# Sources of Technological Progress: An Empirical Investigation

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## An Empirical Investigation *

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# Abstract

The aim of this paper is to empirically investigate the sources of technological opportunities - as one of the major determinants of technical progress at the industry level - using data from Switzerland. This question is looked at from the perspective of Swiss industry as a whole, as well as from the perspective of interindustrial differences. The analysis is based on a survey conducted among Swiss experts (mostly R&D executives of selected firms) during the summer of 1988. Of the 940 experts questioned, 358, or approximately 38%, responded. They represented 127 different lines of business. The most important results can be summarized as follows:

1. Market (profit-oriented) organizations make the most important contributions (of all kinds: financial, individual, informational, etc.) to technical progress. The most important source is firms within the same industry; second is product users; and third, suppliers of materials and equipment used in manufacturing.
2. The contribution of non-market organizations seems relatively unimportant. University research, other government research institutions, state companies and agencies, professional and technical associations and individual inventors make small contributions.
3. The contributions of market and non-market organizations vary from one industry to the other.
4. Science also contributes to technical progress, even if only selectively. Education and training in physics, computer science, materials science, electrical engineering, mechanical engineering and applied chemistry are all considered relevant to technical progress in Switzerland.
5. Generally, university research (domestic and foreign) is not considered as relevant to technical progress in the industries surveyed. In certain fields, such as computer science, materials science and electrical engineering, university research does, however, seem relevant to technical progress.

# Sources of Technical Progress: An Empirical Investigation

## 1 Introduction

The supply of technical innovations in an industry depends, among other things, on the various opportunities of the innovators to obtain economically-usable technical knowledge. Due to variations in the degree of availability of these technological opportunities, innovations are "cheaper" to realize in certain industries than in others. This factor stands - in combination with others - behind the empirically observable interindustrial differences in the rates of technical progress, of total factor productivity and of economic growth.

Technological opportunities are generally accepted as an empirical fact; as a theoretical concept in economic studies, however, they have been described in a different way: "... there is no consensus on how to make the concept of technological opportunity precise and empirically operational" (Cohen/Levin 1989:1083). Accordingly, many attempts have been made to operationalize this concept; some of them are presented below.

Within the framework of neo-classical theory, technological opportunities are defined as "the set of production possibilities for translating research resources into new techniques of production that employ conventional inputs". (Cohen/Levin 1989:1083). Numerous neo-classical scholars have refined this general definition. But, being hindered by insufficient data and various conceptual problems, they have empirically tested this definition in only very few cases. On the one hand, Griliches (1979) has operationalized technological opportunities as "one or more parameters in a production function relating research to increments in the stock of knowledge, with the stock of knowledge entering in turn as an argument, along with conventional inputs, in the production for output". Dasgupta and Stiglitz (1980), on the other hand, have described technological opportunities as "the elasticity of unit cost with respect to R&D spending". (Cohen/Levin 1989:1083).

These attempts to operationalize the concept of technological opportunities within the neo-classical framework of production functions have so far been of limited empirical use. Therefore, other researchers have tried to develop and to test more simple, but empirically more "useful", operationalizations of this concept. These attempts have suggested that the concept of "technological opportunities" cannot be defined and quantified by one single parameter and then be integrated and estimated alongside other determinants of technical progress in a regression equation. The results of numerous empirical and historical investigations of the source of technological opportunities, carried out as concrete case studies, have proven more fruitful (cf. in particular, the work of Rosenberg 1976, Hippel 1988 and others; for an overview, cf. Dosi 1988 and Cohen/Levin 1989). These studies have shown that there is not a single, homogeneous source but rather different sources of technological opportunities, varying from industry to industry and, to a certain extent, from one firm to another.

An important example which appears in this literature is the detailed empirical study of a research team at Yale University (cf. Levin et al. (1983 and 1987) and Nelson 1987). In this study the term "technological opportunity" includes the contributions to technical progress of both market and non-market organizations. The first subgroup consists of the contributions of firms within the same line of business, of material suppliers, of suppliers of equipment used in manufacturing, of suppliers of equipment used in R&D and of product users. The second subgroup encompasses the contributions of university research, of government research labs, of other government agencies, of professional or technical societies and of independent inventors. The Yale study also investigates the relevance of science to technical progress.

Science is considered in this and in other studies as a major source of contributions to technical change. The whole concept of technological opportunities was "originally constructed to reflect the richness of the scientific knowledge base tapped by firms" (Scherer 1992: 1424). Governments spend huge amounts of money on science "not because they think it adorns their culture as opera does (though the comparison is quite commonly made by scientists); but because ever since a nuclear-fission bomb exploded in the New Mexico desert in 1945 they have been tremendously impressed with the ability of today's scientists to produce new technologies and with the ability of new technologies to produce new industries. Money spent on fundamental research has a rate of return of 28% a year, according to Frank Press of America's National Academy of Sciences, and technical innovation accounts for 44-77% of productivity increases." (The Economist 16/2/91, P. 4). David goes even further: "It is widely acknowledged that a major factor in the economic development of western Europe during the past two centuries, and in modern economic growth throughout the world, has been the growing dependence upon a quintessentially nonmarket activity - the organized pursuit of pure scientific knowledge." (David 1991:1)

In this paper data from Swiss industry were used to examine the importance of both market and non-market organizations for technical progress. The contribution of science to technical change will be investigated separately and in more detail. In addition, I will try to establish whether or not there are significant interindustrial differences with respect to these various sources of technical change.

# 2 Technological Opportunity and Technical Progress: Empirical Evidence from Swiss Industry

## 2.1 Data

In the summer of 1988 experts were asked to answer questions related to the issue of technological opportunities in Swiss industry. Since an adequate completion of the questionnaire required solid knowledge of the technology as well as of the market conditions in a certain line of business, the experts questioned were mainly R&D-executives of selected firms.

The sample frame for the survey was formed by R&D-experts working in 1157 firms which were characterized as "firms actively engaged in R&D" (in a publication of the head office of the Swiss Federation for Trade and Industry, see Schweizer Handels- und Industrieverein 1987:11). Experts in 217 firms located in the French and Italian-speaking parts of the country could not complete the German-written questionnaire and were dropped from the survey. Nonetheless, experts in the larger firms in these regions (who could read German) did take part. Of the 940 experts questioned, 358, or 38 percent, completed the questionnaire. These 358 experts were active in 127 different lines of business (as defined by the Federal Office of Statistics (1985)). Taking the industrial structure of their activities at the 2-digit level, 38% of the respondents worked in the machinery and metals industry, 23% in the electrotechnics industry, 10% in the chemicals industry, 2% in the watch-making industry, 3% in the textile/clothing industry, 6% in the food industry, 5% in the synthetics/paper industry; additionally, 4% of the responses came from the construction industry, 7% from technical services and 3% from private research laboratories (cf. Harabi (1991) for a detailed description of this survey).

## 2.2 Results

### 2.2.1 General Sources of Technical Progress

Table 1 shows the experts' responses to the question (see also Levin et al. 1983:18): "Evaluate the contributions (of all kinds: financial, individual, informational, etc.) that each of the following sources has made to technical progress in your line of business since approx. 1970:

1. Firms within your line of business (including domestic and foreign competition)
2. Material suppliers
3. Suppliers of equipment used in manufacturing
4. Suppliers of equipment used in R&D
5. Users of the products of your line of business
6. University research (domestic and foreign)
7. Other government research institutions
8. State companies and agencies
9. Professional or technical societies
10. Independent inventors
11. Other (please specify)."

The experts evaluated these factors on a scale from 1-7: 1=no contribution, 4=medium contribution, 7=very important contribution. The first two columns in Table 1 display the unweighted arithmetic mean of the responses as well as the standard errors (in parentheses); the third and fourth columns display the dispersion of the responses: Q1 stands for the first quartile (25% of the sum of values are to its left and 75% to its right); similarly, Q3 stands for the third quartile (75% of the sum of values are to its left and 25% to its right). This means that the middle 50% of the responses lie between these two limits. The general results from Table 1 can be summarized as follows:

Market (profit-oriented) organizations are the most important source of contributions to technical progress. Firms within the same line of business are cited as the most important source within this subgroup: the average score is 5; the middle 50% of respondents gave a score ranging from 4 to 7. The product users ranked second in importance and the suppliers of materials and of equipment used in manufacturing ranked third.

The contribution of non-market (non-profit) organizations to technical progress appears to be relatively unimportant. In particular, the experts point out the low level of contributions from university research, other government research institutions, state companies and agencies, professional or technical associations and independent inventors. These general results for Swiss industry as a whole should, however, not hide interindustrial differences. Statistical tests, such as the analysis of variance, show that the contributions of material suppliers, of university research and of professional and technical societies differ significantly from one industry to the other (significance level = 0.05). For the other factors, differences among industries exist, but they are statistically negligible.

These interindustrial differences in terms of the subgroups of factors - for both market and non-market organizations are briefly examined below.

**Table 1: The contributions (of all kinds: financial, individual, informational, etc.) of each of the sources of technical progress (1 = no contribution; 7 = very important contribution)**

| | Arithmetic Mean (standard error) | Q1 (25%) - Q3 (75%) |
|---|---|---|
| 1. Firms within the same line of business | 5.02 (0.09) | 4.00 - 7.00 |
| 2. Material suppliers | 4.46 * (0.09) | 3.00 - 6.00 |
| 3. Suppliers of equipment used in manufacturing | 4.45 (0.09) | 3.00 - 6.00 |
| 4. Suppliers of R&D equipment | 3.84 (0.09) | 3.00 - 5.00 |
| 5. Product users | 4.85 (0.09) | 3.00 - 6.00 |
| 6. University research (domestic and foreign) | 3.60 * (0.09) | 2.00 - 5.00 |
| 7. Other government research institutions | 2.90 (0.09) | 1.00 - 4.00 |
| 8. State companies and agencies | 2.17 (0.08) | 1.00 - 3.00 |
| 9. Professional or technical societies | 3.09 * (0.08) | 2.00 - 4.00 |
| 10. Independant inventors | 2.71 (0.09) | 1.00 - 4.00 |

* The responses to this question vary significantly from industry to industry (level of significance: 0.05)

Q1: The first quartile; Q3: the third quartile

### 2.2.1.1 The Contribution of Market Organizations to Technical Progress

The respondents from all industries evaluate the contribution to technical progress of firms within their line of business (including domestic and foreign competition) as important: they gave it an average score of 5 on the scale 1-7. In the food, electrotechnics, chemicals and construction industries this contribution is especially valued; in the other industries this is not the case. The results for the textile and clothing industry are particularly striking: the below-average score of less than 4 suggests that ideas for technical innovations do not come from within the industry, but rather from suppliers, as shown below.

The contribution of product users to technical innovations varies from industry to industry, even if these interindustrial differences are statistically not significant. The relevance of product users as a source of contributions to technical progress in chemicals, machinery/metals processing, electrotechnics and synthetics/paper is above average. But it is below average in the construction and textile/clothing industries. In the latter industries the relevance of product users does not only lie below the overall average, but also below the threshold value of 4.

The experts rank the suppliers of materials and of equipment used in manufacturing third in their relevance to technical progress. But here the contribution also varies from one industry to the other. Material suppliers are considerably important in the food, synthetics/paper, textile/clothing, electrotechnics and construction industries; in the other industries the contribution is either negligible (in the watch-making industry) or moderate (in technical services). These interindustrial differences are similar for the contribution of suppliers of material used in manufacturing.

The least important source of contributions to technical innovation appears to be the suppliers of equipment used in R&D. In general, the respondents believe that these suppliers are only of moderate importance as a source of technical progress. In particular, this evaluation applies to electrotechnics, food and private research laboratories; in other industries - such as the watch-making industry - this contribution is very negligible.

### 2.2.1.2 Contribution of Non-Market Organizations to Technical Progress

As mentioned in section 2.2.2., the contribution of non-market organizations to technical progress in the industries surveyed is generally less important than that of market organizations. Of all non-market organizations, the contribution of university research is the only important one, even if its average score is only around 4. The average score of the other non-market organizations lies far below this. Interindustrial differences are important here as well and can be summarized as follows: the contribution of university research to technical progress is of average importance in four (of ten) industries: in the food, chemicals, electrotechnics industries and in technical services. Second in importance (within this subgroup of organizations) is the contribution of professional or technical societies: in four industries - chemicals, synthetics/paper, construction and technical services - it is given an average score. The contribution of other government research institutions seems relatively important in only one industry, namely in the food industry, where it is given an average score. The contributions of state companies and agencies and of independent inventors are not viewed as important in any of the industries surveyed.

### 2.2.2 Science and Technical Progress

The contribution of science to technical progress has been examined from two different points of view. The first is education and training in basic and applied sciences; the second is research in basic and applied sciences as well as in engineering. While the first aspect is assumed to determine the quantity and quality of the R&D staff employed by firms and other research organizations, the second aspect is assumed to ensure a steady supply of new ideas and problem solving devices and thereby to enhance the development and diffusion of technical innovations.

#### 2.2.2.1 The Relevance of Education and Training in Basic and Applied Sciences for Technical Progress

To empirically investigate the first aspect, the R&D experts were asked the following question (see also Levin et al. 1983:14): "Indicate the relevance of each of the following fields of basic and applied sciences (in Switzerland and worldwide) to technical progress in your line of business in the last 10-15 years.

1. Basic Sciences
   a. Biology
   b. Chemistry (theoretical)
   c. Geology
   d. Mathematics
   e. Physics
   f. Computer science (theoretical)
   g. Other (Please specify)
2. Applied Sciences
   a. Agronomy
   b. Applied mathematics and operations research

c. Computer science (applied)

d. Materials science

e. Medical science

f. Chemistry (applied)

g. Electrical engineering

h. Mechanical engineering

i. Other (Please specify)."

Again, the responses were evaluated on a scale from 1-7, where the value 1 corresponded to "not relevant", 4 to "somewhat relevant" and 7 to "very relevant". The responses to this question are shown in Tables 2 and 3 and can be summarized as follows:

Within the industries surveyed, of all basic sciences, the experts view only theoretical computer science and physics as somewhat relevant to technical progress within the industries surveyed. Theoretical chemistry barely cuts the threshold (cf. Table 2). More than 50% of the respondents gave theoretical computer science and 40 % gave physics and chemistry a score of 5 or more. The other fields were viewed as comparatively irrelevant.

On the whole, applied sciences are judged to be more relevant to technical progress than basic sciences. Applied computer science, materials engineering, electrical engineering, mechanical engineering and applied chemistry (in this descending order) seem especially important. Agronomy, medical science, applied mathematics and operations research seem less important.

**Table 2: The relevance of basic and applied sciences to technical progress in the last 10 to 15 years (1 = irrelevant; 7 = very relevant)**

| | Arithmetic Mean | | Q1 (25%) - Q3 (75%) |
|---|---|---|---|
| 1. Basic sciences | | | |
| a. Biology | 2.40 * | (0.11) | 1.00 - 4.00 |
| b. Chemistry (theoretical) | 3.75 * | (0.11) | 2.00 - 5.00 |
| c. Geology | 1.50 * | (0.07) | 1.00 - 1.00 |
| d. Mathematics | 2.96 | (0.10) | 1.00 - 4.00 |
| e. Physics | 4.10 | (0.11) | 2.00 - 6.00 |
| f. Computer science (theoretical) | 4.40 * | (0.12) | 3.00 - 6.00 |
| 2. Applied sciences | | | |
| a. Agronomy | 1.83 * | (0.10) | 1.00 - 2.00 |
| b. Apllied Math & operations research | 3.30 | (0.10) | 1.00 - 5.00 |
| c. Computer science | 5.01 * | (0.10) | 4.00 - 7.00 |
| d. Materials science | 4.97 * | (0.10) | 4.00 - 6.00 |
| e. Medical science | 2.05 * | (0.10) | 1.00 - 2.00 |
| f. Chemistry (applied) | 4.21 * | (0.11) | 3.00 - 6.00 |
| g. Electrical engineering | 4.80 * | (0.11) | 3.00 - 7.00 |
| h. Mechanical engineering | 4.74 * | (0.10) | 3.00 - 6.00 |

* The responses to this question vary significantly from industry to industry (level of significance: 0.05)

Q1: The first quartile; Q3: the third quartile

**Table 3: The number of experts who gave a score of 5 or more to one of the fields of basic or applied sciences (1 = irrelevant; 7 = very relevant for technical progress)**

| | in % |
|---|---|
| 1. Basic sciences | |
| a. Biology | 19.6 |
| b. Chemistry (theoretical) | 37.1 |
| c. Geology | 3.5 |
| d. Mathematics | 23.1 |
| e. Physics | 42.9 |
| f. Computer science (theoretical) | 50.9 |
| 2. Applied sciences | |
| a. Agronomy | 10.2 |
| b. Apllied Math & operations research | 29.0 |
| c. Computer science | 68.2 |
| d. Materials science | 65.5 |
| e. Medical science | 11.7 |
| f. Chemistry (applied) | 48.9 |
| g. Electrical engineering | 60.4 |
| h. Mechanical engineering | 58.0 |

To understand the dynamics of this source of technical progress, the R&D-experts were asked the following question (see also Levin et al. 1988:15): "Indicate whether the relevance of each of the following areas of basic and applied sciences have decreased or increased in their relevance to technical progress in your line of business over the last 10-15 years." The fields were the same as above. The answers were measured on a scale of 1-7, where 1 corresponded to "decreased relevance," 4 to "unchanged relevance" and 7 to "increased relevance".

**Table 4: The change in the relevance of basic and applied sciences for technical progress over the last 10 - 15 years (1 = decreased relevance; 4 = unchanged relevance; 7 = increased relevance)**

| | Arithmetic Mean | | Q1 (25%) - Q3 (75%) |
|---|---|---|---|
| 1. Basic sciences | | | |
| a. Biology | 4.27* | (0.10) | 4.00 - 5.00 |
| b. Chemistry (theoretical) | 4.51 | (0.08) | 4.00 - 5.00 |
| c. Geology | 3.54 | (0.07) | 4.00 - 4.00 |
| d. Mathematics | 4.18* | (0.07) | 4.00 - 5.00 |
| e. Physics | 4.70 | (0.08) | 4.00 - 6.00 |
| f. Computer science (theoretical) | 5.70 | (0.08) | 5.00 - 7.00 |
| 2. Applied sciences | | | |
| a. Agronomy | 3.75* | (0.08) | 4.00 - 4.00 |
| b. Apllied Math & operations research | 4.50* | (0.08) | 4.00 - 5.00 |
| c. Computer science | 5.92 | (0.07) | 5.00 - 7.00 |
| d. Materials science | 5.43* | (0.07) | 4.00 - 6.50 |
| e. Medical science | 3.94* | (0.09) | 4.00 - 4.00 |
| f. Chemistry | 4.73* | (0.08) | 4.00 - 6.00 |
| g. Electrical engineering | 5.21* | (0.08) | 4.00 - 6.00 |
| h. Mechanical engineering | 4.90* | (0.08) | 4.00 - 6.00 |

* The responses to this question differ from one industry to the other (level of significance: 0.05)

Q1: First quartile; Q3: third quartile

Table 4 shows that theoretical computer science, theoretical physics and theoretical chemistry have gained in importance and that mathematics and biology have remained unchanged in their importance over the last 10-15 years. In applied sciences many fields have increased in their importance for technical progress: applied computer science, electrical engineering and mechanical engineering are all cited as increasingly relevant.

### 2.2.2.2 The Relevance of University Research to Technical Progress

The second aspect of the contribution of science to technical progress in Swiss industry is the set of interlinkages between university research in basic sciences, applied sciences and in engineering on one hand and technical progress in industry on the other hand. For this purpose the experts were asked the following question (see also Levin et al. 1988:16): "How relevant was university research (in Switzerland and worldwide) in the following fields of basic and applied sciences and in engineering to technical progress in your line of business over the last 10-15 years?

1. Basic Sciences
   a. Biology
   b. Chemistry (theoretical)
   c. Geology d. Mathematics
   e. Physics
   f. Computer science (theoretical)
   g. Other (Please specify)
2. Applied Sciences
   a. Agronomy
   b. Applied mathematics and operations research
   c. Computer science (applied)
   d. Materials science
   e. Medical science
   f. Chemistry (applied)
   g. Electrical engineering
   h. Mechanical engineering
   i. Other (Please specify)
3. Engineering
   a. Chemical engineering
   b. Computer science
   c. Electrical energy technology
   d. Electronics and communication technology
   e. Mechanical engineering
   f. Materials engineering
   g. Other (Please specify)." (Harabi 1988:16-17)

Scale: 1 = irrelevant; 4 = somewhat relevant; 7 = very relevant.

The results obtained here are consistent with those discussed in section 2.2.1. University research appears to be relevant to technical progress only in applied computer science and somewhat relevant in materials science and electrical engineering (cf. Table 5). Similarly, in engineering, university research is considered relevant only in the field of computer science and somewhat relevant in the fields of materials engineering, electrotechnics/communication technology, and mechanical engineering (cf. Table 6).

As with the results in the previous sections, the responses here vary to a statistically significant degree from one industry to the other (cf Tables 5 and 6).

**Table 5: The relevance of university research in basic and applied sciences to technical progress over the last 10 - 15 years (1 = decreased relevance; 4 = unchanged relevance; 7 = increased relevance)**

| | Arithmetic Mean | | Q1 (25%) - Q3 (75%) |
|---|---|---|---|
| 1. Basic sciences | | | |
| a. Biology | 2.22* | (0.11) | 1.00 - 4.00 |
| b. Chemistry (theoretical) | 3.01* | (0.11) | 1.00 - 4.00 |
| c. Geology | 1.46* | (0.06) | 1.00 - 1.00 |
| d. Mathematics | 2.60 | (0.10) | 1.00 - 4.00 |
| e. Physics | 3.43 | (0.11) | 1.00 - 5.00 |
| f. Computer science (theoretical) | 4.09* | (0.12) | 2.00 - 6.00 |
| 2. Applied sciences | | | |
| a. Agronomy | 1.83 | (0.10) | 1.00 - 2.00 |
| b. Apllied Math & operations research | 3.02 | (0.10) | 1.00 - 4.00 |
| c. Computer science | 4.55* | (0.11) | 3.00 - 6.00 |
| d. Materials science | 4.10* | (0.10) | 3.00 - 6.00 |
| e. Medical science | 1.93* | (0.10) | 1.00 - 2.00 |
| f. Chemistry | 3.35 | (0.11) | 1.00 - 5.00 |
| g. Electrical engineering | 4.00* | (0.12) | 2.00 - 6.00 |
| h. Mechanical engineering | 3.74 | (0.12) | 2.00 - 5.00 |

* The responses to this question differ from industry to industry (level of significance: 0.05)
Q1: First quartile; Q3: third quartile

**Table 6: The relevance of university research in engineering to technical progress over the last 10 to 15 years (1 = decreased relevance; 4 = unchanged relevance; 7 = increased relevance)**

| | Arithmetic Mean | | Q1 (25%) - Q3 (75%) |
|---|---|---|---|
| a. Chemical engineering | 3.43* | (0.12) | 1.00 - 5.00 |
| b. Computer science | 4.82 | (0.10) | 4.00 - 6.00 |
| c. Electrical and energy engineering | 3.30 | (0.10) | 1.00 - 5.00 |
| d. Electronics and news technology | 4.30 | (0.11) | 3.00 - 6.00 |
| e. Mechanical engineering | 4.01 | (0.11) | 3.00 - 5.00 |
| f. Materials engineering | 4.40* | (0.10) | 3.00 - 6.00 |

* The responses to this question differ from industry to industry (level of significance: 0.05)
Q1: The first quartile; Q3: the third quartile

# 3 Summary and Conclusion

The aim of this study was to empirically investigate the sources of technological opportunities - as one of the major determinants of technical progress at the industry level - using data from Switzerland. This question was looked at from the perspective of Swiss industry as a whole, as well as from the perspective of interindustrial differences. The analysis was based on a survey conducted among Swiss experts (mostly R&D executives of selected firms) in 1988. Of the 940 experts questioned, 358, or approximately 40%, responded. They represented 127 different lines of business. The most important results can be summarized as follows:

1. Market (profit-oriented) organizations make the most important contributions (of all kinds: financial, individual, informational, etc.) to technical progress. The most important source is firms within the same industry; second is product users; and third, suppliers of materials and equipment used in manufacturing.
2. The contribution of non-market organizations seems relatively unimportant. University research, other government research institutions, state companies and agencies, professional and technical associations and individual inventors make small contributions.
3. The contributions of market and non-market organizations vary from one industry to the other.

4. Science also contributes to technical progress, even if only selectively. Education and training in physics, computer science, materials science, electrical engineering, mechanical engineering and applied chemistry are all considered relevant to technical progress in Switzerland.
5. Generally, university research (domestic and foreign) is not considered as relevant to technical progress in the industries surveyed. In certain fields, such as computer science, materials science and electrical engineering, university research does, however, seem relevant to technical progress.

These empirical results are important for a science and technology policy of both the state and individual firms. They show what aspects of the innovation process the responding experts find particularly relevant. The results concerning the sources of technological opportunities and those concerning the relevance of education and research in basic sciences, applied sciences and in engineering are particularly important for technical progress. For they exemplify in what areas policies can be pursued. One possible economic policy implication of this study is the necessity of strengthening the institutional infrastructure of technical progress. This would include (1) encouragement of cooperation in R&D-projects between firms within the same line of business, between producers and users and between the former and the suppliers of inputs and equipment; (2) the fostering of cooperation between the institutions of basic science and applied science and between these and private research laboratories, especially in the fields of science and technology that are most relevant to technical progress. All these measures ought to take into consideration that there are important differences between industries with respect to the nature, mechanisms and institutions of technical progress - as this and other empirical studies on technical innovations have suggested (cf. Dosi, 1988; Cohen/Levin, 1989; Nelson 1988).

The empirical results further emphasize the economic policy implications of new developments in the theory of technical progress. Rosenberg summarizes them as follows: "In addition to nourishing the supply side in a broader range of areas, intelligent policies must be directed at institutional aspects of the innovation process, working to encourage the interaction of users and producers, as well as the iterative interactions between more basic and applied research enterprises... Useful policies would be those directed at the provision of information, from basic research institutions in the non-market sector to private firms and laboratories, as well as from users to producers concerning desired products and characteristics." (Rosenberg 1982: 237f.).

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