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CONTRIBUTIONS OF UNIVERSITY TECHNOLOGY PROGRAMS TO ECONOMIC DEVELOPMENT

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Many states have established university-industry technology programs to stimulate economic development, raising questions about corporate domination of basic research. This Brief summarizes the economic development impact of a University of California program that offers substantial economic benefits from relatively small state investments while avoiding the conflicts between university purpose and private gain.

The Toxic Substances Research and Teaching Program (TSRTP) of the University of California provides an excellent case study of the complex economic impacts of a problem-based technology program. The program defined a broad field in which targeted, multidisciplinary research over a long term could generate internationally important knowledge, jobs, firms, and products that are the basis for emerging industrial clusters capable of becoming key growth industries in the regional economy.

The TSRTP funds training and research related to toxic substances for graduate and postdoctoral students (and a few selected undergraduates) at the nine UC campuses and the affiliated national laboratories (Livermore, Berkeley, and Los Alamos). When the program was established in 1985, research and teaching on toxics were dispersed across many fields and campuses. To strengthen the traditional research and teaching mission of the university while providing incentives to develop a new field, TSRTP's funding emphasized support for student research and training within traditional academic units, rather than support for faculty who had specific links to research projects selected and funded by the private sector.

From 1985 to 1995 the TSRTP trained students and postdocs through approximately $15 million in state-funded grants to more than 150 faculty research sponsors. This support increased the research opportunities and training in toxics and helped recruit top students into the field. The program urged those it funded to view this money as seed funding, and encouraged faculty to develop interdisciplinary research groups that could compete for extramural funding. This initial state investment helped the faculty and campuses to fund student research that won an additional $270 million in funding from other sources. This success rate was strongly enhanced by the building of interdisciplinary teams, as opposed to traditional individual investigator awards. For example, TSRTP-funded teams received three of the original five National Institute of Environmental Health Sciences Superfund awards, resulting in more than $30 million dollars in research funds being awarded to the University of California..

PROGRAM EVALUATION AND FINDINGS

Over the first 10 years of the program (academic years 1985-1995), 661 students and postdoctoral researchers graduated after receiving TSRTP funding to work with faculty members who were part of the program at one of the nine UC campuses. The program's economic impact was evaluated through a 27-question survey administered to all former trainees who received funding between 1985 and 1995 that we could locate (about 60% of the total).

The cohort of student trainees surveyed reported obtaining about $100 million in grants and contracts during the early stages of their career, in addition to the $270 million the university received from external research grants. We estimate that over 80% of the total grant funding stayed in California. The research and business contributions of the 246 graduates led to the creation of new jobs over and above the graduates' personal employment. Moreover, one in six graduates now working in the private sector was involved in a startup company, and new methods for toxic cleanups show great economic promise. Several projects in particular, reported below, illustrate the potential economic development impacts of this program approach.

The results of the survey led us to identify three benefits from the program and its funding of the students: knowledge benefits, employment growth, and product development.

1. Development of Multidisciplinary Technical Knowledge

Nearly two of three respondents reported that this program was very important in shaping their direction of work and research. The fact that this many respondents recognized the role of a program that specifically targeted and supported them while they were students suggests that it helped give many of them a focus on toxics that might not have occurred otherwise.

Our survey respondents reported having initiated successful careers after leaving the university. As mentioned, they leveraged the state's investment in their training into new grant and contract funding of over $100 million. Half of the former trainees who responded reported receiving grants or contracts, with 43 respondents (19%) claiming to have received over a half million dollars each. Twelve graduates received more than $2 million, and seven (3%) reported generating over $3 million.

More than 76% of the respondents had published papers, and 44% had published technical reports. Those who are currently employed in academia have published at a higher rate (83%) than those in government and the private sector (79% and 67%, respectively). The academics averaged 11.4 articles each, compared to 6.1 articles by those in private businesses.

It is impossible to assign a dollar figure to the economic impact intellectual contributions have on the state's economy, because a scientific discovery or a publication may have long-term value only in combination with other discoveries. Nonetheless, three examples of research projects that are currently under way illustrate the potential economic benefits of TSRTP-funded research.

In 1985-1988, the program funded a theoretical study at UC Berkeley of the use of steam injection to

recover solvents from contaminated soil and shallow aquifers. This methodology has matured to the stage of full-scale field demonstrations, in cooperation with Lawrence Livermore National Laboratory, and the development of a startup company to market this novel technology. More recently, the program funded a laboratory project at UCLA to investigate the use of plasma technology to replace the need for solvents as cleaning agents in the semiconductor industry. This method is now being developed commercially with the collaboration of two of the national laboratories. The third project was an ambitious multidisciplinary effort involving investigators from six of the nine UC campuses to remediate a highly contaminated wetlands site at Mare Island Shipyard, a deactivated naval base on the northern edge of the San Francisco Bay. It was highly successful, and has served as a model for other cleanups of former military bases in California.

2. Employment in the Toxics Field

The Toxic Substances Research and Teaching Program helped stimulate economic development by providing recognizable credentials for graduates seeking employment as toxicologists and environmental engineers as these fields gained in economic importance. For many TSRTP trainees, participation in the program provided background knowledge, networks, references, and experience as an entree into the rapidly changing environmental technology industry. For another group, this pathway has lead to specialization in toxics issues in the growing biotechnology industry. Graduates have contributed to both fields by their own work and also by helping to create additional jobs in these areas. Evaluation of the trainees' employment history and job-creation activities provides a central measure of the program's economic impact.

Program respondents currently work in academia (46%), private industry (36%), and the public sector (15%). Two-thirds (68%) have stayed in California, and the remainder are working in other states (23%) or abroad (9%). Therefore, most of the economic impact reported in this survey occurred in California. The international presence of former trainees suggests that the program also has had an impact in regions throughout the world. For example, one former trainee reported that she started a nonprofit company to conduct environmental assessments in the former Soviet Union, where she is helping to improve public health and the environment. Through the expansion of export markets for environmental goods and services, California and the United States may receive some economic benefits from these students working in other countries as well.

Nineteen respondents reported that their work had resulted in founding a startup company. Since only 110 survey respondents reported having ever worked in the private sector, this means that more than one out of six former trainees who entered the private sector helped start a new business. Former TSRTP trainees have not only found their own way into an emerging field, they have helped expand employment in the process. The data suggest that the trainees created several hundred new jobs in the toxics field, which is a very positive side benefit of the program that involved no additional state effort or economic development incentive.

3. Technological Applications and Product Innovation

Research and training programs also contribute to the economy through the development and dissemination of new technologies that lead to marketable products. Research activities the program has funded have led to the development and deployment of new technologies, new industrial processes, and

new management approaches. Applications for patents and the development of new technologies and processes are two ways to evaluate these impacts.

Research by former TSRTP trainees has resulted in several novel pollution prevention and cleanup approaches that have been developed for use by industry in California and elsewhere. Thirty-four former trainees reported having applied for 106 patents, and been awarded 42 at the time the survey was conducted.

The trainees were also asked whether they had either expanded or improved an existing technology or created a new product or service. Respondents described advances in a wide range of areas. These new technologies and processes can create significant impacts on the regional economy because emerging technologies are essential for the long-term competitiveness of the state's industries.

POLICY IMPLICATIONS

The Toxic Substances Research and Teaching Program is an important example of how a state-funded program created an administrative structure for multidisciplinary collaboration that helped make the University of California more competitive in obtaining outside funding. The program increased contributions to the academic, regulatory, and commercial fields of toxic substance management because it could build on the regular state investment in the university and nurture highly skilled and productive students who would be successful in many related fields or programs. Thus, the TSRTP played a catalytic role in enhancing state competency in the toxics field.

Our findings demonstrate that programs designed to strengthen the university's traditional basic research and education role in strategic areas may be a very productive tool for technology transfer, with substantial economic development benefits. Science-based economic development that links universities, government, and industry is at the core of both regional revival and the emergence of new industrial policies.

The policies that support knowledge-based economic development go beyond the question of the immediate number of jobs generated, to forging links between new technologies and the state's existing or potential industries. The TSRTP is a model for how such links can be forged. Students in graduate and postdoctoral programs carry the university's best knowledge into industry, generating technologies, expanding employment opportunities, and developing products. Some stay in university positions to make further discoveries and to train the next generation of students, while others go into government agencies, which set the regulatory environment in which firms and scientists operate, and from which governmental funding originates.

The benefits of a highly focused, problem-based academic research and teaching program are very attractive from a state policy perspective. Such a program taps what universities do best--research and teaching about basic science and its applications, which are at the core of the university mission. The focus on research and teaching helps faculty and administrators avoid the role conflict and goal ambiguity inherent in mobilizing university researchers to become entrepreneurial or to work within the

time-frame, agenda, and financial incentives of business.

At the same time, university-based programs like the Toxic Substances Research and Teaching Program can assist clusters of firms to develop a strategic advantage based on the knowledge resources of a network of faculty and their students, while contributing in a multifaceted manner to the state's well-being by enhancing public health, environmental quality, safety, and quality of life.

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