American University-Industry Research Centers in Biotechnology, Computers, Software, Semiconductors and Manufacturing

Report to the National Academy of Engineering Panel
on
Technology Transfer Systems in the United States and Germany:
Lessons and Perspectives

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EXECUTIVE SUMMARY

- 1. Government is the major source of support for university-industry research centers (UIRCs) in the technology areas of biotechnology, semiconductors, computer hardware and software. In contrast, industry is the major source of support for manufacturing centers.

- 2. Biotechnology and semiconductor centers dedicate the greatest share of their R&D to basic research, about 44%, and manufacturing centers the least, about 33%. Consistent with this pattern, biotechnology centers attribute the least importance to satisfying the goals of industry, while manufacturing centers attribute the most.

- 3. Differences in center productivities are observed across technology areas. A more interesting finding is that across all five technology areas research paper productivity exceeds the productivity of more industrially oriented outputs such as patents, prototypes, new products and new processes by factors of between twenty and one hundred, underscoring the academic character of UIRCs.

- 4. Computed as average aggregate productivity per person, UIRC productivity remains constant as center size increases for all outputs except prototypes and new products where smaller centers appear to be more productive.

- 5. Technology transfer mechanisms involving face-to-face interaction, such as those involving personnel exchange, as well as the delivery of prototypes or designs, are rated as more effective than papers, reports, seminars and telephone conversations.

- 6. Centers indicating a greater commitment to the needs of industry provide participating firms with stronger intellectual property protection and allow firms to impose stronger information disclosure restrictions. These same centers are also typically more productive for outputs of direct interest to industry, such as patents, new processes and prototytpes. The academic productivity of these centers, expressed in terms of research paper productivity, is, however, lower. The major exception to this pattern are the biotechnology centers where paper productivity is relatively constant notwithstanding center commitment to industry. Thus, there appears to be a tradeoff in general between center commitment to industry and higher productivity for outputs of interest to industry against academic productivity and the academic norm of free disclosure, but this tradeoff is partially mitigated in the biotechnology area.

1. Introduction

In the 1980s, university-industry research centers (UIRCs) proliferated throughout the United States. Their spread across American campuses raises the question of whether they serve as effective bridging and transfer mechanisms between the research conducted in American universities and the private sectors' efforts to advance technology. Moreover, to the extent that they satisfy this function, what is the cost--or benefit--to the academic enterprise? Building on an earlier report by Cohen, Florida and Goe (1994), "University-Industry Research Centers in the United States," this report examines for the technology areas of biotechnology, computer hardware, software, semiconductors and manufacturing: 1.) the performance of UIRCs; 2.) UIRC intellectual property conventions and related information disclosure restrictions; and 3.) the effectiveness of the technology transfer mechanisms employed by UIRCs.

2. Background

The 1994 Cohen, Florida and Goe report summarized the findings from a national study that examined the extent, characteristics and activities of UIRCs. The research examined the role of UIRCs in technological innovation and technology transfer, and the effect of industrial funding on the university's research mission. A comprehensive survey of universities and of UIRCs themselves was conducted in 1991 both to identify the population of UIRCs in the United States and to obtain detailed information on them. All 437 universities and colleges that were recipients of industrially-sponsored research between 1981 and 1988 were contacted, and more than 1,000 UIRCs were surveyed. Respondents were UIRC directors. Responses were received from 511 UIRCs nationwide, representing a response rate of 48.4 percent.[1]

From our original survey, we learned that both the number of UIRCs and the magnitude of R&D effort associated with them are quite large. An estimated 1,056 UIRCs were located at more than 200 American campuses as of 1990, with more than half of these established in the 1980s. UIRCs spent an estimated $4.12 billion in 1990.

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[1] See Section 1 of Cohen, Florida and Goe (1994) for a detailed description of the suvey design and administration.

Of this total, we estimated that UIRCs devoted about two-thirds of their effort to R&D, or $2.69 billion, and almost one-fifth to education and training. Their R&D effort was divided roughly equally between basic and applied research, with slightly more than 40 percent going to each.

3. Technology Areas

The NAE requested that we consider the performance, the intellectual property conventions, information disclosure restrictions, and technology transfer mechanisms for UIRC's in the four technology areas of biotechnology, microelectronics computers and manufacturing. The technology area classification scheme employed in our dataset is close but not identical to the NAE panel technology areas. We do not have one area called computers, but break that area into the two areas of computer hardware and software. We also do not have an area called microelectronics, but assign centers to the category of semiconductor electronics. Thus, for the purpose of this report, we will consider UIRC activity in the five technology areas of biotechnology, computer hardware, computer software, semiconductor electronics and manufacturing (defined to encompass industrial automation and robotics). It is important to note that the survey questionnaire asks each respondent to identify all the technology areas to which their research is relevant and they commonly identify more than one.

Table 1 indicates the number and percentage of the sample UIRCs that indicated that their research contributes to each of the five technology areas under consideration. In descending order of representation in our data, we have software, biotechnology, manufacturing, semiconductors and computer hardware centers. Of the sample UIRCs, 26% report that they contributed to the domain of software, 22% report biotechnology, 20% report manufacturing, 13% report semiconductors and 10% report computer hardware.

As shown in Table 2, the federal and state governments are the principal source of support for the centers in biotechnology, semiconductors, computer hardware and software. In these four areas, government provides on average between 42% and 53% of the support for the centers' budgets (adjusted to include in-kind support). The share of support provided by government is the greatest (53%) for biotechnology centers. For manufacturing centers, industry is the principal source of support, providing 41% of the support, with government providing 37%. Of the five technology areas considered, industry contributes the least to the support of biotechnology centers, providing an average of only 21%.

Table 3 shows the allocation of effort across the centers' different activities for the five technology areas. These activities include R&D, education and training, technical assistance, technology transfer and entrepreneurial support. We see observe little difference across the five technology areas in the allocation of UIRC effort to R&D. The centers in all five areas on average allocate close to two-thirds of their effort to R&D. It is interesting to note that the centers for these five areas typically allocate a bit more effort, 13%-18%, to technical assistance and technology transfer than do the centers in the full sample spanning all technology areas[2] which contribute not quite 13% on average to these two activities. Of the five technology areas, the centers in manufacturing and computer hardware dedicate the most effort to these activities, about 18%, and centers in semiconductors the least, about 13%.

Table 3 also provides the centers' allocation of effort across basic and applied research and development. We observe little difference in the allocation of effort to applied research across the five technology areas, but substantial differences in the allocation to basic research and development. The centers in biotechnology and semiconductors dedicate the greatest relative share of effort to basic research, about 44% on average. Centers in manufacturing dedicate the least effort to basic research, about 33%. As might be surmised from the patterns with regard to basic research, biotechnology and semiconductor centers dedicate the least effort to development, about 14% to 15% on average, while manufacturing centers dedicate the most, almost 22%.

The pursuit of activities such as development, technical assistance and technology transfer all reflect the degree to which UIRCs are dedicated to furthering commercial

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[2] See Cohen, Florida and Goe [1994], Table 7.

interests. In our survey questionnaire, we explicitly probed the degree to which UIRCs are committed to the needs of industry by asking center directors to rank three goals on a four point subjective scale ranging from "not important" to "very important." The three goals were: 1.) to transfer technology to industry; 2.) to improve the products or processes of industry; 3.) to create new businesses. Tables 4 through 6 show the center directors' rankings of each of these goals for each technology area, and the means reported are computed by assigning a score of 1.0 to the ranking of "not important" and a score of 4.0 to the ranking of "very important." As seen in Table 6, centers in none of the technology areas rank the goal of creating new businesses highly. The average score across all the centers is slightly over 2.0 (i.e. "somewhat important"). We do, however, observe differences across the technology areas with respect to the two other goals. Across the five technology areas, centers in biotechnology assign the least importance to the goal of improving industry's products or processes and the goal of transferring technology to industry. Relative to the evaluation of these two goals by centers in the four other technology areas, centers in manufacturing assign these two goals the greatest importance. Notwithstanding these differences, however, centers in all five areas claim, on average, that these two goals are "important."

Reflection on Tables 2 through 6 suggest what may be some general patterns across the five technology areas. First, there may be an inverse relationship between the importance of basic research and commitment to industry. For example, while basic research is more important and industry's immediate needs are less important for biotechnology centers, the opposite pattern applies to centers in manufacturing. Moreover, Table 2 suggests that where government support is strongest, namely in biotechnology, commitment to basic research is greatest, and commitment to industry is least. While tempting to suggest that this implies that government support may undercut center commitment to industry, there are in fact numerous state and federal programs that tie public support to industry support.

4. Performance

Evaluating the effects of UIRCs on the pace of innovation and technical advance is a difficult and complicated undertaking due to difficulties in constructing reliable and consistent outcome measures, lags in the innovation process and the complexity of technological change. Also, a complete evaluation of these effects should include firms' own views of their experiences with UIRCs that our survey of UIRC directors does not provide. Nonetheless, there are a series of measures of innovation that can be used to consider the output of UIRCs. We divide the outputs of UIRCs into three classes. First, there are tangible outputs. Examples of such include invention disclosures, patents, patent applications, prototypes, copyrights, licenses and research papers. Second, there are educational outcomes that contribute to the nation's science and engineering human capital. These include Ph.D.'s and Master's degrees awarded on the basis of student participation in UIRCs.

Our third class of outputs, called "intermediate outcomes," was devised to recognize that tangible and even educational outputs do not capture the full contribution of UIRCs to the knowledge base and associated activities of participating firms. Thus, we conceived of a class of intermediate outcomes to reflect some of the intangible effects of UIRC participation on firms' R&D. Accordingly, the survey questionnaire asked center directors to indicate how frequently knowledge produced by UIRCs was used by participating firms to: 1.) improve existing products; 2.) improve existing processes; 3.) introduce new products; 4.) introduce new processes; 5.) make existing R&D projects more efficient; and 6.) introduce altogether new R&D projects.[3] Although this third class of UIRC outcomes offers the advantage of recognizing what some believe to be among the most important contributions of UIRCs to technical advance, namely intangible outputs, our measures of this class of outputs are subject to a range of problems. First, due to the very fact that these outputs are intangible, they are especially subject to measurement error. Second, there may be inter-rater differences in how each of the six outcome types are defined. Moreover, there may be systematic relationships between this measurement error and selected attributes of UIRCs, such as size or age. For

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[3] Respondents were also provided the option of responding "Don't know" to this question.

example, discussions with center directors suggest that what they might have considered a contribution to a participating firm's R&D when their center was small, they would not consider as such now that their center is larger and they have more experience. With these qualifications in mind, we will consider these outcomes simply because there is no other measure available to capture these intangible effects.

In this section, we report the productivities[4] of our sample UIRCs expressed in terms of the three output classes and broken down by the five technology areas under consideration. This is not a straightforward exercise. Cohen, Florida and Goe [1994] reported average center productivities, where producitivity was defined as output per million dollars of center budget. Subsequent research conducted by Randazzese [1995] suggests that while normalizing center outputs (of any type) by center budgets might reveal how much output was produced by a center per dollar of direct center expenditure, it was not telling us how much was being produced per unit of effort. The reason is that what was commonly counted as center outputs appeared to reflect the efforts of faculty and other personnel that are not fully covered by the center budgets. This tendency appears also to be systematically associated with center size, with smaller centers' budgets covering proportionately less of the efforts associated with reported outputs than the budgets of larger centers. Thus, a disproproportionately large share of outputs for smaller centers reflect the use of financial support from outside the center itself, such as departmental funds and so on. This in turn implies that, with regard to their budgets, centers are often not financially self-contained, but benefit from the resources of the broader university environment, and smaller centers tend to benefit in this way more than larger centers. This observation suggests a general feature of UIRCs that needs to be considered when evaluating their productivity. Unlike firms or even universities, UIRCs are typically not stand-alone organizational entities with clear boundaries. They exist within universities, and the boundaries between them and the broader university environment in which they reside can be extremely porous. As a consequence, there may be considerable ambiguity with regard to participation in a

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[4] A "productivity" in this report is defined as an output quantity divided by a quantity of contemporaneous input.

center versus participation in the university setting outside of the center.

In the light of porous center boundaries, we have determined that the best way to evaluate productivity is to normalize center outputs not by budget dollars which do not accurately reflect effort, but by the number of personnel associated with the center. We have found that center directors tend to report the outputs from those faculty and other personnel associated with the center notwithstanding the degree to which those personnel are actually supported by the center budget. Counting personnel associated with centers for the purpose of computing productivity statistics is also not straightforward because the effort from different types of personnel may not be equivalent. In our survey questionnaire, we requested center directors to report the number of faculty, non-faculty research scientists, post-doctoral fellows, graduate students and technical and support staff associated with the center as well as the expenditures associated with each of these personnel categories. For computing productivity per person, we created an aggregate personnel index.[5] In discussions of productivity below, the phrase, "output per person," (or "productivity per person") will signify output per unit of this personnel index.

In addition to suggesting that we normalize output by personnel counts rather than budget dollars, our recent research suggests that we may want compute our summary productivity statistics not by taking the mean value of individual center productivities, but by computing the average productivity per person by dividing total output for all UIRCs (or all UIRCs in a given class) by the sum of all the personnel for all UIRCs (or UIRCs in that class). One rationale for this procedure is that unweighted averages computed on a per center basis will tend to yield extreme values associated with particularly small centers which in turn will skew the results relative to averages computed on what we will call an "aggregate" basis (which are equivalent to size-weighted center averages).

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[5] To create this index, we computed an exchange rate to reflect what the "faculty effort equivalent" was for graduate students and the other personnel categories. Using a method suggested by interviewed center directors, the exchange rate was determined simply by the ratio of the median salary (or support) for a type of personnel (other than faculty) to the median faculty salary for a given technology area. For example, if support for one graduate student represents 25 percent of a full-time faculty member, each graduate student counts as one quarter of a faculty member. Separate exchange rates were computed for each personnel category in each technology area. In related regression analyses of the relationship between center size and output (Randazzese, 1995), we do not have to aggregate across personnel categories, as we do here.

There is a second, more substantive reason for adopting this latter procedure. Using the original procedure of computing average center productivities gives us just that--average center productivities. Using what we are calling the aggregate procedure does not treat the center as the unit of analysis, but the individual as the unit of analysis, and, hence, reports the average productivity per person, not the average productivity per center. The issue is not entirely statistical. The question is whether the output of centers should be attributed to the action of unified, well-delineated organizational entities (as may be appropriate if one were considering the output of an industrial development lab), or to collections of largely autonomous individuals or teams directed by, say, individual faculty members. While it is surely a matter of degree and will vary across centers, our discussions and field research suggests that the latter characterization of centers is a more accurate one. In this regard, centers look more like university entities than industrial R&D labs.[6],[7]

Tables 7 through 10 present productivities for the centers in the five technology areas. Reflecting the above discussion, each of the four tables reflect a different method for

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[6] Four additional points considered in this footnote and the next apply to our method for computing center productivities. First, it is difficult to know whether a blank response for a particular type of output indicates zero or should be treated as a missing value. We adopt the convention that when a respondent answers at least one item in either the tangible or educational output classes, we assume that a blank response to the other output items in that class equal zero. For example, if a respondent reports a positive number for number of Ph.D.'s, but leaves a blank for number of Master's degrees, we interpret that blank as a zero. Second, the presented statistical means were all computed after we trimmed the sample for what were likely spurious outliers. We adopted a common standard for identifying spurious outliers in a distribution which includes all observations lying outside of the range of three interquartile ranges beyond the median observation. To be conservative, we computed the median only on the basis of positive valued observations for any given type of output. This practice typically led to dropping only a small number of observations, on the order of zero to three, for any given output.

[7] Third, in computing the productivity for the intermediate outcomes, we needed to account for the right-censored quality of the data. Unlike the two other classes of outputs for which we requested specific numerical responses, for intermediates, we asked respondents to choose from the following output level categories: zero, 1-5, 6-10, 11-15, and greater than 15 times. To compute the average productivities for these intermediates, we used category midpoints and dropped all observations in the highest, open-ended category of greater than fifteen. We did this because, by including it, we would tend to arrive at very low productivities for the largest centers which would tend to be disproportionately represented in this category. As can be seen in Table 16 of Cohen, Florida and Goe (1994), this procedure leads to relatively few observations being dropped, never more than six percent of the respondents. Fourth, the survey question that elicited the intermediate outcome data was phrased such that each time a center thought it had an impact on a particular firm, that would count as one output. Therefore, the number of outputs could well rise with the number of participating firms. Firm participation tended to be disproportionately higher for smaller UIRCs. To control for this, we normalized the intermediate outcome outputs by the number of participating firms per center. Thus, our intermediate outcome productivities reflect number of outputs per person per participating firm.

computing the productivities. Table 7 reports average center output per million dollars. Table 8 reports average center output per person. Table 9 reports average aggregate output per million dollars. Table 10 reports average aggregate output per person. While the reader is advised to compare results across the four different tables, our discussion focuses on the Table 10 results because it is based on what we believe to be the most sensible of the four computation methods employed.

When comparing productivities across technology areas, it is not reasonable to infer that centers in some area are actually more efficient than in another. Rather, these figures often reflect the fact that some outputs are more relevant to some areas than others, and some areas may lend themselves to one type of output versus another. Also, the same type of output, such as "prototypes," may actually be quite different across areas.

With regard to invention disclosures, manufacturing and semiconductor centers score the highest, with software the lowest. We suspect, however, that software engineers and programmers may not consider new code or new programming methods as an "invention" in many instances. With regard to patents, semiconductors rank first, and software last, probably reflecting that software does not tend to be patented. The oddity here, however, is that biotechnology's patent productivity is almost as low as that of software despite the fact that the propensity to patent in biotechnology is thought to be quite high. This paradox is partially resolved once we note that for patent applications, the productivity of biotechnology is essentially equivalent to the other highest ranking areas of manufacturing and semiconductors. Our interpretation is that biotechnology centers tend to be of somewhat newer vintage than those in the other areas, and the patent figures may reflect a gestation lag. It is also notable that the patent application productivity for manufacturing centers is relatively high despite the observation that the propensity to patent new manufacturing processes by industry tends to be lower than that for new products (e.g. Levin et al., 1987). This may suggest that when the locus of process innovation is outside of the firm, it is more difficult for the firm to keep a process innovation secret. As a result, patents may become more attractive as a mechanism for assuring proprietary control over the invention. With regard to licenses, the top-ranked area is computer hardware, with manufacturing and software not far below.

The top-ranked technology areas in prototype productivity are computer hardware and manufacturing, with biotechnology the lowest. With regard to new product productivity, there are modest differences across the areas. Manufacturing centers are the most productive here, followed by computer hardware and biotechnology. With regard to new process productivity, the two dominant areas are biotechnology and manufacturing, which is sensible given that both of these areas are dedicated principally to process innovation.

Among the tangible outputs overall, the one for which productivity is greatest across all five technology areas is research papers. Underscoring the academic character of UIRCs, the degree to which paper productivity exceeds the productivity for any other tangible output is considerable. Across the different technology areas, center personnel produce on average between six tenths and one paper per person per year. This compares to output of between one one-hundredth and one-twentieth of a unit for any of what might be considered the more industrially oriented outputs such as patents, prototypes, new products and processes, etc. In the paper category, we observe that the differences across technology areas are not that substantial except for computer software, which is relatively low. This is unsurprising if one believes that, for computer software, the currency of academic advancement may include not only papers, but working code.

Regarding the generation of Ph.D.'s awarded principally on the basis of research conducted under center auspices, the semiconductor area was noticeably higher ranked than the other four areas, and software the lowest.

One might be skeptical about reporting from centers with very few faculty, say two or less, because these entities are arguably not centers but reflect the activity of only individual faculty members. Table 11 is identical to Table 10 except that it drops all centers with two or fewer participating faculty. The qualitative results are the same as in Table 10 with only a couple of exceptions. First, for prototypes, centers in the area of manufacturing become the most productive. This makes sense if one believes that the development of prototypes may require somewhat larger teams in the manufacturing area than in other areas, and that the manufacturing area lends itself readily to prototypes as an output. Another modest difference from Table 10 is that the areas of manufacturing and semiconductors now dominate with regard to new product generation.

An important question for policymakers in both the public and private sectors is the relationship between center size and center productivity. The average productivities per million dollars of center budget for the full sample displayed in Table 21 of Cohen, Florida and Goe (1994) appeared to suggest that centers with annual 1990 budgets of a half million dollars or less were considerably more productive than centers whose budgets exceeded that figure for every output type that we examined. In discussing those results, Cohen, Florida and Goe (1994) cautioned the reader not to infer that smaller centers were actually more productive because there were reasons to believe that those original results were artifactual. One of those reasons was that smaller centers were conceivably benefitting more than larger centers from the resources of the university.[8] As suggested in the discussion above on productivity measurement, we have concluded that center budget dollars often do not reflect the effort expended to produce reported outputs, and that smaller centers indeed appear to benefit particularly from personnel effort not covered by the center budget.

Table 12 replicates Table 21 of Cohen, Florida and Goe (1994) for the entire UIRC sample, except that it presents average aggregate productivities per person for centers with budgets of a half million dollars or less versus centers with budgets greater than a half million dollars. The original Table 21 presented average center productivities per dollar. Thus, computed in the same way that the productivities are computed in Table 10 above, the Table 12 figures do not reflect average center productivities but compare the average productivities per person for large versus small centers. In other words, Table 12 addresses the question whether an individual participating in a small center is more productive on average than someone participating in a large center.

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[8] We suspect that, in contrast to smaller centers, larger centers may actually, on balance, contribute to the university through their contributions to overhead.

In contrast to the Table 21 results of Cohen, Florida and Goe (1994), there is no longer a clear pattern suggesting that small centers are more productive for every type of output. Among the first class of outputs, from invention disclosures through patents and papers, the average productivities are quite similar for all nine outputs except for two, namely prototypes and new products for which the smaller centers are about twice as productive as the larger centers. For papers, larger centers appear to be slightly more productive. With regard to the educational outcomes of Ph.D.'s and Master's degrees, there is little difference. Of our three major classes of outputs, there is a systematic pattern only with respect to what we have called the intangible intermediate outcomes. Here, similar to the original results, the smaller centers appear to be five to ten times more productive than the larger centers. Frankly, we are skeptical of these results for the intermediate outcomes for two reasons. First, the inconsistency of these findings with the findings for the other two output classes undermines our confidence. Second, as suggested by the qualitative evidence noted above, there may be a systematic tendency for the directors of smaller, newer centers to overestimate these sorts of contributions relative to the estimates of the directors of larger, more established centers.

Tables 13 through 18 display the average productivities between small and large centers, divided at a half million dollars, for each of the five technology areas. The productivities are computed in the same way as in Tables 10 and 12, and therefore reflect whether an individual is more productive working in a small or large center in each of these technology areas. Examining the tables for all the technology areas reveal almost the same qualitative patterns as suggested by the Table 12 results for the full UIRC sample. Again for prototypes and new products, the smaller centers appear to be more productive. Also, for the intermediate outcomes the small centers appear to be most productive, as in the full sample. There are some exceptions to these general patterns. In biotechnology and semiconductor centers, patent and patent application productivity appears to be roughly twice as high for the smaller centers. In contrast, in computer hardware, the larger centers appear to be more productive with respect to patent applications, research papers and Ph.D.'s. The results in computer hardware will however be especially subject to sampling error since there are only about four observations in the small center class. In computer software, larger centers appear to be more productive in patent applications and licenses.

5. Technology Transfer

The effect of UIRCs on technical advance depends upon the transfer of knowledge and ideas from the UIRC to industry participants. In our survey, technology transfer was defined as the communication of scientific and technological knowledge resulting from UIRC projects to private companies where it could be used in industrial applications. As indicated in Table 4 above, the goal of transferring technology was typically rated as "important" by centers in every technology area, yet, on average, none of the technology areas' centers reported allocations of more than 10% of their effort to this goal, as shown in Table 3.

An important question concerns the effectiveness of the various mechanisms employed to transfer technology from UIRCs to industry. Tables 18 through 22 report on the use and relative effectiveness of technology transfer mechanisms for each of the five technology areas. Tables 18 through 22 report the mean score for each mechanism which is computed by assigning a value of one to a rating of "not effective," through a value of four which is assigned to a rating of "very effective."[9] Not surprisingly, research papers and reports, telephone conversations and informal meetings were cited as the most commonly used mechanisms of technology transfer for all five areas. Seminars and workshops were also widely used.

The technology transfer mechanisms rated as most effective are either those that involve face-to-face interaction (including industry personnel in UIRCs, UIRC personnel in industry labs, and informal meetings with industry personnel) or the delivery of prototypes or designs.[10] These mechanisms were highly rated across all the technology areas. The respondents indicated that the traditional ways of transferring academic

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[9] Note that the effectiveness mean scores are computed only for those centers that have used a given technology transfer mechanism.

[10] The mechanism, "collaborative R&D projects," was rated comparably. We decided, however, that it was difficult to know what was meant by this response, and that it was likely confounded with the other mechanisms that we consider.

findings, namely research papers and technical reports and seminars, were not as effective as these other mechanisms.

6. Intellectual Property and Information Disclosure Policies and Productivity

In this section, we will describe the intellectual property and information disclosure policies for the five technology areas. We will then consider whether, within each technology area, there are differences in productivities associated with the different intellectual property and information disclosure policies.

Cohen, Florida and Goe (1994) indicated the percentage of UIRCs providing different types of intellectual property to participating firms. For the entire UIRC sample (N=511), 45.8% of the centers granted licenses, 26% granted exclusive licenses, 26% granted the assignment of patents, and 14.5% granted copyrights. Table 23 displays the comparable intellectual property right policies for the UIRCs in the five technology areas. These results reflect UIRC responses to the survey question of whether any participating firm in a given center receives the type of intellectual property right in question. The strongest forms of intellectual property protection afforded firms by UIRCs include exclusive licenses and patent assignments for UIRC inventions. We observe that the centers that rank the highest in the granting of exclusive licenses are in the areas of biotechnology and semiconductor electronics, with 40% and 39%, respectively, of the centers in these areas granting such rights, and computer hardware centers come in a close third at 36%. With regard to the assignment of patents to participating firms, computer hardware UIRCs are clearly in the lead, with 44% granting such rights. Manufacturing centers rank second, with 39% of the centers granting patent rights. It is interesting to note that the centers in the four areas excluding computer software grant more exclusive licenses and patents than is average practice for the UIRC sample as a whole.

An interesting question raised by these intellectual property policies is whether those centers that grant stronger forms of intellectual property to industry tend to be more productive. We consider this question for each of the five technology areas by dividing the technology area samples into two intellectual property regimes, distiguished by those centers that confer either patent rights or exclusive licenses versus those that do not.[11] Results are displayed in Tables 24 through 28. In the bottom row of each table, we also report the mean score to the survey question (discussed above) of how important to the center is the mission of improving industry's products or processes. Respondents could answer from "not important," which was scored as a one, to "very important," which was scored as a four.

For biotechnology centers, Table 24 suggests that the most notable differences in productivity between centers which grant participating firms stronger intellectual property protection, versus those that do not, apply to invention disclosures, patent applications and licenses. In contrast to all the other technology areas, in biotechnology there is no difference in research paper productivity between the two intellectual property regimes. There is also almost no difference between centers' degree of commitment to improving industry's products and processes, as shown on the last row of Table 24.

Tables 25 through 28 suggest that for the centers in computer hardware and software and manufacturing, but not in semiconductors, invention disclosure, patent application and license productivity is greater when stronger intellectual property rights are granted to participating firms. Thus, the pattern we observed for biotechnology is reasonably general. No similarly robust pattern seems, however, to apply to new products, processes, prototypes and patents issued, although one may quibble about a couple of these.

We also observe that research paper productivity is much lower for those centers which provide stonger intellectual property protection in three of the five areas. As noted above, in biotechnology, the paper productivity is, however, equal across the two regimes, and for manufacturing centers, paper productivity is slightly greater for the centers granting stronger protection.

The findings regarding the relationship between intellectual property regimes and the

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[11] In light of our skepticism regarding the intermediate outcome class of outputs, we will display the results for this output class along with the others, but do not discuss them.

degree of center commitment to the mission of improving industry's products and processes suggest a possible interpretation of the patterns evident in Tables 25 through 28. For biotechnology and manufacturing centers, the difference between intellectual property regimes in expressed commitment to industry objectives is quite small. This might explain why paper productivity differs little between intellectual property regimes for these two areas. Essentially, there is little difference in the type of activities undertaken between centers associated with these two different intellectual property regimes. In the case of biotechnology, this may be because basic scientific research already yields products of rather immediate interest to industry. As a consequence, greater commitment to industrial objectives need not entail any less of a commitment to academic ones, such as publication. In the case of manufacturing centers, we are observing the outcome of a selection effect. Of the five technology areas, manufacturing is probably the most applied in its orientation. Thus, all the centers in this area tend to do applied work that is relatively close to commercialization. Supporting this view, the last row of Table 28 indicates that manufacturing centers score the highest of all the technology areas with respect to their commitment to the mission of improving industry's products and processes. Thus, reflecting on the patterns for all five technology areas, we suggest that where the level of commitment to industrial concerns does not differ much between intellectual property regimes, as in biotechnology and manufacturing, the centers may not face such a clear tradeoff between doing work which is industrially oriented and academic work. Where that tradeoff is confronted, as in the three other technology areas, greater productivity in terms of outputs of direct interest to industry comes at the cost of academic productivity.

Cohen, Florida and Goe (1994) observed a similar tradeoff with reference to centers' information disclosure policies. For the full sample of UIRCs, centers that adopted more restrictive policies in industry's behalf were more productive for those outputs of interest to industry and less productive for academic outputs such as research papers. Table 29 displays the distribution of these center policies for our five technology areas. The measures we use for these policies are whether the center permits participant firms to affect publication either by imposing a delay or by allowing firms to have information deleted from research papers prior to publication. Of the two restrictions, allowing participating firms to have information deleted from publications may be viewed as representing the greater challenge to the academic norm of free disclosure. Across our five technology areas, the policies of centers in biotechnology, semiconductors and software are close to our overall sample average of almost 35 percent reporting that participating firms can require information to be deleted from papers prior to submission for publication. Computer hardware and manufacturing centers adopt that policy with much greater frequency: 48% of the computer centers and 49% of the manufacturing centers grant firms the right to have information deleted prior to publication.

An important question is whether we see an analogous pattern in productivity differences across centers adopting these different information disclosure policies as we saw across centers adopting different policies regarding intellectual property. Tables 30 through 34 show productivity differences for each of the five technology areas between centers that allow participating firms to have information deleted from papers and those that do not. Again, at the bottom of each table is displayed the mean score (computed on a scale of 1 to 4 signifying importance) for the centers' degree of commitment to improving industry's products and processes. For biotechnology centers, there is a clear pattern: centers that allow the disclosure restriction are more productive, except for paper productivity which is about equal across the two groups. Semiconductor centers display a similar pattern except with regard to new process productivity which is about equal across the two groups, and paper productivity which is much lower for the centers adopting more restrictive disclosure practices. Manufacturing centers show an even stronger pattern of higher productivity for the restricted disclosure group, except that, for that same group, paper productivity is about half of what it is for the centers that do not allow firms to restrict publication. Evidence in computer hardware and software is mixed. In centers in both of these areas, paper productivity is again considerably lower for those centers that allow the imposition of disclosure restrictions, but the productivity for the other outputs is not clearly different between the two groups. For all five areas, we again see the pattern that centers allowing disclosure restrictions rate the importance of improving industry's products and processes much higher than otherwise. This difference is mitigated to some extent for manufacturing centers.

Reflecting on the productivity differences between centers which either provide participating firms stronger intellectual property rights or permit firms to impose strong information disclosure restrictions, we would suggest that neither of these policy differences per se cause the productivity differences that we observe. Rather, we suggest that both of these policies reflect centers' degree of commitment to the objectives and concerns of their industrial participants. We conjecture that to the extent that centers allocate more effort to satisfying the needs of industry, their productivity for the outputs of direct interest to industry increases, but their academic output, expressed in terms of paper productivity, declines. The major exception to this pattern is the set of biotechnology centers. Biotechnology, however, is an area where the basic scientific research that yields papers is already very close to the sort of activity that yields commercial products for industry. As a consequence, biotechnology centers do not have to sacrifice academic research in order to conduct more applied research and development for industry.[12]

We have suggested that what is driving the patterns in productivity differences is the centers' level of commitment to the concerns and goals of industrial participants. We consider this conjecture directly in Tables 35 through 39 by examining the differences in productivity associated with greater degree of commitment to industry as measured by centers' evaluation of the importance of improving industry's products and processes. The broad patterns support the argument posed above, particulary if we combine the two groups at the low end of the scale that claim that the mission is either "not important" or "somewhat important." (We do not combine these two categories in the tables.) The reason for combining these two categories is that there are often very few observations in the group at the lowest end, which is reasonable since these are university-<u>industry</u> centers and we would therefore expect it to be rare for a center to claim that this mission was "not important." Once we do this, the same patterns emerge. Productivity for those outputs of direct relevance to industry tends to increase, while paper productivity tends to decline. The one exception to this pattern is in the semiconductor area where paper

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[12] One output that we have not commented on was Ph.D. productivity. Here, there were no clear robust productivity differences, which may reflect the different role played by Ph.D. engineers and scientists across the different fields.

productivity indeed declines, but productivity with reference to outputs of interest to industry do not display a clear trend.

Cohen, Florida and Goe (1994) observed that UIRCs that were more committed to industry tended to be more productive with respect to outputs of relevance to industry, such as patents and new products, but adopted more restrictive information disclosure policies in behalf of participating firms and were less productive with respect to academic outputs such as research papers. This finding, in turn, suggested that a tradeoff was associated with the deepening of ties with industry. As a consequence of stronger ties, centers were more productive in ways that would tend to have more direct effects on commercialized technical advance, but these stronger ties came at the cost of compromising the academic norms of the the free dissemination of knowledge, and even academic productivity. Our examination of centers in the five technology areas of biotechnology, semiconductors, computers, software and manufacturing affirms the notion that such a tradeoff exists. The one exception, namely centers in biotechnology, suggests an interesting qualification. Where basic research in an area is already close to industrial research, the tradeoff may not be so severe in the sense that academic productivity may not suffer.[13] Another key dimension of that tradeoff does, however, remain in biotechnology; information disclosure restrictions still increase with commitment to industry objectives and concerns, and these restrictions may well impede the ability of academics (and perhaps society generally) to benefit fully from academic research.

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[13] This claim has to be qualified, however, because while paper productivity appears not to change in biotechnology across research disclosure or intellectual property regimes, we do not know whether the composition of research activity changes.

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Table 1

UIRC Research by Technology Area

Technology Area	Number of UIRCS	Percent of UIRCs
Biotechnology	109	22.0
Semiconductors	64	13.0
Computer Hardware	50	10.1
Computer Software	129	26.1
Manufacturing	98	19.8

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

Table 2

Sources of Support for UIRCs: 1990

Source	Biotechnology	N	Semiconductor	N	Computer Hardware	N	Computer Software	N	Manufacturing	N
Government	52.6	102	49.7	56	42.2	43	48.2	115	36.9	90
- Federal Government	36.1	102	39.8	56	33.5	43	39.3	115	28.1	90
- State Government	16.5	102	9.9	56	8.7	43	8.8	115	8.8	90
Industry	21.2	102	29.7	56	38.0	43	33.2	115	41.0	90
University	20.6	102	17.1	56	17.3	43	15.1	115	19.0	90
Private Foundation	3.2	102	1.8	56	2.1	43	2.7	115	2.0	90
Other	2.4	102	1.7	56	0.4	43	0.9	115	1.1	90

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

Table 3

Mission and Focus of UIRCs: 1990

Type of Activity	Biotechnology	N	Semiconductor	N	Computer Hardware	N	Computer Software	N	Manufacturing	N
Percent of Effort Dedicated to:										
Research & Development	64.3	106	67.7	63	64.2	50	64.7	126	63.0	95
Education & Training	18.4	106	17.0	63	13.6	50	16.4	126	16.5	95
Technical Assistance	7.8	106	7.6	63	8.3	50	8.8	126	9.9	95
Technology Transfer	6.9	106	5.3	63	9.6	50	7.7	126	8.2	95
Entrepreneurial Support	2.6	106	2.4	63	4.4	50	2.4	126	2.3	95
Percent of R&D Effort Dedicated to:										
Basic Research	44.5	106	43.8	64	39.7	50	38.0	127	32.6	96
Applied Research	40.7	106	41.8	64	44.4	50	43.8	127	45.8	96
Development	14.8	106	14.4	64	15.9	50	18.3	127	21.6	96

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

Table 4

Distribution of UIRCs by Importance of Selected Goals: Mission To Transfer Technology to Industry

	Not Important	Somewhat Important	Important	Very Important	Mean[1]
Biotechnology (N=109)					
number of centers:	10	30	42	27	2.79
percent:	9.2	27.5	38.5	24.8	-
Semiconductor (N=62)					
number of centers:	3	14	28	17	2.95
percent:	4.8	22.6	45.2	27.4	-
Computer Hardware (N=49)					
number of centers:	4	8	21	16	3.00
percent:	8.2	16.3	42.9	32.7	-
Computer Software (N=127)					
number of centers:	11	26	51	39	2.93
percent:	8.7	20.5	40.2	30.7	-
Manufacturing (N=94)					
number of centers:	3	14	42	35	3.16
percent:	3.2	14.9	44.7	37.2	-

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] where 1 = not important; 2 = somewhat important; 3 = important; and 4 = very important.

Table 5

Distribution of UIRCs by Importance of Selected Goals: Mission To Improve Industry Products or Processes

	Not Important	Somewhat Important	Important	Very Important	Mean
Biotechnology (N=106)					
number of centers:	15	32	34	25	2.65
percent:	14.2	30.2	32.1	23.6	-
Semiconductor (N=63)					
number of centers:	6	21	20	16	2.73
percent:	9.5	33.3	31.7	25.4	-
Computer Hardware (N=49)					
number of centers:	5	15	15	14	2.78
percent:	10.2	30.6	30.6	28.6	-
Computer Software (N=125)					
number of centers:	9	38	41	37	2.85
percent:	7.2	30.4	32.8	29.6	-
Manufacturing (N=96)					
number of centers:	1	17	41	37	3.19
percent:	1.0	17.7	42.7	38.5	-

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] where 1 = not important; 2 = somewhat important; 3 = important; and 4 = very important.

Table 6

Distribution of UIRCs by Importance of Selected Goals: Mission To Create New Businesses

	Not Important	Somewhat Important	Important	Very Important	Mean
Biotechnology (N=107)					
number of centers:	35	37	23	12	2.11
percent:	32.7	34.6	21.5	11.2	-
Semiconductor (N=64)					
number of centers:	19	26	14	5	2.08
percent:	29.7	40.6	21.9	7.8	-
Computer Hardware (N=50)					
number of centers:	14	17	13	6	2.22
percent:	28.0	34.0	26.0	12.0	-
Computer Software (N=124)					
number of centers:	42	54	21	7	1.94
percent:	33.9	43.5	16.9	5.6	-
Manufacturing (N=96)					
number of centers:	21	48	18	9	2.16
percent:	21.9	50.0	18.8	9.4	-

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] where 1 = not important; 2 = somewhat important; 3 = important; and 4 = very important.

Table 7

1990 UIRC Productivity: Average Across Centers

Output per million dollars

	BIOTECHNOLOGY	SEMICONDUCTORS	COMPUTER HARDWARE	COMPUTER SOFTWARE	MANUFACTURING (Industrial Automation and Robotics)
Innovation Outcomes:					
Invention Disclosures	1.29(81)	1.14(43)	0.47(29)	0.57(88)	0.90(66)
Patent Applications	0.86(79)	0.95(44)	0.44(29)	0.43(88)	0.49(67)
Patents Issued	0.42(78)	0.84(44)	0.17(30)	0.18(89)	0.25(66)
Licenses	0.18(79)	0.05(43)	0.14(30)	0.30(89)	0.22(67)
Prototypes	0.96(81)	1.92(43)	2.21(30)	2.04(89)	1.88(66)
New Products Invented	0.91(80	0.52(43)	0.81(29)	0.62(89)	0.37(67)
New Processes Invented	0.28(78)	0.19(42)	0.49(28)	0.87(88)	0.23(66)
Copyrights	0.26(80)	0.27(43)	0.47(29)	0.79(88)	1.20(65)
Research Papers	21.77(73)	29.68(42)	21.55(29)	16.38(87)	19.70(65)
Education Outcomes:					
Ph.D.s Granted	2.56(72)	5.26(40)	3.48(33)	2.64(88)	2.67(66)
Master's Degrees Granted	3.89(71)	7.51(41)	9.52(32)	5.10(85)	9.06(66)

Table 7 (Continued)

Intermediate Outcomes:[1]					
Improve Existing Products	0.91(51)	0.75(28)	1.63(22)	1.31(69)	1.20(46)
Improve Existing Processes	1.06(47)	0.98(30)	0.26(24)	0.79(64)	1.51(47)
Introduce New Products	0.73(51)	0.63(28)	0.17(16)	0.79(60)	0.35(40)
Introduce New Processes	0.52(45)	0.80(26)	0.15(16)	0.28(49)	0.59(39)
Make R&D More Efficient	1.56(40)	1.39(29)	0.17(20)	0.95(58)	0.82(43)
Introduce New R&D Projects	1.01(44)	0.54(24)	0.14(21)	1.51(61)	0.73(42)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 8

1990 UIRC Productivity: Average Across Centers

Output per person

	BIOTECHNOLOGY	SEMICONDUCTORS	COMPUTER HARDWARE	COMPUTER SOFTWARE	MANUFACTURING (Industrial Automation and Robotics)
Innovation Outcomes:					
Invention Disclosures	0.0744(87)	0.0506(47)	0.0226(36)	0.0222(103)	0.0472(74)
Patent Applications	0.0526(85)	0.0342(48)	0.0389(36)	0.0209(103)	0.0333(75)
Patents Issued	0.0159(84)	0.0224(49)	0.0168(37)	0.0099(104)	0.0184(74)
Licenses	0.0063(85)	0.0051(48)	0.0254(37)	0.0163(104)	0.0168(76)
Prototypes	0.0523(87)	0.0708(48)	0.1355(37)	0.0747(104)	0.0935(74)
New Products Invented	0.0381(86)	0.0228(48)	0.0410(36)	0.0242(104)	0.0253(76)
New Processes Invented	0.0245(84)	0.0242(47)	0.0242(35)	0.0354(103)	0.0258(74)
Copyrights	0.0157(86)	0.0265(48)	0.0610(36)	0.0413(103)	0.0592(74)
Research Papers	1.2742(77)	1.1593(46)	1.1651(35)	0.8115(100)	0.9848(73)
Education Outcomes:					
Ph.D.s Granted	0.1366(79)	0.1863(48)	0.1185(39)	0.0945(104)	0.1063(76)
Master's Degrees Granted	0.1695(79)	0.3741(49)	0.2339(38)	0.1693(101)	0.3021(76)

Table 8 (Continued)

Intermediate Outcomes:[1]					
Improve Existing Products	0.0473(51)	0.0450(33)	0.0414(26)	0.0354(78)	0.0455(51)
Improve Existing Processes	0.0691(48)	0.0792(35)	0.0213(27)	0.0267(72)	0.0576(53)
Introduce New Products	0.0600(52)	0.0501(35)	0.0203(21)	0.0276(70)	0.0183(47)
Introduce New Processes	0.0545(45)	0.0573(32)	0.0127(20)	0.0198(59)	0.0365(47)
Make R&D More Efficient	0.0742(40)	0.0698(32)	0.0360(24)	0.0323(66)	0.0389(48)
Introduce New R&D Projects	0.0323(48)	0.0364(30)	0.0286(24)	0.0638(68)	0.0325(47)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 9

1990 UIRC Average Aggregate Productivity

Output per million dollars

	BIOTECHNOLOGY	SEMICONDUCTORS	COMPUTER HARDWARE	COMPUTER SOFTWARE	MANUFACTURING (Industrial Automation and Robotics)
Innovation Outcomes:					
Invention Disclosures	0.37(81)	0.52(43)	0.36(29)	0.19(88)	0.49(66)
Patent Applications	0.23(79)	0.27(44)	0.22(29)	0.12(88)	0.25(67)
Patents Issued	0.08(78)	0.16(44)	0.11(30)	0.06(89)	0.10(66)
Licenses	0.04(64)	0.08(37)	0.07(25)	0.03(74)	0.05(58)
Prototypes	0.18(81)	0.32(43)	0.43(30)	0.31(89)	0.38(66)
New Products Invented	0.14(80)	0.12(43)	0.12(29)	0.13(89)	0.14(67)
New Processes Invented	0.25(78)	0.08(42)	0.10(28)	0.14(88)	0.16(66)
Copyrights	0.17(81)	0.98(44)	1.04(30)	0.66(89)	0.90(67)
Research Papers	8.88(73)	10.15(42)	9.04(29)	6.96(87)	10.42(65)
Education Outcomes:					
Ph.D.s Granted	1.01(72)	2.05(40)	1.60(33)	1.21(88)	1.45(66)
Master's Degrees Granted	3.89(71)	4.00(41)	3.06(32)	2.06(85)	3.85(66)

Table 9 (Continued)

Intermediate Outcomes:[1]					
Improve Existing Products	0.07(51)	0.14(28)	0.10(22)	0.10(69)	0.11(46)
Improve Existing Processes	0.08(47)	0.15(30)	0.08(24)	0.11(64)	0.14(47)
Introduce New Products	0.07(51)	0.10(28)	0.07(16)	0.11(60)	0.05(40)
Introduce New Processes	0.06(45)	0.12(26)	0.06(16)	0.08(49)	0.09(39)
Make R&D More Efficient	0.12(40)	0.20(29)	0.10(20)	0.15(58)	0.16(43)
Introduce New R&D Projects	0.07(44)	0.10(24)	0.07(21)	0.17(61)	0.14(42)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 10

1990 UIRC Average Aggregate Productivity

Output per person

	BIOTECHNOLOGY	SEMICONDUCTORS	COMPUTER HARDWARE	COMPUTER SOFTWARE	MANUFACTURING (Industrial Automation and Robotics)
Innovation Outcomes:					
Invention Disclosures	0.0377(87)	0.0420(47)	0.0259(36)	0.0177(103)	0.0415(74)
Patent Applications	0.0229(85)	0.0237(48)	0.0196(36)	0.0115(103)	0.0241(75)
Patents Issued	0.0077(84)	0.0185(49)	0.0133(37)	0.0070(104)	0.0137(74)
Licenses	0.0063(85)	0.0070(48)	0.0133(37)	0.0104(104)	0.0124(76)
Prototypes	0.0175(87)	0.0282(48)	0.0441(37)	0.0284(104)	0.0447(74)
New Products Invented	0.0141(86)	0.0106(48)	0.0157(36)	0.0120(104)	0.0174(76)
New Processes Invented	0.0261(84)	0.0098(47)	0.0092(35)	0.0131(103)	0.0162(74)
Copyrights	0.0204(86)	0.0418(48)	0.0290(36)	0.0303(103)	0.0439(74)
Research Papers	0.9542(77)	0.8607(46)	0.7965(35)	0.5797(100)	0.8715(73)
Education Outcomes:					
Ph.D.s Granted	0.1090(79)	0.1514(48)	0.1048(39)	0.0786(104)	0.1055(76)
Master's Degrees Granted	0.1792(79)	0.2782(49)	0.1979(38)	0.1354(101)	0.2728(76)

Table 10 (Continued)

Intermediate Outcomes:[1]					
Improve Existing Products	0.0088(51)	0.0129(33)	0.0144(26)	0.0109(78)	0.0128(51)
Improve Existing Processes	0.0111(48)	0.0123(35)	0.0101(27)	0.0118(72)	0.0160(53)
Introduce New Products	0.0071(52)	0.0078(35)	0.0077(21)	0.0085(70)	0.0056(47)
Introduce New Processes	0.0062(45)	0.0088(32)	0.0057(20)	0.0075(59)	0.0100(47)
Make R&D More Efficient	0.0146(40)	0.0137(32)	0.0119(24)	0.0138(66)	0.0151(48)
Introduce New R&D Projects	0.0098(48)	0.0086(30)	0.0075(24)	0.0162(68)	0.0142(47)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 11

1990 UIRC Average Aggregrate Productivity Excluding Small Centers

Output per person

	BIOTECHNOLOGY	SEMICONDUCTORS	COMPUTER HARDWARE	COMPUTER SOFTWARE	MANUFACTURING (Industrial Automation and Robotics)
Innovation Outcomes:					
Invention Disclosures	0.0352(70)	0.0430(40)	0.0269(28)	0.0185(82)	0.0402(61)
Patent Applications	0.0204(69)	0.0234(40)	0.0184(28)	0.0115(82)	0.0240(61)
Patents Issued	0.0073(70)	0.0174(41)	0.0125(29)	0.0066(82)	0.0141(61)
Licenses	0.0063(69)	0.0073(41)	0.0135(29)	0.0097(82)	0.0120(61)
Prototypes	0.0152(70)	0.0247(41)	0.0360(29)	0.0241(82)	0.0411(59)
New Products Invented	0.0131(70)	0.0107(41)	0.0172(29)	0.0126(82)	0.0176(61)
New Processes Invented	0.0261(70)	0.0097(40)	0.0084(29)	0.0119(82)	0.0153(59)
Copyrights	0.0207(70)	0.0375(40)	0.0128(28)	0.0255(81)	0.0442(60)
Research Papers	0.9469(64)	0.8757(40)	0.7867(28)	0.5756(80)	0.8767(60)
Education Outcomes:					
Ph.D.s Granted	0.1082(67)	0.1522(43)	0.0929(31)	0.0737(84)	0.1070(64)
Master's Degrees Granted	0.1796(67)	0.2824(43)	0.2057(31)	0.1385(82)	0.2806(64)

Table 11 (Continued)

Intermediate Outcomes:[1]					
Improve Existing Products	0.0069(40)	0.0115(30)	0.0125(20)	0.0090(65)	0.0121(42)
Improve Existing Processes	0.0084(39)	0.0093(31)	0.0100(21)	0.0110(60)	0.0152(45)
Introduce New Products	0.0046(42)	0.0065(30)	0.0063(16)	0.0068(58)	0.0049(38)
Introduce New Processes	0.0038(37)	0.0075(28)	0.0051(16)	0.0057(50)	0.0086(38)
Make R&D More Efficient	0.0111(32)	0.0103(30)	0.0103(18)	0.0136(56)	0.0143(40)
Introduce New R&D Projects	0.0090(40)	0.0075(28)	0.0062(18)	0.0119(56)	0.0143(40)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 12

UIRC Productivity by Size: 1990

UIRC Average Aggregate Productivity per Person

	Small Centers (Budget ≤ $500K) Mean	Large Centers (Budget > $500k) Mean
Innovation Outcomes:		
Invention Disclosures	0.0298(77)	0.0332(260)
Patent Applications	0.0265(77)	0.0237(258)
Patents Issued	0.0113(77)	0.0110(264)
Licenses	0.0081(79)	0.0091(264)
Prototypes	0.0500(78)	0.0180(259)
New Products Invented	0.0388(78)	0.0136(261)
New Processes Invented	0.0265(77)	0.0198(262)
Copyrights	0.0173(79)	0.0156(261)
Research Papers	0.7732(74)	0.8631(248)
Education Outcomes:		
Ph.D.s Granted	0.1043(75)	0.0995(259)
Master's Degrees Granted	0.1890(78)	0.1621(256)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0797(51)	0.0091(180)
Improve Existing Processes	0.0787(50)	0.0119(187)
Introduce New Products	0.0575(45)	0.0106(174)
Introduce New Processes	0.0459(41)	0.0077(161)
Make R&D More Efficient	0.0907(44)	0.0174(170)
Introduce New R&D Projects	0.0922(40)	0.0130(175)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

TABLE 13

1990 UIRC Average Aggregate Productivity by Size: Biotechnology

(Outputs per person)

	Small Centers (Budget ≤ $500K)	Large Centers (Budget > $500k)
Innovation Outcomes:		
Invention Disclosures	0.0517(11)	0.0404(65)
Patent Applications	0.0426(10)	0.0248(64)
Patents Issued	0.0239(10)	0.0083(63)
Licenses	0.0000(11)	0.0073(63)
Prototypes	0.0611(11)	0.0192(65)
New Products Invented	0.0473(10)	0.0154(65)
New Processes Invented	0.0000(9)	0.0319(64)
Copyrights	0.0141(11)	0.0162(64)
Research Papers	1.0918(9)	0.9647(59)
Education Outcomes:		
Ph.D.s Granted	0.0882(10)	0.1097(60)
Master's Degrees Granted	0.1233(10)	0.1982(59)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0470(6)	0.0069(41)
Improve Existing Processes	0.0403(5)	0.0097(39)
Introduce New Products	0.0193(4)	0.0072(42)
Introduce New Processes	0.0180(5)	0.0062(36)
Make R&D More Efficient	0.0789(4)	0.0107(32)
Introduce New R&D Projects	0.0462(5)	0.0075(36)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 14

1990 UIRC Average Aggregrate Productivity by Size: Semiconductors

(Outputs per person)

	Small Centers (Budget ≤ $500K)	Large Centers (Budget > $500k)
Innovation Outcomes:		
Invention Disclosures	0.0439(8)	0.0431(31)
Patent Applications	0.0439(8)	0.0248(32)
Patents Issued	0.0502(8)	0.0124(32)
Licenses	0.0000(8)	0.0073(31)
Prototypes	0.1067(8)	0.0263(31)
New Products Invented	0.0502(8)	0.0088(31)
New Processes Invented	0.0065(7)	0.0096(31)
Copyrights	0.0000(8)	0.0479(31)
Research Papers	1.0785(7)	1.0275(31)
Education Outcomes:		
Ph.D.s Granted	0.1577(7)	0.1501(31)
Master's Degrees Granted	0.1569(8)	0.2889(31)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0625(4)	0.0117(23)
Improve Existing Processes	0.1076(5)	0.0105(24)
Introduce New Products	0.0598(4)	0.0081(22)
Introduce New Processes	0.0687(4)	0.0080(20)
Make R&D More Efficient	0.3324(3)	0.0134(24)
Introduce New R&D Projects	0.1732(2)	0.0083(22)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 15

1990 UIRC Average Aggregate Productivity by Size: Computer Hardware

(Outputs per person)

	Small Centers (Budget ≤ $500K)	Large Centers (Budget > $500k)
Innovation Outcomes:		
Invention Disclosures	0.0105(4)	0.0316(22)
Patent Applications	0.0105(4)	0.0274(22)
Patents Issued	0.0000(4)	0.0161(23)
Licenses	0.0000(4)	0.0204(23)
Prototypes	0.1363(4)	0.0536(23)
New Products Invented	0.0629(4)	0.0130(22)
New Processes Invented	0.0105(4)	0.0155(21)
Copyrights	0.0000(4)	0.0559(22)
Research Papers	0.6502(4)	1.0795(22)
Education Outcomes:		
Ph.D.s Granted	0.0846(5)	0.1462(26)
Master's Degrees Granted	0.2750(5)	0.2387(25)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0533(3)	0.0102(17)
Improve Existing Processes	0.0151(3)	0.0093(19)
Introduce New Products	0.0000(1)	0.0093(14)
Introduce New Processes	0.0109(2)	0.0074(13)
Make R&D More Efficient	0.0000(1)	0.0151(17)
Introduce New R&D Projects	0.0000(1)	0.0090(19)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 16

1990 UIRC Average Aggregate productivity by Size: Computer Software

(Outputs per person)

	Small Centers (Budget ≤ $500K)	Large Centers (Budget > $500k)
Innovation Outcomes:		
Invention Disclosures	0.0231(16)	0.0132(68)
Patent Applications	0.0185(16)	0.0099(68)
Patents Issued	0.0046(16)	0.0060(69)
Licenses	0.0046(16)	0.0132(69)
Prototypes	0.1388(16)	0.0249(69)
New Products Invented	0.0509(16)	0.0110(69)
New Processes Invented	0.0416(16)	0.0124(68)
Copyrights	0.0185(16)	0.0428(68)
Research Papers	0.5320(16)	0.6106(67)
Education Outcomes:		
Ph.D.s Granted	0.0828(17)	0.0929(69)
Master's Degrees Granted	0.1693(17)	0.1446(66)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0559(13)	0.0080(52)
Improve Existing Processes	0.0397(11)	0.0089(49)
Introduce New Products	0.0364(12)	0.0081(45)
Introduce New Processes	0.0122(11)	0.0065(35)
Make R&D More Efficient	0.0517(9)	0.0138(45)
Introduce New R&D Projects	0.1240(8)	0.0139(50)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 17

1990 UIRC Average Aggregate Productivity by Size: Manufacturing and Industrial Automation

(Outputs per person)

	Small Centers (Budget ≤ $500K)	Large Centers (Budget > $500k)
Innovation Outcomes:		
Invention Disclosures	0.0301(12)	0.0426(51)
Patent Applications	0.0181(12)	0.0229(52)
Patents Issued	0.0061(11)	0.0102(52)
Licenses	0.0060(12)	0.0123(52)
Prototypes	0.1445(12)	0.0313(51)
New Products Invented	0.0361(12)	0.0135(52)
New Processes Invented	0.0000(11)	0.0176(52)
Copyrights	0.0422(12)	0.0503(50)
Research Papers	0.7226(12)	0.9793(50)
Education Outcomes:		
Ph.D.s Granted	0.0843(13)	0.1104(52)
Master's Degrees Granted	0.3186(14)	0.2669(51)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0919(9)	0.0063(34)
Improve Existing Processes	0.1377(8)	0.0078(36)
Introduce New Products	0.0301(7)	0.0045(31)
Introduce New Processes	0.0517(7)	0.0067(30)
Make R&D More Efficient	0.0738(7)	0.0157(33)
Introduce New R&D Projects	0.0636(5)	0.0144(35)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 18

Use and Effectiveness of Technology Transfer Mechanisms: Biotechnology

	Number of Centers Using Mechanism	Mean Effectiveness Score[1]
Collaborative R&D Projects	74	3.30
Seminars, workshops, symposiums	80	2.86
Research papers & technical reports	89	2.89
Telephone conversations	88	3.01
UIRC personnel in industry labs	21	3.19
Industry personnel in UIRC	32	3.38
Informal meetings with industry personnel	29	3.38
Delivery of prototypes or designs	22	3.41

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] where 1 = not important; 2 = somewhat important; 3 = important; and 4 = very important.

Table 19

Use and Effectiveness of Technology Transfer Mechanisms: Semiconductors

	Number of Centers Using Mechanism	Mean Effectiveness Score[1]
Collaborative R&D Projects	51	3.43
Seminars, workshops, symposiums	49	2.94
Research papers & technical reports	54	2.81
Telephone conversations	55	2.87
UIRC personnel in industry labs	20	3.25
Industry personnel in UIRC	26	3.42
Informal meetings with industry personnel	54	3.24
Delivery of prototypes or designs	21	3.33

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] where 1 = not important; 2 = somewhat important; 3 = important; and 4 = very important.

Table 20

Use and Effectiveness of Technology Transfer Mechanisms: Computer Hardware

	Number of Centers Using Mechanism	Mean Effectiveness Score[1]
Collaborative R&D Projects	39	3.69
Seminars, workshops, symposiums	38	2.76
Research papers & technical reports	43	2.77
Telephone conversations	42	2.74
UIRC personnel in industry labs	17	3.24
Industry personnel in UIRC	20	3.30
Informal meetings with industry personnel	45	3.33
Delivery of prototypes or designs	21	3.52

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] where 1 = not important; 2 = somewhat important; 3 = important; and 4 = very important.

Table 21

Use and Effectiveness of Technology Transfer Mechanisms: Computer Software

	Number of Centers Using Mechanism	Mean Effectiveness Score[1]
Collaborative R&D Projects	92	3.49
Seminars, workshops, symposiums	99	2.95
Research papers & technical reports	111	2.81
Telephone conversations	110	2.86
UIRC personnel in industry labs	39	3.33
Industry personnel in UIRC	49	3.51
Informal meetings with industry personnel	110	3.23
Delivery of prototypes or designs	40	3.45

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] where 1 = not important; 2 = somewhat important; 3 = important; and 4 = very important.

Table 22

Use and Effectiveness of Technology Transfer Mechanisms: Manufacturing

	Number of Centers Using Mechanism	Mean Effectiveness Score[1]
Collaborative R&D Projects	70	3.43
Seminars, workshops, symposiums	80	3.00
Research papers & technical reports	88	2.82
Telephone conversations	83	2.84
UIRC personnel in industry labs	26	3.35
Industry personnel in UIRC	33	3.61
Informal meetings with industry personnel	89	3.26
Delivery of prototypes or designs	43	3.47

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

[1] where 1 = not important; 2 = somewhat important; 3 = important; and 4 = very important.

Table 23

Forms of Intellectual Property Granted by UIRCs to Participating Companies by Technology Area

Technology Area	Licenses	Patents	Exclusive Licenses	Copyrights	N
Biotechnology	54.13	32.11	40.37	19.27	109
Semiconductors	57.81	34.38	39.06	17.19	64
Computer Hardware	64.00	44.00	36.00	32.00	50
Computer Software	49.61	25.58	27.91	23.26	129
Manufacturing	53.06	38.78	31.63	29.59	98

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

Table 24

1990 UIRC Average Aggregate Productivity by Intellectual Property Protection Regime: Biotechnology

(Outputs per person)

	Do Not Receive Strong Intellectual Property Protection	Do Receive Strong Intellectual Property Protection
Innovation Outcomes:		
Invention Disclosures	0.0178(43)	0.0514(44)
Patent Applications	0.0136(42)	0.0294(43)
Patents Issued	0.0060(41)	0.0089(43)
Licenses	0.0004(41)	0.0103(44)
Prototypes	0.0098(43)	0.0229(44)
New Products Invented	0.0123(42)	0.0153(44)
New Processes Invented	0.0449(40)	0.0132(44)
Copyrights	0.0060(42)	0.0302(44)
Research Papers	0.9533(37)	0.9550(38)
Education Outcomes:		
Ph.D.s Granted	0.0875(39)	0.1276(40)
Master's Degrees Granted	0.1899(38)	0.1703(41)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0158(23)	0.0057(28)
Improve Existing Processes	0.0164(19)	0.0088(29)
Introduce New Products	0.0128(21)	0.0051(31)
Introduce New Processes	0.0087(17)	0.0051(28)
Make R&D More Efficient	0.0110(17)	0.0170(23)
Introduce New R&D Projects	0.0105(21)	0.0094(27)
Importance of Industry Mission	2.5000(54)	2.8077(52)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 25

1990 UIRC Average Aggregate Productivity by Intellectual Property Protection Regime: Semiconductors

(Outputs per person)

	Do Not Receive Strong Intellectual Property Protection	Do Receive Strong Intellectual Property Protection
Innovation Outcomes:		
Invention Disclosures	0.0387(24)	0.0440(23)
Patent Applications	0.0290(24)	0.0204(24)
Patents Issued	0.0201(25)	0.0174(24)
Licenses	0.0060(24)	0.0076(24)
Prototypes	0.0296(25)	0.0273(23)
New Products Invented	0.0130(25)	0.0091(23)
New Processes Invented	0.0097(24)	0.0099(23)
Copyrights	0.0154(25)	0.0592(23)
Research Papers	0.9868(23)	0.7821(23)
Education Outcomes:		
Ph.D.s Granted	0.1264(24)	0.1815(24)
Master's Degrees Granted	0.3158(25)	0.2327(24)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0181(12)	0.0110(21)
Improve Existing Processes	0.0197(14)	0.0083(21)
Introduce New Products	0.0089(12)	0.0075(23)
Introduce New Processes	0.0183(10)	0.0062(22)
Make R&D More Efficient	0.0297(13)	0.0079(19)
Introduce New R&D Projects	0.0104(13)	0.0076(17)
Importance of Industry Mission	2.3824(34)	3.1379(29)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 26

1990 UIRC Average Aggregate Productivity by Intellectual Property Protection Regime: Computer Hardware

(Outputs per person)

	Do Not Receive Strong Intellectual Property Protection	Do Receive Strong Intellectual Property Protection
Innovation Outcomes:		
Invention Disclosures	0.0224(18)	0.0310(18)
Patent Applications	0.0112(18)	0.0322(18)
Patents Issued	0.0047(19)	0.0262(18)
Licenses	0.0032(19)	0.0286(18)
Prototypes	0.0126(19)	0.0917(18)
New Products Invented	0.0047(19)	0.0326(17)
New Processes Invented	0.0032(18)	0.0181(17)
Copyrights	0.0260(19)	0.0337(17)
Research Papers	0.8753(18)	0.6803(17)
Education Outcomes:		
Ph.D.s Granted	0.0829(21)	0.1586(18)
Master's Degrees Granted	0.2082(20)	0.1724(18)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0194(10)	0.0114(16)
Improve Existing Processes	0.0101(11)	0.0100(16)
Introduce New Products	0.0075(7)	0.0079(14)
Introduce New Processes	0.0112(6)	0.0039(14)
Make R&D More Efficient	0.0171(11)	0.0089(13)
Introduce New R&D Projects	0.0092(12)	0.0061(12)
Importance of Industry Mission	2.1667(24)	3.3600(25)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 27

1990 UIRC Average Aggregate Productivity by Intellectual Property Protection Regime: Computer Software

(Outputs per person)

	Do Not Receive Strong Intellectual Property Protection	Do Receive Strong Intellectual Property Protection
Innovation Outcomes:		
Invention Disclosures	0.0126(65)	0.0237(38)
Patent Applications	0.0070(65)	0.0167(38)
Patents Issued	0.0023(65)	0.0124(39)
Licenses	0.0070(65)	0.0143(39)
Prototypes	0.0213(65)	0.0368(39)
New Products Invented	0.0103(65)	0.0139(39)
New Processes Invented	0.0131(64)	0.0132(39)
Copyrights	0.0293(65)	0.0315(38)
Research Papers	0.6940(63)	0.4489(37)
Education Outcomes:		
Ph.D.s Granted	0.0754(66)	0.0839(38)
Master's Degrees Granted	0.1583(64)	0.0974(37)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0136(46)	0.0086(32)
Improve Existing Processes	0.0122(41)	0.0114(31)
Introduce New Products	0.0109(38)	0.0071(32)
Introduce New Processes	0.0080(33)	0.0070(26)
Make R&D More Efficient	0.0163(41)	0.0113(25)
Introduce New R&D Projects	0.0199(43)	0.0125(25)
Importance of Industry Mission	2.6623(77)	3.1458(48)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 28

1990 UIRC Average Aggregate Productivity by Intellectual Property Protection Regime: Manufacturing

(Outputs per person)

	Do Not Receive Strong Intellectual Property Protection	Do Receive Strong Intellectual Property Protection
Innovation Outcomes:		
Invention Disclosures	0.0253(35)	0.0477(39)
Patent Applications	0.0193(35)	0.0259(40)
Patents Issued	0.0048(34)	0.0171(40)
Licenses	0.0048(35)	0.0152(41)
Prototypes	0.0458(35)	0.0442(39)
New Products Invented	0.0036(35)	0.0026(41)
New Processes Invented	0.0099(34)	0.0185(40)
Copyrights	0.0302(35)	0.0493(39)
Research Papers	0.8103(35)	0.8965(38)
Education Outcomes:		
Ph.D.s Granted	0.0974(38)	0.1115(38)
Master's Degrees Granted	0.3553(38)	0.2132(38)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0261(18)	0.0079(33)
Improve Existing Processes	0.0293(20)	0.0092(33)
Introduce New Products	0.0077(13)	0.0052(34)
Introduce New Processes	0.0237(15)	0.0068(32)
Make R&D More Efficient	0.0234(17)	0.0123(31)
Introduce New R&D Projects	0.0126(16)	0.0148(31)
Importance of Industry Mission	3.0625(48)	3.3125(48)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 29

Research Disclosure Restrictions by Technology Area

Technology Area	Information Can be Deleted from Publications	Publication can be Delayed	Both Restrictions	N
Biotechnology	33.64	60.75	30.84	107
Semiconductors	33.87	58.06	27.42	62
Computer Hardware	48.00	64.00	40.00	50
Computer Software	36.80	50.40	31.20	125
Manufacturing	49.46	64.52	45.16	93

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.

Table 30

1990 UIRC Average Aggregate Productivity by Ability of Affiliated Firms to Delete Information from UIRC Publications: Biotechnology

(Outputs per person)

	Cannot Delete	Can Delete
Innovation Outcomes:		
Invention Disclosures	0.0296(56)	0.0616(31)
Patent Applications	0.0181(54)	0.0374(31)
Patents Issued	0.0065(55)	0.0114(29)
Licenses	0.0056(56)	0.0084(29)
Prototypes	0.0134(56)	0.0298(31)
New Products Invented	0.0114(55)	0.0222(31)
New Processes Invented	0.0316(54)	0.0097(30)
Copyrights	0.0244(55)	0.0083(31)
Research Papers	0.9616(49)	0.9351(28)
Education Outcomes:		
Ph.D.s Granted	0.1178(47)	0.0916(31)
Master's Degrees Granted	0.1588(49)	0.2227(29)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0075(33)	0.0145(18)
Improve Existing Processes	0.0081(28)	0.0225(20)
Introduce New Products	0.0052(38)	0.0192(14)
Introduce New Processes	0.0040(31)	0.0181(14)
Make R&D More Efficient	0.0112(26)	0.0331(13)
Introduce New R&D Projects	0.0066(33)	0.0238(15)
Importance of Industry Mission	2.4286(70)	3.0294(34)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 31

1990 UIRC Average Aggregate Productivity by Ability of Affiliated Firms to Delete Information from UIRC Publications: Semiconductors

(Outputs per person)

	Cannot Delete	Can Delete
Innovation Outcomes:		
Invention Disclosures	0.0356(30)	0.0538(16)
Patent Applications	0.0266(31)	0.0202(16)
Patents Issued	0.0170(31)	0.0211(17)
Licenses	0.0082(30)	0.0053(17)
Prototypes	0.0245(30)	0.0368(17)
New Products Invented	0.0082(30)	0.0158(17)
New Processes Invented	0.0105(30)	0.0093(16)
Copyrights	0.0677(30)	0.0000(17)
Research Papers	0.9547(29)	0.7563(16)
Education Outcomes:		
Ph.D.s Granted	0.1536(31)	0.1499(16)
Master's Degrees Granted	0.2399(32)	0.3713(16)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0133(19)	0.0122(14)
Improve Existing Processes	0.0126(21)	0.0117(14)
Introduce New Products	0.0089(21)	0.0065(14)
Introduce New Processes	0.0080(18)	0.0096(14)
Make R&D More Efficient	0.0168(20)	0.0097(12)
Introduce New R&D Projects	0.0077(18)	0.0099(12)
Importance of Industry Mission	2.5500(40)	2.9523(21)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 32

1990 UIRC Average Aggregate Productivity by Ability of Affiliated Firms to Delete Information from UIRC Publications: Computer Hardware

(Outputs per person)

	Cannot Delete	Can Delete
Innovation Outcomes:		
Invention Disclosures	0.0272(18)	0.0253(18)
Patent Applications	0.0272(18)	0.0161(18)
Patents Issued	0.0191(19)	0.0105(18)
Licenses	0.0249(19)	0.0077(18)
Prototypes	0.0367(19)	0.0477(18)
New Products Invented	0.0073(19)	0.0198(17)
New Processes Invented	0.0076(18)	0.0099(17)
Copyrights	0.0668(18)	0.0119(18)
Research Papers	0.9498(18)	0.7287(17)
Education Outcomes:		
Ph.D.s Granted	0.1692(21)	0.0618(18)
Master's Degrees Granted	0.1816(22)	0.2091(16)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0230(10)	0.0088(16)
Improve Existing Processes	0.0093(11)	0.0108(16)
Introduce New Products	0.0125(10)	0.0053(11)
Introduce New Processes	0.0055(9)	0.0058(11)
Make R&D More Efficient	0.0137(11)	0.0109(13)
Introduce New R&D Projects	0.0070(13)	0.0080(11)
Importance of Industry Mission	2.4800(25)	3.0833(24)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 33

1990 UIRC Average Aggregate Productivity by Ability of Affiliated Firms to Delete Information from UIRC Publications: Computer Software

(Outputs per person)

	Cannot Delete	Can Delete
Innovation Outcomes:		
Invention Disclosures	0.0148(64)	0.0213(37)
Patent Applications	0.0114(64)	0.0118(37)
Patents Issued	0.0065(65)	0.0076(37)
Licenses	0.0137(65)	0.0065(37)
Prototypes	0.0230(65)	0.0346(37)
New Products Invented	0.0117(65)	0.0126(37)
New Processes Invented	0.0201(64)	0.0057(37)
Copyrights	0.0492(64)	0.0099(37)
Research Papers	0.6496(63)	0.4985(35)
Education Outcomes:		
Ph.D.s Granted	0.1008(63)	0.0523(38)
Master's Degrees Granted	0.1145(62)	0.1570(36)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0122(48)	0.0083(29)
Improve Existing Processes	0.0143(44)	0.0075(27)
Introduce New Products	0.0101(50)	0.0057(20)
Introduce New Processes	0.0090(42)	0.0049(17)
Make R&D More Efficient	0.0158(45)	0.0101(20)
Introduce New R&D Projects	0.0192(46)	0.0110(22)
Importance of Industry Mission	2.6667(75)	3.0652(46)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 34

1990 UIRC Average Aggregate Productivity by Ability of Affiliated Firms to Delete Information from UIRC Publications: Manufacturing

(Outputs per person)

	Cannot Delete	Can Delete
Innovation Outcomes:		
Invention Disclosures	0.0248(35)	0.0584(37)
Patent Applications	0.0131(36)	0.0352(37)
Patents Issued	0.0076(35)	0.0199(37)
Licenses	0.0131(36)	0.0119(38)
Prototypes	0.0220(36)	0.0658(36)
New Products Invented	0.0041(36)	0.0305(38)
New Processes Invented	0.0105(35)	0.0220(37)
Copyrights	0.0536(34)	0.0358(38)
Research Papers	1.1543(35)	0.5733(36)
Education Outcomes:		
Ph.D.s Granted	0.0903(36)	0.1225(37)
Master's Degrees Granted	0.2574(37)	0.2915(36)
Intermediate Outcomes:[1]		
Improve Existing Products	0.0085(21)	0.0165(29)
Improve Existing Processes	0.0098(22)	0.0229(29)
Introduce New Products	0.0063(20)	0.0050(26)
Introduce New Processes	0.0100(22)	0.0101(24)
Make R&D More Efficient	0.0104(20)	0.0198(26)
Introduce New R&D Projects	0.0065(21)	0.0231(25)
Importance of Industry Mission	3.0426(47)	3.2889(45)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 35

1990 UIRC Average Aggregate Productivity by Importance of Mission of Improving Industry's Products or Processes: Biotechnology

(Outputs per person)

	Not Important	Somewhat Important	Important	Very Important
Innovation Outcomes:				
Invention Disclosures	0.0040(11)	0.0356(27)	0.0253(27)	0.0929(20)
Patent Applications	0.0040(11)	0.0208(27)	0.0157(25)	0.0616(20)
Patents Issued	0.0053(11)	0.0082(26)	0.0039(27)	0.0169(19)
Licenses	0.0000(11)	0.0055(27)	0.0065(27)	0.0118(19)
Prototypes	0.0013(11)	0.0109(27)	0.0148(27)	0.0511(20)
New Products Invented	0.0094(11)	0.0098(27)	0.0153(26)	0.0221(20)
New Processes Invented	0.0027(11)	0.0142(27)	0.0488(26)	0.0119(18)
Copyrights	0.0000(11)	0.0153(27)	0.0340(27)	0.0130(19)
Research Papers	1.4876(11)	0.7206(23)	0.7823(22)	1.2497(19)
Education Outcomes:				
Ph.D.s Granted	0.0902(13)	0.0854(22)	0.0858(24)	0.2221(19)
Master's Degrees Granted	0.2083(13)	0.1265(22)	0.1763(24)	0.2318(18)
Intermediate Outcomes:[1]				
Improve Existing Products	0.0065(7)	0.0071(13)	0.0083(19)	0.0117(10)
Improve Existing Processes	0.0029(5)	0.0109(12)	0.0111(20)	0.0140(9)
Introduce New Products	0.0043(8)	0.0059(14)	0.0049(18)	0.0170(11)
Introduce New Processes	0.0029(5)	0.0071(11)	0.0049(19)	0.0099(10)
Make R&D More Efficient	0.0095(6)	0.0264(8)	0.0141(19)	0.0064(6)
Introduce New R&D Projects	0.0055(7)	0.0113(13)	0.0077(18)	0.0108(9)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 36

1990 UIRC Average Aggregate Productivity by Importance of Mission of Improving Industry's Products or Processes: Semiconductors

(Outputs per person)

	Not Important	Somewhat Important	Important	Very Important
Innovation Outcomes:				
Invention Disclosures	0.0317(4)	0.0721(12)	0.0313(17)	0.0434(13)
Patent Applications	0.0079(4)	0.0293(12)	0.0170(17)	0.0362(14)
Patents Issued	0.0000(4)	0.0304(13)	0.0152(17)	0.0159(14)
Licenses	0.0000(4)	0.0088(12)	0.0054(17)	0.0091(14)
Prototypes	0.0238(4)	0.0261(13)	0.0143(17)	0.0594(13)
New Products Invented	0.0000(4)	0.0196(13)	0.0072(17)	0.0137(13)
New Processes Invented	0.0000(4)	0.0109(13)	0.0135(16)	0.0024(13)
Copyrights	0.0000(4)	0.0022(13)	0.0694(16)	0.0295(14)
Research Papers	2.4573(4)	1.0827(11)	0.7744(17)	0.3585(13)
Education Outcomes:				
Ph.D.s Granted	0.1611(5)	0.1636(17)	0.1553(14)	0.0990(11)
Master's Degrees Granted	0.5069(5)	0.2337(18)	0.2418(14)	0.1502(11)
Intermediate Outcomes:[1]				
Improve Existing Products	0.0055(3)	0.0135(7)	0.0108(14)	0.0178(8)
Improve Existing Processes	0.0101(3)	0.0147(9)	0.0096(14)	0.0188(8)
Introduce New Products	0.0178(2)	0.0051(8)	0.0049(14)	0.0165(10)
Introduce New Processes	0.0195(3)	0.0113(7)	0.0065(12)	0.0113(9)
Make R&D More Efficient	0.0177(3)	0.0276(3)	0.0086(14)	0.0134(6)
Introduce New R&D Projects	0.0167(2)	0.0084(9)	0.0077(13)	0.0099(6)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 37

1990 UIRC Average Aggregate Productivity by Importance of Mission of Improving Industry's Products or Processes: Computer Hardware

(Outputs per person)

	Not Important	Somewhat Important	Important	Very Important
Innovation Outcomes:				
Invention Disclosures	0.0244(2)	0.0452(10)	0.0187(12)	0.0346(11)
Patent Applications	0.0000(2)	0.0283(10)	0.0086(12)	0.0519(11)
Patents Issued	0.0000(2)	0.0161(11)	0.0086(12)	0.0260(11)
Licenses	0.0000(2)	0.0375(11)	0.0031(12)	0.0260(11)
Prototypes	0.0000(2)	0.0241(11)	0.0086(12)	0.1989(11)
New Products Invented	0.0000(2)	0.0110(10)	0.0062(12)	0.0605(11)
New Processes Invented	0.0000(2)	0.0083(10)	0.0023(12)	0.0398(10)
Copyrights	0.0000(2)	0.0295(11)	0.0161(11)	0.0836(11)
Research Papers	2.3408(2)	0.9671(11)	0.6953(11)	0.5363(10)
Education Outcomes:				
Ph.D.s Granted	0.1647(5)	0.1478(12)	0.0710(10)	0.0536(11)
Master's Degrees Granted	0.4542(5)	0.1890(11)	0.1085(10)	0.1501(11)
Intermediate Outcomes:[1]				
Improve Existing Products	0.0030(2)	0.0288(5)	0.0100(9)	0.0129(9)
Improve Existing Processes	0.0080(2)	0.0067(6)	0.0137(10)	0.0100(8)
Introduce New Products	0.0085(1)	0.0038(4)	0.0037(8)	0.0158(7)
Introduce New Processes	0.0162(2)	0.0038(4)	0.0047(7)	0.0055(6)
Make R&D More Efficient	0.0299(3)	0.0111(6)	0.0084(9)	0.0196(5)
Introduce New R&D Projects	0.0299(3)	0.0030(8)	0.0070(9)	0.0108(4)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 38

1990 UIRC Average Aggregate Productivity by Importance of Mission of Improving Industry's Products or Processes: Computer Software

(Outputs per person)

	Not Important	Somewhat Important	Important	Very Important
Innovation Outcomes:				
Invention Disclosures	0.0149(6)	0.0171(34)	0.0184(33)	0.0204(27)
Patent Applications	0.0050(6)	0.0116(34)	0.0074(33)	0.0247(27)
Patents Issued	0.0050(6)	0.0034(34)	0.0074(34)	0.0107(27)
Licenses	0.0000(6)	0.0110(34)	0.0042(34)	0.0311(27)
Prototypes	0.0198(6)	0.0281(34)	0.0131(34)	0.0783(27)
New Products Invented	0.0198(6)	0.0096(34)	0.0042(34)	0.0397(27)
New Processes Invented	0.0149(6)	0.0157(34)	0.0116(34)	0.0100(26)
Copyrights	0.0000(6)	0.0089(34)	0.0334(33)	0.0665(27)
Research Papers	1.4379(6)	0.5316(33)	0.5846(33)	0.4749(25)
Education Outcomes:				
Ph.D.s Granted	0.1253(9)	0.0881(31)	0.0704(31)	0.0592(30)
Master's Degrees Granted	0.3133(9)	0.1175(28)	0.1085(31)	0.1173(30)
Intermediate Outcomes:[1]				
Improve Existing Products	0.0096(5)	0.0134(23)	0.0082(28)	0.0124(20)
Improve Existing Processes	0.0075(5)	0.0108(21)	0.0110(27)	0.0129(16)
Introduce New Products	0.0183(5)	0.0095(19)	0.0047(27)	0.0164(17)
Introduce New Processes	0.0094(4)	0.0067(16)	0.0058(21)	0.0097(15)
Make R&D More Efficient	0.0285(7)	0.0243(15)	0.0095(27)	0.0127(14)
Introduce New R&D Projects	0.0656(6)	0.0189(22)	0.0093(28)	0.0218(12)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."

Table 39

1990 UIRC Average Aggregate Productivity by Importance of Mission of Improving Industry's Products or Processes: Manufacturing

(Outputs per person)

	Not Important	Somewhat Important	Important	Very Important
Innovation Outcomes:				
Invention Disclosures	.	0.0374(10)	0.0259(35)	0.0667(29)
Patent Applications	.	0.0150(10)	0.0132(36)	0.0432(29)
Patents Issued	.	0.0114(9)	0.0138(36)	0.0141(29)
Licenses	.	0.0000(11)	0.0162(36)	0.0094(29)
Prototypes	.	0.0857(11)	0.0134(34)	0.0827(29)
New Products Invented	.	0.0149(11)	0.0054(36)	0.0366(29)
New Processes Invented	.	0.0186(11)	0.0097(35)	0.0258(28)
Copyrights	.	0.0037(11)	0.0640(34)	0.0235(29)
Research Papers	.	1.5295(10)	0.7313(35)	0.9322(28)
Education Outcomes:				
Ph.D.s Granted	0.1897(1)	0.0730(12)	0.1111(31)	0.0975(31)
Master's Degrees Granted	0.5422(1)	0.3197(12)	0.2535(30)	0.1891(32)
Intermediate Outcomes:[1]				
Improve Existing Products	.	0.0078(7)	0.0088(25)	0.0213(18)
Improve Existing Processes	.	0.0055(10)	0.0119(25)	0.0313(17)
Introduce New Products	.	0.0021(5)	0.0050(24)	0.0076(17)
Introduce New Processes	.	0.0082(5)	0.0072(24)	0.0154(17)
Make R&D More Efficient	.	0.0151(8)	0.0153(24)	0.0136(15)
Introduce New R&D Projects	.	0.0077(6)	0.0164(26)	0.0123(14)

Source: Cohen, Florida and Goe, *UIRC Survey*, Carnegie Mellon University, 1991.
Note: N in parentheses.

[1] Excluding "don't know" responses from the distribution. To compute indices for intermediate outcomes, we assigned values of 0 to "zero times," 3 to "1-5 times," 8 to "6-10 times," 13 to "11-15 times" and 15 to "15+ times."