HIGH-TEMPERATURE SUPERCONDUCTIVITY RESEARCH:
AN INDICATOR OF NATIONAL SCIENCE-AND-TECHNOLOGY-
POLICY RESPONSIVENESS

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High-temperature superconductivity has been used as a probe for evaluating science and technology policy-making in various countries. Differences in response time and behavior have been detected among the three main actors: The US, Japan, and EEC. While the US had by far the highest response rate, national research laboratories and the universities with extensive government grants responded significantly slower than did corporate research laboratories and universities with less government support. The study suggests that dependency on large government contracts dampen the ability to make quick decisions and change policy direction mid-stream. In Europe, the response process has been slow and indicates a need to re-evaluate science policy to increase responsiveness to major events.

In late 1986 a virtual scientific explosion hit the professional literature. The hitherto accepted temperature upper limit (critical temperature) for superconductivity was pushed considerably above the 1973 limit of 23K (-418.27 °F) to 92K (-294 °F) by February 1987. There were two significant achievements in this work: the high value of the new critical temperatures and the class of materials used to achieve these temperatures. These well-known materials, copper-oxide-based ceramics, were previously known but never before tested for superconductivity. The great scientific value of the discovery was fully recognized within a very short time and in 1987 was already awarded a Nobel Prize.

For researchers, the discovery represents a scientific and intellectual challenge. For the public, there is the possibility of very high economic promise. It has been claimed that the basic patents on high-temperature superconductors may yield up to $50-billion in royalties during their 17-year lifespans.

From the point of view of the science-policy decisionmaker, the surprise was complete. The new findings were published at a period when superconductivity appeared to be an already-solved problem with a sound theoretical explanation. The US, in January 1986, for example, had committed $4.4-billion to building a superconducting supercollider. Many leading researchers had either left the field or were engaged in applied research. The small number of people who claimed that high-temperature superconductivity (HTSC) was possible were concentrating on fancy organic materials. The results were not very encouraging. Following the announcement of HTSC in 1986, the makers of science policy were confronted with an immediate challenge.

High-temperature superconductivity has several characteristics that made it particularly interesting to those who deal with science policy:

- The discovery is of great scientific value, seemingly inexplicable by existing theories.
- The discovery is perceived as holding tremendous economic promise in a great variety of areas—from transportation and electricity distribution to super broadband information networks and medical diagnostic equipment.
- None of the economic promises are realizable with off-the-shelf technology.
- The cost of meaningful scientific research, at least in the preliminary stages of elucidating the HTSC phenomenon, was quite inexpensive and well within the reach of most physics laboratories in the world.

The latter point is particularly worth stressing. While the HTSC discovery surprised most everybody, unlike most big science/high technology ventures, the cost of entering the research club was small. Furthermore, as a result of scientific and technological innovativeness, anybody with a new application could corner an appreciable market for themselves. The combination of a relatively low entrance cost and high possible revenue is a powerful incentive.

The unforeseen nature of the discovery pro-
provided an unexpected probe—a "pulse of opportunity"—to test the efficiency of science and technology policies in various countries. The opportunity to evaluate the science-policy mechanism is rare. Normally, the study of a national policy cannot produce artificial excitations in the national economy. The price is simply too high and there are too many external parameters. Thus, it is only on occasions like the discovery of HTSC, when a relatively well defined excitation comes from an outside source, that the modes of response of national policy system can be investigated.

The value of a time-response analysis as a measure of scientific and technological progress has been stressed in previous papers. (6) This assertion is based on the concept that while scientific knowledge and technological know-how are distributed worldwide, the distribution in geographical-time-space is not homogeneous. Advantage is achieved by nations that retain know-how and exploit it more rapidly than others. If we assume that the aim of science and technology policymakers is to create an environment that will encourage scientific and, therefore, economic leadership, then the rapid opening of knowhow gaps or their expedient gap closures would be important to the nation's welfare.

The purpose of this paper, then, is to evaluate the methodology and response time of science-policy decisionmakers in the US, Japan, and the European Economic Community (EEC) to a scientific breakthrough of economic significance.

METHODOLOGY

The methodology adopted in this paper is based on the assumption that the intensity of scientific research in a given field is represented by the observed rate of scientific publications. This is especially true in hot fields where almost instantaneous merit can be attained by rapid publication. We recognize that the validity of this assumption is not uniform. Obviously, subjects that are closely related to matters of national security as well as subjects with great and immediate economic applications tend to be less visible in the literature. The correlation of scientific intensity and rate of publication may also be culturally dependent. That is, the USSR is significantly more secretive than other developed countries on economic outcomes.

In order to minimize any tendencies against disclosure, we have chosen to analyze only the earliest scientific publications following the 1986 discovery by K.A. Muller and J.G. Bednorz. At this early stage, we assume that the preliminary nature of the discoveries and the normal desire of scientists for peer recognition would have prevailed over possible security or economic considerations encouraging non-publication.

An online search on HTSC in the SPIN (Searchable Physics Information Notices) database of the American Institute of Physics is the basis for this paper's analysis. It was by far the most comprehensive database available to me. Relevant publications found by other means (e.g. other databases, journals, and abstracts) were checked against SPIN before they were included.

The wave of publications in the first half of 1987 grew very rapidly. The accumulated number of papers increased from 50 in March 1987 to 500 by June 1987. Prior to analysis of the origins of these papers, they were divided into five groups: the first 50, 100, 150, 200, 300 publications, which were regrouped according to country of origin, type of institution, and other similar criteria.

The material was analyzed according to the country and institution where the research was performed. In cases where two research institutes were involved or two laboratories based in two countries were collaborating, the paper was credited to each separately, so that some double counting is involved, but the ensuing inconsistency is no more than a few percent of the total.

A special study was also conducted on work of European origin. Researchers and science-policy people were interviewed in relation to the paradigm of science-policy on HTSC presented in Figure 1. This study was preliminary as far as scope was concerned. The convergence of the data collected in the interviews gave the conclusions more credibility than could be derived from a purely statistical evaluation. The countries where interviews were conducted are shown in Table 1 together with the institutional ties of subjects.

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