of 6.989 years.

As indicated, we develop a comparison sample of all people publishing in labor economics in top, general-interest journals during this period. We use this sample to estimate the mean age for the typical contributor to labor economics during this period. To adjust for any differences in the distribution of publication years between the human

capital contributions and the set of all labor contributions, we break the period into intervals.[8] In estimating the mean experience among all labor contributions, we weight the data in each interval by the share of human capital contributions in that interval divided by the number of all labor contributions during that interval.

On average the human capital contributions were made 5.885 years after the contributors received their Ph.D.s with a standard deviation of 6.279 years. The human capital contributors had 2.331 more years of experience than the average labor contributor during this period. The standard error for the difference is 1.164 years. Thus the human capital contributors tended to be more experienced than the average contributor to labor economics.

While we do not find that the human capital contributors had less experience than the average contributor to labor economics during this period, we nevertheless find that vintage plays an important role in determining the participation in the human capital revolution. We measure each contributor's vintage using the year in which he earned his Ph.D. Figure 3 shows the distribution of Ph.D. years for human capital contributors. The figure shows that three quarters of the contributions were made by people who earned their doctorates in the decade between 1963 and 1972, which began 5 years after the initial work on human capital. Close to half of the contributions were made by people who earned their Ph.D.s in the mid-1960s.

Again, we compare our results for the human capital sample to the vintages for all contributors to labor economics. As above, we adjust for differences in the distribution of publication years between the human capital contributions and the set of all labor contributions by breaking the period into intervals. We then estimate the distribution of Ph.D. years for each year interval. We construct an overall distribution by taking a

[8] From 1963 to 1977 we use the 5 year intervals shown in figure 1 (the period 1958-1962 is excluded because only Becker, Mincer, and Schultz published during this period). We also include the 2-year period 1978-1979.

weighted average of the distributions for each interval where the weight applied to each interval is the share of the human capital contributions that were published during that interval.

The publication-year adjusted distribution of Ph.D. years for all labor contributions is also shown in Figure 3.[9] The distribution of Ph.D years for all labor publications is quite similar to that for the human capital contributions until 1962. As indicated above, close to half or the labor contributors earned their Ph.D.s between 1963 and 1967, but the share of all labor contributors earning their Ph.D.s during that period is barely half that level. Beginning in 1968, the share of all labor contributors earning their Ph.D.s exceeds that for human capital contributors, with the gap being particularly large for people earning Ph.D.'s in or after 1973. Table 2 reports the two distributions of Ph.D. years. It also reports a test for the equality of the two distributions, which is rejected soundly.[10]

We do not find that youngest labor economists are most likely to contribute to the human capital revolution – the human capital contributors tended to be more experienced at the time they published their contributions than the average productive labor economist. We do find strong support for the strong form of Planck's principal insofar as the human capital contributors were in graduate school during the 1960s when the early work on human capital was emerging. Thus, experience at the time of publication appears to be less relevant than does exposure to the innovation in one's formative professional years.

III.C. Geography and Contributions

This section investigates how geography is related to probability of making a

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[9] Insofar as the all labor contributions include some human capital contributions, the difference between the two distributions is understated.

[10] In calculating the χ^2 –statistic for the equality of the distributions, we treat the distribution for all labor contributors as known because it is based on 1,142 observations and is a composite of 4 distributions.

human capital contribution. We measure geography using the school from which a person earned his Ph.D. Because the University of Chicago and Columbia were the home institutions of Becker, Mincer, and Schultz, we separate these schools from all other doctoral programs.

Insofar as people who were interested in working on human capital selected graduate schools where human capital research was being done, these estimates will not give the causal effect of attending a particular school on the probability of making a human capital contribution. We suspect that such selection is relatively small, if only because most entering graduate students are not aware of the specific approaches at schools. Moreover, if graduate schools have no effects on the type or success of work, there is no reason for such selection to operate. In this case there is no reason to expect a difference between the schools of human capital and all labor contributors.

Table 3 reports the distribution of graduate schools for people making human capital contributions. The table also reports the distribution for all labor contributors. To control for any changes in the distribution of graduate schools among labor economists over the period, we follow a procedure similar to that above where the distribution for all contributors is a weighted average of the distributions for the sub-intervals.

The differences in the two distributions are striking. Whereas only one eighth of all labor contributors earned a Ph.D. from the University of Chicago, close to 40% of the human capital contributors did. Columbia is also over-represented among the human capital contributors, but by a smaller margin. As shown in the table, a χ^2-test for the equality of the two distributions is rejected soundly.

As indicated, signaling or screening models are a primary alternative to the human capital model as an explanation for the relationship between schooling and earnings. We study how graduate schools are related whether a person makes a contribution to signaling or screening versus human capital. Because of the small number

of graduates from Columbia, we focus only on people who graduated from the University of Chicago and schools other than Chicago or Columbia.

Table 4 shows that only one of the 13 human capital contributions by the University of Chicago graduates related to signaling, or 8%. By contrast, over one third of the non-Chicago, non-Columbia human capital contributions related to signaling. The difference is statistically significant at the 10% level.

One concern with our estimates is that our human capital sample is defined based on publications in the *Journal of Political Economy* and citations in review articles, some of which were written by people who were closely associated with the University of Chicago or Columbia University. To see if our estimates are skewed by these sample selection criteria, we defined a second human capital sample based on citations by people without strong ties to the University of Chicago or Columbia.[11] The results for this sample are virtually identical to those for the full sample – 38% of contributions were made by graduates of the University of Chicago, 7% were made by graduates of Columbia University, and 57% were made by graduates of other schools.[12] We conclude that our sample construction does not bias our results toward people who attended the University of Chicago or Columbia University.

Another question is whether the contributors to human capital who attended the University of Chicago or Columbia worked in the area because their advisors steered them to this area for their dissertations. Such an effect would imply the importance of geography, but one that is specific to the dissertation process. We inspected the leading footnote of each article (or acknowledgements of each book) for whether the pieces were from a dissertation. Only 3 of the pieces in our human capital sample indicate that they

[11] For this sample we took the pieces that were cited in Blaug's [1976] self-described "jaundiced" survey of human capital and also cited in Freeman [1986].

[12] In order to increase the sample size, we added the pieces cited in both Blaug [1976] and Card [2001] to those cited in both Blaug [1976] and Freeman [1986]. In this sample, 39% of the contributions were by graduates of the University of Chicago, 11% were by graduates of Columbia University; and 50% were by

contained dissertation material. This finding is consistent with our earlier result that the human capital contributors were published on average 8 years after they received their Ph.D.s. Thus, our evidence indicates that being exposed to human capital in one's formative years was more important than being nudged into writing a thesis on the topic.

Geography matters in that attending the Chicago and, to a lesser extent Columbia, is associated with a substantially higher probability of making a human capital contribution among labor economics contributions, and within human capital contributions a lower probability of making a signaling or screening-related contribution. Laying aside the causality issues discussed above, our estimates do not indicate whether attending the Chicago and Columbia is associated with a higher probability of working on human capital-related topics or a higher probability of making an important contribution conditional on working on a human capital-related topic. We suspect that both played important roles.

IV. Conclusion

We study how geography and vintage are related to innovation using evidence from a scientific revolution. Human capital developed in phases. The three founders of the human capital approach, Gary Becker, Jacob Mincer, and Theodore W. Schultz dominated the first decade of human capital research. In the next phase, others made the majority of contributions to the human capital paradigm. In the final phase, substantial attention was devoted to screening and signaling as an alternative to human capital.

We find strong evidence that geography is related to human capital contributions. Graduates of the University of Chicago and, to a lesser extent, Columbia are significantly over-represented among human capital contributions relative to other productive labor economists during this period. Geography also affects the nature of contributions – Chicago and Columbia graduates are less likely to publish papers on the screening

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graduates of other institutions.

alternative to human capital. To the best of our knowledge ours is the first study to estimate the effect of geography on innovative activity from data on individual productivity.

We also find evidence that vintage is related to the probability of contributing to the human capital revolution. While human capital contributors are not younger than the average productive labor economist during this period, the human capital contributors are significantly more likely to have been in graduate school in the early years of the human capital revolution, earning their doctorates during the mid-1960s. Here too, we are unaware of other evidence on how vintage relates to participation in scientific revolutions.

Our results also indicate that a small numbers of contributors played a large role in the development of human capital, especially in its early stages. Given the size of their role and the spillovers that are suggested by the geographic concentration, it is plausible that human capital would have developed differently or more slowly in their absence.

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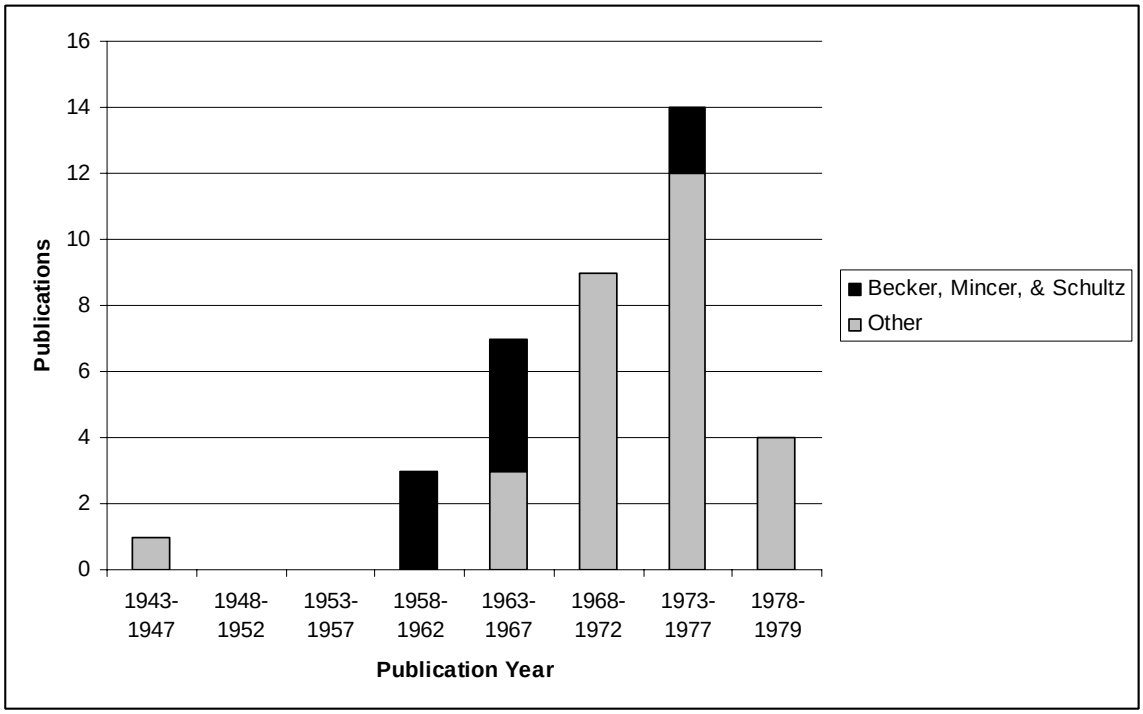
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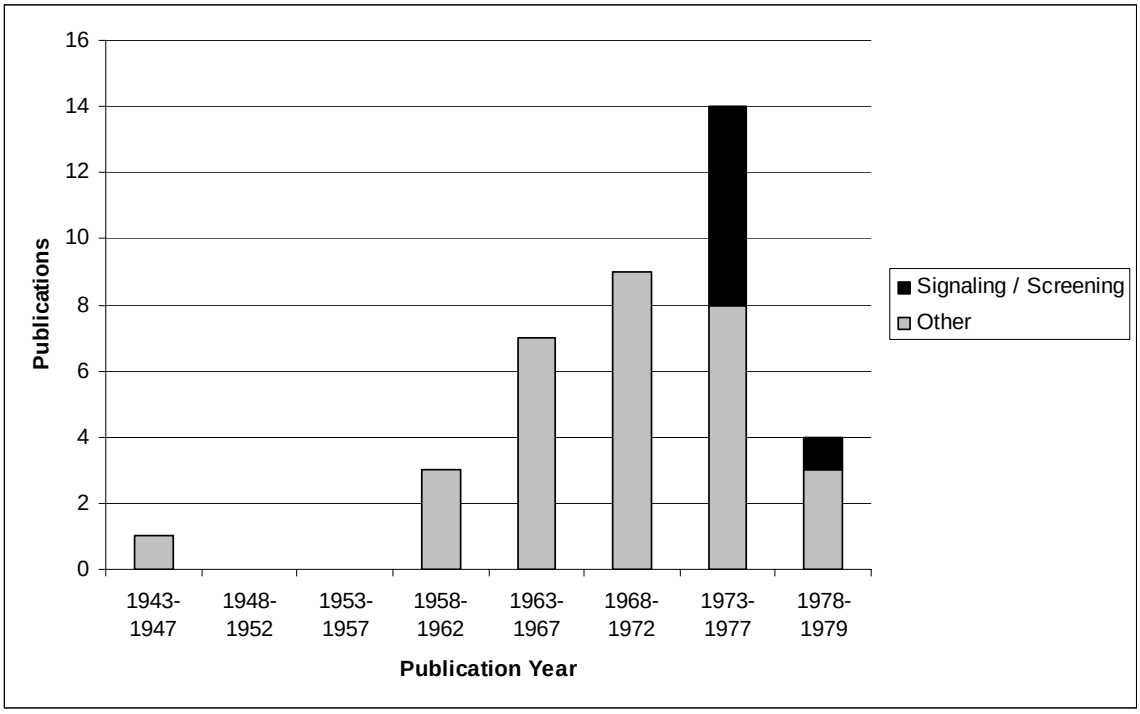
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Figure 1. Time Distribution of Human Capital Contributions, by Author.



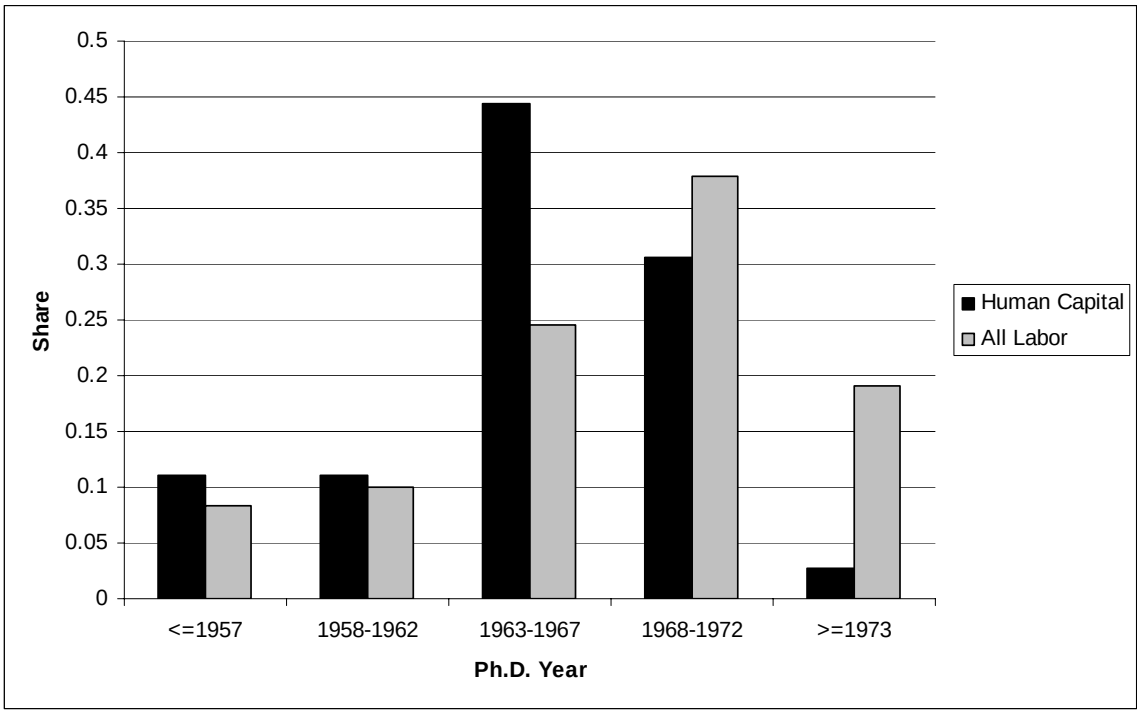
Note. Publications are the unit of observation.

Figure 2. Time Distribution of Human Capital Contributions, by Signaling / Screening versus Other.



Note. Publications are the unit of observation.

Figure 3. Vintage of Graduate Degree among Human Capital and All Labor Contributors.



Note. The time distribution for all labor publications is adjusted to match that for labor contributions for publication years.

Table 1. Time Distribution of Human Capital Contributions, by Screening / Signaling versus Other.

	Screening / Signaling		Other	
	Number	Share	Number	Share
1943-1947	0	0	1	0.032
1958-1962	0	0	3	0.097
1963-1967	0	0	7	0.226
1968-1972	0	0	9	0.290
1973-1977	6	0.857	8	0.258
1978-1979	1	0.143	3	0.097
$\chi^2(5)$ for equality of Screening / Signaling and Other Distributions		10.194		

Note. Critical value for a χ^2 with 5 degrees of freedom at 90% is 9.24.

Table 2. Distribution of Ph.D. Years for Human Capital and All Labor Contributions.

	Human Capital Contributions	Share of Human Capital Contributions	Share of All Labor Contributions
<=1957	4	0.111	0.084
1958-1962	4	0.111	0.100
1963-1967	16	0.444	0.246
1968-1972	11	0.306	0.379
>=1973	1	0.028	0.191
$\chi^2(4)$ for equality of Human Capital and All Labor Distributions		11.700	

Note. The time distribution for all labor publications is adjusted to match that for labor contributions for publication years. Critical value for a χ^2 with 4 degrees of freedom at 95% is 9.49.

Table 3. Distribution of Graduate Schools for Human Capital and All Labor Contributions.

	Chicago	Columbia	Other
Human Capital Contributions	14	3	19
Share of Human Capital Contributions	0.389	0.083	0.528
Share of All Labor Contributions	0.125	0.066	0.809
$\chi^2(2)$ for equality of Human Capital and All Labor Distributions		23.639	

Note. The time distribution for all labor publications is adjusted to match that for labor contributions for publication years. Critical value for a χ^2 with 2 degrees of freedom at 95% is 5.99.

Table 4. Relationship between Graduate Schools and Type of Human Capital Work.

	University of Chicago		Non-Chicago, Non-Columbia	
	Number	Share	Number	Share
Human Capital	12	0.923	13	0.650
Screening / Signaling	1	0.077	7	0.350
$\chi^2(1)$ for equality of Human Capital and Screening / Signaling Distributions		3.199		

Note. Critical value for a χ^2 with 1 degrees of freedom at 90% is 2.71.