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THE MEANING OF PATENT CITATIONS: REPORT ON THE NBER/CASE-WESTERN RESERVE SURVEY OF PATENTEES

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ABSTRACT

A survey of recent patentees was conducted to elicit their perceptions regarding the importance of their inventions, the extent of their communication with other inventors, and the relationship of both importance and communication to observed patent citations. A cohort of 1993 patentees were asked specifically about 2 patents that they had cited, and a third "placebo" patent that was similar but which they did not cite. One of the two cited inventors was also surveyed. We find that inventors report significant communication, at least some of which is in forms that suggests spillovers from the cited inventor to the citing inventor. The perception of such communication was substantively and statistically significantly greater for the cited patents than for the placebos. There is, however, a large amount of noise in citations data; it appears that something like one-half of all citations do not correspond to any perceived communication, or even necessarily to a perceptible technological relationship between the inventions. We also find a significant correlation between the number of citations a patent received and its importance (both economic and technological) as perceived by the inventor.

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1. Introduction

It is well understood that the non-rival nature of knowledge as a productive asset creates the possibility of "knowledge spillovers," whereby investments in knowledge creation by one party produce external benefits by facilitating innovation by other parties. At least since Griliches' seminal paper on measuring the contributions of R&D to economic growth (1979), economists have been attempting to quantify the extent and impact of knowledge spillovers. One line of research of this type has utilized patent citations to identify a "paper trail" that may be associated with knowledge flows between firms.[1]

Very little of this research has attempted to determine the modes or mechanisms of communication that actually permit knowledge to flow. Further, most of the work has simply assumed that citations or other proxies are sufficiently correlated with knowledge flows to allow statistical analysis of the proxies to be informative regarding the underlying phenomenon of interest.[2]

This paper reports on a preliminary attempt to improve this situation. We undertook a small but systematic survey of inventors to try to learn about the extent and

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[1] Patent citations or references appear on the front page of a granted patent. They serve the legal function of identifying "prior art" upon which the current invention builds. For more detail, see Jaffe, Trajtenberg and Henderson, 1993.

modes of their communication with earlier inventors, and about the extent to which the appearance of citations in their patents is indicative of this communication. The results suggest that such communication is important, and that patent citations do provide an indication of communication, albeit one that also carries a fair amount of noise.

2. Survey Design

The idea for the survey emerged from a series of interviews with patent attorneys, R&D directors, and inventors for a project on commercialization of federal lab technology.[3] We quickly learned that each brought a different perspective and a different willingness to discuss patent citations. Patent attorneys were least willing to share information about citations; R&D directors represented the organization's broader strategic perspective; and the inventor clearly had the best knowledge of R&D spillover mechanisms. These discussions suggested to us that patent citations are a noisy but potentially valuable indicator of both the importance of the technology as well as the extent of knowledge spillovers. But it also became clear that the inventors were an under-exploited source of insight into these issues. Given that the inventors are all identified on the computerized patent records, we decided to undertake a systematic survey of inventors to learn their views about knowledge flows, patent citations, and the relationship between them.

We began by first developing questions to explore the validity of patent citations for analyzing the technological and commercial importance of patents as well as their use in evaluating knowledge spillovers (The surveys for citing and cited inventors are reproduced in the Appendix.) After developing draft questions, we tested the survey on a

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[2] A partial exception is Jaffe, Fogarty and Banks (1998), in which a limited number of interviews with inventors were used to shed light on the relationship between citations and knowledge flows.

[3] These interviews were conducted by two of the authors during 1996. See Adam B. Jaffe, Michael S. Fogarty, and Bruce A. Banks, "Evidence from Patents and Patent Citations on the Impact of NASA and other Federal Labs on Commercial Innovation," Journal of Industrial Economics, V. XLVI (June 1998), No. 2, 183-205. The interviews included: the Electro-Physics Branch (EPB)chief, EPB personnel, selected firms working with EPB, NASA-Lewis' patent attorney, TRW's patent attorney, BF Goodrich's director of Corporate Technology (Specialty Chemicals Division), Picker, International's patent attorney, Picker's Director of Technology Marketing, Owens-Corning's R&D Director, Owens-Corning's patent attorney, and a former R&D director of GE's engine division.

sample of inventors. The test group consisted of twenty inventors drawn from four types of institutions: universities, government labs, research hospitals, and industry. The draft survey was then revised to incorporate the inventors' numerous comments and suggestions.

A. Selection Criteria and Qualifying 1993 Patents

Our goals for the survey were to learn about the mechanisms and pathways by which inventors learn of previous work, and to test or measure the extent to which citations are a useful proxy for knowledge flows and/or the technological significance of patents. We surveyed two groups, one in which we asked inventors about citations *made* in their patents to previous patents (the "***citing inventor***" survey), and one in which we asked inventors about citations *received* by their patents from subsequent patents (the "***cited inventor***" survey). Our expectation, based on the interviews we had conducted with a small number of inventors and other research personnel, was that citing inventors would be inclined to understate their reliance on the work of prior inventors, while cited inventors would tend to overstate the extent to which they had influenced those who came after. By surveying both groups, we hoped to "triangulate" (Helper, 2000) and get a more robust picture of the knowledge flows.

Since communication or knowledge flows are inherently difficult to measure quantitatively, the best we could hope to get from inventors was qualitative rankings on a Likert scale. This means that, whatever answers we got about the extent of communication, it would be hard to say whether the reported communication between citing and cited inventors was significant or not. To overcome this problem, we introduced into the "citing" inventor surveys "placebo" patents. That is, we asked inventors about their communication with the inventors of several previous patents, some of which were cited by the surveyed inventor's patent, and some of which were not. Of course, the citing inventors were not told that any of the previous patents were "placebos." All of the previous patents were referred to in the survey as "cited patents." The "placebo" patents were chosen to match the cited patents by technology class and date. Our basic strategy then is to *compare* the rankings of the citation and placebo

patents, and look for statistically and economically significant differences between the responses for the citations and the responses for the placebo patents.

Because tens of thousands of patents are granted to American inventors every year, there is a large universe from which to pick a sample for a survey of patentees. From this universe, we selected samples of ***citing*** and ***cited*** inventors. The samples were designed to be unbiased along the important dimensions, while taking into account cost constraints, as well as a desire to focus on inventions recent enough that the inventors would have good recall of the events surrounding them. At the same time, we wanted patents that were old enough so that there would be significant citation information related to them. In balancing these considerations, we chose 1993 patents for the ***citing*** inventor survey. For the ***cited*** inventor survey, we identified patents cited by 1993 patents, which were issued in 1985 or later. In order to allow the citing inventor survey to cover also older citations, we included there questions about other citations going back to 1975.

To select the patents for the citing inventor survey, we began by identifying all U.S. patents granted in 1993 that meet the following criteria:

1) The principal (first listed) inventor should have a U.S. address.[4]
2) The patents should contain 3 or more citations made to patents issued 1985 or later, which themselves meet the following criteria:
   a) There should be no inventor on a cited patent that is the same as the inventor on the 1993 citing patent.
   b) The assignee on the cited patent should not be the same as the assignee on the 1993 citing patent.
3) In addition to the 3 post-1985 citations, patents should have 1 or more additional citations to patents issued 1975 or later.

The selection criteria produced 14,762 "citing" patents. Based on desired sample size, expected response rates and resource constraints, we decided on an initial stratified target sample of approximately 600 citing inventors to be surveyed. A stratified sample

[4] This requirement was meant to maximize the chances of actually finding the inventor.

was called for because we believe that the patterns of knowledge flows (as well as inventors' ability to recall) might be different for more "important" patents, and we know from previous research that most patents are relatively "unimportant" (at least as measured by citation counts). Thus, the sample was designed so as to oversample from more highly cited (and hence presumably more important) patents. First, we included *all* of the 100 most cited 1993 patents that otherwise met our criteria. (Each of these had at least 10 citations.) In addition, we drew a random sample of those patents with 4 or more citations, and a separate random sample of those that received 1-3 citations. We did not survey any patents that themselves received zero citations.

Each of the citing inventors was queried about 3 earlier patents, two actual citations that appeared on their patent (one granted after 1985, and the other after 1975) and a "placebo" that does not appear among the citations on their patent, but that matches the second cited patent by technology class and grant year. For the ***cited*** inventor survey, we identified the primary inventor of the first citation about which the citing inventor was queried (the cited patent granted after 1985). This inventor was queried about her patent, the citing patent, and the relationship between the two (that is, there were no "placebos" in the cited inventor surveys.)

We then undertook the time-consuming task of searching for addresses and telephone numbers, both in internet directories (Yahoo, Excite, Lycos), and in other sources such as the 1998 edition of CD ROM 88 Million.Phone Book. In the end, 1306 surveys were mailed to inventors, approximately equally divided between citing and cited inventors. Of these, 165 were returned as undeliverable. After the initial mailing, a reminder postcard was sent; inventors who had not responded within about two months were sent a second copy of the survey. In addition, about 150 inventors who had not responded, but whose counterpart citing/cited inventor had responded, were contacted by telephone to encourage their participation. Based on these calls, we estimate that at least 10% of the *remaining* possible respondents never received copies of the survey. Therefore, the actual number of possible respondents came down to slightly over 1,000.

In the end, we have 166 partial or complete responses to the ***citing*** survey, and 214 partial or complete responses to the ***cited*** inventor survey. Of these, 72 represent matched pairs. The combined gross return rate is about 30%, while the return rate adjusted for the likely undelivered surveys is about 37%.

The mailing included a cover letter describing the purpose of the survey, the survey questionnaire, and abstracts of the relevant patents. Each abstract and associated information was copied from the USPTO and Community of Science web sites. These were then combined with the standard questionnaire format.[5] The ***citing*** inventors were thus sent information on 4 patents (theirs plus the 2 citations and the placebo), whereas the ***cited*** inventor was sent information on two patents (theirs and the citing patent).

As can be seen in the Appendix, the questions asked fall into 3 broad categories. First are questions that ask each inventor about her patent, without regard to its relationship to other patents (questions 1-6 both in the citing and cited inventor surveys). Second are the group of questions that focus on the extent, timing, and nature of any learning that the citing inventor may have gotten from the cited invention (questions 7-10 in the citing inventor survey and 7-9 in the cited inventor survey). Finally, we asked two questions about the technological relationship between the cited and citing inventions (questions 11-12 in the citing inventor survey and 10-11 in the cited inventor survey). Despite their placement at the end of the survey, we begin by examining the answers regarding the technological relationship between the inventions. We then turn to the communication questions, including the issue of whether the citing and cited inventors differ in their assessment of the extent of communication that may have occurred. Finally, we examine for all of the surveyed inventors whether their perceptions regarding the economic and technological significance of their inventions is correlated with the number of citations the patents received.

[5] A number of inventors said that patent claims would have provided more useful information on the patent than the abstract. Consequently, any future survey should probably include also the patent claims.

3. Citations and the Technological Relationship Between Inventions

The decision by the patent examiner that patent X must cite patent Y is supposed to indicate that patent Y represents prior art upon which patent X builds. Based on conversations with inventors and patent attorneys, it seemed to us that the nature of the technological relationship that this represents could take one or both of two generic forms. It could be that patent X represents an alternative way of doing something that patent Y did before. (For example, you built a better mousetrap by using titanium in the spring; I built a better mousetrap by using zirconium in the spring.) Alternatively, it could be that patent X does something different than what patent Y does, but utilizes a similar method to that used by patent Y, albeit for a different purpose. (You built a better mousetrap by putting titanium in the spring; I built a better Jack-in-the-Box by putting titanium in the spring.)[6] We refer to the first of these possibilities as "similarity of application" and the second as "similarity of technology." As a first indication of the meaning of citations, we explore the extent to which the inventors perceive that patents linked by citation are related along these two dimensions.

Figure 1 shows the distribution of responses for the citing inventors (combining their answers to the two patents that they cited), and for the cited inventors. The top panel presents the perceived relatedness in technology, and the bottom panel the perceived relatedness in application. Overall, 44% of the citations did not rank above 2 on either relatedness dimension. This suggests a fair amount of noise in the citations, a theme that will recur throughout this paper. At the other extreme, only 14% of the citations were rated at 4 or greater on either relatedness dimension. In addition, the two dimensions of relatedness are highly correlated, with a correlation coefficient of 0.62.

As expected, the cited inventors tend to see a much higher degree of relatedness between the citing and cited patents than do the citing inventors. From their perspective, only 25% of the pairs score at 2 or less on both relatedness dimensions, while 37% score 4 or more on at least one dimension. Overall, the mean relatedness in application is 2.6

[6] In principle, the case where X does the same thing as Y, and does it in the same way, should not be observed, as in that case X is not novel and should not be patentable.

as perceived by the citing inventors and 3.3 as perceived by the cited inventors; the corresponding means for relatedness of technology are 2.6 and 3.2. Further, for the 56 citation pairs where these questions were answered by both the citing and cited inventors, the correlation between the different inventors' answers is not very high (.14 for application and .33 for technology). Indeed, the correlation between the *citing* inventor's rating on relatedness of *technology* and the *cited* inventor's rating on relatedness in *application* is higher (.37) than the correlation of their answers to the same questions. This, combined with the high correlation across questions for a given respondent leads us to believe that the respondents were not quite able to distinguish clearly between these two dimensions. For this reason, we combined the two answers to form a composite relatedness score that runs from 2 to 10. Figure 2 shows the distribution of this composite score for the cited patents (using the answers of both the citing and cited inventors) and for the placebo patents. Despite the apparent ambiguity in the meaning of the questions, and the relatively low consistency of answers for the matched pairs, it does seem that the citations are clearly different from the placebos. Fully two-thirds of the placebos were judged unrelated) on *both* dimensions (composite Likert score=2), and only 10% merited a composite score of 5 or more, compared to 50% of the citations meriting composite scores of 5 or more, even as judged by the citing inventors.

The conclusion that we draw from these questions is that a cited patent is significantly more likely to be perceived as related by technology and application than a contemporaneous uncited patent in the same technology field. It does appear, however, that a significant fraction of citations are to patents judged by the inventors themselves to be unrelated, even if the judgment is made by the cited inventor. Further, the concepts of relatedness in application and relatedness in technology do not seem to have been successfully distinguished by the questionnaires. It is unclear whether this is because they are not really effectively distinct concepts, or because the questionnaires were not sufficiently clear about the distinction between them.

4. Results Regarding Extent, Timing and Nature of Communication

I. General responses on sources of invention

Question 6 in both surveys asked the inventors to check off one or two "significant influences on the development of your invention." Figure 3 shows the fraction of respondents who selected each of the named influences. Not surprisingly, by far the most frequently noted influence is "awareness of commercial opportunity," noted by almost 60% of all respondents. "Technological opportunity," in the form of availability of computing power or new analytical tools, is cited by perhaps one-fifth of the inventors.[7] Influences that bear some connection to spillovers or communication are also frequently noted: word of mouth, personal interaction or viewing a presentation or demonstration (about 25%), joint work with others (about 10%) and technical or patent literature (about 20%). The distribution of responses for the citing and cited inventors are generally similar, although the cited inventors (patents granted between 1985 and 1992) more often noted technical literature, new analytical tools and computing power than did the citing inventors (patents granted in 1993). Overall, the answers are generally consistent with expectations, including a confirmation of a significant role for spillovers in the process.

B. Citing Inventor Responses

Figures 4-7 show the distribution of responses of the *citing* inventors to questions 7-10 regarding their communication with the "cited" inventors. The actual wording of each of these questions is shown in the Appendix. Figure 4 gives responses on a 5-point Likert scale to a question regarding the overall degree of familiarity of the citing inventor with the cited invention. For the patents that were in fact cited, 28% of the responses indicated a 4 or 5 on the Likert scale, indicating high familiarity; just under half of the respondents rated their familiarity at the low end of the scale. In contrast, over 80% of the respondents rated their familiarity with the "placebo" patent at the lowest possible level.

Figure 5 indicates the inventors' responses to a question regarding *when* they learned about the "cited" invention.[8] For the "true" citations, about 38% of respondents indicated that they had learned about the cited invention either before or during the development of their own invention. About one-third indicated that they had learned about it after essentially completing their invention. Based partially on the responses to the next question, we believe that this includes a significant number of cases where they learned about the cited invention during the preparation of their own patent application. A little less than one-third indicated that, despite the presence of the patent citation, they had not learned about the cited invention before receiving our survey. This is not surprising, because citations to inventions unknown to the inventor can be generated by the inventor's patent attorney or the patent office examiner.

Figure 6 relates to a question regarding the mode of knowledge spillover. Even for the "true" citations, only about 18% indicated that they had had either direct communication or had been exposed to some kind of presentation or demonstration of the cited invention. Another 18% indicated that they learned through "word of mouth" or had read the patent document itself. Consistent with the answers regarding timing, almost 40% indicated that it was the process of their own patent application that had caused them to learn of the previous invention.

Figure 7 presents the distribution of answers to a question that, perhaps ambitiously, tried to get at the issue of the nature of assistance that the citing inventor may have received from the cited invention. Respondents were given a set of choices that we thought possible, and also invited to "write in" their own responses. About 60% of the respondents indicated some specific way in which they had benefited from the "cited" invention; the single most common response was that the cited invention represented a concept that could be improved upon. The "other" responses stated by the

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[7] A majority of the comments supplied in the "other" category also pertained to specific technical developments that facilitated the invention.

[8] Specifically, the question asks about when the inventor learned about the "research or work underlying the patented invention," in order to include the possibility that the inventor knew about this work without being familiar with the specific embodiment of that work that is captured in the cited patent.

inventors provide some insight into the nature of possible interactions. Examples include:

> "The technology from patent 1 was incorporated in the product which used my invention."
>
> "new market for our new technology!"
>
> "The other patents gave credibility to our idea- they showed our ideas were 'feasible' to the people not intimately involved in our idea."

Other explanations confirmed that many citations derive from the patent process and probably are not related to any spillover:[9]

> "did not learn of patents before filing - therefore these patents were not a factor in our work"
>
> "a patent cited by the patent examiner with no direct ties to my patent"

Assuming that these responses can be taken at face value (an issue we return to below), they suggest that a significant, but not preponderant, fraction of the "links" indicated by a patent citation correspond to some kind of spillover. Across the different aspects captured by each of these questions, typically one-quarter of the responses correspond to a fairly clear spillover; perhaps one-half of the answers indicate no spillover, and the remaining quarter indicate some possibility of a spillover. It appears that addition of citations by the inventor's patent lawyer or the patent examiner is the primary reason for citations to patents unknown to the inventor.

Figures 4-7 suggest strongly that the extent of perceived spillover is greater for the cited patents than for the placebos. In order to explore this issue further, we constructed a composite spillover index for each "cited" patent, using the answers to all 4 questions. This index was constructed by consolidating the possible answers to each question to produce a score of 0, 1 or 2, and then adding these scores across the 4 questions. The distribution of this composite spillover index for both the true citations

[9] All of the quoted comments relate to the "true" citations. Interestingly, several of the inventors told us that the "placebo" patent—which we had described as a citation in order not to bias their responses—was a mistake, i.e. that they had not cited it. It is not possible for us to know if they knew this from memory, or if they took the trouble to go back and check their actual patent document.

and the placebos is shown in Figure 8. Not surprisingly, the distribution of the composite index is more skewed than that of the individual questions. Figure 8 confirms the general pattern that the upper tail of the distribution for the true citations is much thicker than for the placebos, and that about half of the citations are not distinguishable from the placebos.

Table 1 presents the results of an ordered probit analysis of this score, using as regressors variables that would seem likely to foster communication between the cited and citing inventors, variables that might foster the inventor's *remembering* that communication occurred, other controls, and a dummy variable for whether the score pertains to a "true" citation as opposed to a placebo. Columns 1 and 2 include the combined sample of citations and placebos. Column 3 looks only at the placebos, and columns 4 and 5 only at the citations.

Overall, the results confirm that citations can be interpreted as providing a (noisy) signal of spillovers. The difference in spillover score between the citations and placebos is quantitatively and statistically significant. The other variables generally have plausible and often significant effects. Overall, the spillover score is higher if the "cited" patent is more recent. Interestingly, columns 4 and 5 show that this combined effect mixes a significantly positive effect for the citations with a significantly negative effect for the placebos. For the citations, this is consistent with more recent patents being more useful, and older citations being more likely to be non-spillovers included by the lawyer or examiner. It could also reflect the possibility that the inventor's memory of actual communication is better with respect to more recent technology. Conversely, for the placebos, the spillover index is *lower* the more recent the "cited" invention. Since these represent patents that ***were not*** cited, there should not have been communication. Thus the negative coefficient for the placebos is consistent with the inventors' giving more accurate answers with respect to more recent patents, and more often "mistakenly" indicating communication with respect to older patents.

We included the (log of) total citations received by the "cited" patent to control for the overall "importance" of that patent. Its positive effect means that more important patents are perceived to have generated greater spillovers, either because the spillovers are truly greater or because these patents are more likely to be remembered by the respondent. Similarly, cited patents whose inventors reside in the same state are perceived to have generated greater spillovers. We interpret the *lack of* a significant effect for these two variables when looking only at the placebos as further confirming that citations are meaningful, in the sense that the perceived extent of spillovers is correlated with variables that *ought to* be linked with spillovers for the true citations, but is uncorrelated with these same variables for the placebos. We also included the total number of citations *made by* the citing (i.e. responding) patent, to control for the possibility that the inventor would have difficulty remembering or sorting out the effect of any one cited patent, if there were many cited. And indeed, citations made has the predicted negative effect.

The effects for technology fields are reasonably large, and statistically significant within the citations group. There are two slightly different interpretations of this result: One is that spillovers are simply greater, on average, in Chemicals and Drugs, and less in Electronics and Computers and Communications (C&C), with the Mechanical and Other group being intermediate. A slightly different interpretation is that what varies by field is the extent to which patent citations are a good indicator of spillovers. Under this latter interpretation, the results would be consistent with the conventional wisdom that the general importance or centrality of patents in the innovation system is highest in Chemicals and Drugs and lowest in Electronics and C&C.

Finally, columns 3 and 6 add to the regressors the inventors' perceptions regarding the "relatedness" of the patent pair, as reflected in the answers to questions 11 and 12 discussed above. Both of these have a significant positive association with the perceived extent of spillovers, whether looked at in the combined sample or for the

citations alone.[10] Again, there are two possible interpretations to this result. One is that related patents are more likely to generate spillovers. The other is that these concepts are not clearly distinguished in the respondents' minds, or their memories are hazy, so that they are more likely to indicate the presence of spillovers if the inventions are related, or more likely to indicate relatedness if they remember communication.

C. Comparison of Citing and Cited Inventors' Perceptions

By definition, the acknowledgement of a spillover from a cited inventor to a citing inventor diminishes to some extent the perceived accomplishment of the latter and augments the accomplishment of the former. For this reason, we would expect that the citing inventors would tend to underestimate the extent of spillovers and the cited inventors would tend to overestimate it. By asking both the citing and cited inventors to evaluate the likelihood of spillover, we hoped to probe the extent to which the citing inventors' "admissions" of spillover might understate their true dependence on the cited inventions.

Overall, the results for the ***cited*** inventors do suggest indeed a greater degree of perceived spillovers. In particular, Question 9 of the cited inventor survey ("What is the likelihood that the citing inventors were aware of or relied upon knowledge of your work") is qualitatively symmetric to Question 7 in the citing inventor survey ("indicate the degree to which you were familiar with the research being conducted by [the cited research lab]"). As expected, the mean Likert response by the cited inventors was 3.2, compared to 2.5 for the citing inventor responses shown in Figure 4. Of course, it is impossible to determine the extent to which the difference is due to understatement by the citing inventors or overstatement by the cited inventors, or possibly connected to the slightly different wording of the two questions.

In addition to comparing the means, we can examine the correlation between the evaluations of the cited and citing inventors for those cases where both responded with

[10] These variables are also significant within the placebo group (results not reported).

respect to a given citation link. Unfortunately, we have only 72 such matched pairs, and only 61 of these contain responses to all of the questions discussed in this section. For these pairs, the correlation between the cited inventor's answer to Question 9 with the citing inventor's answers to the various spillover questions is typically about .25. While this correlation is high enough to suggest that the survey responses are "consistent" at least in this sense, it reminds us that the responses are themselves only noisy indicators of the "true" underlying process.

Two other questions in the cited inventor survey provide some insight into the extent of spillovers, as perceived by their presumed "source".. Question 7 asks about the cited inventors' knowledge of the research of the citing inventors. About 14% of the cited inventors indicated that they knew that the citing inventor was engaged in this kind of research. About 10% either knew that research of this sort was underway but didn't know who was doing it, or knew of the citing inventor but not that they were working on the citing invention. Approximately three-fourths indicated knowledge of the citing inventors or their research. Question 8 asks about memory of communication with the citing inventor. About 80% of the cited inventors indicated that they had no knowledge of communication with the citing inventor; 9% did remember communication and 9% were not sure.

In comparing these responses to those of the citing inventors, there are presumably two offsetting effects. While the cited inventors may have generally a greater tendency to indicate communication than the citing inventors, some forms of communication (e.g. reading the cited inventor's papers) occur without the knowledge of the cited inventor. In Figure 6, about 6% of citing inventors reported "direct communication" with the cited inventor, and another 12% indicated that they had viewed a presentation or a demonstration. Assuming that the citing inventor's viewing a demonstration or presentation might or might not be something that the cited inventor would know about, this seems quite consistent with both the 14% of cited inventors who knew the citing inventors and their work, and the range of 9-18% for the fraction of cited inventors who believe that communication occurred.

5. Citations and Perceived Importance

In addition to the use of individual citation "links" as possible evidence of knowledge flow, a number of authors have utilized the total number of citations received by a patent as an indicator of the relative significance of patents.[11] Both our citing and cited inventor surveys asked the inventors to rate the "technological significance" and the "economic importance" of the inventions, and also asked whether the patent had been licensed and whether it had been commercialized. Table 2 examines the extent to which each of these different concepts of importance are associated with highly cited patents. In addition, we constructed a composite index of importance by adding up scores on each of these 4 questions in a manner similar to what was described above for the spillover questions.

Each column reports the regression of the log of total citations received on a particular indicator of importance. For this purpose, the citing and cited responses were combined into one dataset. In order to control for variations in citation practice by field and changes in propensity to cite and extent of truncation over time, all regressions include technology field and grant year dummy variables. In addition, based on the findings of Lanjouw and Schankerman (1999), we also included the log of the number of claims made by each patent, to allow for the possibility that patents that contain more claims are more highly cited.

The results do provide some evidence that citations are correlated with significance or importance as perceived by the inventors themselves. Each of the indicators is positively correlated with log citations, with the coefficients achieving t-statistics that vary from just below to just above 2, depending on the question. Not surprisingly, use of the composite index increases the significance of the correlation slightly. There is no particular indication as to whether citations are more associated with technological versus economic significance. The claims variable is strongly significant,

though its elasticity of about .25 suggests strong "diminishing returns" to increasing the number of claims, as distinct from the constant returns relationship suggested by Lanjouw and Schankerman. If claims is excluded from the regression (column 6), the effect of the perceived importance variable increases, suggesting that importance, as perceived by the inventor, reflects both the "size" of the patent as indicated by the number of claims, and the importance or significance of each of the claims.

6. Concluding Remarks

Many of the important concepts in the economics of technological change are fundamentally unobservable. We routinely rely, therefore, on proxies or indicators for the concepts of interest. Often, our only test of the validity of these measures is the extent to which the correlation of the proxies with other variables matches the pattern of correlations predicted by theory. In this paper, we provide an additional kind of evidence about the unobservable process of knowledge flow, and the relationship of patent citations to that process. While survey evidence has its own limitations, including small sample sizes and the biases of the survey respondents, it allows us to get "inside the black box" and potentially achieve a richer and deeper understanding of the processes that we are studying.

The results suggest a "half-full cup" with respect to the validity of patent citations as indicators of knowledge spillovers. Taking the responses at face value, the likelihood of knowledge spillover, conditional on the observation of a patent citation, is significantly greater (in both the statistical and quantitative senses) than the unconditional likelihood. Nonetheless, a large fraction of citations, perhaps something like one half, do not correspond to any apparent spillover. We believe that these results are consistent with the notion of citations as a noisy signal of the presence of spillovers. This implies that aggregate citation flows can be used as proxies for knowledge spillover intensity, for example between categories of organizations or between geographic regions. Further

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[11] See, for example, Trajtenberg (1990) and Henderson, Jaffe and Trajtenberg (1998). For a discussion of citations as one of several indicators of patent importance, see Lanjouw and Schankerman (1999).

work is needed, however, to refine our understanding of the mechanisms by which these flows move and the relationship of those mechanisms to the citation process.

More generally, the results provide some context for the widely-held view that invention is a cumulative process where inventors build in important ways on the work that came before them. They suggest a possibly significant role for direct communication between inventors as part of this cumulative process. Clearly, more work is needed in this area, both to assess the importance of communication and to understand its determinants. In particular, our survey says nothing about what attributes of inventors or technologies influence the extent to which different kinds of communication are used or are effective. For future work, consideration should be given to collecting more information about the inventors themselves, so that these relationships could begin to be explored.

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Lanjouw, Jean O. and Mark Schankerman, 1999, "The Quality of Ideas: Measuring Innovation with Multiple Indicators," ***National Bureau of Economic Research Working Paper No. 7345***

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Table 1
Ordered Probit for Spillover Index

	All Answers	All Answers	Placebos Only	True Citations Only	True Citations Only
True Cited Patent	0.861	0.511			
	**(.145)	**(.160)			
"Cited" Grant Year	0.016	0.008	-0.048	0.036	0.028
	(.012)	(.013)	*(.024)	**(.014)	(.014)
Log of Total Citations	0.187	0.104	0.202	0.186	0.08
Received by Cited Patent	**(.071)	(.076)	(.153)	*(.081)	(.087)
Same State	0.414	0.418	0.196	0.43	0.421
	*(.189)	*(.201)	(.461)	*(.210)	(.219)
Total Citations Made by	-0.0086	-0.0072	-0.019	-0.007	-0.006
Citing Patent	*(.0040)	(.0042)	(.012)	(.004)	(.005)
Chemicals and Drugs	0.258	0.375	-0.208	0.383	0.465
	(.169)	*(.177)	(.370)	*(.194)	(.202)
Electronics, Computers	-0.503	-0.451	-0.288	-0.558	-0.508
and Communication	**(.128)	**(.135)	(.265)	**(.147)	(.154)
Technology-		0.174			0.141
Relatedness		**(.061)			*(.064)
Application-		0.264			0.248
Relatedness		**(.056)			**(.059)
Dependent Mean	1.68	1.77	0.53	2.21	2.3
No. of Observations	467	429	148	319	297

Note: excluded technology group is Mechanical and Other.

Table 2
Citations Received as a Function of Inventors' Perception of "Importance"

	Technological Significance[1]	Economic Importance[2]	Licensed[3]	Commercialized[4]	Composite Index	Composite Index
Importance Indicator	0.073	0.076	0.098	0.089	0.041	0.05
	(.038)	*(.035)	(.051)	(.051)	*(.019)	*(.020)
Log of Claims	0.241	0.239	0.243	0.251	0.25	
	**(.054)	**(0.054)	**(.053)	**(.053)	**(.052)	
No. of Observations	367	364	368	344	380	380
R^2	0.237	0.24	0.237	0.262	0.242	0.195
Indicator Mean	3.6	3.3	0.86	2.3	4.8	4.8

Notes: Dependent variable is log of citations received.
All Equations also include dummies for each year and technology field (6 fields) dummies.

[1] Likert scale (5 point)
[2] Likert scale (5 point)
[3] "no"=0; "maybe"=1 and "yes"=2
[4] "not incorporated in any product or process"=0; "incorporated in commercially unsuccessful product or process"=1
"incorporated in product or process, too soon to tell if successful"=2;
"incorporated in a commercially successful product or process"=3

Figure 1a
Perceived Similarity of Technology Between Citing and Cited Patents

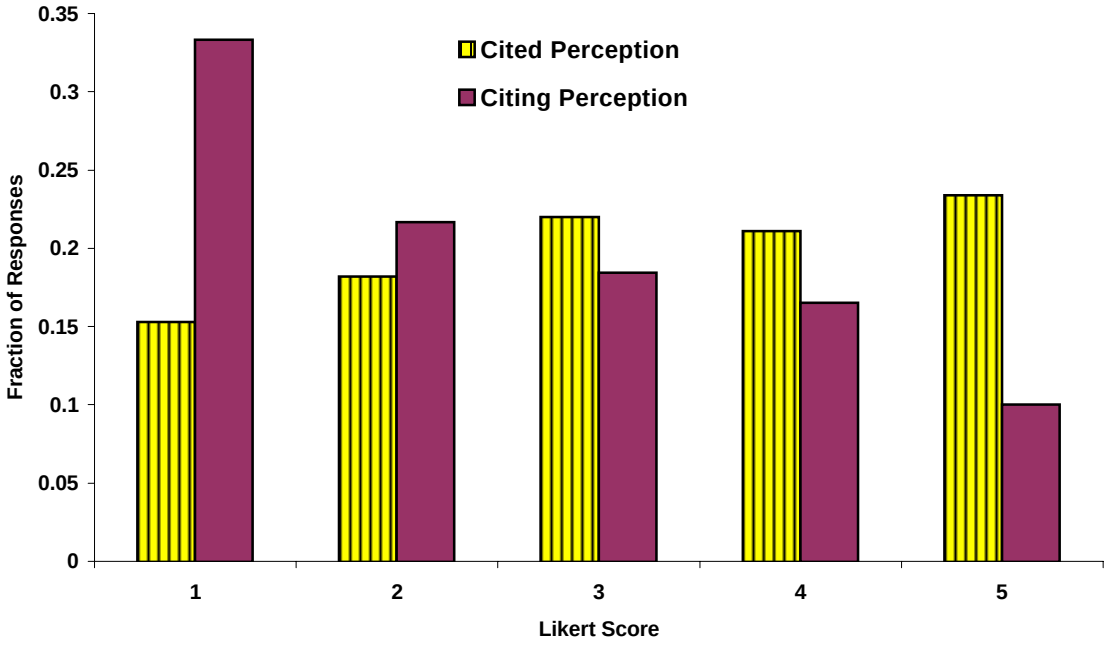


Figure 1b
Perceived Similarity of Application Between Citing and Cited Patents

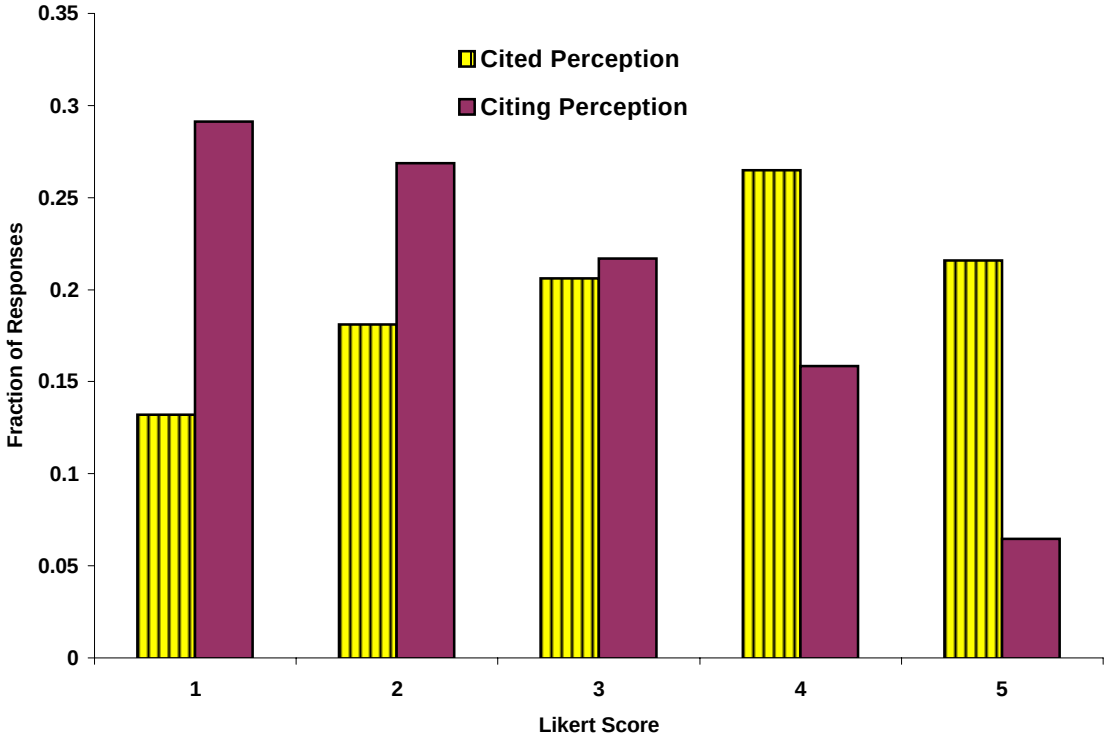


Figure 2
Distribution of Composite "Relatedness" Index

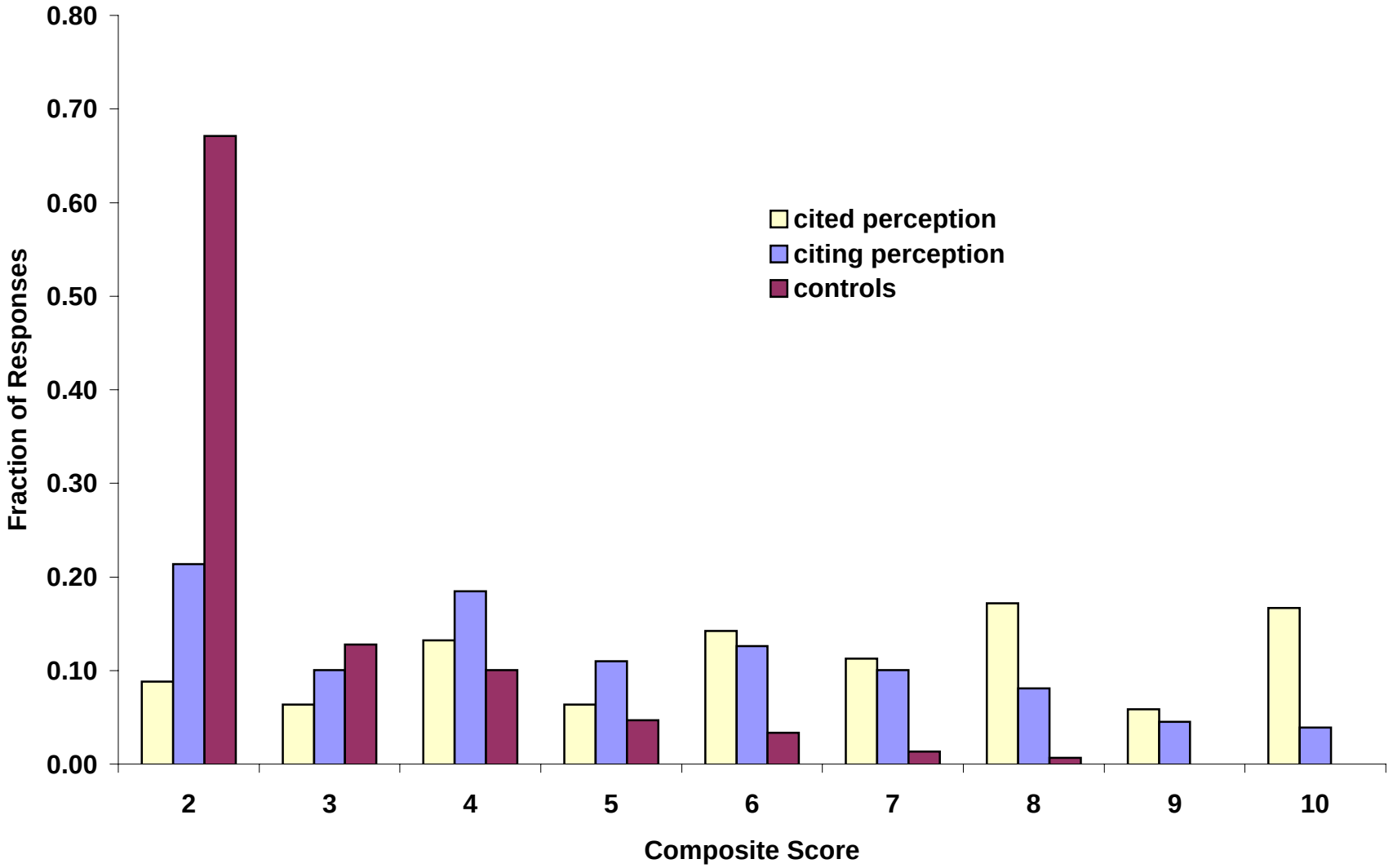


Figure 3
Significant Influences on the Development of Inventions

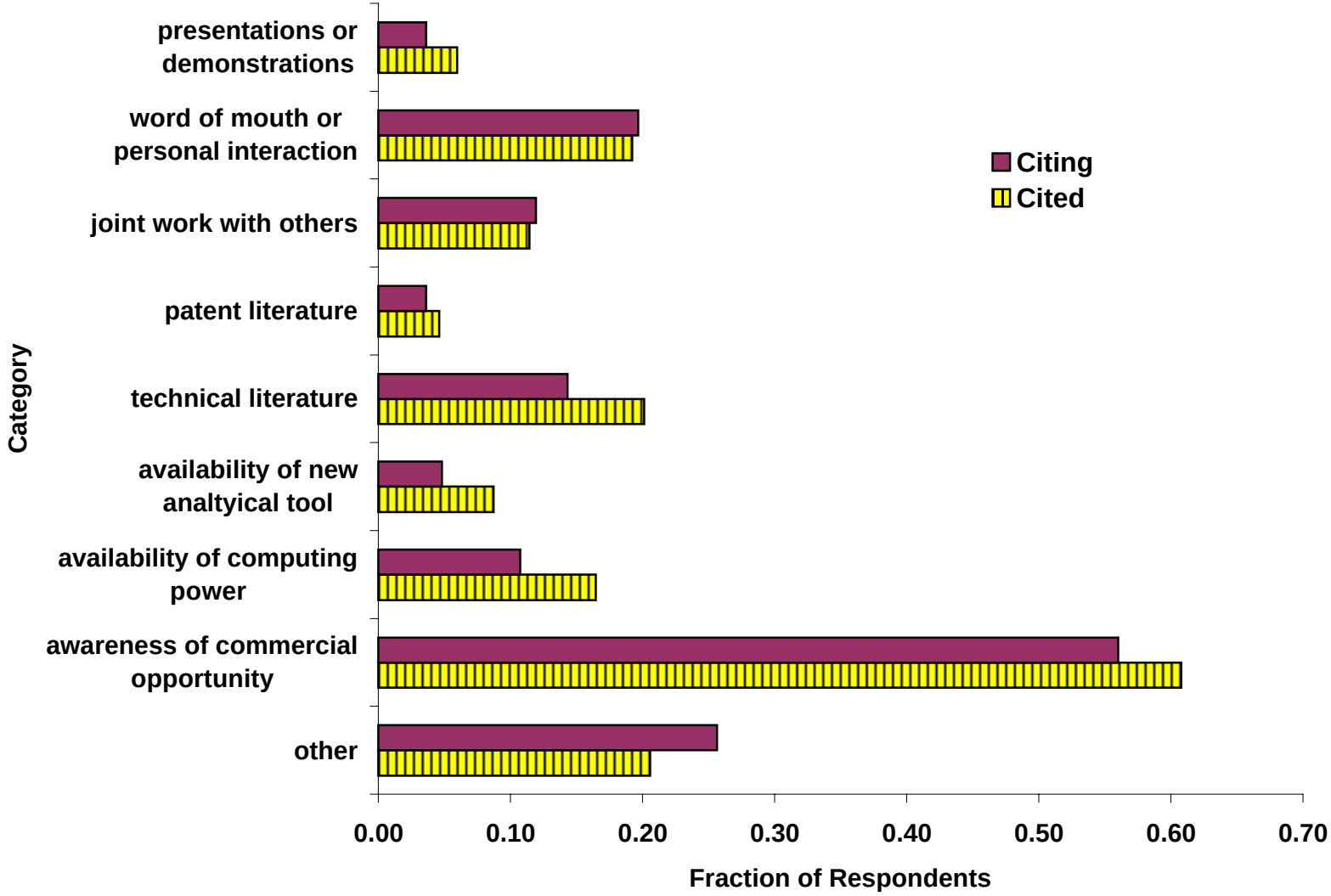


Figure 4
Distribution of Answers to: Degree of Familiarity with Previous Invention

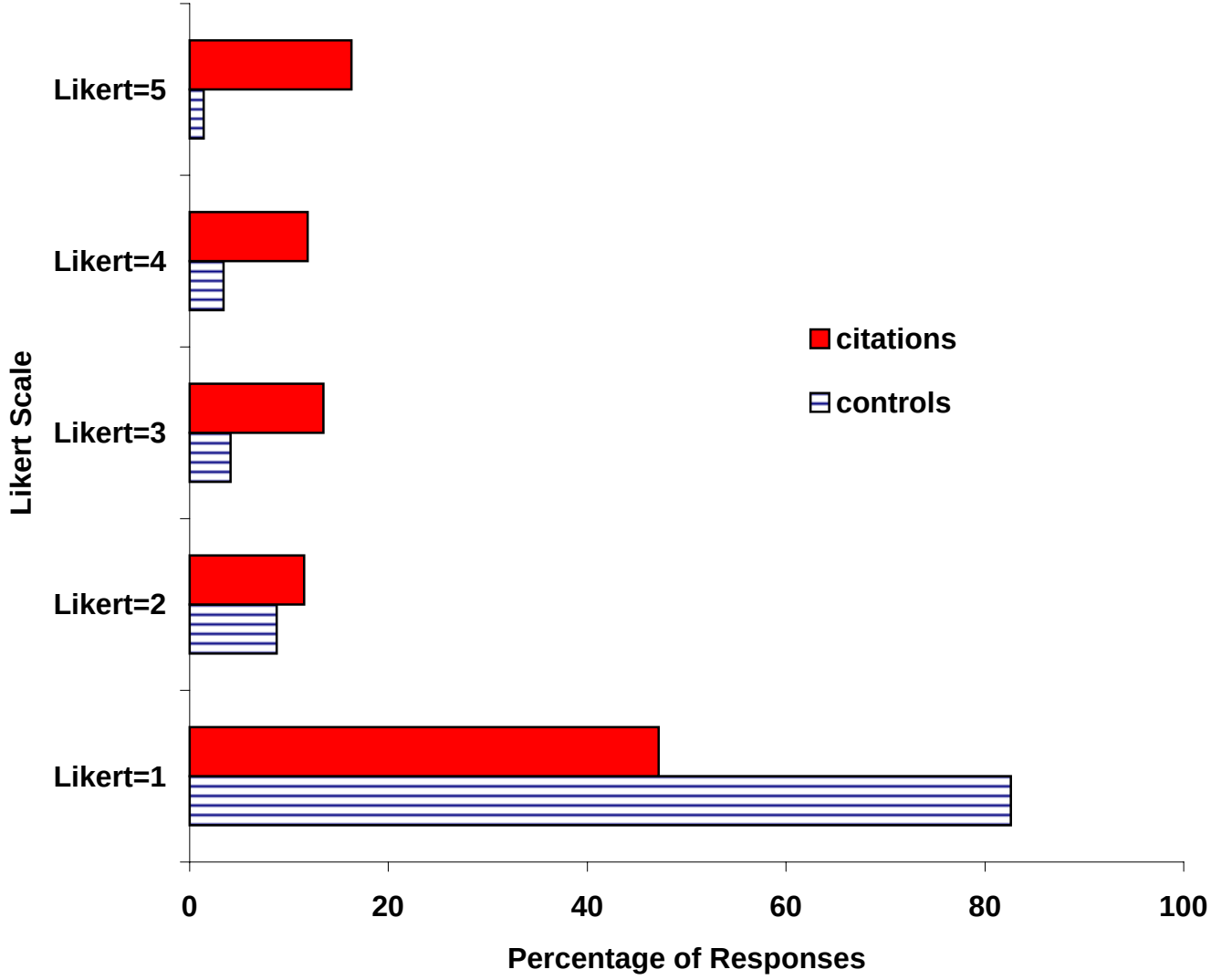


Figure 5
Distribution of Answers to: When did you learn about the previous invention

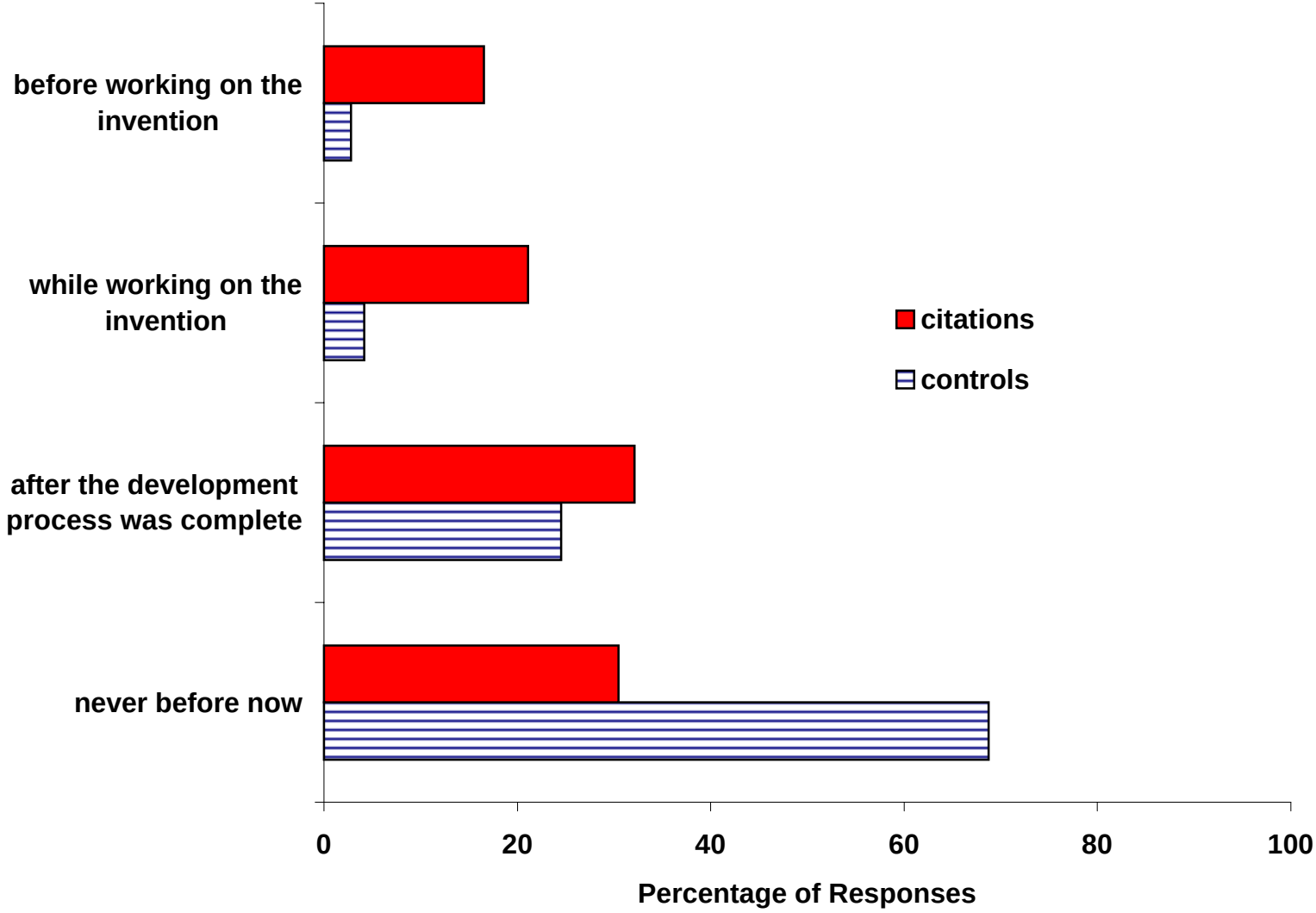


Figure 6
Distribution of Answers to: How did you learn about previous patent

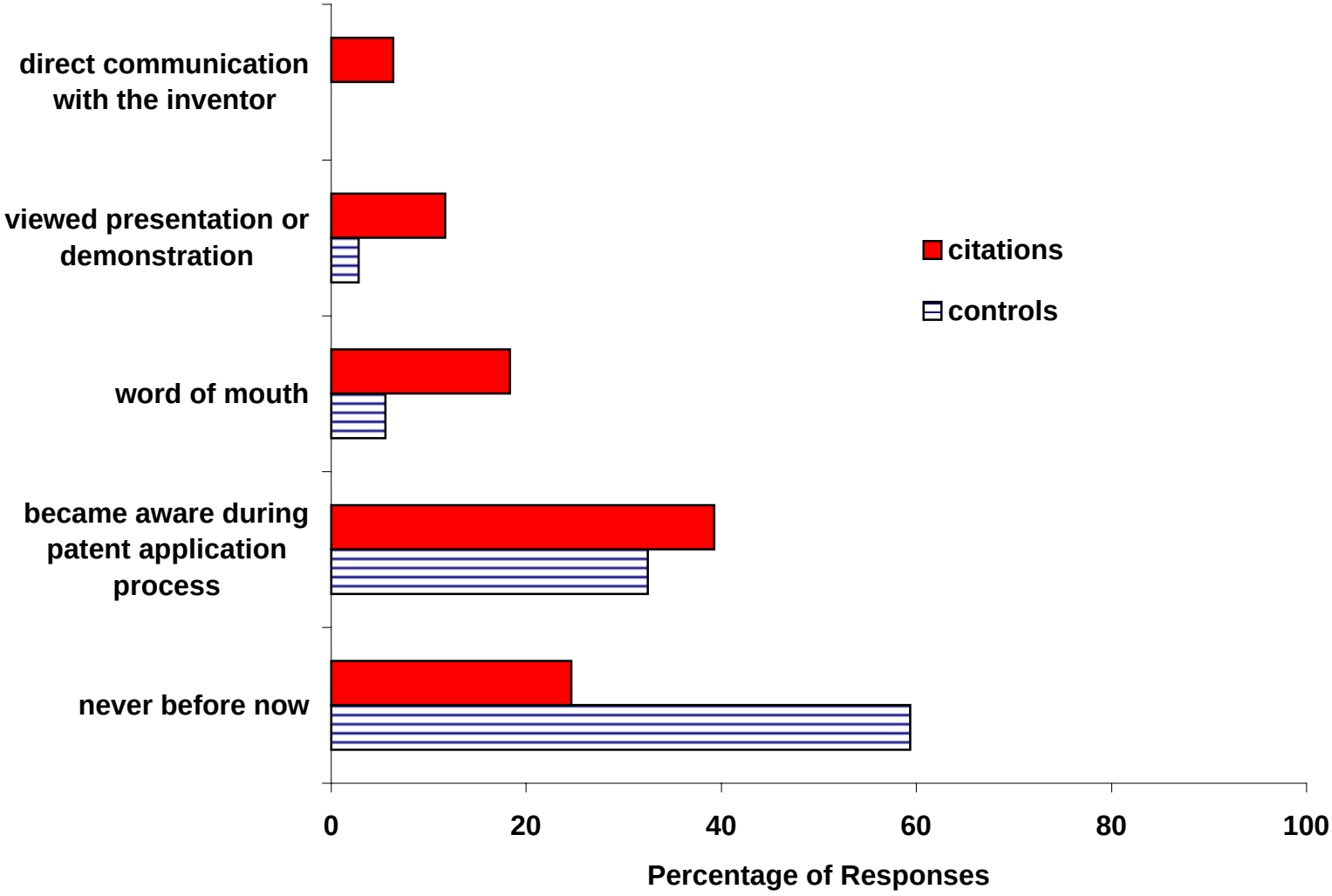


Figure 7
Distribution of Answers to: What did you learn from the previous invention

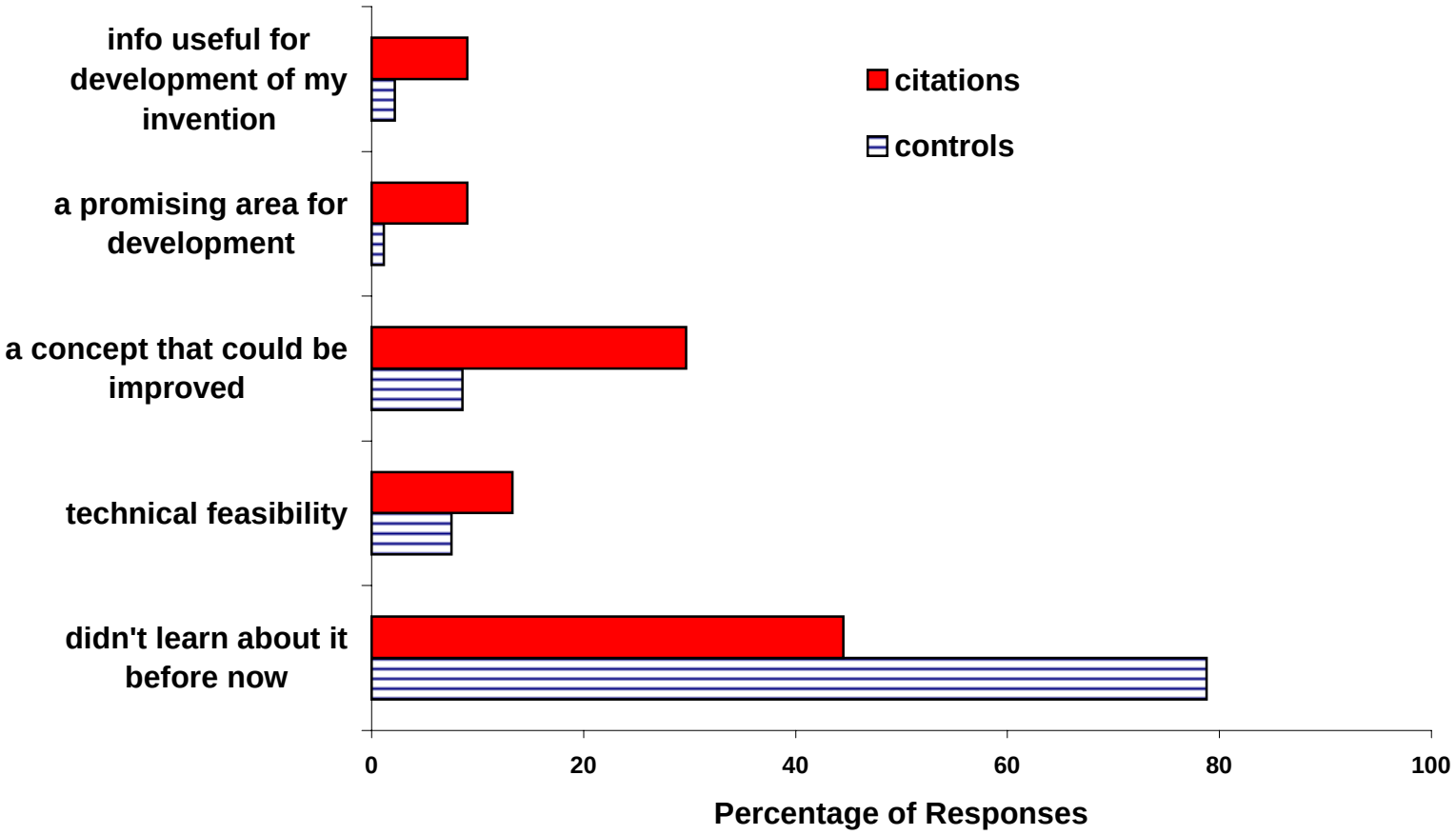
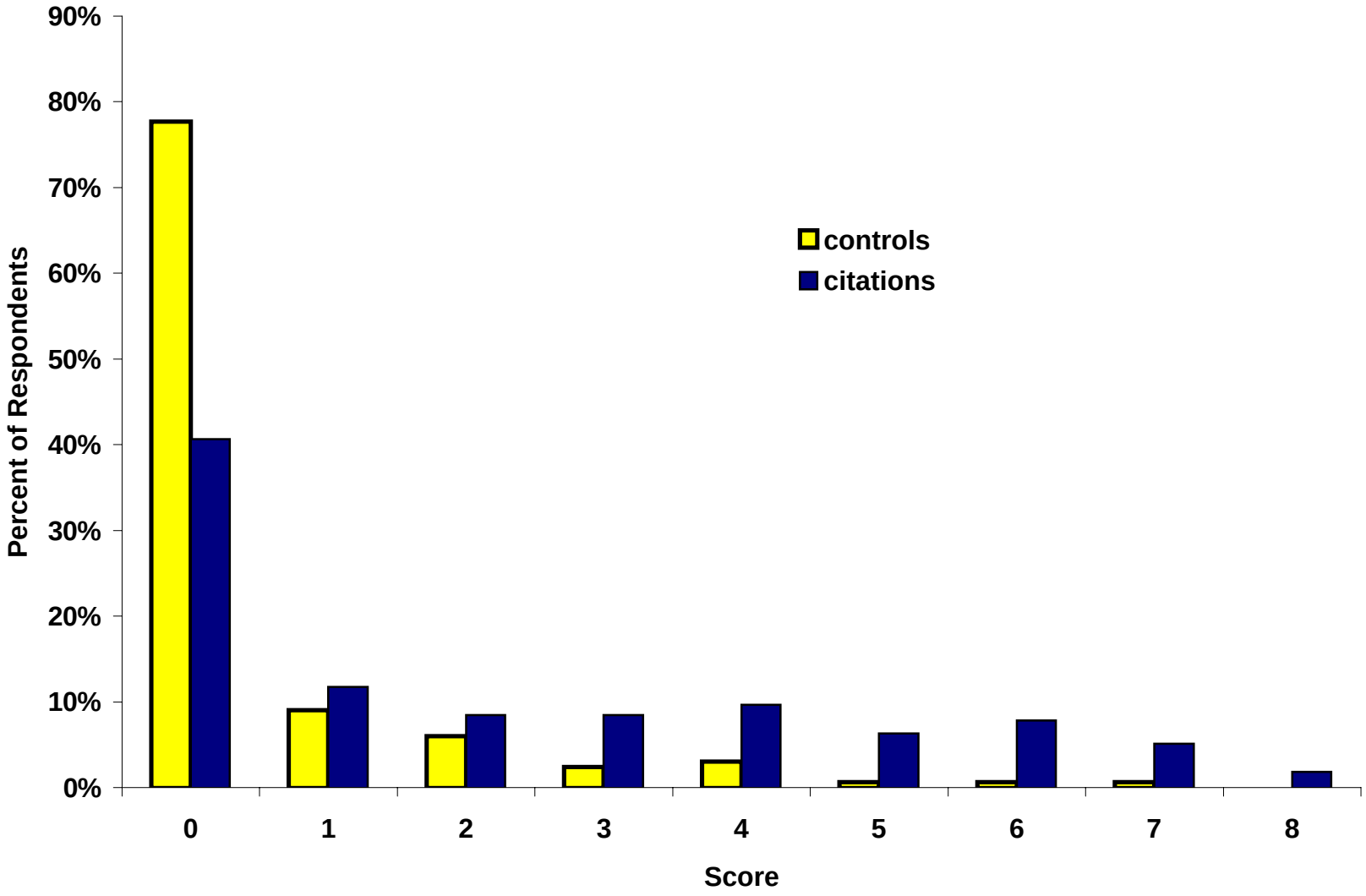


Figure 8
Distribution of Composite Spillover Score



SURVEY OF
PATENTS AND INOVATION
1998
CITING INVENTORS QUESTIONNAIRE

Instructions

- Please answer all questions.
- Refer to the enclosed abstract of one of your patents, as well as the abstracts of three other patents cited by your patent.
- You may consult with a co-inventor if you choose.
- If you are not sure of an answer, please make an educated guess or write "Don't know."
- We welcome any comments at the end of the survey that would explain your answers or improve the questionnaire.

Pledge of Confidentially

Information obtained will be released in aggregate form so that responses of individuals cannot be identified.

Please return the completed survey in the enclosed addressed envelope within one week of the date of receipt. The ID number on the label is the number assigned to you for confidentially and reference. If you have any questions regarding the survey or the completion date, please call the Center for Regional Economic Issues at 216-368-5539 or contact REI by e-mail at rca4@guinness.som.cwru.edu.

Questions 1 through 6 refer only to your patent.

1. **Rank the technological significance of your invention relative to other patented inventions in the same area as yours. *Check one.***

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

not significant ⟶ highly significant

2. **Rank the economic importance of your invention relative to other patented inventions in the same area as yours. *Check one.***

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

not important ⟶ highly important

3. **Has your invention been licensed?**

☐ no ☐ not sure ☐ yes

4. **Which of the following most accurately describes the commercialization of your invention? *Check one.***

(a) not yet incorporated in any product or process ☐

(b) incorporated in a commercially unsuccessful product or process ☐

(c) incorporated in a product or process, but it is too soon to judge if it will be commercially successful ☐

(d) incorporated in a successful commercial product or process ☐

(e) do not know ☐

5. **Very briefly describe the source of the most important core idea leading to the development of your invention (e.g., recognition of a problem, serendipity, or some commercial product).**

_____

_____

_____

_____

6. Which of the following had a significant influence on the development of your invention? ***Check the <u>one or two</u> most significant statements.***

(a) recent availability of enhanced computing power ☐

(b) awareness of commercial opportunity ☐

(c) work carried out jointly with a consultant, contractor, or other outside organization ☐

(d) availability of a new analytical tool or technique ☐

(e) technical literature ☐

(f) word of mouth or personal interaction ☐

(g) patent literature ☐

(h) presentations or demonstrations ☐

(i) other (please specify): _____ ☐

_____

_____

_____

Questions 7 through 12 address the possible relationship between your patent and the cited patents. Please respond to these questions <u>separately</u> for each of the three patents.

7. Indicate the degree to which you were familiar with the research being conducted by the assignee (or inventor, if there is no assignee) in the general area of each patent you cited. *Check <u>one</u> for each patent.*

	1	2	3	4	5
for patent # 1	☐	☐	☐	☐	☐
for patent # 2	☐	☐	☐	☐	☐
for patent # 3	☐	☐	☐	☐	☐

not familiar ⟶ very familiar

8. <u>When</u> did you learn about the research or work underlying the inventions in the patents you cited? *Check <u>one</u> statement for each patent.*

	for patent # 1	2	3
(a) before I began working seriously on the idea underlying this invention	☐	☐	☐
(b) during the time period when I was actively working on this invention	☐	☐	☐
(c) after the development process was essentially complete	☐	☐	☐
(d) never before now	☐	☐	☐

9. How did you learn about the technology underlying each patent you cited? *Check the <u>one or two</u> most important statements that apply.*

	for patent # 1	2	3
(a) word of mouth	☐	☐	☐
(b) direct communication with the inventor(s) on the cited patent	☐	☐	☐
(c) presentation(s) or paper(s) by the inventor(s) on the cited patent	☐	☐	☐
(d) demonstration or viewing of a product or prototype	☐	☐	☐
(e) read the cited patent	☐	☐	☐
(f) became aware of cited patent during the patent application process	☐	☐	☐
(g) did not learn about the cited patent before now	☐	☐	☐
(h) other (please specify): _____	☐	☐	☐

_____

_____

_____

10. <u>What</u> did you learn from the technology underlying each patent you cited? *Check the <u>one</u> statement that best applies.*

	for patent # 1	2	3
(a) information useful for the development of my invention	☐	☐	☐
(b) about a promising area for development	☐	☐	☐
(c) a concept which could be improved	☐	☐	☐
(d) about the technical feasibility of a process or approach	☐	☐	☐
(e) did not learn about the cited patent before now	☐	☐	☐
(f) other (please specify):_____	☐	☐	☐

_____

_____

_____

11. Indicate the degree to which you believe your invention is related by <u>common technology or method</u> to the invention in the patents you cited. *Check <u>one</u> box for each patent.*

	1	2	3	4	5
for patent # 1	☐	☐	☐	☐	☐
for patent # 2	☐	☐	☐	☐	☐
for patent # 3	☐	☐	☐	☐	☐

not related → closely related

12. Indicate the degree to which you believe the <u>application or use</u> of your invention is related to that of the invention in the patents you cited. *Check <u>one</u> box for each patent.*

	1	2	3	4	5
for patent # 1	☐	☐	☐	☐	☐
for patent # 2	☐	☐	☐	☐	☐
for patent # 3	☐	☐	☐	☐	☐

not related → closely related

Thank you very much for your cooperation. We would like to express our appreciation by sending you a copy of the survey results and data analysis when they become available. To receive a copy, please print your name and address below.

Name _____

Address _____

City _____ State _____ Zip _____

When you have completed the survey, please return it in the enclosed addressed envelope. If you have any questions, please contact:

Case Western Reserve University
Center for Regional Economic Issues **Phone: 216-368-5539**
10900 Euclid Ave. **Fax: 216-368-5542**
Cleveland, OH 44106-7208 **E-mail: rca4@guinness.som.cwru.edu**

Please add any comments on ways to improve the survey or amplify your answers to offer a better understanding of how the patent system promotes the advancement of technology.

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SURVEY OF

PATENTS AND INOVATION

1998

CITED INVENTORS QUESTIONNAIRE

Instructions

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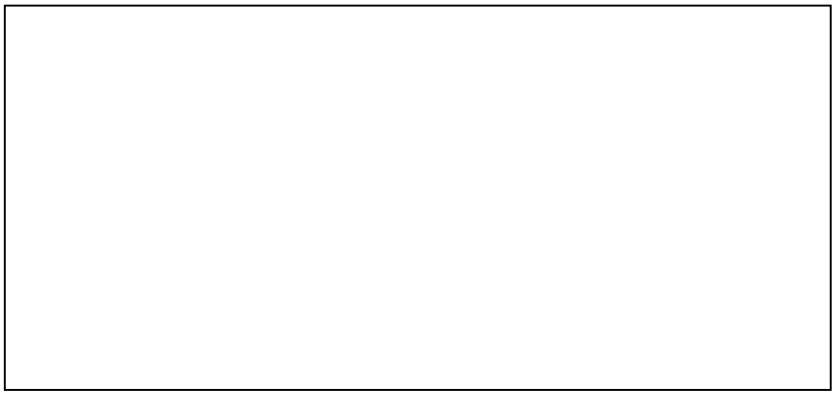
Information obtained will be released in aggregate form so that responses of individuals cannot be identified.



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☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

not significant → highly significant

2. **Rank the economic importance of your invention relative to other patented inventions in the same area as yours. *Check one*.**

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

not important → highly important

3. **Has your invention been licensed?**

☐ no ☐ not sure ☐ yes

4. **Which of the following most accurately describes the commercialization of your invention? *Check one*.**

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(b) incorporated in a commercially unsuccessful product or process ☐

(c) incorporated in a product or process, but it is too soon to judge if it will be commercially successful ☐

(d) incorporated in a successful commercial product or process ☐

(e) do not know ☐

5. **Very briefly describe the source of the most important core idea leading to the development of your invention (e.g., recognition of a problem, serendipity, or some commercial product)**.

_____

_____

_____

_____

_____

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(a) recent availability of enhanced computing power ☐

(b) awareness of commercial opportunity ☐

(c) work carried out jointly with a consultant, contractor, or other outside organization ☐

(d) availability of a new analytical tool or technique ☐

(e) technical literature ☐

(f) word of mouth or personal interaction ☐

(g) patent literature ☐

(h) presentations or demonstrations ☐

(i) other (please specify): _____ ☐

_____

_____

_____

Questions 7 through 11 address the possible relationship between your invention and the invention disclosed in the patent citing your patent.

7. Which of the following best describes your (or your co-inventor's) awareness of the research leading to the invention in the citing patent? *Check one.*

(a) have no knowledge of the research leading to the invention disclosed in the citing patent nor of the inventor(s) ☐

(b) know of the research leading to the invention disclosed in the citing patent but was not aware of who did it ☐

(c) know the inventor(s) but not of the research leading to the invention disclosed in the citing patent ☐

(d) know of the research leading to the invention disclosed in the citing patent and know who did it ☐

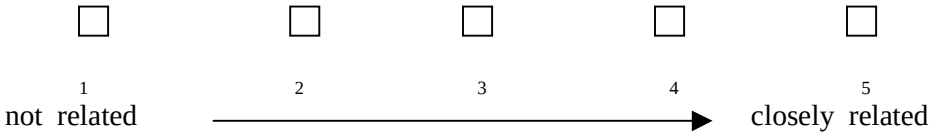
8. Did you or any of your co-inventors ever have any direct communication concerning the technology underlying your invention with any of the inventors credited with the citing patent? *Check one.*

☐ no ☐ not sure ☐ yes

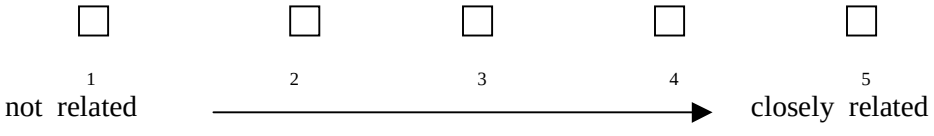
9. What is the likelihood the citing inventor(s) were aware of or relied upon knowledge of your work when they developed their invention. Rely upon your best judgment even if you have no direct knowledge. *Check one.*

☐ 1 not likely ☐ 2 ☐ 3 ☐ 4 ☐ 5 very likely

10. Indicate the degree to which you believe your invention is related by common <u>technology or method</u> to the invention in the citing patent. *Check <u>one</u>*.



11. Indicate the degree to which you believe the <u>application or use</u> of your invention is related to that of the invention in the citing patent. *Check <u>one</u>*.



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Please add any comments on ways to improve the survey or amplify your answers to offer a better understanding of how the patent system promotes the advancement of technology.

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