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A Regression Model of the Interactions Between Higher Education and High-tech Industries in East Tennessee and Southwest Virginia

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A REGRESSION MODEL OF THE INTERACTIONS BETWEEN HIGHER EDUCATION AND HIGH-TECH INDUSTRIES IN EAST TENNESSEE AND SOUTHWEST VIRGINIA

A Dissertation
Presented to
the Faculty of the Department of
Educational Leadership and Policy Analysis
East Tennessee State University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

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by
William Hugh Blanton
May 1992

APPROVAL

This is to certify that the Graduate Committee of

William Hugh Blanton

met on the

31st day of March, 1992.

The committee read and examined his dissertation, supervised his defense of it in an oral examination, and decided to recommend that his study be submitted to the Graduate Council and the Associate Vice-President for Research and Dean of the Graduate School, in partial fulfillment of the requirements for the degree of Doctor of Education in Educational Leadership and Policy Analysis.

Ernest K. Bentley, Jr.
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Signed on behalf of the Graduate Council

Associate Vice-President for Research and Dean of the Graduate School

ABSTRACT

A REGRESSION MODEL OF THE INTERACTIONS BETWEEN HIGHER EDUCATION AND HIGH-TECH INDUSTRIES IN EAST TENNESSEE AND SOUTHWEST VIRGINIA

by

William Hugh Blanton

This study examined the interactions--(1) research grants and contracts, (2) faculty consultation, (3) employee training, (4) student internships and co-ops, (5) universities sharing firm facilities, and (6) firms sharing university facilities--between higher education and high-tech industries in East Tennessee and Southwest Virginia using multiple regression modeling. The purpose of the study was the development of a vision of what the future could be and the strategies to successfully overcome the threats and enrich the opportunities that exist between higher education and high-tech industries.

Data were collected from the engineering and engineering technology faculty at Tennessee Technological University, East Tennessee State University, Virginia Polytechnical Institute and State University, the University of Tennessee at Knoxville, and the University of Tennessee at Chattanooga and selected high-tech firms in East Tennessee and Southwest Virginia. The analytical process included four phases: (1) data collection and preparation, (2) reduction of independent variables, (3) model refinement, and (4) model validation.

The analysis suggested that large universities with well-defined organizational channels seemed to have an advantage in obtaining research grants and contracts from large firms that were strongly involved in research and development. Likewise, faculty members seemed to use the facilities of large high-tech firms that were near to the university. More importantly, the study emphasized the mutual benefits that universities and industries could share through university-industry interactions if each could overcome formidable barriers that have been established through tradition, culture, and bureaucratic processes.

INSTITUTIONAL REVIEW BOARD APPROVAL

This is to certify that the following study has been filed and approved by the Institutional Review Board of East Tennessee State University.

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Principal Investigator: William Hugh Blanton

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DEDICATION

This is dedicated to my mother, Anna Martha Smith Blanton, who provided life, love, support, and direction. She was loved by so many and died so young. I truly miss you at times like this.

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CHAPTER 1

Introduction to the Problem

The Overview

As the United States approaches the 21st century, federal and state governments, businesses, and universities have encountered "a variety of social, political, economic, and technological shifts" (Boulton, 1984, p. 103). It has become apparent that the U.S. is enmeshed in an increasingly more competitive world: "one characterized by ever increasing rates of change, realigned social and cultural values, and dramatic changes in work force composition and demographic trends" (Stata, 1989, p. 63). A consequence of an increasingly more competitive world has been the emergence of a global economy where knowledge has surpassed natural resources and low-cost labor as the principle commodity (National Science Board, 1989).

The Japanese have demonstrated that the firm of the future must develop new technology and new ideas and then rapidly diffuse the knowledge into practice. Unfortunately, the international competitiveness of American businesses has diminished as American management has strained to solve the competitive problems of the latter 20th century using the techniques of the 1930s and 1940s. Former U.S. Secretary of Commerce Malcolm Baldridge observed that:

> After World War II, we were the overall leaders in world management. We lived off that

> leadership while the rest of the world was rebuilding, but we were blinded by the success American industry enjoyed during the population boom of the 1950s and 1960s...Our major industries gave little thought to long-range strategies. Management rested on its laurels...We were beaten with technology that we invented, but failed to apply and follow through...We were simply out-managed. Most of all we lost our reputation for quality (Link & Tassey, 1987, p. 3).

With greater worldwide importance placed upon knowledge, "universities are increasingly seen as resources to aid government and industry in reversing the competitive decline" (Fairweather, 1989, p. 390). Federal and state leaders have encouraged university-industry partnerships in order to revitalize the American economy. These new demands upon governments, businesses, and universities have come at a time of burgeoning demands and dwindling resources. Federal and state governments are beleaguered by mushrooming national and state debts, voter abhorrence of new taxes, offshore production by American firms, and the lost competitiveness of domestic industry (Fainstein & Fainstein, 1989). Many American companies have not recovered from their nemeses of the 1980s: the high cost of capital, an overvalued dollar, a deteriorating education system, over-consumption at the expense of investment, government regulations, emphasis on military as opposed to economic security, and undisciplined government spending (Stata, 1989). Academic administrators are occupied by forces that have threatened to transform the structure of American higher learning: the changing student clientele, the disintegrating college curriculum, the increased competition within higher education, the technological imperative, the faculty conundrum, and the tightening grip of outside controls (Keller, 1983).

The elimination of high-paying manufacturing jobs as regional industries have continually closed or relocated offshore has attracted political attention and attached a political urgency to the concerns over competitiveness and innovative capability in most state political arenas. In order to stop the hemorrhaging of jobs, states have become proactive in the search for new, expanding industries of which the majority have proven to have a high technology component (Minshall & Wright, 1989).

These high technology activities are often characterized by strong demands for career fields that provide steady employment, training opportunities, fringe benefits, and promotional opportunities that have provided wage increases and supervisory opportunities (Blakely, 1989). To lure high-tech, knowledge-intensive industries, states have turned to their strong research universities as the centerpiece of their economic development policies hoping to replace declining regional industries with high-tech industries or massive federal projects (National Science Board, 1989). The rapid changes in the nature of scientific and technological research have created a keen awareness by states concerning the determining factors upon which business organizations decide on location of new facilities, federal projects are awarded, and new equipment, facilities, and new institutional structures are chosen to compete for economic development (Joint Economic Committee, 1982; National Science Board, 1989).

Research and Development

Although American research and development (R&D) has continued to remain vibrant and productive, the United States no longer dominates science and technology (National Science Board, 1989). Foreign entries into science and technology markets have rewritten the rules of competition. Among the suggested actions to recapture competitive markets has been better cooperation between industries and universities (Fairweather, 1989).

Universities have continued to be the prime developers of new knowledge, but industry has persisted as the institution that has transformed ideas into products that generate economic growth. Cultural incongruities and differences (Table 1) have often hampered interactions between the two.

Among the most controversial issues associated with university-industry interactions has been the issue of confidentiality. Universities have insisted upon the freedom to publish, while industry have sought to delay the disclosure of relevant information. Academic freedom of study, dissemination, and research into new areas are acknowledged emblems of the modern university (Giovengo, 1986) and have prompted strong faculty allegiance to basic research.

The National Science Foundation (1982) reported that most faculty believe that there are less intervening restrictions imposed by outside agencies in basic research. Faculty are convinced that applications and

Table 1

University-industry cultural differences (American Association of State Colleges and Universities, 1986, p. 51)

Attribute	Academic	Industrial
Driving interest	Respect of peers	Profit
Time horizon	Long	Short, medium
Mode of thought	Generic	Particular
Mode of work	Solo	Collaborative
Mode of expression	Abstract, qualified	Simple, absolute
Desired outcome	Original insight	Commercial application
Preferred form of conclusion	Multiple solutions, uncertainties emphasized	Profitable, uncertainties resolved
Concern about feasibility	Small	Great
Stability of interest in topic	Low	High
Confidentiality interests	Freedom to publish	Proprietary interest

developmental research associated with industries are often shrouded in a cloak of proprietary concerns that limit the dissemination of information and consequently constrain faculty opportunities for professional advancement. An American business or industry is naturally predisposed to profits and wishes to maintain its comparative and competitive advantages for which proprietary knowledge is paramount.

Regardless of various cultural differences, university-industry partnerships have established many mutually beneficial alliances (American Association of State Colleges and Universities, 1986). University-industry interactions have historically provided industries with the "access to technical manpower, a *window* on technology, and access to university facilities" (National Science Foundation, 1982, p. 34). Such ties have yielded scholarships, internships, and co-op opportunities for students. University-industry cooperation has developed industrial allies for the development of new disciplines and procurement of state resources. Industrially supported programs have helped attract new students during times of declining enrollments.

East Tennessee/Southwest Virginia Development

Ironically, the technological innovations in farming methods eliminated agriculture as the dominant way of life within East Tennessee and Southwest Virginia (Gilmer & Pulsipher, 1989). Scientific methods and mechanization developed between 1940 and 1960 made the small, hilly farms of the region uneconomical for full-time farming. During the same period, manufacturing employment within the region went from a less-than-average to an above-average proportion of the work force.

The vitalization of manufacturing was an outgrowth of labor shortages after World War II. The combined consequences of rising wages in the North and the surplus labor in the Southeast enticed firms to locate branch plants in the area. The more cheaply operated branch facilities were located nearer to Southern markets and used low-skilled, low-wage labor to produce goods that had reached the latter phases of their product life cycles. Recently, the inflation of the 1970s and 1980s and the resulting stronger dollar put competitive pressures upon these branch factories to move offshore or across the border.

As the United States transforms from manufacturing-oriented jobs to service-oriented jobs, there will inevitably be less manufacturing jobs nationally and in East Tennessee and Southwest Virginia. The salvation of those manufacturing facilities that remain will be increased product quality and productivity. Employees will be forced to work smarter, implying an abiding commitment to the best possible education throughout the area (Gilmer & Pulsipher, 1989).

A steadfast commitment to the best possible education throughout Tennessee is hampered by the statistical realities within the state. Folger and Wisniewski (1989) reported that Tennessee has a higher percentage of uneducated adults than the national average and has consistently ranked near the bottom among states in expenditures for education. These deficiencies are compounded by an inelastic state tax structure that is primarily based upon a state sales tax. Although Virginia has access to more sources of tax revenues, including a lottery, Southwest Virginia continues to share many of the deficiencies associated with Tennessee.

University-Industry Interactions

The tableau of impending forces affecting East Tennessee and Southwest Virginia seems insurmountable until one recalls that Japan, with essentially no natural resources, overcame the massive destruction of a world war to become one of the preeminent industrial nations in the world. They proved that a nation could rise to industrial power through management innovation (Stata, 1989). Keys and Miller (1989) proposed reasons for the Japanese manufacturing advantage: emphasis on human resource development, statistical quality control, organizational philosophy, etc. Yet, the U.S. has had access to the same pertinent knowledge of manufacturing processes, but the U.S. may not have had the commitment to the proper interdependencies of political, economic, educational, and social attributes.

If we assume that (1) technology has become a key ingredient in economic development, (2) increasing technological knowledge implies costs and complexities which are best managed by shared resources, and (3) present university-industry interactions are underutilized, the evolving paradigm for competitive success seems to be predominantly based upon the use of total resources to maximize outputs. This implies synergistic cooperation between governments, businesses, and universities in order to provide bridges between basic research and applied research and development that can reduce the time between product inception and product production.

More specifically for Tennessee and Virginia, policymakers will be required to provide an environment that "(1) prepares the citizens of the region to compete in an increasingly competitive world and (2) attracts and develops industries which pay average or above-average wages regardless of the financial, educational, or demographic impediments" (Oliphant & Jernigan, 1989, p. 39). Because new technology is more complex than the simple exchange of a tractor for a mule or a television for a radio, the interaction between the existing regional manufacturing base and research, training, and education will become more important as production facilities are forced to face the challenges of improving quality control and growth in productivity. The solution will require flexible partnerships between the financial community, business planners, labor, and technologists along with the aid of a state government sensitive to the need for intertwining advanced technology with traditional manufacturing enterprises. The study of university-industry interactions furnishes the opportunity to discover solutions, models, and potential policies which could forge such interdependencies.

The Problem

The overview has established the basis for the emergence of a new world order and an associated new set of rules that will be based upon international competition and innovative new technologies. The evolving new world order has led this researcher to conclude that higher education is approaching a defining point in its history where closer relationships between universities and industries will be required in order to maintain and improve the economy of a region. Thus, this researcher investigated university-industry interactions in East Tennessee and Southwest Virginia and attempted to develop a model of such interactions.

Purpose of the Study

Among the principle motives for such an investigation of university-industry interactions was the development of a vision of what the future could be and the strategies to successfully overcome the threats and enrich the opportunities. Miller and Cote (1985) indicated that a good strategy is based on a "sound diagnosis" (p. 120), and an appropriate diagnosis requires solid information. The information sought through this study was concerned with the assessment of existing and potential university-industry interactions within East Tennessee and Southwest Virginia.

Throughout the study, *university-industry interactions* referred to the following six interactions which will be used as the dependent variables for the descriptive dissertation: (1) research grants and contracts to university personnel funded by private high-tech firms or public research facilities, (2) consultations by university personnel for high-tech industries, (3) student internships (cooperative training) through cooperative agreements at high-tech firms, (4) training of firm employees at universities, (5) sharing of high-tech firms' research facilities by university personnel, and (6) sharing of university research facilities by high-tech firm personnel. These university-industry interactions were hypothesized to be related to 10 independent variables: (1) the proportion of skilled labor to total employees in the firm, (2) the dollar amount invested by a firm in R&D, (3) the size of the firm, (4) faculty rank, (5) the availability of research facilities at the university, (6) the availability of research facilities at the high-tech firms, (7) faculty teaching load, (8) the distance between the university and industry, (9) the university size, and (10) the use of organizational channels.

Definitions

Research Grants and Contracts were defined as formal arrangements made between one corporation and individual academic departments or professors primarily for research with a specific objective and time frame (Giovengo, 1986).

Consultation included the short-term, individually-initiated interaction between professors and industry for the purpose of advising or disseminating information.

Employee training was defined as the remedial, developmental, required, and continuous training that enhances knowledge of the most technologically relevant techniques, thinking, reasoning, and problem-solving skills (National Science Foundation, 1982).

Student internships or co-ops referred to the cooperative arrangements between students and industry wherein the students generally leave school and are hired by firms to work for predetermined lengths of time.

Sharing facilities included the use of laboratories, libraries, and information centers to complement the firm's or the university's facilities.

Skilled labor was defined as the proportion of professionals such as engineers, scientists, and technologists to total employees (Min, 1989).

Research and development expenditure was the amount of money annually applied to internal and external basic, applied, or developmental high-tech R&D.

Faculty rank represented the academic status and stature and the recognition of professional achievement accorded to professors in an academic institution by their peers. The most common ranks in ascending order are assistant professor, associate professor, and professor.

Size of the firm referred to the number of employees employed in the particular high-tech business.

Availability of research facilities alluded to the availability of surplus research capacity such as computer facilities and lab facilities to outside university or industrial representatives.

Faculty teaching load was the number of courses taught in an academic term.

Size of the university was the number of students that attend the university during a school term.

Distance was the distance between the university and the firm.

Organizational channels included those aspects of an organization that enhance communication that fosters university-industry interaction.

High-tech industries were labor-intensive, science-based organizations with a higher percentage of technicians, engineers, and computer scientists than other manufacturing companies.

Positively-correlated interactions referred to a corresponding increase in the value of the dependent variable due to an increase in the value of the independent variable.

Inversely-correlated interactions referred to a corresponding decrease in the value of the dependent variable due to an increase in the value of the independent variable.

Constant dollars or real dollars were nominal values deflated by a price index.

Hypotheses

The primary goal of the study was to develop a model of university-industry interactions using multiple regression methods. With the establishment of a model, policymakers can determine the factors that enhance the university-industry interaction of interest.

In general, the researcher expected interactions to increase when (1) the university and industry are located near each other, (2) the R&D investment by the firm is substantial, (3) excess facilities are available to industry or the university, (4) professors have reduced teaching loads, (5) the university is substantially large, and (6) well-defined organizational structures are established within the university to promote university-industry interactions.

The size of the firm was expected to affect specific university-industry interactions. Research grants and contracts were presumed to dominate among larger firms; consulting was presumed to dominate among smaller firms. Employee training and student internships were assumed to be more prevalent among larger firms than smaller firms, since larger firms were more likely to have retained earnings for such activities. Larger firms were anticipated to have better facilities and equipment than universities, while universities are anticipated to have better facilities and equipment than smaller firms.

Skilled labor was also expected to affect specific university-industry interactions. A more highly skilled labor force was presumed to diminish the needs for research grants and contracts, consulting, university facility use, and employee training. The higher concentrations of engineers and scientists often was assumed to indicate the presence of modern equipment and elaborate facilities that should attract student interns and entice faculty use of the industrial facility. Faculty rank was another variable that was expected to affect specific university-industry interactions. Assistant and associate professors were assumed to be more committed to research grants and contracts, since those activities are favorably viewed during tenure and promotion evaluations. Professors were assumed to be engaged in more consulting activities because of their academic stature and expertise. Professors were also assumed to be tenured, allowing them more freedom to seek opportunities outside sanctioned university activities.

The null hypothesis for each interaction variable was that there was no correlation with the predictor variables. That is, each of the regression coefficients (β_i) was zero. Using the previous assumptions and conclusions, the alternate hypotheses were:

H.1: The size of research grants or contracts would be significantly and positively correlated with the high-tech firm's investment in R&D, the surplus capacity of university and industrial facilities, the size of the firm and university, and the use of well-defined organizational channels.

H.2: The size of research grants or contracts would be significantly and inversely correlated with the proportion of skilled labor to total employees in a firm , the distance between the firm and the university, faculty rank, and the faculty's teaching load.

H.3: The frequency with which a professor consults with a firm would be significantly and positively correlated with the size of the university, faculty rank, the surplus capacity of university and industrial facilities, the R&D investment by the firm, and the use of well-defined organizational channels.

H.4: The frequency with which a professor consults with a firm would be significantly and inversely correlated with the proportion of skilled labor to total employees in a firm, the size of the firm, the distance between the university and industry, and the faculty teaching load.

H.5: The number of students participating in internship or co-op experiences at the firm would be significantly and positively correlated with the level of R&D investment, the proportion of skilled labor, the size of the firm, the surplus capacity of industrial and university facilities, the size of the university, and the use of well-defined organizational channels.

H.6: The number of students participating in internships or co-op experiences at the firm would be significantly and inversely correlated with the distance between the university and the firm and faculty teaching load.

H.7: The number of firm employees participating in training programs would be significantly and positively correlated with the level of R&D investment, the size of the firm, the surplus capacity of industrial and university facilities, the size of the university, and the use of well-defined organizational channels.

H.8: The number of firm employees participating in training programs would be significantly and inversely correlated with the proportion of skilled labor, the faculty teaching load, and the distance between the university and the firm.

H.9: The frequency of the firm's use of university facilities would be significantly and positively correlated with the surplus capacity of university facilities, the size of the university, and the use of well-defined organizational channels.

H.10: The frequency of the firms' use of university facilities would be significantly and inversely correlated with the level of R&D investment, the surplus capacity of industrial facilities, the faculty teaching load, the proportion of skilled labor, the size of the firm, the faculty rank, and the distance between the university and the firm.

H.11: The frequency of university personnel's use of firm facilities would be significantly and positively correlated with the level of R&D investment, the proportion of skilled labor to total employees, the surplus capacity of the industrial facilities, the size of the firm, and the use of well-defined organizational channels.

H.12: The frequency of university personnel's use of firm facilities would be significantly and inversely correlated with faculty rank, teaching load, the surplus capacity of university facilities, and the distance between the university and industry.

Table 2 presents a summary of the proposed hypotheses and the effects of the independent variables upon the dependent variables.

Table 2

Assumed relationships between variables

Dependent Variables	Independent Variables: 1 Distance	2 R&D Expenditures	3 University Facility Capacity	4 Firm Facility Capacity	5 Faculty Teaching Load	6 Organizational. Channels	7 Firm Size	8 Skilled Labor	9 University Size	10 Faculty Rank
1. Research Grants and Contracts	−	+	+	+	−	+	+	−	+	−
2. Consultations	−	+	+	+	−	+	−	−	+	+
3. Student Coop	−	+	+	+	−	+	+	+	+	na
4. Employee Training	−	+	+	+	−	+	+	−	+	na
5. University Facilities Use	−	−	+	−	−	+	−	−	+	−
6. Industry Facilities Use	−	+	−	+	−	+	+	+	−	+

na = not applicable

+ = positively correlated

− = negatively correlated

Significance of the Study

Over their history, universities have metamorphosed from the closed, self-sufficient organizations intended to train the clergy, the aristocrats, and the political elites to open social structures dependent upon their external environment for essential resources and legitimization of institutional goals (Palmer, 1985). Major changes within higher education have arisen due to external forces--such as the Morrill Act of 1862, that created the land-grant institutions and emphasized their service role; the increase in federally sponsored research beginning in World War II, that strengthened university research roles; and the postwar baby boom, that, together with federal student aid, greatly expanded college enrollments.

Because higher education has expanded its reliance on external sources, educational leaders have become more aware of and responsive to the external environment and those technological, social, economic, and political forces that are affecting higher education. The American Association of State Colleges and Universities (1986, p.2) reported that the external trends and pressures that are most likely to affect higher education in the near future are:

- Industry needs--Skilled work force pool; increased productivity; strong research base; new commercial products; available technical assistance; available consulting expertise; access to cutting-edge technology; access to competent faculty members; access to top-quality facilities.

- State government needs--jobs for residents; competitive industries; generation of new firms; attraction of new firms;

increased tax base; data/analytical support.

- Local community needs--Data and policy analysis; good town relations; jobs for residents; local economic development; neighborhood development.

- Societal pressures--Declining birth rate; criticism of higher education; waning public support; limited public dollars; new federal budget cuts.

In addition, higher education is facing many internal needs (p. 6) that must be met to maintain the educational sovereignty of higher education. Among the needs and wants are:

- Research and resource needs--equipment to attract/keep top-level researchers; new topics for research and special areas of excellence; capacity to do cutting-edge work; long-term funding; professional stimulation.

- Education needs--attract students; exciting new programs; cutting-edge curricula; attract/keep faculty members; real problems for study; relevant education.

- Public-service needs--image as contributor to the community; positive community relations; positive industry relations.

- Political needs--positive image; political allies; support for resources; support for missions; good system relations.

Palmer (1985) indicated that university-industry interaction and collaboration can develop a new vision of how education, industry, invention, and innovation can be used to solve the short and long term problems of a nation. Moreover, the American Association of State Colleges and Universities (1986, pp. 64-65) proposed a list of scenarios of possible roles that universities might face in the future:

> ...(universities) can proactively and aggressively develop their full role in university-industry interactions in ways that support the institution and serve the mission of the university....(they) can react to external pressures allowing external factors--state or industry--to set priorities and define its role, imposing new restrictions and threatening academic independence and freedom...(they) can choose to remain aloof to university-industrial interactions and become increasingly irrelevant...The industrial requirements for a better-trained work force, more research, more effective technology transfer must be met somehow. If the existing institutions remain unable or unwilling to meet them, then state and private resources for education, research, and technology development will begin to flow to more responsive institutions.

By examining the literature on university-industry interactions, performing a survey of universities and high-tech industries in East Tennessee and Southwest Virginia, and analyzing the data about the various variables concerning university-industrial interactions, perhaps this study can assist those academic leaders at higher-education institutions in East Tennessee and Southwest Virginia who are interested in achieving their full role in university-industry interactions.

Assumptions and Limitations

Ary, Jacobs, and Razavieh (1985) stated that *validity*--the extent to which the study measures what it is intended to measure--is an important characteristic of any study. In terms of content validity for the interactions between higher education and high-tech industries, one wonders if the chosen dependent variables--research grants, consultation, student internships, employee retraining, and facility sharing--provided a reasonable representation of the universe of variables that might be considered for university-industry interactions. Similar doubt surrounded the appropriateness of the chosen independent variables--the proportion of skilled labor, R&D investments, firm and university size, availability of facilities, distance, faculty rank and teaching loads, and use of organizational channels--as predictors of university-industry interactions. An absolute yes or no was obviously out of the question, since any measurement is clouded by unknown or unknowable factors (Deming, 1986). According to Deming, one must start with a best known model consisting of those variables based essentially upon judgement and redefine the model as analysis dictates. As such, this researcher adopted the beginning model based upon the preceding dependent and independent variables.

Another major assumption of this study was the correlation between high-tech industries and Standard Industrial Codes (SIC). Although these correlations were citable, a certain amount of subjectivity was used to include technologically motivated industries that did not have corresponding high-tech SIC codes and delete non-technical industries that did.

The limitations, of which one was constantly aware, included typically mundane properties such as time and territorial limitations. A looming limitation of this study was related to the demographics of the area. The study area encompassed Central Appalachia, an area which demographically resembled many third world countries (Matvey, 1986). As such, East Tennessee and Southwest Virginia have had a comparative advantage in the production of those products requiring a strong work ethic and low salaries. Such products are often located in the declining phase of their product life cycle and would not require the technical work force associated with the expanding growth phases of high-tech industries. In such a scenario, there might be a deficiency of high-tech industries within the region.

Research Outline

This dissertation was organized into five chapters. The first chapter was the introduction to the problem. Chapter one consisted of the overview, the research problem, the significance of the study, the research hypothesis, and the research method.

A literature review concerning university-industry interactions was presented in the second chapter. Included in the literature review was an assessment of the classic research done on university-industry interactions, the history of university-industry interactions, the effects of university-industry interactions on the national and Tennessee competitiveness, and the critical arguments concerning university-industry interactions.

The third chapter described the methods that were used in the study. The chapter concentrated on approaches and methodologies for examining the hypotheses constructed in the introduction. The methods of data collection, survey design, analysis, reliability, and validity were also explained.

The data were analyzed in the fourth chapter using multiple regression techniques. The fifth chapter summarized the findings, presented conclusions, and made recommendations.

CHAPTER 2

The Literature Review

Universities, industry, and states have been affected directly or indirectly by university-industry interactions. For universities, such interactions have provided access to new sources of money and ideas and the esteem to attract faculty, students, and industrial and government research grants. For industry, such interactions have provided access to competent scientists and engineers, sources of potential employees, and sources of ideas, knowledge, and technology for new products or processes. For the state, such interactions have provided promotional opportunities to persuade industries to locate and expand operations within a region, providing jobs and expanding the tax base. For the public, such interactions have provided more, better, and higher paying jobs. Minshall and Wright (1989, p. II-1) have suggested that the collective aspiration of these university-industry interactions is economic development and the fulfillment of the *American dream*:

- Improved public education.
- Better highways and public service infrastructure.
- More direct access to affordable, often better, health care services.
- Improved housing and community amenities.
- Preserved and/or enhanced environmental quality.
- More disposable income and the higher quality of life that it usually brings.

- A greater number and more diversity of employment opportunities.

With such a broad range of possible outcomes, university-industry interaction seems an appropriate subject for any one contemplating a leadership position in higher education, business administration, or public administration. Obviously, a subject with such broad appeal has a broad collection of literature. To uncover the essence of modern thought about the subject, a literature search was performed using the following database abstracts, indexes, and directories:

- SILVERPLATTER (Educational Resources Information Center (ERIC) and Current Index to Journals in Education (CIJE) databases)
- SILVERPLATTER (Government Documents (GPO) database)
- WILSONDISC (Applied Science and Technology database)
- ABI/INFORM (Business Journal database)
- INFOTRAC (Information Tracking)
- *Dissertation Abstracts*
- Standard Periodical Directories
- Standard Library of Congress card catalog
- Appendices of the Literature

In each of these databases, the following topics were examined for relevant literature:

- Higher-Education/Industry/Interactions
- University/Industry/Interactions

- University Research
- Industrial Research
- Regression Analysis
- Statistical Analysis
- Economic Development

The relevant literature from the literature search was classified into the following groups:

1. The problem of declining industrial technology in the United States and its effect on the United States' ability to compete in world markets.

2. The historical development of university-industry interactions.

3. State activism in the development of university-industry interactions.

4. Related studies concerning university-industry interactions.

The overwhelming conclusion that can be drawn from the literature search is that greater university-industry interaction would benefit each of the participants, universities and industries, by improving product and process quality, increasing productivity, boosting the American economy, and in general providing a better quality of life. Unfortunately, tradition, culture, and bureaucratic processes have provided formidable barriers to long-term commitment and interaction. Universities have seldom looked beyond the academic year, while industries have seldom looked beyond the next annual report.

Competing in World Markets

Throughout history, ideas and ideals have been important in determining the destiny of mankind (Ayres, 1988). Ancient theologians, Greek philosophers, and Roman and Medieval writers stressed the moral aspects of humanity (Anvari, 1987). Political ideas like freedom, security, justice, and equality influenced the modern development of Europe and the birth of the United States. Today, economic issues have ascended to the forefront. Ideas like free markets, hard currency, property, profits, deficits, and international competition are influencing human history, and "technology has become the engine of economic progress and wealth creation" (Dorf & Worthington,1990, p. 251).

Throughout America's two hundred year history, the seeds of change for both growth and decline have been sown by the prevailing economic climate of the day (Patterson, 1988). Sustained prosperity has historically engendered a caretaker philosophy among managers. Fearing the adverse consequences of any change, managers have often chosen bureaucratic rigidity through the proliferation of policies and procedures during thriving economic cycles. The rigid rules and regulations have impeded innovation which have inhibited the progression of new technologies and new products. Conversely, the panic in the boardrooms associated with various economic downturns have compelled senior management to seek new approaches that will generate new products or curb costs. Regardless of the prevailing economic climate, business strategy has often yielded to strong identifiable trends creating a herd mentality. Strong trends have provided the blinders that have obscured the sign posts of inevitable cyclic changes (Patterson, 1988). Prosperity has often masked underlying problems; hardships have clouded the potential for recovery. Regardless, the statistical fact has persisted that periods of above average and below average prosperity must always regress to the norm.

The United States owes much of its recent economic prosperity to the world economic devastation caused by World War II. A by-product of the war was the total destruction of Europe's and Asia's production capacity. The United States was the only major industrial nation to escape destruction. As a result, the American dollar became *good as gold*, simply because the dollar had value backed by economic goods. American business quickly became a great *world lion*, with the world at its feet (Patterson, 1988). All business had to do was design, build, and sell its products. With no competition and abundant supplies of cheap energy, America prospered, and there was seemingly little interest in university-industry interactions. The only perceived threats were from the Red Menace provided by Russia and the communist-aligned block of nations. With the importance attached to national security and defense issues, more emphasis was placed upon the interactions between universities and the federal government. Thus, there were relatively few articles concerning university-industry interactions before 1980 as industries tried to protect their international market share through the *status quo*.

As the European and Asian economic infrastructures have been rebuilt, the United States has faced growing economic competition that will culminate with the free flow of economic factors (capital, labor, and technology) in Europe in 1992. With approximately 100 million more people than the United States, the European Economic Community (EEC) will replace the U.S. as the world's largest economic market (Bakerjian & Mishne, 1988). These new economic threats have precipitated an explosion of journal articles and national discussions concerning the competitive advantages of university-industry cooperation as industries have sought new and innovative solutions to address the American competitive malaise.

As the world has become more quality and cost conscious, technological innovations are increasingly having significant economic and social implications on nations, and throughout the developed world, education has been given the task of creating a "new technological culture" (Tchijov, 1989, p. 269). The driving force behind the development of knowledge-intensive high-technology has been the computer (Hax, 1989). The development of the computer and all of its associated parts--semiconductors, robots, and telecommunications--have provided a cornucopia of possibilities, but in a Dr. Jekyll-Mr. Hyde scenario, the computer revolution has revealed potentially devastating risks. Advanced technology has become both a threat and an opportunity in the business operations of the future. Dorf and Worthington (1990) suggested that if new technologies are ignored or if firms unwisely invest in technology, the technology becomes a threat. The full potential of technology has depended on people; therefore, mistakes made by poorly trained, poorly motivated workers can cause and have caused enormous damage, as demonstrated by Three Mile Island and Chernobyl. Conversely, maintaining an awareness of emerging technologies and the potential for improving productivity, services, and products have provided better opportunities of growing and thriving in the future.

Although higher education has the capacity to be a major contributor to technology, the fact remains that educational programs have generally lagged behind current, leading-edge technological progress (Tchijov, 1989). With the exception of the most research minded institutions, there has generally been a critical shortage of teachers who are able to teach students the latest achievements in science and technology, and teachers have normally lacked adequate technical means and equipment for teaching. Yet, industries have continued to seek a highly skilled work force, opportunities for expanding worker skills, a strong research base from which new products and processes flow, and access to highly qualified experts and cutting-edge laboratories (American Association of State Colleges and Universities, 1986).

The introduction of new technology has created demand for new computer-literate professionals (Tchijov, 1989). The creation of new professions has not been without a cost. Tchijov (p. 265) reported that every "1 million dollars (in 1979 prices) invested in automation in the iron and steel industries reduces employment by 37 workers, demanding only an additional 4 technicians". The same investment in the auto industry is predicted to cut employment by 36 workers.

Losses in jobs have placed a somber burden on the less well educated. The Bureau of Labor Statistics (Duggan, 1985) found that over 5 million workers were dislocated from 1979 to 1984. Of these 5 million, nearly one-third had been in their jobs for 10 or more years. Sixty percent of the dislocated workers found jobs, but half were making less money than they had previously, with over 600,000 having taken pay cuts of 20% or more.

The burden of job losses is additionally aggravated by the fact that retraining of the older generation of industrial workers is more difficult due to three basic factors (Tchijov, 1989). First, the older workers have demonstrated little basic knowledge or experience in dealing with computers. Second, the older generation professionals have resented the devaluation of their lifelong personal experiences. Finally, they have assumed that their educational capabilities have been diminished by age.

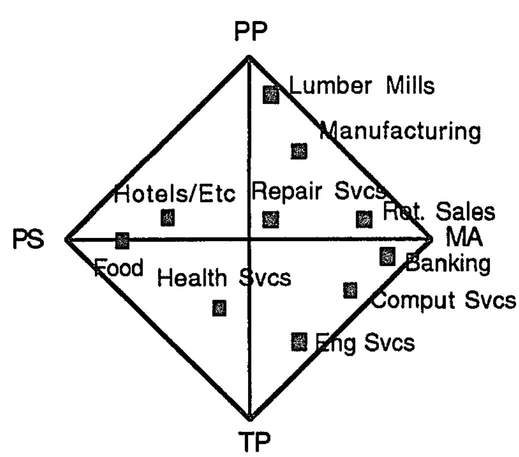
Weber (1988, p. 8) reported that there is "a changing market place, changing workers, and a changing role education will play in successfully uniting the new type of job seekers with the new available jobs." Just as agriculture lost its central role in the American economic structure, manufacturing is predicted to lose its economic importance by the turn of the century. As a result, the jobs for the beginning of the 21st century will be high-tech and/or service-oriented jobs. Those seeking entry into the fastest growing job categories will generally be required to have more than the median level of education for all jobs. Of those entering jobs growing at below-average rate, not one will be required to have more than the median education. The opportunities for employment and the quality of employment will be limited for the least skilled and will be expanded among the more highly educated.

Swyt (1988) developed a parallel work force construct based upon four major manufacturing typologies. The first typology is designated *physical-production* consisting of four standard labor classes: laborer, operative, precision-production, and craft. The second typology is called *physical-service* consisting of single-class, service occupations, such as hospital orderlies, parking-lot attendants, custodians, security guards, and fast-food workers. The third typology is labeled *managerial-administrative* consisting of the three broad occupational classes: managerial/administrative, clerical, and sales. The last typology is *technical-professional* including engineers, doctors, scientists, financial analysts, nurses, accountants, technicians, and paraprofessionals.

From these descriptions and using Bureau of Labor Statistics data, Swyt (1988) formulated a diamond diagram showing work force trends. The vertical axis is plotted with precision-production (PP) at the top and technical-professional (TP) at the bottom. The horizontal axis has physical-service (PS) on the left and managerial-administrative (MA) on the right. Figure 1 presents the diamond diagram with selected industrial sectors

Figure 1

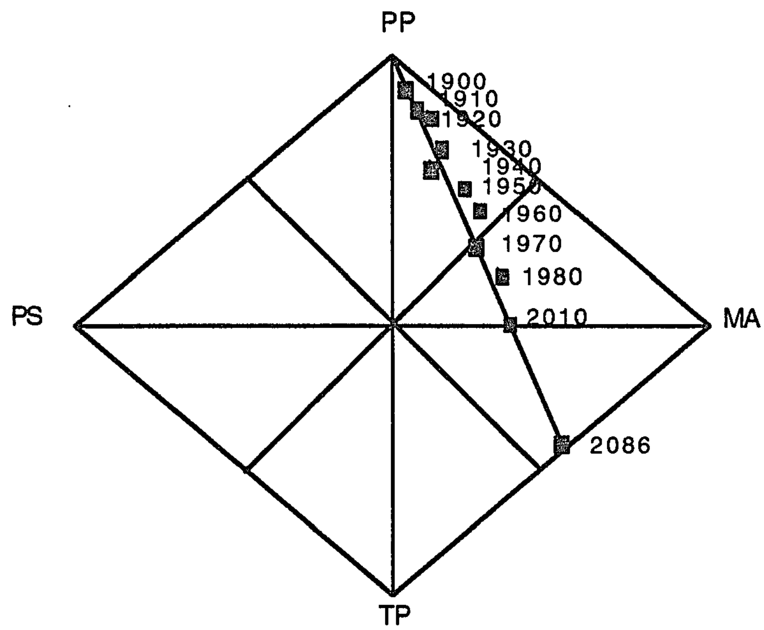
Diamond diagram (Swyt, 1988, p. 236)



included for clarification. Lumber mills are almost purely physical-production, banks are almost purely managerial-administrative, engineering services are associated with technical-professional, and food services are almost purely physical-service. Figure 2 presents the occupational distribution of the U.S. work force over the period 1900-1980 and projects the occupational distribution through 2086. Reference grids

Figure 2.

Occupational distribution (Swyt, 1988, p. 238)



are added dividing the diagram into a blue-collar physical-production quadrant at the top, a tan-collar physical-service quadrant at the left, a white-collar managerial-administrative quadrant at the right, and a no-uniform technical-professional quadrant at the bottom. An additional geometric line that represents the trajectory of the occupational distribution trend has been drawn from the vertex at the top to the midpoint of the line between managerial-administrative and technical-professional.

The trajectory of the occupational distribution is apparent. Figure 2 shows a physical-to-mental transition having taken place around 1970. The diagram predicted that in less than a generation (2010), the work force will cross a point where there will be more workers in the technical-professional occupations than in the physical-production occupations. Future generations will see occupations that are exclusively technical-professional or managerial-administrative with only a small fraction appearing in either of the current physical-production or physical-service groups. The service workers will be technical-professionals in a knowledge-intensive service economy, not the service-occupation workers in menial jobs.

These reports have suggested that the natural link between higher education as the producer and purveyor of knowledge and the emerging knowledge-based economy may simply be too great to ignore. The new requirements--a better trained work force, more research, more effective technology transfer--must be satisfied. Folger and Wisniewski (1989) similarly proposed that higher education must play an increasingly important role in the "dissemination of research knowledge and applications through an increasing involvement in policy research, special services, and training programs for managers and business professionals" (p. 83). They have fostered the opinion that university-industry alliances develop partnerships and service activities, and consultant relationships bring the specialized and technical expertise of the university to bear on practical problems faced by government, business, and industry. These knowledge-generating and sharing arrangements can be used to increase the competitive advantages of some states in economic growth and assist the nation overall in international competition. If universities are unable or unwilling to address new issues, then state and private resources for education, research, and technology development may flow to more responsive institutions such as industry-sponsored education and training institutions (e.g. corporate universities).

Universities have demonstrated their potential to provide the stocks and flow of new technologically-literate professionals to high-tech industries (McNamara, Kriesel, & Deaton; 1988). In order to fulfill their expanding roles in state development and national competitiveness, universities must step to a new academic plateau where they become scholarly strong enough to be visible and attractive both regionally and nationally. By developing university-industry interactions, universities will be allowed access to new, additional sources of revenues, while industries will be provided access to new technological thought and inquiry.

The History of University-Industry Interactions

Early American Higher Education

Prior to the 19th century, most technological innovations were provided by individual, independent inventors, many of whom had little formal education (Giovengo, 1986). These individual inventors were subsequently supplanted by huge industrial, corporate laboratories such as General Electric, Westinghouse, DuPont, and Bell Telephone during the latter decades of the 19th century and the early decades of the 20th century. The *university-industry* complex was established to provide manpower for these burgeoning corporate laboratories, matured during World War II, and has continued to expand as knowledge has surged during the latter decades of 20th century. Recently, successful technological innovations have often been cooperative endeavors using the intellectual resources of the university and the financial resources of industry (Studt, 1991; Owen & Entorf, 1989; Johnson, 1984).

Although many of the recent, leading-edge technological innovations had their beginnings in academic laboratories (Giovengo, 1986), the essential elements--free inquiry and scientific research--for innovation have been relatively recent developments in the evolution of higher education. In the beginning, the early universities--Harvard (1636), Yale (1701), Dartmouth (1769), Brown (1764), Queen's College (Rutgers, 1766), King's College (Columbia, 1754), College of New Jersey (Princeton, 1726), and William and Mary (1693)--existed in the Oxford-Cambridge tradition to prepare clerics, gentlemen, and the political elite. They existed as *ivory towers* where "students were trained to think within existing structures, refining and transmitting established knowledge" (Giovengo, 1986, p. 94).

By the end of the 18th century, 17 colleges existed in the country. By 1860, 182 colleges had been established with "nine out of every ten having some connection with a religious affiliation" (Gwynne-Thomas, 1980, p. 194). The established mission of these colleges was to strengthen and extend faith, piety, and prayer. College presidents were nearly always ministers. Harvard was substantially supported by the gifts of John Harvard, a Puritan minister, who bequeathed 260 books and £780. The Connecticut Calvinists supported Yale while the New Hampshire Calvinists supported Dartmouth. The Baptists established the New England college, Brown College, in Rhode Island. Queen's College (Rutgers) was formed by the Dutch Reformed Church in New Jersey while King's College (Columbia) was chartered by the Anglicans in New York. The Presbyterians established the College of New Jersey (Princeton). The only college in the South during the colonial period was William and Mary, founded in 1693 by James Blair, an Anglican.

Button and Provenzo (1983) reported that no more than one boy in 200 attended college during this era. They attended colleges because of the lingering tradition that a gentleman should have a liberal education or because they were to become ministers, lawyers, or physicians. Latin, Greek, rhetoric, philosophy, religion, medieval arts, and sciences were the foundation of university curriculum (Giovengo, 1986). This formula for education existed until the Civil War.

The Industrial Revolution

The Germans, specifically Wilhelm von Humboldt, established the breakthroughs which heralded the modern university (Keller, 1983; Giovengo, 1986). The breakthroughs that have become the foundation of the modern university were (1) academic freedom of study and dissemination, (2) research into new areas, and (3) the supersession of the study of science over the transmission of religion and established moral knowledge (Giovengo, 1986). These reforms in American education coupled with the emergence of science and technology and the establishment of Agricultural and Mechanical (land grant) schools by the Morrill Act of 1862 provided the impetus for America's first economic revolution. The result of this first technologically-driven economic revolution was increased farm productivity that has been fundamental in reducing the farm population from 95% of the American labor force to less than 5% today (Vonderembse & White, 1986). The Morrill Act of 1862 was enhanced with the Morrill Act of

1890, the Adams Act of 1906, the Nelson Act 1907, and the Smith-Lever Act of 1914 (Giovengo, 1986).

In addition to improving agricultural methods, the Morrill Acts of 1862 and 1890 indirectly opened technical university education to people at all levels by relaxing enrollment requirements and reducing tuition fees (Johnson, 1984). Engineering schools began rapidly springing up throughout the nation: "4 in 1860 to 17 in 1871, 40 in 1872, 85 in 1880, and 126 in 1918" (Giovengo, 1986, p. 116). The engineering schools began in civil and mechanical areas and expanded to electrical engineering in the 1880s. An accumulation of new knowledge and theories evolved from these new colleges and universities, from abroad, and from American workshops (Button & Provenzo, 1983). Practical knowledge including the how and why had a direct effect upon academic thoughts and beliefs. Expanding knowledge in physics and mathematics enhanced the accumulated experiences of the machine shop and foundry. The marriage of theory and practice quickly elevated engineering beyond the traditional master craftsmen.

Engineering curriculums were based upon scientific methods rather than shop methods, insuring their quick professional acceptance in education. Although there were actually few technological discoveries made in university laboratories in the early 1900s, engineers quickly became an esteemed profession as universities provided the technical talent necessary for the technological improvements in manufacturing productivity that ushered the second industrial revolution, freeing human resources for the eventual expansion of service industries (Tchijov, 1989, Vonderembse & White, 1986).

The increasing demand for the development of technology during the turn of the century coupled with the emerging reliance of national defense upon technological innovation during World War I created an explosion of corporate-owned industrial research laboratories (Giovengo, 1986). The 1920s witnessed the tripling of both the number of corporate-owned research laboratories and the number of people employed in such laboratories. Although the Great Depression slowed laboratory growth during the 1930s, the number of research workers continued to expand, doubling in size throughout the 1930s and 1940s. The sheer numbers of talented, skilled workers required by these corporate-owned laboratories provided a large market for university-trained scientists and engineers. On occasion, those universities with better personnel and equipment than their corporate counterparts would be sought to solve theoretically-based problems. The epitome of university-industrial interaction during this period between 1900 and 1930 was the Massachusetts Institute of Technology (MIT). The interactions with MIT were haphazard until 1920, when MIT instituted a *Technology Plan* that devised a standard contract for a standard fee and created a *Division of Industrial Cooperation* (Giovengo, 1986). The division acted as a clearinghouse between industry and faculty consultants. In addition, the Division of Industrial Cooperation often arranged for industrial fellowships and job placement for graduate students. Over 150 companies signed these standard contracts.

Not only was the curriculum undergoing dramatic changes during the turn of the century, but old guard clerical leaders were succumbing to the industrial giants of the era. These wealthy industrialists had made their fortunes using the new methods and processes. With increasing frequency, the industrial barons--Andrew Carnegie, John D. Rockefeller, Johns Hopkins, etc--provided buildings and capital to establish technologically-oriented universities or new research institutes within existing universities. Eventually, these industrial benefactors were invited to assume seats on the governing boards, replacing the dominant influence of the clergy of the earlier eras with a dominant technological influence of industrialists and financiers. Even today, these industrial czars of a foregone era have continued to influence universities through their endowments, and the corporations they produced have continued to philanthropically contribute to engineering education by bestowing student scholarships and fellowships, donations of modern equipment, and construction of new facilities.

Modern University-Industry Interactions

Though the development of university-industry interactions began early in the 20th century, World War II was the event that bonded present day high-tech university-industry interactions. Government-university-industry associations had been mobilized during World War I. The brevity of the U. S. involvement impeded long lasting relations. Yet, the method for the mobilization of technology for war had been developed. With the outbreak of hostilities during World War II, the U. S. quickly reinstituted the technological infrastructure with extensive military support for defense projects at universities. Through the auspices of the National Defense Research Committee (NDRC) and the Committee of Medical Research that became the Office of Scientific Research, academia was able to develop the "atomic bomb, radar, penicillin, and synthetic rubber" (Giovengo, 1986, p.

134). These successes proved the value of basic scientific research to national security and economic development.

The scientific successes of World War II propelled the alliance between national security and science into the post-war period. Several key journal articles and policy initiatives supported the development of a National Science Foundation, which came to fruition in 1955 (Peters, 1989). Although there was considerable academic anxiety concerning the effects of government involvement upon academic freedom, the National Science Foundation adopted a policy of funding peer-reviewed, individual investigator-initiated proposals and allowing the investigators complete freedom in the administration of small to moderate-sized research grants. With the availability of Federal funds and an enlightened federal attitude toward the expansion of academic research capabilities, university research flourished with some schools emerging as significant national research institutions. Regional institutions, including technical institutes and most land grant schools, expanded their engineering programs.

The G.I. Bill following World War II, like the Morrill Acts, provided new educational opportunities for previously excluded sectors of the American population and perhaps engendered a new paradigm that elevated higher education to a civil right as opposed to an elite privilege. Veterans, generally older and more pragmatic, sought education that was related to professional ambitions rather than aesthetic and philosophical inquiry. They also frequently developed special relationships with local industries.

By 1945, some professors at small colleges and most professors at universities had obtained Ph.D.s (National Science Board, 1989). Organized research units proliferated on campuses. These new research units usually had a more applied orientation than the academic departments, and research sometimes took precedence over teaching. Unlike their colonial predecessors who believed in general education, the scholars of this period became specialists. Scholarly knowledge of the period was expanding so rapidly that researchers were forced to make their contributions to narrow segments of an established field. New disciplines and college departments emerged as accumulated knowledge was expanding far faster than even the gifted mind was able to grasp.

The successful alliance between defense and education during World War II and the perceived hostile threats of communism entrenched the government-university collaboration. In 1930, 70% of the funds used for research and development came from industry, 15% from the federal government, and the remainder from private philanthropy (Giovengo, 1986). In 1950, 75% of the funds were being generated from the government. Industries--particularly those performing defense and space work--were attracted to the supply of talent at universities or at specialized government installations (e.g., California, Texas, and Florida for space programs; California, Massachusetts, and Washington for defense). By locating businesses in these areas, concentrations of regional development emerged.

The 1960s saw the beginning of the elimination of many of the industrial laboratories or their reorganization to reflect more immediate needs of operating divisions (Giovengo, 1986; Drucker, 1990). Among the list of contributing factors for R&D discontinuations that Drucker compiled are: (1) overly optimistic expectations about the role and possible returns of basic research, (2) difficulties in managing and integrating research laboratories into the remainder of company activities, (3) the predominance of a cost-accounting approach to management that gave long-range activity lower priority, and (4) the economic recessions of the late 1950s and the 1970s.

As industrial R&D facilities have shrunk and high-tech applications have expanded, industry researchers and mangers have looked to academic institutions and other research centers for expert help. Unfortunately, culturally ingrained conflicts between open-access, knowledge-oriented universities and profit-oriented, competitive industries have arisen. The barriers to university-industry cooperation have consistently revolved around nagging issues like proprietary rights, patent rights, publication of results, foreign students, and government restrictions (National Science Foundation, 1982).

Industry has sought to be the first into the market with their products. Thus they have placed a high value on confidentiality (proprietary information) concerning the development of new products. This has been contrary to the fundamental belief of an open exchange of ideas held by a large number of college faculty. Moreover, faculty promotions and salaries are jeopardized by the delay in information dissemination. Cooperation is further aggravated by the fact that many of the engineering programs have a strong contingent of foreign students. The foreign complexion of these programs have hampered cooperation based upon national security, both from a defense and competitive view.

State Activism

Fosler (1988) organized several case studies concerning state economic development strategies. He found that many state and local governments have become actively involved in economic development (the attraction, retention, and creation of industry) as (1) manufacturing jobs have declined throughout the nation, (2) state and local industries have become more vulnerable to foreign competition, and (3) certain political responsibilities have been delegated to the states by the federal government. As each state has developed its strategy, they have been forced to expand their vision from the *business climate* (unemployment compensation, workers' compensation, and regulation) to the broader concerns of *economic climate* (education, universities, and public services) to create an *entrepreneurial climate* that encourages and stimulates innovation and growth.

Among the strategies examined, Massachusetts has developed efforts that provide an attractive business environment to potential investors. Tennessee has sought a strategy of recruiting branch plants. Arizona, Minnesota, and Indiana have attempted to stress the importance of education, infrastructure, and quality of life. Michigan has strived to be more selective in its recruitment efforts in order to seek assets that will aid in the creation and generation of new enterprises. Regardless of the strategy used to enhance the business, economic, and entrepreneurial climates, Fosler (1988) found that knowledge and technology production, dissemination, and support were commonly state-controlled functions.

Although states are the "major producers and disseminators of knowledge and supporters of research and development of new technology" (Fosler, 1988, p. 313), historically, states have been seemingly reluctant partners of higher education. One might say that the states were hoodwinked into the education business, especially higher education. Since the Constitution of the United States made no direct reference to education, jurisdiction of education was delegated, perhaps by default, to the individual states by the Tenth Amendment (Kaplan, 1985). Nevertheless, there was wide discussion concerning a National University throughout the early decades of the Republic. George Washington, who favored the establishment of a national university, donated $25,000 for the establishment of a national university in Washington, D.C. and declared:

> Knowledge is in every country the surest basis of public happiness. In one, in which the measures of government receive their impression so immediately from the sense of community, as in ours, it is proportionably essential. To the security of a free constitution it contributes in various ways; by convincing those who are intrusted with the public administration that every valuable end of government is best answered by the enlightened confidence of the people, and by teaching the people themselves to know and to value their own rights. (Gwynne-Thomas, p.193).

The university was never established and no one knows what became of the $25,000.

Early in colonial American history, states seemed to maintain the traditional view that university education was a privilege reserved for the elite, relying on private rather than public institutions for higher education. States often sanctioned higher education, but were less eager to provide financial support. Such a paradox arose when the University of Georgia (1785) was the first state university to be chartered, but the University of North Carolina (1795) was the first to be opened. One state, New Hampshire, even tried to annex an existing private university, Dartmouth, to establish its State university system (Kaplan, 1985).

Without the appropriation of public funds to support a State university system, state development of higher education was undramatic until the Morrill Act of 1862 provided 30,000 acres of public land for each of its national senators and representatives (Gwynne-Thomas, 1983). Income from the sale of the property was to be applied to the establishment of one or more land-grant colleges to teach courses related to agriculture and mechanical arts. The Morrill Act of 1890 established allocation of Federal money to the land-grant colleges. With funds available to administer universities, the state-chartered universities were often designated as the land-grant college. Where there were no state-chartered universities, land-grant colleges often became State universities. Once the flurry associated with Morrill Acts settled down, state activism in higher education diminished. The dormancy was only interrupted by an occasional infusion of money by an industrial benefactor of the period.

The *status quo* continued until the quick succession of hot and cold wars once again provided the states with access to abundant money. Returning World War II, Korean, and Viet Nam veterans loaded with G.I. Bill vouchers strained the existing higher education infrastructure, both physically, fiscally, and philosophically. These veterans became the pioneers in a succession of paradigm changes as education changed from a privilege to a right, as educational institutions changed from a benevolent parent--*in loco parentis*, and as educational curriculums changed from predominantly liberal to predominantly professional curriculums. A college education had become the means of entering nearly all professions and management positions (Button & Provenzo, 1983). With this new reality, universities seemed to lose a certain innocence and naivety. No longer were colleges a place to live for four years and "earn gentlemen's Cs, cheer for football teams, and vote for the campus queens" (Button & Provenzo, 1983, p. 285). College degrees were now a means to an end.

Although the 1950s and 1960s were froth with changes, overall the period was probably the most prosperous in American education history. This era represented a golden age for higher education (Keller, 1983). Students increased, educational facilities doubled, faculty increased, research and development increased tenfold in terms of dollars, and the majority of Nobel laureates came from the U.S. during this period. Building construction proliferated as state institutions prepared for the coming *baby boom*.

Perhaps the golden era of education was only the calm before the storm. The social pressures of the 1970s, student and faculty protests related to the Viet Nam War, the indiscretions of the Nixon administration, and the inherent inflation associated with oil shocks of the period contributed to the disenchantment and tension between the liberal intelligentsia associated with educational institutions on one extreme and the conservative element associated with social and public establishments on the other extreme. Each of these confrontations disenchanted the general public, and financial support for higher education deteriorated rapidly (Henton & Waldhorn, 1988).

The liberal-conservative struggle was joined by Reagan in the 1980s as he sought to reverse the national malaise that developed during the Carter era by dissolving many of the the social programs established by Roosevelt and augmented by the subsequent Democratic administrations (Fainstein & Fainstein, 1989). Reagan's strategy involved major tax cuts combined with substantial expansion of military expenditures and reallocation of functional responsibilities from Washington to lower levels of government. The objective was to empower business, weaken labor, and reduce the penetration of governmental regulation into business decision making. The Reagan attack had mixed results. Although numerous domestic programs were substantially reduced, a strong liberal Congress prevented total implementation of Reagan's strategy. As a result, Reagan was not able to achieve the reductions he sought. Additionally, the revenue payoffs of supply-side economics never occurred, resulting in a mushrooming national debt.

With no clear winner and no capitulation by either the President or Congress, many American companies were plagued by the high cost of capital, an overvalued dollar, a deteriorating education system, over consumption at the expense of investment, government regulations, emphasis on military as opposed to economic security, and undisciplined government spending. Local industries like the *smokestack* industries in the North and the Midwest and oil production industries in the oil producing states--Texas, Oklahoma, and Alaska--declined. The reallocation of functional responsibilities from Washington to lower levels of government, ever-increasing national and state debt, voter abhorrence of new taxes, offshore production by American firms, and loss of competitiveness of domestic industry placed more responsibilities on states, which also faced dwindling sources of revenues.

As a result of these realities, 38 states have established agencies to promote science and technology development (National Science Board, 1989). The purpose for the creation of these agencies was (1) to create and attract knowledge-intensive industries to replace those declining because of new technologies, reduced markets, or foreign competition and (2) encourage modernization by existing, but troubled, manufacturing industries. Most of the state strategies have involved showcasing state higher education institutions.

Moreover, the strong competitive nature for technologically oriented projects now existing between the various states and the realities of a bulging national debt have been reflected in the Federal approach to science investments. Many new Federal programs have begun to require state and/or industrial matching funds. States are now keenly aware of the size of some large new scientific and technological enterprises--e.g., Department of Defense's Sematech (a consortium to develop manufacturing technologies) and the Microelectronics and Computer Technology Corporation (MCC), both now located in Texas--and the need for coordinated efforts involving state, industrial, and university resources in competing for such initiatives. The changes in the nature of scientific and technological research have created a political awareness of how these awards are made and the new equipment, facilities, and new institutional forms needed to compete for these awards.

California

California represents the prototype of a technologically innovative state. From its origins in the 1850s, California's economy has been fueled by entrepreneurs who took advantage of the opportunities that arose and had a enduring belief they could engineer solutions to the problem at hand (Henton & Waldhorn, 1988). California's capacity for innovation has been the key aspect of every stage of its industrial evolution. The innovations began with efforts to extract gold and control water and has led to aerospace and microelectronics.

California's ascendancy to the technology throne has been more by accident than plan. The *Gold Rush* brought people to California, local manufacturing grew to produce and supply items which were too expensive to import, and manufacturing growth established major cities that became major financial, shipping, and trading centers. Agriculture developed as the population grew even more. Irrigation and aqueduct technology were applied to agriculture to overcome the arid climate, and the scarcity of farm labor stimulated the production of farm machinery. Knowledge accumulated to overcome agricultural adversities established the technological and manufacturing infrastructure needed to develop the oil industries during the 1920s and provided construction industries that developed California's massive transportation system and the toolmakers who established the California aerospace industries.

California's population continued to grow as servicemen who had passed through California during World War II stayed and as businesses continued to invest in technology. The first integrated circuit was invented in California in 1959 for aerospace applications. Defense technology began to crossover into commercial uses. T . microprocessor soon followed, and Silicon Valley had become the center of high technology involving a network of producers, suppliers, service industries, venture capitalists, and lawyers. By 1980, California had:

- the world's greatest concentration of high technology industry.
- the highest industry spending in R&D.
- over 30% of the nation's scientists and engineers.
- received the most federal funds for R&D.
- led the nation in the creation of new knowledge.

Henton and Waldhorn (1988) reported that those states that have tried to emulate California have paid too much attention to the numbers of jobs created and the number of industries relocating in the state. They have suggested that the underlying strength of California is its capacity to develop a good business climate consisting of a fair and equitable tax system, a flexible regulatory process, and an efficient government; and then make sure that there are skilled workers, access to technology, and venture capital. The California experience is contrary to the experience of many other states that have tried to attract, retain, and grow industries through low-cost land, labor, or taxes.

East Tennessee and Southwest Virginia

Just as California flourished as a result of impending threats, Central Appalachia consisting of parts of East Tennessee, Western North Carolina, Southwest Virginia, Southern West Virginia, and Southeast Kentucky have a history of socioeconomic deprivation while resting upon the nation's most bountiful natural resources (Matvey, 1987). The rugged Appalachian Mountains have provided the borders for one of America's severest underclass societies. The natural barriers have been buttressed by the cultural values of Central Appalachia impeding the development and progress both from within and without the region. The seemingly unforgiving natural forces of the area rewarded rugged individualism, stoicism, and fatalism, preventing the development of a manufacturing base. The stereotype of the backward hillbilly, the uneducated mountaineer, and the rebellious coal miner has produced *defacto* discrimination by other regions toward the area. As a result, the region has never developed the skilled labor nor the manufacturing infrastructure needed to compete effectively with the national manufacturing centers located in the North. The region has only had a comparative advantage in industries that intensively use natural resources and unskilled labor, promoting a concentration in traditionally low-wage industries (Bartik, 1988). The low-wage industries that located in the region have never advanced job skills or encouraged a supporting industrial infrastructure. Today, foreign competition and the economic advantages of innovative technology have eroded low-wage industries and created new demands on the labor force.

Tennessee has provided a geographical and political anomaly. The state is defined by its three *Grand Divisions* in terms of statutes, in terms of geography, in terms of culture, and in terms of the three stars that exist on the state flag. These three divisions are West Tennessee, Central Tennessee, and East Tennessee. Each of these divisions has more closely identified over history with its neighboring regions in other states than with the remainder of Tennessee (Bartik, 1988).

Memphis forms the metropolitan hub of West Tennessee. Lying next to the Mississippi River, West Tennessee has historically developed as and continues to be a distribution center. West Tennessee has often aligned itself more closely with Arkansas and Mississippi in terms of culture, history, and social concerns. During the Civil War, West Tennessee was strongly aligned with the Confederacy. East Tennessee which has been historically isolated by the Appalachian Mountains has formed a closer cultural affinity and economic alliance with North Carolina and Southwest Virginia. During the Civil War, East Tennessee aligned with the Union. After the Civil War, the region developed into a manufacturing region. Central Tennessee can be culturally ranked somewhere between the two extremes of West Tennessee and East Tennessee. Like the other two regions, Central Tennessee has aligned more closely with Southern Kentucky than with any region of the state. The natural barriers provided by the Appalachian Mountains have likewise separated Southwest Virginia from the remainder of Virginia.

Unlike California, which has historically united in order to solve common socioeconomic problems, Tennessee problems have often been addressed during the maelstrom of regional tensions. Fortunately, Tennessee has made significant strides in the last 30 years as transportation and communications have improved (Fox & Price, 1991). There has been a significant restructuring of the state economy, major demographic changes have taken place, government has expanded in size and scope, and the state has increasingly been integrated into the broader world economy.

Between 1960 and 1990, Tennessee's population grew from nearly 3.6 million to almost 5 million, reflecting a 38.9% increase while population growth for the U.S. over this period was 37.1% (Fox & Price, 1991). This provided an important source for economic growth. Unfortunately, above average growth is not expected over the next decade, implying that productivity by the existing Tennessee work force must improve in order to maintain or create wealth.

Fox and Price (1991) have reported that educational attainment is an important barometer of quality of life and work force skill. Despite educational improvements, Tennessee has consistently ranked low in the Southeast and across the U.S. in terms of various measures of educational performance. One of the most important public policy issues of 1990s will be to provide further improvements and refinements to the state's system of education and insure that all students have the skills and flexibility to adapt to a changing world. Similarly, Virginia officials must discover techniques that will assimilate Southwest Virginia into the mainstream of Virginia economics. These provisions will be essential to the economic development of the region and the economic welfare of the region's residents.

The Critical Arguments

Classical Studies

Modern thought concerning university-industry interaction began with the landmark report presented by the Joint Economic Committee of the Congress of the United States (1982). Analyzing 691 high-tech firms, the study discovered that access to skilled labor was the most significant factor in the location of high-tech firms (Table 3). The Joint Economic Committee concluded that universities provided skilled workers in the form of professors for consultation, graduate students for internships, and graduates for permanent employment.

Among the most prodigious areas of technological growth--Silicon Valley (California), Route 128 (Massachusetts), and the Research Triangle (North Carolina)--the study (Joint Economic Committee, 1982) found that higher education had been an integral component of the area's development. Silicon Valley and Route 128 represented areas of spontaneous, haphazard development involving prestigious universities, while the Research Triangle represented planned development involving the combined resources of the University of North Carolina, North Carolina State University, and Duke University.

One aspect of the study (Joint Economic Committee, 1982) that should provide encouragement to less technologically developed regions such as East Tennessee and Southwest Virginia was the report's assessment that the most technologically advanced states (California and Massachusetts) have become overgrown and overdeveloped. In essence they are reaching a saturation point in which growth will expand at ever decreasing rates. As

Table 3.

Factors that affect high-tech firm location (Joint Economic Committee, 1982, p. 25)

Rank	Attribute	Percent Significant or Very Significant
1	Availability of workers	96.1
	Skilled	88.1
	Unskilled	52.4
	Technical	96.1
	Professional	87.3
2	State and/or local government tax structure	85.5
3	Community attitudes towards business	81.9
4	Cost of property and construction	78.8
5	Good transportation for people	76.1
6	Ample area for expansion	75.4
7	Proximity to good schools	70.8
8	Proximity to recreational and cultural opportunities	61.1
9	Good transportation facilities for for materials & production	56.9
10	Proximity to customers	46.8
11	Availability of energy supplies	45.6

a result, entrepreneurial factors like investment capital, quality of life, and labor may eventually be more efficiently used and developed in other regions of the country.

About the same time as the Joint Economic Commission's study (1982), the National Science Foundation (1982) gathered information from 95 of the major American research universities and 66 research based firms. From their research, they identified 464 examples of university-industry interactions consisting of four broad categories: (1) general research support, (2) cooperative research support, (3) support for knowledge transfer, and (4) technology transfer. General research support consisted of philanthropy or gifts to the institution. Cooperative research entailed projects in which cooperative technical planning was involved. Knowledge transfer incorporated two mechanisms: (1) formal, contracted methods such as contracted seminars and formal workshops and (2) informal methods such as consulting, the exchange of people, seminars, speaker programs, and publication exchanges. Technology transfer was based upon the agricultural extension programs in which generic technology centers were established.

The study uncovered a number of looming issues that could affect future university-industry interactions. The main issue discussed was the declining federal support of universities. The researchers speculated that lower government funding will require universities to seek additional support to replace these funds. Without sufficient funds, the authors proposed that the research infrastructure--advance research instrumentation, sufficient facilities, and personnel--would collapse. The study recommended commercializing university research, seeking mechanisms that encourage shared instrumentation, and creating research centers that enhance faculty salaries by allowing universities to hire *clinical-like* engineers who are allowed to maintain a *practice* (e.g. contract work or consulting) as viable alternatives to reduced revenues. Additionally, the researchers suggested that universities and industries might need to examine fundamental changes in well established principles. For instance, several industries have developed large scale research organizations--the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI)--to distribute research grants and alleviate the effects of reduced federal funding.

The study (National Science Foundation, 1982) cited several universities that have established and expanded programs intended to provide advanced education outside the university setting. Some universities have even examined the structural aspects of the university that inhibit interdepartmental research such as grouping scholars by disciplines and granting tenure within departments.

Contemporary Studies

Although the classical studies of university-industry interaction have provided the foundation for university-industry thought and sounded the early warnings concerning complacency, the 1990 recession has underscored the economic vulnerability that states and the nation face in the future. Yet, universities, businesses, and governments have seemingly entered Woody Allen's world where:

> We've reached a crucial turning point. One road leads to hopelessness; the other to utter despair. We

> must have the courage to make the right decision.
> (Schmitt, 1989, p. 18).

Giovengo (1986) proposed that the 1980s marked a historical transition in technological innovation and its organizational structure. The author presumed that the most visible harbingers of this new era of university-industry interactions have been symbolized by (1) shorter time gaps between basic and applied research, (2) the increasingly interdisciplinary nature of problems, (3) the new industries and new firms emanating from university research, (4) the increased frequency and magnitude of university-industrial relationships, (5) new forms and complexities for these relationships, and (6) university efforts to utilize their resources to contribute to regional economic development.

The study (Giovengo, 1988) suggested that the motivations that have encouraged universities to seek interactions with industry are (1) a need for non-government sources of funds to supplement diminishing federal support, (2) a desire to obtain greater federal support through government-sponsored university-industry joint support (3) a disenchantment with regulations inherent with federal funding, (4) a desire to provide students with exposure to so-called *real world* problems, relevant industrial training, and increased opportunities for internships and future job offers, (5) an access to frontier advances in fields where industrial laboratories are the primary repositories of expensive, state-of-the-art equipment and groundbreaking results, (6) a desire to enhance the university's ability to attract high-quality faculty and students, and (7) an increased potential to transfer university basic research into commercial applications. Those motivations that have encouraged industries to interact with universities are (1) an access to talented students and faculty for consulting, personnel exchange, and job opportunities, (2) an access to a *window* on scientific and technological advances, (3) an access to problem-solving capacity or information unavailable elsewhere, (4) an access to state-of-the-art university facilities in certain fields unavailable elsewhere, (5) an opportunity to perform some research projects more economically, (6) a desire to increase company prestige and image through association with a prestigious university, and (7) a desire to insure the long-term supply of well-educated personnel and foster good community relations. These motivations have been impeded by (1) debates over ownership of intellectual property, including patent and licensing agreements among individual faculty, universities, and firms, (2) prepublication reviews and publication restrictions, pitting long-established values of academic freedom against proprietary secrecy, (3) fear of administrative coercion to work in areas of industrial interest rather than areas of faculty interest, (4) the loss of a core of faculty excellence in specific academic areas, (5) conflict of interest concerning faculty ownership of commercial ventures or extensive consulting activities, and (6) the differing administrative structures, time frames, and goals of academia and industry.

Min (1989) has examined several physical and nonphysical factors hypothesized to contribute to the level of university-industry interaction in South Korea. The investigation prioritized the most important factors as:

- Surplus capacity of university research facilities
- Surplus capacity of industry research facilities

- Distance between the university and industry
- Level of R&D investment by the firm
- Available faculty research time

In addition, the study considered the development of a formal or informal organizational structure to encourage interactions between universities and industries.

The study (Min, 1989) found that the larger universities were most closely associated with research activities while the smaller universities were most closely associated with consultation. The direct benefits attributed to university-industry interactions were:

- human resource development
- enhanced personal income of professors and students
- increased productivity of the business community
- more available university and industry jobs

Roessner and Bean (1991) surveyed 139 firms concerning the interaction between industry and federal laboratories based upon industry experiences in 10 types of possible interaction: (1) information dissemination, (2) workshops and seminars, (3) individual lab visits, (4) technical consultation, (5) use of lab facilities, (6) employee exchanges, (7) cooperative research, (8) sponsored research, (9) contract research, and (10) licensing. The four most frequent interactions were:

- Information dissemination
- Workshop/seminar

- Lab visits
- Technical consultation

The significance of other factors were reported to fall off dramatically.

Sissom (1989) and Cutler (1991) listed human interactions as the greatest benefit of university-industry interactions. Such interactions have launched companies, developed consulting firms, and spawned entire industries. Unfortunately, such interactions are difficult to maintain due to the distinctively different objectives of the university and industry. Sissom reported that most of the barriers to interaction come from the university in the form of rigid accreditation and tenure requirements.

Summary

Higher education has played an important role in the 200 year development of the United States. The principles of democracy were laboriously developed and eloquently expressed by learned men in the *Declaration of Independence* and the *Constitution*, the development of agricultural and mechanical state colleges was the precursor of the industrial revolution, research universities provided a distinctive advantage during World War II, and the expansion of engineering after Sputnik led to the computer revolution.

For most of their history, universities have essentially existed through charitable support. Unfortunately, the coffers of the principle benefactors, federal and state governments, are empty. Nevertheless, university costs have continued to rise (Studt, 1991). Meanwhile, industries have been seeking technological innovations that will improve productivity, reduce manufacturing costs, and optimize product quality. The feasible solution to both needs seems to be converging on university-industry cooperation and interaction.

The development of new ideas, new products, and new processes has been accomplished through varying applications of (1) basic research, (2) applied research, or (3) development (Min, 1989; National Science Board, 1989; Giovengo, 1986). University R&D has been most closely associated with basic research. Total expenditures for basic research have accounted for 9% to 14% of the total U.S. R&D expenditures, of which 70% is performed in university and nonprofit research centers (Studt, 1991; National Science Foundation, 1982). Applied research expenditures have accounted for 21% to 24% of total R&D expenditures while developmental activities have fluctuated between 63% and 69% of total R&D expenditures. Private firms have performed 85% of applied and development research.

Economic and competitive pressures have generated a downward trend in industrially generated basic research while industrially applied and development research have witnessed an upward trend (Studt, 1991). This consequence has become more prominent as corporations have tended to reduce their involvement in basic R&D beginning in the 1960s. Industries, with their interest focused upon capturing market share, have generally proven more amenable toward projects that have instant application (Johnson, 1984).

Industry priorities have also changed demands upon universities. With more emphasis on applied knowledge, industries have become supporters of technology parks that cross many academic disciplines (Goldstein & Luger, 1990). Competitive fears have overtaken monopolistic fears, reducing the federal interference with corporate cooperation in strategic technologies. Since technology parks are often established as separate entities, they have bypassed many of the bureaucratic rules and regulation associated with state government organizations. Since most of the research is privately financed, the criteria associated with tenure have been devalued. The speed with which new technology is replacing old technology has created stress upon the traditional method of education while creating opportunities for short-term training methods. By centralizing expensive equipment in technical parks, companies have limited their technical and financial liability in the tortuous route from inception to innovation.

Universities have seen basic research develop into spin-off industries which have become the growth industries of the future (National Science Foundation, 1982; Joint Economic Committee, 1982). This fact has not gone unnoticed as some universities have adopted commercialization of research as a solution to declining sources of revenues (McMillen, 1991). So far, universities have not had a distinguished record when it comes to administration of lucrative enterprises. Most notably, college athletics have provided impressive payoffs that have often corrupted admission practices and academic standards.

Although industries have always had a philanthropic relationship with universities, many industries have developed a more eager interest in research activities (National Science Foundation, 1982). Many of these activities are in the form of research contracts. The overshadowing concern is the potential corruption of academic freedom of action that such relations may solicit.

The thesis presented in the literature search seems to be fairly evident. University-industry interaction finds itself at a defining point in history.

Universities face the perceived dilemma that too much interaction with industry can be bad for long term growth of independent scholarly inquiry, but the absence or diminution of resources assures the decline in independent research. Industries face the perceived dilemma of appropriating scarce resources and foregoing economic opportunities for research that may or may not become a viable product or process. Moreover, technological innovations have proven to have an enormously long incubation period between the original idea and a potentially profitable product. The solution to these dilemmas might rest in long-term agreements between universities and industries that look past the short horizons of an academic year or the next annual report.

CHAPTER 3

Methods

Social and behavioral phenomena are controlled by many unknown and unknowable factors (Deming, 1986). Under such circumstances, absolute understanding and prediction of phenomenological events may require formidable quantities of data and applications of very complicated rules that are beyond our present capabilities. Thus, an objective of this study was not to incontrovertibly explain each result, but to establish a point of view. Establishing a point of view extends knowledge allowing more and more facts to assume the aspects of common sense (Wehr, Richards, & Adair; 1986).

Since the study revolved around existing phenomenological information, a true experimental design was not deemed appropriate. Therefore, a descriptive methodology was chosen for the study. Specifically, multiple regression methods were used to determine the correlation between response variables (dependent variables) and predictive variables (independent variables).

Multiple regression analysis is one of the most widely used statistical tools and is frequently employed to analyze observational data (Neter, Wasserman, & Kutner; 1990). Although a strong correlation between variables does not necessarily assure that a relation occurred between the variables, the possibility of the existence of relationships between variables is a reasonable question to investigate (Ary et al., 1985).

The basic strategy employed in this study was adapted from a model presented by Neter et al. (1990). Overall, the analytical process included four phases:

- Data collection and preparation
- Reduction of the number of independent variables
- Model refinement and selection
- Model validation

Data Collection and Preparation

The existing literature concerning the general topics of higher education, economic development, high-tech industries, and university-industry cooperation and interaction were extensively searched to aid in the selection of independent and dependent variables. The dependent variables and independent variables were chosen based upon the frequency they appeared within the literature and the perceived degree to which the observations could be measured accurately, quickly, and economically.

Dependent Variables

Table 4 shows the variables chosen as dependent variables. Research grants and contracts, consultation, employee training, and student co-op were recurring forms of university-industry interaction listed in the literature. The inclusion of the use of academic and industrial facilities as dependent variables was much more nebulous. Nevertheless, one must often start with a model consisting of variables based upon judgement (Deming, 1986). Deming commented that as information is gained, new questions will arise as the answers to old questions are obtained.

Table 4.

Operationalization of the Dependent Variables

Concept	Operation	Scale	Measure
1. Research Grants and Contracts	Dollar value of grants or contracts	Ratio	Dollars
2. Consultations	Number of consul./yr.	Ratio	Consultations
3. Employee training	Number of employ./yr.	Ratio	Employees
4. Student co-op	Number of students	Ratio	Students
5. Use of university's facilities	Number of industrial personnel/week	Ratio	Industry personnel
6. Use of firm's facilities	Number of university personnel/week	Ratio	University personnel

Research Grants and Contracts. In terms of university-industry interaction, research grants and contracts represented the most clearly and broadly identifiable interaction in the literature. Giovengo (1986) listed basic research activities in a particular field as one of the most popular forms of university-industry linkages. The National Science Foundation (1982) reported that over 50% of all industrially supported research at universities is by way of contracted research. Many of the citations (Owen & Entorf, 1989; Johnson, 1984; Giovengo, 1986) referred to the more than 5,000 research centers that are variously incorporated in departments or schools of colleges and universities or as separate units affiliated with higher educational institutions.

Practically every article that touched on research suggested the mutual benefits associated with R&D cooperation between high-tech firms and universities. College faculty and graduate students have historically demonstrated their ability to develop new products and processes and to generate new ideas for industrial products. Johnson (1984) reported that the major R&D universities are more able to attract high quality faculty and students are assured that the faculty expertise is relevant.

Consultation. Although formal R&D was the most visible form of academic-industry interactions, faculty consulting has been described as "the most pervasive academic-industrial connection" (National Science Foundation, 1982; p. 11). Because consulting is typically unregulated within the university, the extent of consulting which actually takes place is unknown. Nevertheless, Owen and Entorff (1989) reported that 82% of university faculty consult on occasion with business and industry. Consulting fees generally vary between 0.6% to 2% of the participating faculty's annual salary (National Science Foundation, 1982).

Some institutions, most notably MIT, have encouraged consulting relationships by providing broker arrangements between industries and professors with compatible interests (Giovengo, 1986). Such higher education institutions have often considered consulting demand as an indicator of one's excellence as an engineer and have used consulting as a consideration at the time of promotion and tenure. Most institutions, however, have followed a hands-off policy concerning consulting, while some institutions have discouraged consulting all together.

Regardless of an institution's preference, the literature has reported a growing concern among institutions over the possible conflicts of interest that may arise during consulting. These opinions seemed to be related to the size of educational institution and the particular school within the educational institution.

Several high technology companies have developed rosters of university consultants (National Science Foundation,1982). These rosters have been formulated through the perusal of the scientific literature, recommendations of professional staff, and participation in workshops, seminars, and conferences.

Typically, faculty members are allowed one day per week for consulting, assuming such consulting does not detract from other academic duties. The benefits for the institution have included supplemental income for the faculty, development of additional faculty expertise, maintenance of industrial linkages, and attraction of additional research contracts for the institution (American Association of State Colleges and Universities, 1986).

Employee training. Employee training can be classified using a number of categories including (1) a particular subject that would add specific knowledge in a new field for current employees, (2) a formal set of courses that would permit existing technical employees to keep abreast of new advances in their own field, or provide the basis for converting to a new field, (3) a formal set of courses for new employees that would provide them with the theoretical and experimental state of the art in industry, assuming this was more advanced than their previous university training, and (4) a formal degree-granting program run by a company or industry in cooperation with a university for either current employees who wish to advance themselves, or potential new employees required by the company or industry.

Carnevale (1990) and Wiggenhorn (1990) argued that investment in employee's education has increased industry's marginal productivities and that the increase has compensated for the costs of obtaining the skills. Wiggenhorn reported that Motorola was getting a $33 return for every dollar spent for training, including the cost of wages paid while people sat in class.

With the strong possibility that the skills of over 40% of the current work force may become obsolete over the next two decades and given the large number of unemployed workers in older industrial areas and the importance of skilled labor to high-technology companies, training has become a key ingredient in state initiatives to maintain and promote technological development (Johnson, 1984). To avoid recurrent obsolescence of programs, Johnson asserted that it is necessary to teach generic as well as specialized skills and to augment the credit curriculum with more flexible, tailor-made, noncredit offerings.

Training activities are normally generated through continuing education departments within universities and are depicted by short courses, seminars, or workshops. Occasionally these activities have introduced industry participants to university capabilities and provided new areas of science and technology inquiry. Additionally, the short courses, seminars, or workshops can be used to transfer research results to sponsors.

Student internships or co-ops. Student internships have allowed students to obtain practical industrial training, college credits, and spending money. Ph.D., Master's, and other research projects have often presented a new, fresh, and inexpensive perspective to supporting firms.

An indirect benefit to industrial sponsors has been the industry's ability to evaluate potential employees. Graduate students working on an industry sponsored research project have frequently been offered permanent positions with the sponsor upon graduation. Hiring such graduates has reduced the costs of recruiting and initial on-the-job training. Moreover, the employer has had an opportunity to evaluate the performance and capabilities of the new graduate, thereby increasing the likelihood of a mutually long and satisfying career relationship.

Sharing facilities. Academic facilities have acted as conduits between the typical university and outside world, thereby furnishing a mechanism for coordinating programs to attract industry. Often specialized laboratories and centers have formed to meet specific industrial needs and concerns. They have served as a focus, provided a piece of equipment, or added coherence to related research efforts conducted in a general topic area. Allowing industrial use of academic facilities has acted as a drawing card for many universities.

Modern research and teaching has depended upon advanced instrumentation. Yet the capital costs associated with high technology research have continued to increase. The budget limitations of the university have led many research administrators to hold back on modernization in order to maintain their research staff. To offset the deferral of capital equipment, university personnel have performed research projects by using a firm's facilities and enriched their teaching and research by collecting new materials that would have been denied without cooperative arrangements. In special circumstances, the National Science Foundation has provided seed money to aid the center in commencing its research program.

Independent Variables

Johnson (1984) listed a number of factors that spawn research interaction. The organizational characteristics and environmental conditions associated with industry were size, structure, profitability, and nature of business. For academic institutions, they included the type of institution, size, financial health, stature of scientific and engineering programs, and the orientation of research programs. The external factors that played a role include geographic proximity, alumni in key positions, and migration of faculty to industry and of industry personnel to academia. These factors were supplemented with the data obtained from Roessner and Bean (1991) who identified (1) person-to-person contact, (2) flexibility in approach, (3) existence of a transfer "champion", (4) support of company middle management, (5) support of (university) middle management, (6) support of (university) upper management, and (7) clarification of proprietary rights factors influencing successful interactions.

This dissertation used 10 factors (Table 5)--(1) the proportion of skilled labor to total employees in the firm, (2) the dollar amount invested by a firm in R&D, (3) the size of the firm, (4) faculty rank, (5) the availability of research facilities at the university, (6) the availability of research facilities at the high-tech firms, (7) faculty teaching load, (8) size of the university, (9) the distance between the university and industry, and (10) the use of organizational

Table 5.

Operationalization of the Independent Variables

Concept	Operation	Scale	Measure
1. Skilled labor	% of skilled labor	Ratio	Skilled labor
2. R&D investment by the firm	Dollars invested for R&D	Ratio	Dollars
3. Faculty rank	Faculty rank	Ordinal	Prof., Assoc. Prof, Asst. Prof.
4. Size of the firm	Number of employ.	Ratio	Persons
5. Available univ. facilities	Industry personnel/ week	Ratio	Industry personnel
6. Available indust. facilities	Academ. personnel/ week	Ratio	Academic personnel
7. Faculty teaching load	Number of courses/ academic term	Ratio	Courses
8. Distance	Distance (between university and firm)	Ratio	Miles
9. Organizational channel	Formal or informal use	Nominal	Formal/Informal
10. Size of the univ.	Number of students	Ratio	Students

channels--to summarize the organizational characteristics, environmental conditions, and external factors that affect university-industrial interactions.

Skilled labor. High-tech jobs have required more mental agility--the ability to compute, to analyze, and to read and understand complicated instructions--to survive in a rapidly changing world (Lopez, 1989). Lower labor turnover, a more trainable work force, and greater labor productivity have been the benefits that have accrued to firms that hire employees with higher levels of education (McNamara, Kriessel, & Deaton, 1988). Since their location is not restrained by access to customers, distribution networks, or natural resources; high-tech industries have generally tended to be more *footloose* than their low-tech counterparts (Joint Economic Committee, 1982). Moreover, technical managers and professionals have proven to be more easily transportable from one region of the country to another region. The major resource deficiency has occurred among the technicians and craftsmen. These groups have tended to be deeply rooted and intransigent.

High-tech industries have always sought well-educated professionals for the development of new products and new production processes. Because of the needs for specialized resources, particularly skilled labor, high-tech firms have preferred to cluster around regions providing highly specialized resources such as labor skills and education and those factors that make it easier to attract and maintain a skilled work force (Joint Economic Committee, 1982). Universities such as Harvard, Stanford, the Research Triangle (including Duke/UNC/NC State), and the University of Texas which have maintained a solid record of knowledge production, knowledge dissemination, or state and regional leadership clearly have had a national competitive advantage and have attracted multi-billion dollar high-tech government and business activities to their areas (Folger & Wisniewski, 1989).

Research & development expenditure. Mansfield (Johnson, 1984) listed expenditures on industrial R&D as the most critical factor related to the development of important inventions and a high-tech's growth rate. Johnson reported that technological change depends upon the amount and quality of research and development. Minshall and Moody (1984) rated R&D expenditures by far the most important characteristic of high technology activities. When McDonnell Douglas, the defense contractor, reduced R&D expenditures between 1968 and 1973, net earnings reduced (Min, 1989).

Studt (1991) reported that basic research accounts for 14% of the total amount of the U.S. R&D budget. Universities and nonprofit laboratories performed 70% of the basic research. In the past five years, while research at government and industry facilities grew 8% in real dollars, research at universities grew by 28%. Nevertheless, there were demographic, technological, and competitive gremlins looming on the horizon that may fundamentally change the tableau of basic research.

Demographically, the U.S. has produced a deficiency of research engineers and scientists during the past several decades. This deficiency has been overcome by using American trained foreign Ph.D. recipients. These people have recently started returning home (Studt, 1991). In addition, there will be a large increase in the number of people retiring from science and engineering over this decade of the 90s. Technologically, there has been an extraordinary and unexpected increase in the costs of performing research. Utility, health insurance, library, journal, and environmental safety costs have begun to rise far faster than the rate of inflation. Competitively, international competition has forced a departure from basic research in favor of applied and development research.

Faculty rank. The most common ranks are assistant professor, associate professor, and professor. The rank of assistant professor is normally associated with a new or relatively inexperienced professor. The rank of associate professor is usually conferred according to some time requirement and a peer evaluation. Quite often, the rank of associate professor is awarded concurrently with tenure. The rank of professor is also conferred based upon a time requirement and peer evaluation and infers distinguished accomplishments in scholarship, teaching, and service.

Size of the firm. There has been some controversy concerning size of firms. Some have argued that larger firms are more innovative, while others have argued that smaller firms are more innovative (Min, 1989). The larger firms have had a comparative advantage due to economies of scale, while smaller firms have had a comparative advantage due to their entrepreneurial organizational structure and the inherent flexibility such an organizational structure possesses.

The larger firms have possessed the access to capital reserves needed for the development of innovative processes. The inherent bureaucratic management structure of the larger capitalized firms have often hindered the timely development and introduction of innovative products. The flat organizational structures of the smaller high-tech firms provide the direct communications necessary to develop and market new products. Innovative product development by smaller firms has been legendary. Hewlett and Packard started a major business in their garage in Palo Alto, California. They soon became one of the charter members of Silicon Valley. Their neighbor, Apple Computer, dared to challenge Big Blue (IBM). Now they have reached a position of preeminence in the personal computer market.

Large organizations have maintained the financial ability to underwrite application specific research (Owen & Entorf, 1989; Johnson, 1984). This implies that they are more likely to acquire faculty services for longer periods of time such as with research grants. Larger firms have also encouraged their employees to seek additional education and training. Boulton (1984) reported that IBM had a larger education budget than Harvard University. Carnevale (1990) reported that high-tech employees with two and four years of formal education have a 20% and 50% greater chance, respectively, of receiving on the job training while postgraduate education increases job training by almost twice as much as a college graduate. Those who had received on-the-job training enjoy an earnings advantage of 25% or more over those who do not.

Smaller firms have not had the same financial capabilities as the capitalized firms. Yet, they still have required the same urgent need for innovative new ideas. Their limited resources have demanded that they enter into short-term arrangements with universities such as consultation and student internships. Their limited resources have encouraged the use of university facilities whenever possible.

Availability of research facilities. The availability of university facilities have ranged from libraries, to lecture and conference rooms, laboratories, and data processing equipment. Since small high-technology firms often do not have sufficient funds to purchase new computer and lab equipment for the development of innovative products, they are more likely to use university facilities than larger high-tech firms, especially when the the small high-tech firm is a spin-off from university R&D. In such a situation, the members of the spin-off firm have often been professors at the university and may have perpetuated close collegial relationships that may help open doors to the use of equipment and facilities.

Additionally, access to faculty consultants, equipment, and library and computer services have helped entrepreneurs develop to the stage where they are able to set up their own plants. Universities have recently developed low-rent incubators on campus as part of an institution-wide effort to foster high-tech entrepreneurship. Occupants of incubators may be inventors, faculty members, or students. Several fledgling companies within incubators were reported to already be producing pharmaceutical products, solar collectors, robot control systems, and automated test equipment (National Science Foundation, 1982).

The main benefit industrial facilities have offered is modern, up-to-date equipment and facilities. Higher education is replete with problems among which are aging facilities and faculty shortage in technical fields (Miller, 1988). Modern industrial laboratories and equipment have provided opportunities for faculty to test new theories and experiment with new approaches that otherwise would have been impossible.

Faculty teaching load. The classical view of faculty workload has continued to be the descriptive load of 15 credit hours per week (with two hours allowed for preparation and grading for each credit hour taught) and has persisted throughout higher education (Yuker, 1984). Studies on faculty workloads have been conducted since 1919 and on all types of post-secondary institutions. Virtually every study has concluded that the credit hour, contact hour, student hour, or student contact hour were unreliable indicators of faculty members' workload.

Most experts have segmented faculty workload into the following categories: instruction, research, professional development, institutional service, advisement/counseling, public service, and personal activities (Yuker, 1984). Pessen (in Yuker, 1984) claimed that it takes 14 hours per week to keep up with the literature, while Fairchild (in Yuker, 1984) reported that most scholars spend 10 to 12 hours per week reading books and journals and as many as 25% reported 16 hours or more.

Skolnik's survey (in Yuker, 1984) of nearly 600 faculty showed that faculty are concerned over the lack of appreciation educational administrators show toward class size, preparation and evaluation of students, student contact outside of class, field supervision, maintenance of equipment, curriculum review, liaison with industry, and adaptation to new technology. Yuker confirmed that time devoted to teaching can vary from a low of 40% to a high of 70% of an instructor's work week, although it tends between 6 and 15 credit hours. Teaching loads are recorded to be lower at high-quality institutions than at low-quality institutions. This is probably due to the fact that research is emphasized at the so-called high-quality institutions.

Size of the university. Like industries, size has provided universities with the resources to exploit innovative university-industry interactions (Giovengo, 1986). As the rate of expansion in external resources has diminished, the larger universities have looked internally to support important projects (National Science Board, 1989).

Basic research has been concentrated among a few of the larger universities and supported by a few of the larger corporations (Studt, 1991; Johnson, 1984). The top 10 schools for R&D universities in 1990 are shown in Table 6. Because of the importance of research grants among many of

Table 6.

The top 10 R&D schools (Studt, 1991, p. 44)

University	R & D Amount
Johns Hopkins University	$648 million
MIT	$287 million
Cornell University	$287 million
Stanford University	$286 million
University of Wisconsin, Madison	$286 million
University of Michigan	$281 million
Texas A&M University	$251 million
University of California, Los Angeles	$228 million
University of Washington	$222 million

the top research universities, some universities have hired marketing companies to study ways that universities may better market their research (Johnson, 1984).

Distance. Clustering of universities and industries reduces the cost for travel between the two. Research parks near the university have reduced spatial barriers and have made it easier for academic and industrial researchers to interact more frequently and intensely, share each other's facilities, and develop cooperative programs (Joint Economic Committee, 1982). Clustering around universities has enabled firms to share faculty at the university. Closeness has allowed social exchange opportunities and reduced travel cost and travel time.

Organizational channels. The development of science and technology has too often taken place in a solitary atmosphere without adequate mechanisms to link it to business and industry where its potential can be fully realized. The National Science Foundation (1982) found successful interactions are almost always initiated and nurtured by a single, key individual, and that most interactions were managed and conducted by the chief investigator with little administrative interference from the academic hierarchy. Nevertheless, most academic institutions have continued to maintain an Office of Sponsored Programs and many have maintained a Vice President of Research. Each normally reports to the Vice President for Academic Affairs. Industries generally have had easier access to the university than universities have had to industry.

The National Science Foundation (1982) has proposed that in order for universities to substantially increase university-industry interactions, they must develop a team and/or project approach. This suggests the development to organizational channels to plan, organize, coordinate, control, and communicate research activities. In a world of increasing wants and diminishing resources, successful universities will be required to market their research abilities. Kotler and Goldgehn (1981) are convinced that schools have not clarified target models, identified customer needs, or prepared offerings that are competitive in the market place.

Population

In order to test the hypotheses developed in chapter one, five universities--East Tennessee State University, The University of Tennessee at Knoxville, Tennessee Technological University, Virginia Polytechnic Institute and State University (Virginia Tech), and the University of Tennessee at Chattanooga--and their associated faculty and the high-tech industries located in East Tennessee and Southwest Virginia were chosen for the emphasis of this study (Figure 3). East Tennessee represents one of the three *Grand Divisions* of Tennessee (Bartik, 1986) and is more specifically defined for this study as the region containing the counties in Table 7. Southwest Virginia is defined by the counties in Table 8. The high-tech industries are specifically chosen from the Tennessee and Virginia Manufacturing Directory using the Standard Industrial Classification (SIC) codes.

Universities. The Carnegie Foundation for the Advancement of Teaching (1987) developed a widely used classification of colleges and universities consisting of (1) Ph.D. granting and research institutions, (2) comprehensive institutions, (3) liberal arts institutions, (4) specialized institutions, (5) two-year institutions, and (6) other institutions. These classifications are based upon on a combination of factors (National Science Board, 1989, p. 47), including:

Figure 3.

Region used in the study

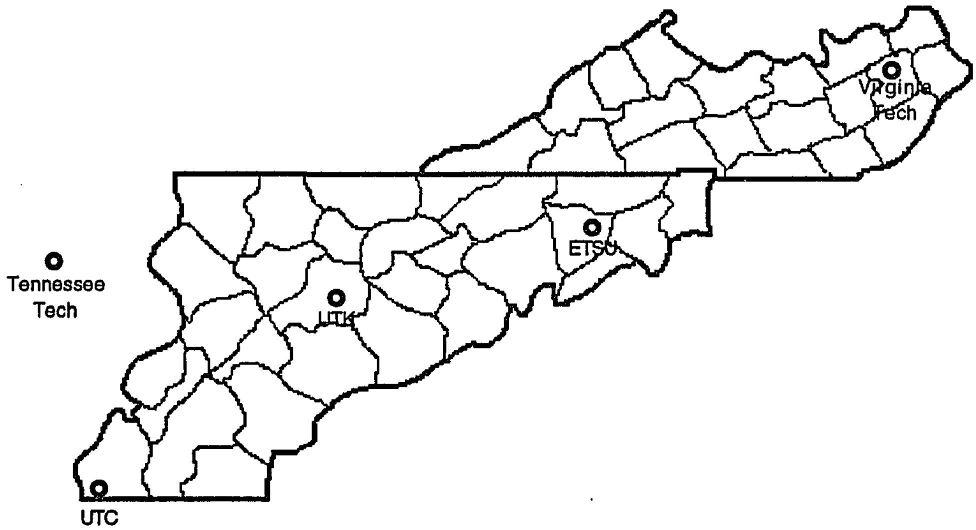


Table 7.

Counties included in East Tennessee

Anderson	Blount	Bradley	Campbell
Carter	Claiborne	Cocke	Grainger
Greene	Hamblen	Hamilton	Hancock
Hawkins	Johnson	McMinn	Meigs
Monroe	Morgan	Polk	Rhea
Roane	Scott	Sevier	Sullivan
Unicoi	Union	Washington	

Table 8.

Counties included in Southwest Virginia

Bland	Buchanan	Carroll	Craig
Dickenson	Floyd	Giles	Grayson
Lee	Montgomery	Pulaski	Roanoke
Russell	Scott	Smyth	Tazewell
Washington	Wise	Wythe	

- Amount of federal support
- Number and levels of degrees awarded and numbers of programs awarding such degrees
- An index of institutional selectivity (for liberal arts institutions) developed from a number of measures

Most public colleges and universities can be classified as comprehensive. Many of these institutions began as teacher's colleges or technical schools and evolved into larger missions. The comprehensive universities have normally emphasized undergraduate education and applied research. A relatively small number of public institutions have developed into special institutions with many having an orientation toward science and technology. Both their technical nature and history have provided these specialized institutions with a much closer linkage with industry and a stronger role in such areas as research and technology transfer. The Ph.D. granting and research universities have normally represented the elite universities of a state. They have served the entire state and normally have had a strong research and development character.

East Tennessee State University (ETSU) is a comprehensive university and is one of the principle campuses of the State University and Community College System of Tennessee. Its primary purpose is to serve as a center for intellectual and cultural growth in the Northeast Tennessee region. ETSU has provided students for careers and professional service at the certificate, associate, baccalaureate, master's, and doctoral levels of preparation. Emphases have been placed on teaching and learning; however, appropriate research and public service have been deemed necessary to realize the university's goals and objectives.

Established in 1911 as a normal school, it has become a multipurpose university organized into the schools of Applied Science and Technology, Nursing, Public and Allied Health, and the Graduate school. There are four colleges: Arts and Science, Business, Education, and Medicine. The enrollment is approximately 12,000 students.

With the main campus located in Johnson City and centers located in Kingsport, Bristol, and Elizabethton, ETSU serves a region of one million people living within a 50 mile radius of Johnson City. Sherrod Library has nearly one-half million volumes arranged in open-stacks. Microforms, periodicals, serials, federal documents, and the university's archives comprise the research holdings of the library.

The University of Tennessee at Knoxville (UTK) has developed as the Ph.D. granting, research university of the University of Tennessee system that contains campuses in Martin, Chattanooga, Memphis, and Knoxville. The University offers more than 300 degree programs to more than 25,000 students. The graduate programs are enhanced by the cooperation with Oak Ridge National Laboratory (ORNL) and the Tennessee Valley Authority (TVA). The Science Alliance is the largest in Tennessee's Centers of Excellence program for higher education. The University's libraries have retained more than two million volumes and volume-equivalents. Continuing education programs have responded to the needs of working adults who are seeking college degrees or preparing for career advancement. The University of Tennessee can trace its origins to 1794. In 1869, the state legislature selected the University of Tennessee at Knoxville as the state's Land-Grant Institution, under the terms of the Morrill Act of 1862.

The College of Engineering operates two interdisciplinary research centers: The Measurement and Control Engineering Center and the Center of Materials Processing. The Measurement and Control Engineering Center is primarily supported through an annual membership fee from industrial participants. Contract research is also performed at the Center. The Center for Materials Processing is supported by the State of Tennessee through a Chair of Excellence. Engineering faculty also participate in research projects which are administratively assigned to the office of the Vice Provost for Research.

The American Society of Engineering Education's Engineering College Research and Graduate Study (Weese, 1990) listed the University of Tennessee at Knoxville with a combined total of 177 full-time engineering and research faculty in 13 different engineering programs. Twenty-seven doctorate degrees were awarded in the 1988-1989 academic year with acceptable research areas being computational fluid and solid mechanics, aerodynamics, waste management, controls, biotechnology, mass transfer, environmental engineering, image processing, electronics, power electronics, artificial intelligence, polymer engineering, metallurgy, ceramic engineering, thermal sciences, radiation protection engineering, and transport phenomena. One hundred and five faculty, three post-doctoral fellows, and 222 graduate students were engaged in a total $18,341,430 of research of which $4,283,834 (23%) was supported by business and industry.

Tennessee Technological University was established in 1915 and is located in Cookeville on a 235 acre campus. The university represents a special institute in the State University and Community College System of Tennessee. The library contains collections approaching 760,000 titles with extensive holdings in microfilm and media.

The American Society of Engineering Education's Engineering College Research and Graduate Study (Weese, 1990) listed Tennessee Tech with a combined total of 85 full-time engineering and research faculty in six different engineering programs. Six doctorate degrees were awarded in the 1988-1989 academic year with acceptable research areas being applied mathematics, cellulosic insulation, electric distribution system simulation, electronic filters, metal cutting, and stresses in concrete. Seventy-three faculty and 194 graduate students were engaged in a total of $6,870,000 research of which $682,000 (9.9%) was supported by business and industry.

The University of Tennessee at Chattanooga (UTC) was founded as Chattanooga University in 1886 and represents one of the comprehensive institutions in the University of Tennessee system. In 1907, the name, University of Chatanooga, was adopted. It remained a private school until 1969 when the University of Chattanooga and Chattanooga City College, a junior college, merged with The University of Tennessee in Knoxville to form the University of Tennessee Chattanooga campus. The University of Chattanooga retained its traditional liberal education disciplines and expanded its degree programs in professional and engineering studies. The University of Tennessee at Chattanooga has an enrollment of more than 7,600 and is located near urban Chattanooga, which has a population of 162,170 and claims more than 600 industries.

The American Society of Engineering Education's Engineering College Research and Graduate Study (Weese, 1990) listed UTC with a combined total of 31 full-time engineering and research faculty in seven different engineering programs. No doctorate degrees were awarded in the 1988-1989 academic year. Eleven faculty and four graduate students were engaged in a total of $365,000 research of which $19,900 (5.5%) was supported by business and industry.

Virginia Polytechnical Institute and State University was established in 1872 under the provisions of the Morrill Act of 1862. Originally established as the Virginia Agricultural and Mechanical College, the name was officially changed to Virginia Polytechnical Institute in 1944. The 1970 Virginia legislature required the addition of State University. Located in Blacksburg, in Southwest Virginia, Virginia Tech is a Ph.D. granting, research institution that strives to fulfill the missions of instruction, research, and extension.

The American Society of Engineering Education's Engineering College

Research and Graduate Study (Weese, 1990) listed Viginia Tech with a combined total of 247 full-time engineering and research faculty in 15 different engineering programs. Eighty-six doctorate degrees were awarded in the 1988-1989 academic year with acceptable research areas including turbulent flow, computational fluid dynamics, vehicle dynamics, element substituted aluminophosphates, trace organics in water, waste sludge processing, power conversions, microprocessors, magnetic materials and structures, mobile satellite systems, acoustic scattering, shell dynamics, ergonomics, automation, group technology, ultralow thermal expansion, geometric modeling, CAD/CAM software development, rock mechanics, minerals processing, coal preparation, etc. Two hundred and nine faculty, 28 post-doctoral fellows, and 549 graduate students were engaged in a total of $27,327,189 research of which $3,386,507 (12.4%) was supported by business and industry.

East Tennessee and Southwest Virginia. Historically, geographically, economically, politically, and culturally associated with Central Appalachia, East Tennessee and Southwest Virginia have had a history of socioeconomic deprivation even though it rests upon the nation's most bountiful natural resources (Matvey, 1987). The area has many of the characteristics that existed in world colonies at the beginning of the 20th century and continue to linger in third world countries at the century's end.

Small backwoods and mountain farmers have dominated the area for much of Appalachia's history. The region has had neither the skilled labor pool nor the manufacturing infrastructure needed to compete effectively with the manufacturing centers located in the North (Bartik, 1988). The region has only had a comparative advantage in industries that intensively used natural resources and unskilled labor. Manufacturing growth in the area during the late 19th and early 20th centuries, therefore, was concentrated in industries such as textiles, lumber, food processing, cottonseed products, and some iron and steel, and these industries still have a major influence within the region (Bartik, 1988). Despite this growth, the region's manufacturing share remained well below the national average. The low-wage industries that located in the South did not advance job skills or encourage a supporting industrial infrastructure. Manufacturers had chosen the South because they did not require such skills or infrastructure. Also, continual advances in agricultural productivity helped expand the surplus of unskilled labor in the South, reinforcing the South's relative attractiveness to low-wage, labor intensive industries.

East Tennessee has provided an interesting set of paradoxes and paradigms. Although the wage gap between Tennessee and the rest of the United States has narrowed somewhat in recent years, Bartik (1988) reported that average manufacturing wages in Tennessee still remained 15% below the national average. Knoxville, Chattanooga, and the Tri-Cities (Johnson City, Kingsport, and Bristol) were the major population areas of the region and are close to or above the national average in per capita income. In rural areas, Bartik reported that the situation is quite different. Ten rural counties have had per capita incomes less than one-half the national average, while an additional 40 counties have had per capita income between one-half and two-thirds the national average. Many of income between one-half and two-thirds the national average. Many of these rural counties are remotely located, far away from interstate highways and urban amenities; they have offered little to potential industry except low wages and hard workers.

Oak Ridge National Laboratory has been the area's technologically innovative island. Located near the University of Tennessee at Knoxville, the Oak Ridge/Knoxville area has over 2000 residents with Ph.D.s, almost 5000 engineers, and 1200 computer-related personnel (Bartik, 1988). It has been the epitome of a high tech industry and has been the beacon for technological growth in East Tennessee for decades. The paradox lies in Oak Ridge's historical focus on nuclear energy. With the events that have taken place at Three Mile Island and Chernobyl, the prospects of nuclear energy development look somber in the short run.

High-tech industries. The concept of *high-tech industries* is very broad and open to extensive controversy. Basically, they are defined as a group of heterogeneous firms that share several attributes (Joint Economic Committee, 1982). First, they are labor-intensive rather than capital intensive, with a higher percentage of technicians, engineers, and computer scientists than other manufacturing companies. Second, the companies are science-based relying on technological advances in products and processes. Third, R&D is much more important to the continued successful operation than in other manufacturing industries. Generally, high technology industries are equated by SIC codes (Joint Economic Committee, 1982; Minshall and Moody, 1984). After screening almost 500 types of manufacturing and service functions in terms of the factors discussed previously, Minshall and Moody (p. III.5) developed Table 9 that provides clear examples of high technology activities.

Survey Instrument

Preliminary industrial and academic surveys (Appendix A) were developed using modified versions of existing surveys (Min, 1989; Joint Economic Commission, 1982; Conference Board, 1988; Weese, 1990). The preliminary surveys were mailed to 25 industrial and 25 academic participants. The results and comments from the preliminary surveys were used to develop the final survey instruments.

After the development of the final survey instrument, a random sample of subjects was chosen from the population of industries listed in the Tennessee and Virginia Manufacturing Registers and faculty rosters obtained from university catalogs, respectively. The actual study was performed between December, 1991 and March 1992. Every effort including additional mailings, reminders (Appendix B), and telephone interviews were used to obtain an adequate number of responses.

Neter et al. (1990) suggested that between 6 and 10 subjects be used for each independent variable. Therefore, acceptable responses were sought from between 120 to 200 industrial and academic subjects each. Half of the responses were used as model-building data, and the remaining responses were used as validation data.

Data Preparation

Once the data was collected, edit checks and plots were performed to identify gross data errors as well as extreme outliers. Among the edit checks and remedial measures used were:

Table 9.

Representative High-Tech Activities (Minshall & Moody, 1984, p. III.5)

SIC	Industry
2831	Biological Products
2833	Medicinals and Botanicals
2869	Industrial Organic Chemicals
2879	Agricultural Chemicals
3569	General Industrial Machinery
3573	Electronic Computing Equipment
3633	Industrial Controls
3662	Radio and TV Communication Equipment
3674	Semiconductor Related Equipment
3678	Electronic Connectors
3693	X-Ray Apparatus and Electro-Medical Equipment
3769	Missile, Space, and Vehicle Parts
3822	Environmental Controls
3823	Process-Control Instruments
3824	Fluid Meters and Counting Devices
3829	Measuring and Controlling Devices
3841	Surgical and Medical Instruments
3861	Photographic Equipment and Supplies
7372	Computer Programming and Other Software Services

- Partial regression plots to check for curvature
- Studentized residuals to check for extreme outliers
- DFFITTS, DFBETAS, and Cook's distance measure to decide whether the outliers should be retained or eliminated
- Ridge regression to check for strong interaction between independent variables (multicollinearity)
- Weighted least squares to check for equal error variances (homoscedasticity)

Model Refinement

Once the data were collected and properly edited, the formal modeling process began by using a stepwise regression procedure to reduce the number of independent variables and provide the appropriate functional form (linear, quadratic, etc.). This process provided a method of screening variables for the purpose of reducing the number of independent variables. The stepwise regression procedure essentially introduced or deleted predictor variables based upon an F statistic. In contrast to the all-possible-search method that arrives at a set of possible models, the automatic search method determines one regression model as the *best* model.

Although the automatic search methods provided a seemingly direct method to uncover the best regression model, the available SPSS™ computer package provided a variety of options. The diversity of options that one may use emphasized the point that there is no unique method to arrive at a suitable model and the importance that subjectivity plays in the development of a final regression model.

Model Validation

Model validity refers to the stability and reasonableness of the regression coefficients, the plausibility and usability of the regression function, and the ability to generalize inferences drawn from the regression analysis (Neter et al., 1990). The method used for validating the regression model in this study was data-splitting. Data were divided into two sets: the model-building set and the validation set. Held-out data was used to check the model and its predictive ability and used to compare the results with theoretical expectations. Although collection of new data is considered the best means of validation (Neter et al., 1990), one must weigh the enrichment of the collection of new data over the data-splitting method against the disadvantages of the protraction of the analysis and the added expense required.

The model-building set must be sufficiently large so that a reliable model can be developed. The appropriate number of cases sought for the study was at least 6 to 10 times the number of independent variables (Neter et al., 1990) implying that at least 120 to 200 cases should be included in this study.

Summary

Multiple regression analysis was chosen for this study as the statistical tool to investigate the interactions between higher education and high-tech industries. Sometimes, relevant theory may indicate the appropriate functional form. More frequently, however, the functional form of the regression relation is not known in advance and must be decided upon once the data have been collected and analyzed. Since, *a priori* knowledge of the appropriate independent variables and of the functional form of the regression relation was not inherently evident, several independent regression relation was not inherently evident, several independent variables were chosen for the study. The more complex model containing additional independent variables was believed to be more helpful in providing sufficiently precise predictions of the response variables.

The empirical consideration in making the choices for independent variables was the extent to which a chosen variable contributes to reducing the remaining variation in the response variable after allowance are made for the contribution of other predictor variables that have tentatively been included in the regression model. Subjective considerations included the importance of the variable as a causal agent in the process under analysis; the degree to which observations can be obtained more accurately, or quickly, or economically than on competing variables; and the degree to which the variable can be controlled.

The advantage of regression analysis was that relations are often evident and easy to identify using relatively moderate numbers of data sets. The down side to such a study was the questionable results, since a strong correlation is not necessarily an indicator of cause-and-effect relationships between the two variables.

CHAPTER 4

Survey Analysis

Introduction

Within the context described in the methods chapter, returned questionnaires that had been sent to the universities and industries in the East Tennessee and Southwest Virginia region during the period between December 1, 1991 and March 1, 1992 were analyzed and compared in this chapter. Demographic descriptions were presented on the sample responses, the model-building responses, and the validation responses for the academic group. An overall demographic description of the industrial surveys was presented. Data from the model-building surveys were used to generate models for each of the dependent variables: (1) research grants and contracts, (2) consultations, (3) student co-ops, (4) employee training, (5) university facility use by firms, and (6) firm facility use by universities. Data from the validation group were fitted to the formulated models to check the validity of the formulated models. For completeness, an academic aggregate model that included all the academic responses and an industry aggregate model that included all the industry responses were developed. Corresponding findings were reported for each interaction.

Academic Demographics

Sample Demographics

Five hundred and twenty-five engineering and engineering technology faculty at the University of Tennessee at Knoxville (UTK), East Tennessee State University (ETSU), Virginia Polytechnic Institute (VPI), Tennessee

Tech University (TTU), and the University of Tennessee at Chattanooga (UTC) were chosen as the population for the academic study. The faculty members were selected from the respective university catalogs.

Engineering faculty were selected because of their recognized association with high-tech industries. By limiting the selection to only engineering faculty, it was hoped that the homogeneity of the group would eliminate some of the confounding variables which may occur in demographically diverse groups.

An initial mailing of 250 questionnaires was sent to randomly selected faculty in December, 1991. A second mailing was sent as a reminder to faculty in early January, 1992. During the second mailing, the survey was expanded by 50 additional surveys to compensate for the indicated proportion of faculty who had departed their respective universities. In mid-February, a special request for responses was initiated through a follow-up at the University of Tennessee at Chattanooga since this university appeared to be underrepresented in the academic study. Similar follow-up requests were made to faculty members at East Tennessee State University.

Of the 149 responses returned, 14 responses were returned unopened and unanswered as a result of faculty departure from the various universities; 19 respondents chose not to respond to the survey for various reasons; and 115 usable responses were applied to the study. These responses made up 49.7%, 4.7%, 6.3%, and 38.3%, respectively, of the total responses mailed. Each usable response was numbered sequentially and entered into a data file as it arrived.

Of the 115 responses used in the study, 37 responses (32.2%) came from

UTK, 11 responses (9.6%) came from ETSU, 41 responses (35.7%) came from VPI, 17 responses (14.8%) came from TTU, and 9 responses (7.8%) came from UTC (Figure 4). One lecturer, 12 assistant professors, 29 associate professors, and 73 professors provided 0.87%, 10.4%, 25.2%, and 63.5% of the responses, respectively (Figure 5).

Figure 4.

Percentage of total responses by university

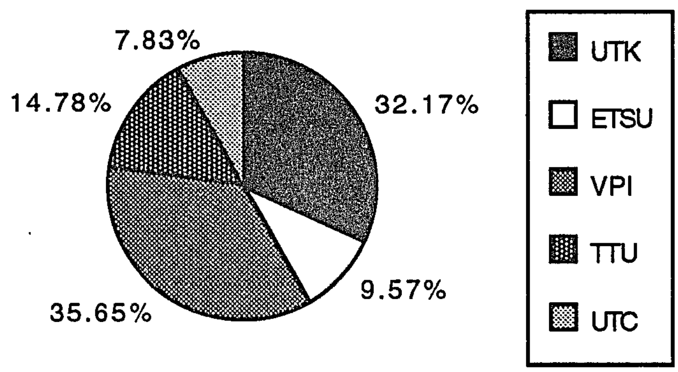
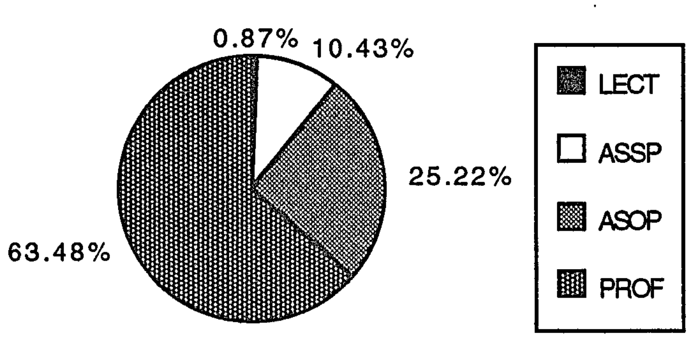


Figure 5.

Percentage of total responses by faculty rank



Those faculty who responded reported more activity in government-supported research (55.7%) than in industrially-supported research (49.6%) or consulting (38.3%) (Figure 6). The faculty who received extra compensation for performing industrially-supported research or consulting received a mean of 17.58% pay above their academic salary. The teaching load (Figure 7) for the responding faculty varied from 0 classes per (semester/quarter) term to 4 classes per term with the mean being slightly more than 2 classes per term. Almost 72% of the respondents were involved to some extent in basic research, 92% were involved in applied research, and 52% were involved in developmental research (Figure 8).

Fifty-five percent of the respondents reported no involvement in technology transfer events, 64% reported no use of their facilities by outside firms with 70% reporting no surplus capacity for such use, and 81% reported that they did not use industrial facilities. Seventeen percent of the respondents reported that they had used only well-defined formal organizational channels to develop research and consulting associations, 65% reported that they had only used informal organizational channels to develop research and consulting associations, and 18% reported that they used both formal and informal organizational channels.

Model-Building Group Demographics

Sixty surveys from the eligible 115 responses were chosen for the sample to develop a model of university-industry interactions. The surveys were assumed to have arrived randomly through the mail. To increase the prospect of randomness, alternate surveys were selected from the sequential data file to eliminate the possibility of groupings of surveys.

Figure 6.

Percentage of days allotted to research and consulting by total group

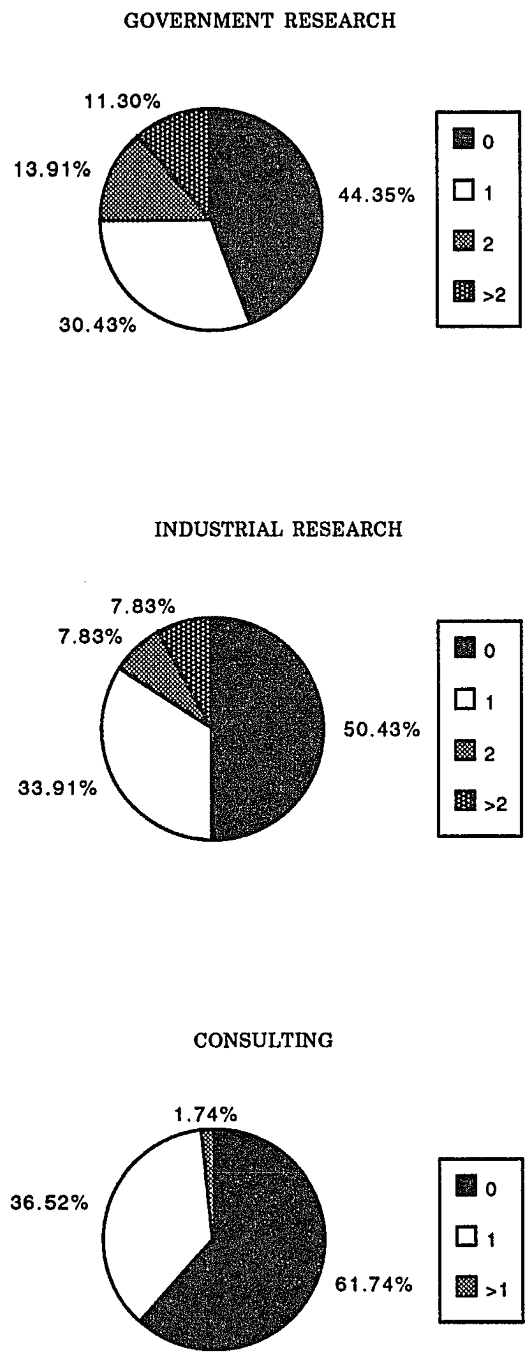


Figure 7.

Percentage of classes taught per term by total group

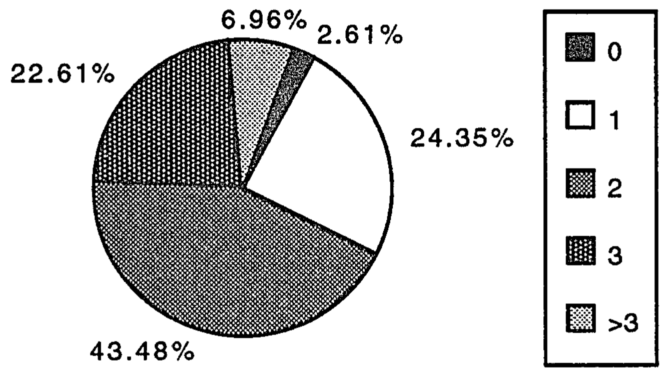
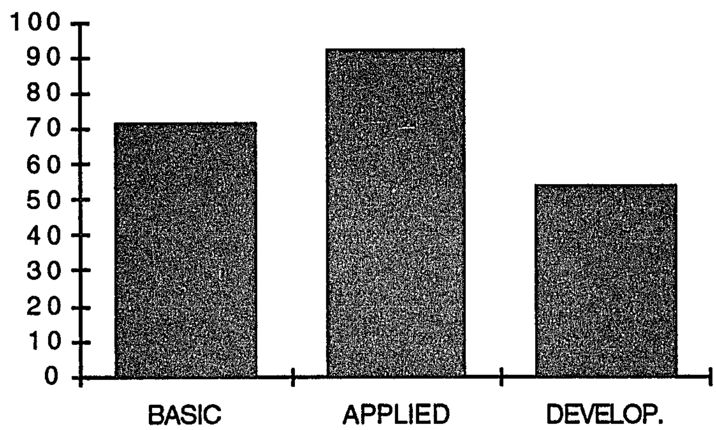


Figure 8.

Distribution of research activities of the total group



Three additional surveys were selected at random to complete the group of 60 surveys.

Of the responses used in the model-building pool, 22 responses (36.7%) came from UTK, 5 responses (8.3%) came from ETSU, 21 responses (35%)

came from VPI, 8 responses (13.3%) came from TTU, and 4 responses (6.7%) came from UTC (Figure 9). Seven assistant professors, 16 associate professors, and 37 professors provided 11.7%, 26.7%, and 61.7% of the responses, respectively (Figure 10). The model-building respondents

Figure 9.

Percentage of model-building responses by university

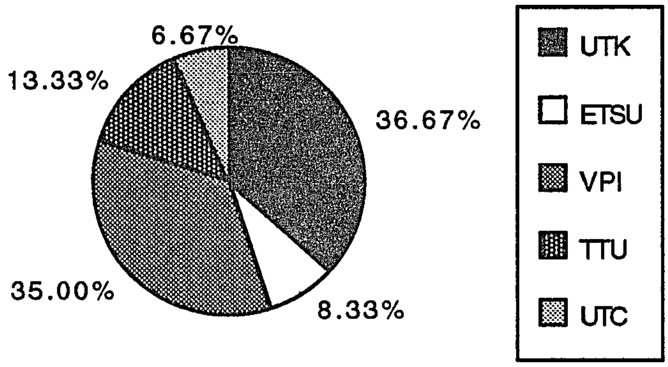
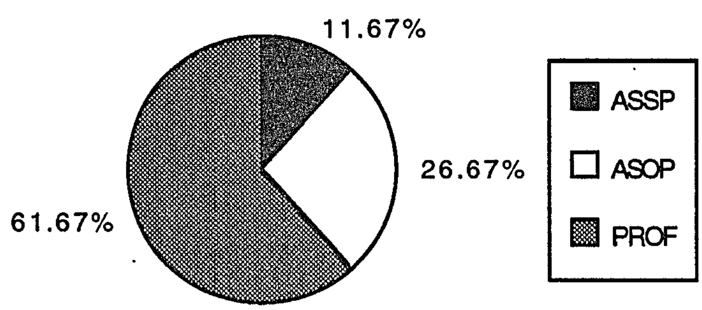


Figure 10.

Percentage of model-building group responses by rank



reported slightly more involvement in government-supported research (55%) than in industrially-supported research (53.3%), while consulting involvement was reported in 45% of the responses (Figure 11). Those performing industrially-supported research or consulting received a mean of 16.78% pay above their academic salary. The teaching load for the responding faculty varied from 0 classes per (semester/quarter) term to 4 classes per term with the mean being slightly more than 2 classes per term (Figure 12). Seventy-three percent of the respondents were involved in basic research, 95% were involved in applied research, 60% were involved in developmental research (Figure 13).

Forty-one percent of the respondents reported no involvement in technology transfer events, 67% reported no use of their facilities by outside firms, 66% reported no surplus capacity for such use, and 78.9% reported that they did not use industrial facilities.

Fifteen percent of the respondents reported that they used only formal organizational channels to develop research and consulting associations, 63% reported that they had used informal organizational channels to develop research and consulting associations, and 18% reported that they had used both formal and informal organizational channels.

Validation Group Demographics

The remaining 55 responses were used as the validation group. Of these 55 responses, 15 responses (27.3%) came from UTK, 6 responses (10.9%) came from ETSU, 20 responses (36.4%) came from VPI, 9 responses (16.4%) came from TTU, and 5 responses (9.1%) were provided by UTC (Figure 14). The validation pool included 1 response from a lecturer (1.8%), 5 responses

Figure 11.

Percentage of days allocated to research by model-building group

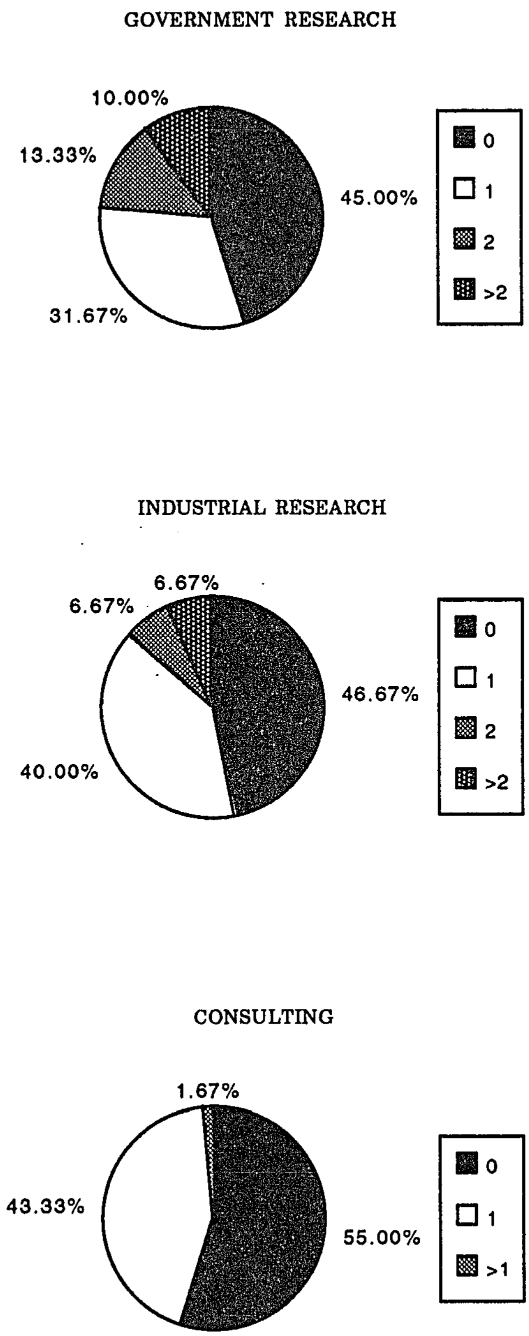


Figure 12.

Percentage of classes taught each term by model-building group

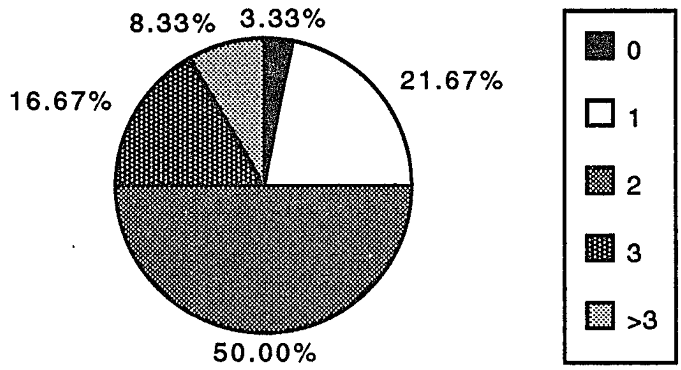


Figure 13.

Distribution of research activity by model-building group

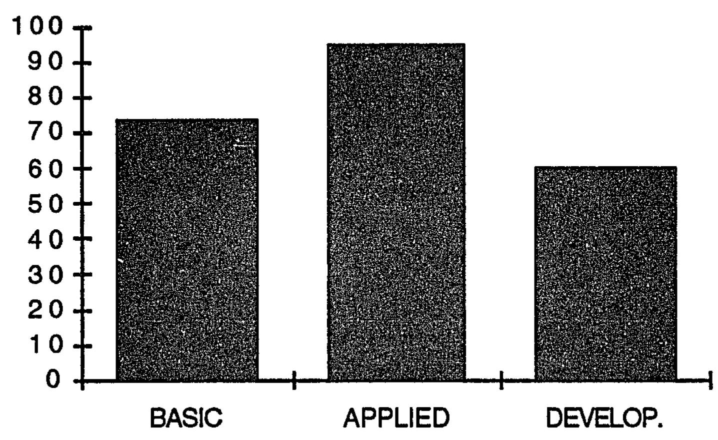
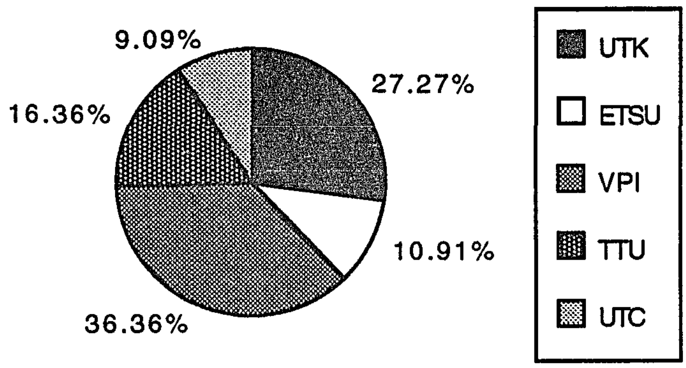


Figure 14.

Percentage of validation-group responses by university



(9.1%) from assistant professors, 13 responses (23.6%) from associate professors, and 36 responses (65.5%) from professors (Figure 15). More respondents reported involvement in government-supported grants (56.4%) than in industrially-supported grants (45.5%) or consulting (30.9%) (Figure 16). The normal teaching load for the validation group was slightly higher

Figure 15.

Percentage of validation-group responses by faculty rank

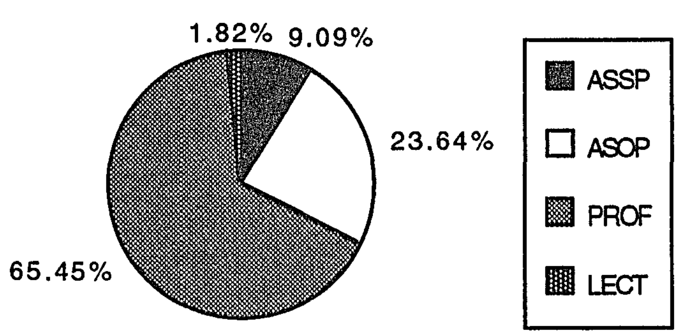
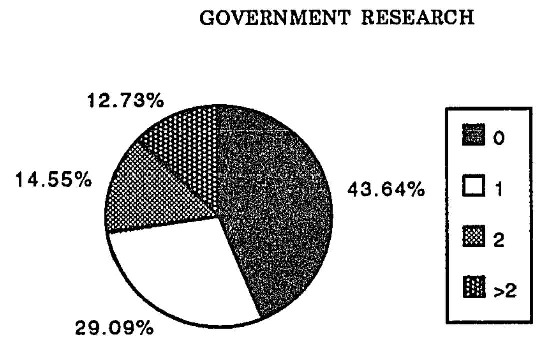
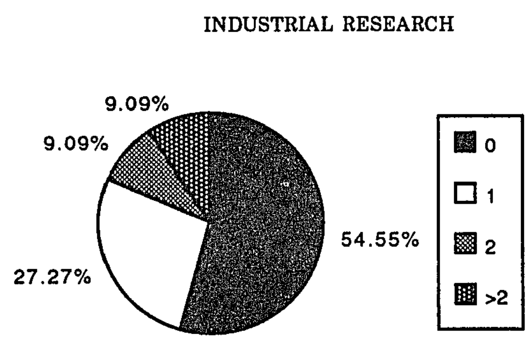
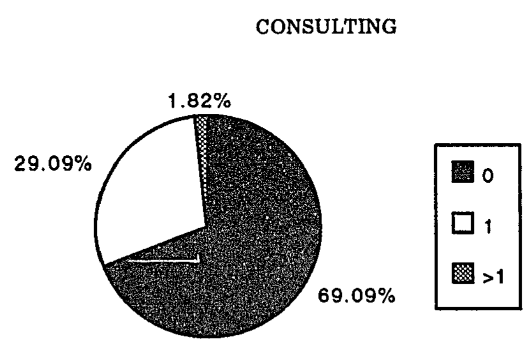


Figure 16.

Percentage of days allocated to research by validation group



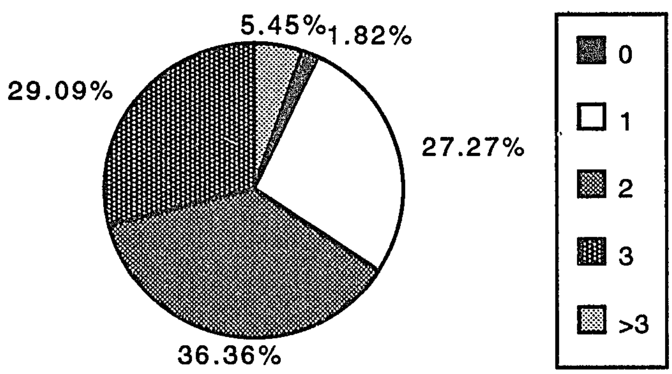




than two classes per term (Figure 17).

Figure 17.

Percentage of classes taught each term by validation group

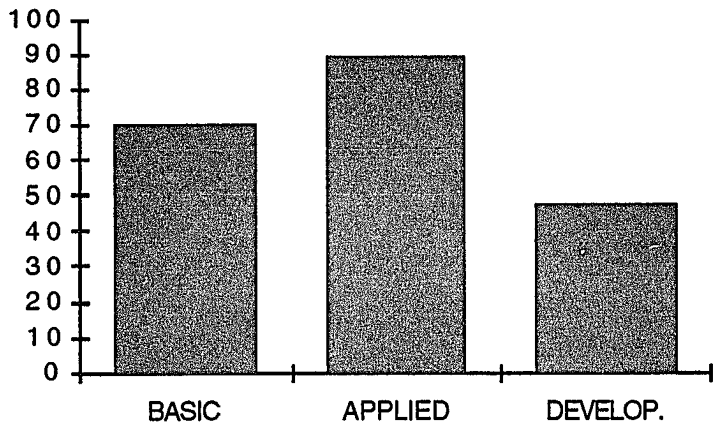


The validation respondents reported involvement in basic research 73.6% of the time, involvement in applied research 88.7% of the time, and involvement in developmental research 49.1% of the time (Figure 18). Forty-nine percent of the respondents reported no involvement in technology transfer events, 56% reported no use of their facilities by outside firms with 70% reporting no surplus capacity for such use, and 87% reported that they did not use industrial facilities.

Twenty percent of the respondents reported that they had only used formal organizational channels to develop research and consulting associations, 49% reported that they had only used informal organizational channels to develop research and consulting associations, and 18% reported that they had used both formal and informal organizational channels.

Figure 18.

Distribution of research activity by validation group



Comparisons

The percentage of responses by university for the model-building group and validation group was 36.7% from UTK, 8.3% for ETSU, 35% for VPI, 13.3% for TTU, and 6.7% for UTC and 27.7% for UTK, 10.9% for ETSU, and 36.4% for VPI, 16.4% for TTU, and 9.1% for UTC, respectively. This compares to a percentage for the aggregate group of 32.2% for UTK, 9.6% for ETSU, 35.7% for VPI, 14.8% for TTU, and 7.8% for UTC. The distribution between the model-building group and validation group seemed to mirror the aggregate relatively well. Only UTK showed a noticeable departure from the aggregate with the model-building group being more weighted than the validation group. This point of concern was eliminated by conducting a χ^2 test for multinomial distributions. The test showed no significant difference between either the model-building group or the validation group and the aggregate group.

In terms of rank, the percentage of responses for the model-building group was 11.7% for assistant professors, 26.7% for associate professors, and 61.7% for professors and for the validation group was 1.8% for lecturers, 9.1% for assistant professors, 23.6% for associate professors, and 65.5% for professors. This compares to a percentage for the aggregate group of 0.87% for lecturers, 10.4% for assistant professors, 25.2% for associate professors, and 63.5% for professors of the responses. A χ^2 test for multinomial distributions showed no significant difference between either the model-building group or the validation group and the aggregate group.

Industry Demographics

Sample Demographics

Two hundred and ninety-six high-tech firms were chosen as the population for the industry study. Each firm was chosen from the 1991 *Tennessee Business Directory* and *Virginia Business Directory* based upon its SIC code. An initial mailing was sent to all members of the population in early January, 1992. A second mailing was sent in early February to those members who had not responded.

Of the 110 responses returned, 28 were returned unopened, 21 respondents declined to respond to the survey for various reasons, and 62 responses were applied to the study. These responses constituted 37.2%, 9.5%, 7.1%, and 20.9%, respectively, of the total responses mailed. Each response was numbered sequentially and entered into a data file as it arrived.

Of the 62 responses used in the study, 27 respondents reported interactions with UTK, 6 respondents reported interactions with ETSU, 7 respondents reported interactions with VPI, 2 respondents reported interactions with TTU, 6 respondents reported interactions with UTC and 6 respondents reported interaction with other universities or no university interaction at all (Figure 19). Fifty-one percent of the firms had some involvement in basic research, 88% had some involvement in applied research, and 88% were involved in developmental research (Figure 20).

Figure 19.

Percentage of interactions with universities

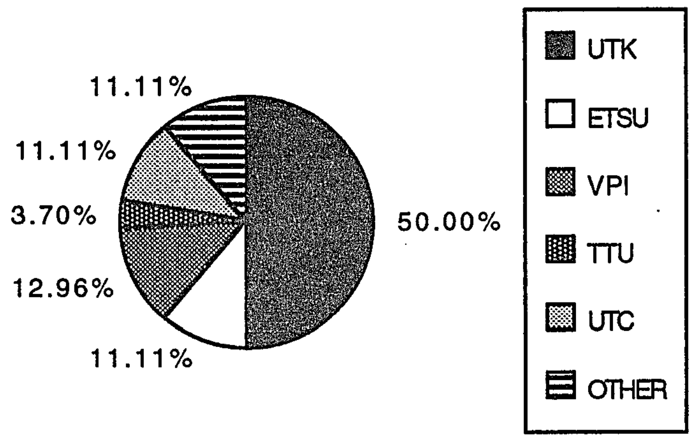
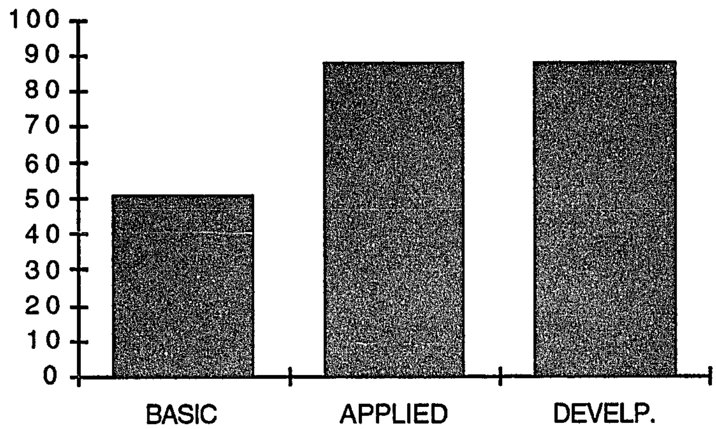


Figure 20.

Distribution of research by industry respondents



Only 13% of the respondents reported any grant activity with universities. Of those reporting a preference in the faculty rank sought for research projects, a slight preference was shown for professors (31%) over associate professors (25%). These ranks had a distinct preference over assistant professors (6%).

Consulting interactions were reported by 56% of the respondents. The disparity was more widespread when there was preference shown for faculty rank in consulting projects. Professors were preferred in 39% of the cases, associate professors were preferred in 17% of the cases, and assistant professors were preferred in 6% of the cases.

Eighty percent of the respondents reported that their employees participated in employee training activities, 68% of the firms used university facilities, and only 18% reported any use of their facilities by university personnel. Only 8% of the respondents used formal well-defined organizational channels solely in the development of university-industry interactions, 28% reported the exclusive use of informal organizational channels, and 61% reported the use of both formal and informal organizational channels.

Model Development and Validation

The academic responses were subdivided into two groups: a model-building group and a validation group. The model-building group was established by choosing alternate responses from the sequential data file. The remaining responses formed the validation pool. Data lists of the academic and industry responses were printed and checked for obvious transcription errors. Suspicious data were checked against the survey and appropriate corrections were made. The academic data and industrial data used for each regression and the corresponding correlations were recorded in Appendix C and Appendix D, respectively.

A stepwise regression analysis was performed on valid model-building responses that had non-missing values and values greater than zero for the interaction factor of interest. Independent variables were checked for a correlation with the specific interaction factor at the .05 and .1 levels of significance. Included in the regression analysis was a correlation analysis to check for correlations among the predictor variables. Strong correlations between predictor variables (multicollinearity) were diminished by dropping one of several independent variables that showed high correlation. A Cook's distance analysis was also included in the regression analysis to identify any extreme outliers. Possible outliers were identified and checked for any excessive influence on the results.

When a satisfactory model was obtained, (1) the regression coefficients (β_i) of the significant variables , (2) the standardized regression coefficients ($s(b_i)$) of the significant variables, (3) the mean squared error (MSE), (4) the coefficient of multiple determination (R^2), and (5) the number of cases included in the analysis were recorded in a table. Validation of the academic model was performed by fitting the academic validation data to the formulated academic model. The resulting regression coefficients (β_i), the standardized regression coefficients ($s(b_i)$), the mean squared error (MSE), the coefficient of multiple determination (R^2), and the number of valid cases were tabulated and compared to those of the model. A close correlation between respective values suggested an acceptable model.

For completeness, an aggregate model of the academic surveys was developed using the same stepwise regression methods established in the model-building analysis. The results from the aggregate model were used to further clarify the conclusions derived from the model-building and validation analysis.

The limited number of industry responses prevented the partition of the responses into a model-building and validation group. Therefore, only an aggregate model was developed. The results from the industry survey were merged with the results from the academic survey to form a point of view concerning university-industry interactions.

Research Grants and Contracts

The size of research grants and contracts was hypothesized (H.1) to be directly related to the size of the university or high-tech firm, surplus capacity within the university or high-tech firm, R&D investment by the firm, and the use of well-defined organizational channels. Conversely, the size of research and grants was hypothesized (H.2) to be inversely related to the proportion of skilled labor within a high-tech firm, the distance between educational institutions and high-tech firms, faculty rank, and faculty teaching load.

Model Development. The stepwise regression analysis of the 38 eligible model-building entered variables that were significant at the .05 and .1 level of significance. The process indicated that only the proportion of skilled labor was positively correlated at the .05 level of significance. All other predictor variables were insufficiently significant to enter the regression model.

Theoretically, this model was the best model. However, four iterations of the process were performed to arrive at the *best* model because of indicated remedial actions to eliminate suspected outliers. The four iterations passed and removed such variables as formal well-defined organizational channels, firm size, and faculty rank into and out of the model before settling upon the proportion of skilled labor. The model that listed firm size as a significant factor actually demonstrated the best fit (most appropriate R^2 and MSE values) of all of the analyses.

Model Validation. The results obtained when the validation data were fitted to the best model showed little correspondence with the results obtained in the model-building analysis. The insufficiency of the best model should not be totally unexpected since it exhibited a relatively low coefficients of multiple determination, R^2. In addition, the reliability of the models was jeopardized by the reduced number of both eligible model-building surveys and validation surveys.

Aggregate models. An aggregate model was developed for each the academic responses and the industry responses using the methods outlined in the model-development section for the size of research grants and contracts. The academic aggregate model used 68 eligible responses. University size and the use of well-defined formal organizational channels were found to be significant at the .05 level of significance. All other predictor variables were insufficiently significant to enter the regression model.

The industry aggregate model used 6 eligible responses to predict that large firms with a strong commitment to R&D and excess facility capacity should be the strongest supporters of large research grants. All other predictor variables were insufficiently significant to enter the regression model.

Findings. The different iterations associated with model-building, validation, and aggregation (Table 10) consistently suggested that university size, firm size, the use of well-defined organizational channels, R&D investment, and excess industrial capacity directly influence the size of research grants. Although skilled labor was identified in the model-building development as being directly related to grant size, the validation model suggested that skilled labor was inversely related. The vacillation in the results along with the poor fit between the models suggested a degree of uncertainty for this particular variable. Finally, rank consistently demonstrated a inverse relationship which is compatible with the original hypotheses.

<u>Consultations</u>

The number of consulting projects was hypothesized (H.3) to be positively related to the size of the university, the faculty rank, surplus capacity of university and industrial facilities, R&D investment by high-tech firms, and the use of well-defined organizational channels. The frequency of consulting projects was hypothesized (H.4) to be inversely related to higher proportions of skilled labor in a high-tech organization, the size of the firm, the distance between institutions, and the faculty teaching load.

Model Development. After two iterations, the stepwise regression analysis of the 38 eligible model-building responses indicated that only the size of universities was a inversely significant factor at the .05 level of

Table 10.

Regression results based on model-building, validation, and aggregate data sets for research grants and contracts

Statistic	Model Build. Data Set	Validation Data Set	Academic Aggregate	Industrial Aggregate
Firm Size (β)				61.84**
Firm Size (s(b))				.700**
University Size (β)			133422**	
University Size (s(b))			.404**	
Formal (β)			133421**	
Formal (s(b))			.343**	
Skilled Labor (β)	346**	–216		
Skilled Labor (s(b))	.389**	–.026		
R&D (β)				25.44**
R&D (s(b))				.223**
Firm Capacity (β)				1018**
Firm Capacity (s(b))				.104**
Constant	32687	103857	–53905	–20982
R^2	.151	.001	.273	1.00
MSE	.622E9	28.4E9	24.6E9	.232E6
Cases	35	30	68	6

*p < .1 **p < .05

significance. All other predictor variables were insufficiently significant to enter the regression model.

Model Validation. The 29 validation responses were fitted to the model using university size as the lone independent variable. Again the validation results corresponded poorly with the model-building results. In fact, the validation model contradicted the formulated model by suggesting that the size of the university tended to be positively correlated with consulting activities. As in the research grant and contract analysis, there was a large degree of unexplained variance remaining in the model that may be one explanation of the inefficiency of the model.

Aggregate models. The 68 cases used to develop the academic aggregate model predicted that there were no significant independent variables at the .05 or .1 levels of significance. Similarly, the 32 industrial cases predicted that there were no significant independent variables indicated at the .05 or .1 levels of significance.

Findings. No conclusive evidence (Table 11) was found to suggest any correlations between the predictor variables and consultations.

Student Co-ops

The number of student co-ops was predicted to be directly related to the proportion of skilled employees, the size of the firm or university, the level of firm R&D involvement, surplus capacity within the university or high-tech firm, and the use of well-defined formal organizational channels (H.5). Distance between the firm and university and higher teaching loads was expected to produce lower numbers of student co-ops (H.6).

Table 11.

Regression results based on model-building and validation data sets for consultations

	Model Build. Data Set	Validation Data Set
Statistic		
University Size (β)	−1.63**	1.20
University Size (s(b))	−.409**	.085
Constant	3.92	5.91
R^2	.167	.007
MSE	3.28	49.28
Cases	37	29

*p < .1 **p < .05

Model Development. Two iterations on the 45 eligible responses indicated no significant factors at the .05 level of significance and listed the excess university capacity as a significant factor at the .1 level of significance. All other predictor variables were insufficiently significant to enter the regression model.

Model Validation. The results developed by fitting the 40 cases in the validation pool of data to the formulated model showed little correlation to the predicted results specified in the model-building section. Thus, there is insufficient evidence to conclude that the formulated model is a reliable indicator of student co-op activity.

Aggregate models. An academic aggregate model of 86 responses was developed. The regression analysis could not recognize any significant factors at either the .05 or .1 levels of significance. Likewise, the regression analysis of 23 eligible industry responses yielded no significant factors at either the .05 or .1 levels of significance.

Findings. No conclusive evidence (Table 12) was found to suggest any correlations between predictor variables and student co-ops .

Table 12.

Regression results based on model-building and validation data sets for student co-ops

Statistic	Model Build. Data Set	Validation Data Set
University Capacity (β)	2.21*	–4.07
University Capacity (s(b))	.367*	–.103
Constant	31.91	62.17
R^2	.135	.011
MSE	1024	9751
Cases	44	40

*p < .1 **p < .05

Employee Training

Hypotheses H.7 and H.8 predicted that employee training events would be positively correlated to firm R&D investment, the size of the firm, the surplus capacity of industrial and university facilities, the size of the university, and the use of well-defined organizational channels and inversely correlated to skilled labor in a firm, faculty teaching load, and the distance between the university and the firm, respectively.

Model Development. The number of eligible surveys used in the analysis was 34. The stepwise regression analysis of the eligible responses indicated that there were no significant factors at the .05 or .1 levels of significance. Since there were no indications of correlation among the experimental variables, the results were accepted and no remedial procedures were instituted.

Aggregate models. The academic aggregate model using 60 eligible responses confirmed the model-building results that there were no significant correlations between the dependent variable and the independent variables at the .05 or .1 levels of significance.

Twenty-three eligible industry responses were used in the industry aggregate analysis. The stepwise regression analysis indicated that formal well-defined organizational channels were negatively correlated at the .1 level of significance. All other predictor variables were insufficiently significant to enter the regression model.

Findings. No conclusive evidence (Table 13) was found to suggest any correlations between the predictor variables and employee training.

<u>University Facility Use</u>

University facility use by high-tech firms was expected to be positively

Table 13.

Regression results based on the industry aggregate data set for employee training

Statistic	Industrial Aggregate
Formal Channels (β)	–7.143*
University Capacity (s(b))	–.500*
Constant	1.716
R^2	.250
MSE	45
Cases	20

*p < .1 **p < .05

influenced by surplus capacity within the university, the size of the university, and the use of well-defined formal organizational channels (H.9). Higher faculty teaching loads, a higher proportion of skilled labor, firm size, excess firm capacity, firm R&D involvement, faculty rank, and distances between universities and firms were expected to be inversely related (H.10).

Model Development. The stepwise regression analysis of the 19 eligible responses indicated that excess university capacity, firm size, and proportion of skilled labor were significant factors at the .1 level of significance. All other predictor variables were insufficiently significant to enter the regression model.

Validation model. Based upon the information gathered in the model-building section, 16 responses were fitted to a model using surplus university capacity, firm size, and proportion of skilled employees as entering variables. The results had little correlation to the results derived in the model-building scenario.

Aggregate models. An academic aggregate model containing 34 eligible responses was computed using the academic data. After two iterations to assuage remedial concerns, the analysis could not find any significant factors at either the .05 or .1 levels of significance. The stepwise regression analysis of the 39 eligible industrial responses indicated that industrial R&D investment was positively correlated at the .05 level of significance. All other predictor variables were insufficiently significant to enter the regression model.

Findings. Those variables that surfaced as possible significant academic factors (Table 14) were firm size, excess university capacity, and skilled labor. Unfortunately, the significance of these variables was diminished by the contradictory nature between the formulated model and validation model. Like previous analyses, the reliability of the results was further reduced by the limited number of cases in the formulated model and validation model. When a larger sample of cases were included in the aggregate model, the best model suggested no significant predictor variables. The industry aggregate model indicated that firms that demonstrated stronger R&D involvement tended to use university facilities more often.

Table 14.

Regression results based on model-building, validation, and aggregate data sets for university facility use

Statistic	Model Build. Data Set	Validation Data Set	Industrial Aggregate
Firm Size (β)	1.25E-4*	–1.85E3	
Firm Size (s(b))	.591*	–.029	
University Capacity (β)	.578*	–.051	
University Capacity (s(b))	.569*	–.190	
Skilled Labor (β)	.047*	–9.05	
Skilled Labor (s(b))	.384*	–.176	
R&D (β)			.223**
R&D (s(b))			.627**
Constant	.200	2.825	3.316
R^2	.648	.075	.394
MSE	6.97	3.72	14.98
Cases	17	16	38

*p < .1 **p < .05

Firm Facilities Use

The frequency of visits to high-tech firms by university personnel to use facilities was hypothesized to be directly related to the proportion of skilled employees, firm R&D investment, the size of the firm, excess capacity within the firm, and the use of well-defined formal organizational channels. The frequency of visits were expected to be inversely influenced by faculty rank, teaching load, the surplus capacity at universities, and the distance between the organizations.

Model Development. The stepwise regression analysis used 12 eligible responses and indicated that there were two significant factors at the .05 level of significance. The size of the firm was found to be positively correlated to the use of firm facilities, and the distance between the university and firm was found to be inversely correlated to the use of firm facilities. All other predictor variables were insufficiently significant to enter the regression model. Although remedial action was indicated, a concern over the reduction of any further variables restrained remedial action.

Validation model. Only 7 eligible cases existed for analysis in the validation process. Although the reliability of the results was once again tainted by the lack of model-building data and validation data, the two models seemed to be relatively compatible. This compatibility provided a sense of optimism about the validity of the formulated model.

Aggregate models. The academic aggregate model was developed using 19 eligible responses. The stepwise regression analysis recognized firm size as a positively correlated significant factor at the .05 level of significance. All other predictor variables were insufficiently significant to enter the regression model.

The aggregate model related to the industrial surveys included 8 cases. Although the results were somewhat diminished by the low number of cases and the high relative MSE, the regression analysis suggested that excess firm capacity was significant at the .1 level of significance. All other predictor variables were insufficiently significant to enter the regression model.

Findings. Three variables surfaced in the analysis (Table 15): (1) firm

Table 15.

Regression results based on model-building, validation, and aggregate data sets for firm facility use

Statistic	Model Build. Data Set	Validation Data Set	Academic Aggregate	Industrial Aggregate
Firm Size (β)	6.55E-4**	1.96E-3	2.08E-4**	
Firm Size (s(b))	.997**	.891	.935**	
Distance (β)	–4.37E-3**	–9.42E-4		
Distance (s(b))	–.139**	–.177		
Firm Capacity (β)				1.839*
Firm Capacity (s(b))				.406*
R&D (β)				
R&D (s(b))				
Constant	2.434	1.56	1.195	8.56
R^2	.981	.974	.874	.837
MSE	5.15	1.90	1.61	325
Cases	12	7	16	8

*p < .1 **p < .05

size, (2) distance, and (3) excess firm capacity. Of these, firm size dominated throughout the analysis. Even the industrial aggregate model indirectly indicated firm size via a significant correlation between excess firm capacity and firm size. Distance entered into the initial calculations for both the model-building and academic aggregate assessments. Moreover, distance helped reduce the variation in the validation analysis.

Summary

Data received from an academic survey were separated into a model-building and validation group. Each group was statistically compared to the aggregate sample with regard to university and faculty rank in order to assure that the each group was representative. The limited number of industry surveys did not allow the separation of responses into the two groups. The responses of each group, academic and industry, were analyzed using stepwise regression according to the methods presented by Neter et al. (1990).

The stepwise regression process entered or removed predictor variables based upon a significant F-statistic. Independent variables with a F-statistic greater than the significant F-value were entered into the regression model; independent variables with a F-statistic less than the significant F-value were eliminated from the regression model (the entering F-value was higher than the leaving F-value). This process reduced the complex models to simpler models.

Those interactions for which significant predictors were found confirmed the general hypotheses that had been developed. Overall, the findings indicated that larger research grants and contracts are obtained by larger universities with well-defined organizational channels. These grants are generally acquired from larger firms that are significantly involved in R&D activities. In addition, there seemed to be more use of firm facilities at larger firms with excess capacity near the university.

CHAPTER 5

Findings, Conclusions, and Recommendations

Introduction

This study sought information on the current state of university-industry interactions in East Tennessee and Southwest Virginia. This researcher believed that these findings were timely because of a deep conviction that higher education is poised at the threshold of a defining point in its historical development. The new era is expected to display closer relationships between universities and industries in order to optimize the economic potential of a region. With information on university-industry interactions, educational and political leaders can develop a vision of what the future could be and the strategies to successfully overcome the threats and enrich the opportunities

Six interactions were chosen from the literature in order to develop a point of view concerning the present state of university-industry interactions in East Tennessee and Southwest Virginia. These interactions were (1) size of research grants and contracts, (2) number of consultations, (3) number of student co-ops, (4) number of technical training events, (5) use of university facilities, and (6) use of firm facilities.

Throughout this chapter, the significant findings about regional university-industry interactions were summarized. These findings were expanded through conclusions and recommendations.

Findings

Stepwise regression performed by SPSS™ was used to examine factors that affected the interactions between universities and high-tech industries in the region of interest. Validation data obtained from data-splitting the responses of an academic survey were fitted to the models produced by the stepwise regression. Finally, a stepwise regression was performed on the aggregate data collected from the academic survey, and a stepwise regression was performed on the aggregate data collected from the industrial survey.

Demographics

Demographically, the university faculty demonstrated more involvement in research than in consulting and more commitment to basic and applied research than developmental research. The demographics showed little university capacity for outside use, and the university faculty showed little interest in using firm facilities.

Contrastingly, the industry respondents showed more interest in consulting than in research and more commitment to applied and developmental research than basic research. The demographics showed little firm capacity for outside use, but the firm personnel showed significantly more interest in using university facilities.

Analysis

With respect to hypotheses one and two, this study suggested that the size of research grants was more prominent among large universities with well-defined organizational channels between the university and the firm. In addition, these grants were suggested to emanate from large high-tech firms with excess firm capacity and a strong commitment to R&D.

With respect to hypotheses three and four, there was no conclusive evidence to reject the null hypotheses. That is, there was no conclusive evidence that a relationship existed between consultations and the predictor variables.

With respect to hypotheses five and six, there was no conclusive evidence to reject the null hypotheses. That is, there was no conclusive evidence that a relationship existed between student co-ops and the predictor variables.

With respect to hypotheses seven and eight, there was a significant inverse correlation suggested between employee training and well-defined organizational channels. With respect to hypotheses nine and ten, there was a significant positive correlation noted between university facility use and firm R&D involvement. With respect to hypotheses eleven and twelve, firm size seemed to have a positive influence on the use of firm facilities while larger distances seemed to reduce the use of firm facilities.

Conclusions

Demographics

The demographics generally corroborated the results reported throughout the literature. That is, faculty are more inclined to perform basic research and applied research than developmental research, while industry is more interested in applied research and developmental research. Surprisingly the regional responses suggested that the faculty within the region seemed to be more involved in applied research than basic research. The expectation developed from the literature review would have been the reverse, more basic research than applied research. This may be one more piece of proof suggesting the low concentration of high-tech industries requiring new knowledge within the region.

Overall, the demographics seemed to support the notion that regional universities and industries do not have a large degree of formal university-industry interaction. This was proposed by the low levels of correlations among many of the predictor variables and interaction variables.

Research Grants and Contracts

Concerning the interaction associated with research grants and contracts, there was a degree of confidence that can be attached to the point of view that large universities with well-defined organizational channels will generally receive larger research grants from large firms that are committed to research and have excess facilities. These conclusions were based upon the consistency of the regression results, the compatibility with the original hypotheses, and the studies described in the literature review.

Contrastingly, the reliability of the results was flawed by the limited number of responses, especially the industry responses. The small number of industrial responses concerning research grants and contracts extended the premise described in the literature that many of the manufacturing facilities in Tennessee may be branch plants. As a result, one would expect limited interest in research.

Although the results were not overwhelmingly conclusive, Deming (1986) would suggest that these correlations represent identifiable variables that could be plotted and analyzed using statistical quality control methods, and Ary et al. (1985) would suggest that a valid correlation should appear regardless of the number of responses. Thus, an academic leader seeking larger grants would be remiss by totally ignoring the results.

<u>Consultations</u>

Concerning consultations, the general conclusions that could be drawn from the analysis were quite limited. The strongest statement that could be made was that consultations might simply be randomly occurring interactions. As the literature explained, consultations lie on the periphery of sanctioned university activities. Thus, some universities have developed policies in favor of consulting, some have developed policies against consulting, and others have no policies concerning consulting.

Whether consultations were randomly occurring events or not, there were underlying indications that the size of the firm, excess firm capacity, the proportion of skilled labor might positively influence consultations while the size of the university and the distance between the firm and university might be inversely correlated to consultations. Of these possible influencing factors, the proportion of skilled labor and the size of the university seemed to contradict the assumptions made in the hypotheses.

The assumption concerning skilled labor was that the skilled labor would sufficiently handle the vast majority of projects within the firm. Moreover, large universities with their exceptional ability to hire the best minds would have a distinct advantage in the consulting arena. What might be happening is that those firms with the highest levels of skilled labor might have more projects within the area of faculty interests. Also in the present period of industrial retrenchment and economic instability, the larger high-tech industries might be seeking part-time professionals and consultants to meet their technological requirement while waiting for the economy to settle.

Concerning the inverse correlation between university size and consulting, large universities might be promoting research grants and contracts more strongly than consulting through various university traditions and policies. Moreover, small universities might be conceding the large, typically national research grants to the larger universities while seeking a niche in consultation to gain and maintain local and regional support.

Student Co-ops

The results associated with student co-ops could be explained by the fact that the interaction was once again on the periphery of sanctioned university activities. In addition, some institutions, both universities and high-tech firms, may have had strong student co-op programs while others did not. Moreover, one would have expected to find strong co-op programs where there is a concentration of high-tech industries. Such a concentration of high-tech industries simply may not exist within the region of study.

Employee Training

None of the selected predictor variables were found to significantly affect employee training within the regional academic community. In the industrial community, formal well-defined organizational channels were recognized as being inversely correlated with employee training.

Two reasons for the academic results can be presumed. First, like consulting, employee training rests upon the periphery of formally endorsed activities within the university. Second, the proposed theories developed in the literature review concerning the development of branch plants in the region of study may be true, suggesting that many of the products being manufactured within the region were in the declining stages of production. During this stage of the production life cycle, the methods are well established, and the need for new innovative processes and products may simply not exist. The inverse correlation between employee training and formal organizational channels generated in the industry aggregate model suggested that industry may be seeking faculty that have an established reputation through publications, workshops, or through the recommendations of students that have attended university classes.

University Facility Use

The industry aggregate model embellished the proposition that firms strongly involved in R&D used university facilities more often. At a minimum, they probably used the library facilities of the university. At most, firms used the facilities associated with university parks or research parks.

Firm Facility Use

Although this interaction showed the most significant correlation among the various models, the limited number of surveys reporting firm use in each of the surveys confused the results. Nevertheless, one should not lightly disregard the possibility that there is a greater use of firm facilities at larger firms with excess capacity near the university, especially since the results have consistently surfaced throughout the literature.

Implications

A major implication of the study was that large universities have developed efficient formal organizational channels with large high-tech industries near the universities that have a strong commitment to R&D and excess firm capacity. These observations suggested that a university like the University of Tennessee at Knoxville located near a large research center like Oak Ridge National Laboratories will have more access to research grants and contracts and more access to research facilities. These conclusions are by no means revolutionary. Such occurrences were demonstrated at the Research Triangle in North Carolina, Route 128 in Boston, Silicon Valley in California, and the Silicon Prairie in Texas.

The noteworthy conclusions may be a consequence of those interactions which showed no significant correlations. That is, the universities located in East Tennessee and Southwest Virginia showed little or no significant formal commitment to peripheral interactions such as consultations, student co-ops, employee training, university facility use. This implication suggested that universities and their associated elites in East Tennessee and Southwest Virginia may have embraced conservative, perhaps somewhat myopic traditions and policies concerning university-industry interactions. These conservative attitudes may limit market penetration.

In addition, the conservative attitudes may represent a questionable strategy at this time. The nation and the region are in an international economic battle where conservative policies and procedures have the effect of stifling innovativeness. What is needed is more interaction with smaller manufacturers so that the small firms can improve their productivity and become more competitive. This implies stronger commitments by the educational elite to consulting, employee training, access to students, and facility sharing. Likewise, high-tech firms must become more supportive of higher education. The literature listed innumerable benefits that universities and firms can share if they each can overcome the formidable barriers that have developed through tradition, culture, and bureaucratic processes.

The data from the academic and industrial surveys suggested that research grants are elevated above the other interactions. Perhaps this is an aberration caused by an abundance of small branch industries within the region that are producing products that have reached their maturity stage or declining stage of their product life cycle. Therefore, they are not as dependent upon new knowledge for their short-term existence. Perhaps this is an aberration related to the fiscal expediency that adds funds to the university coffers through the attachment of a direct cost fee to research grants.

Regardless, not all of the universities within the region are large universities, and there are very few large regional high-tech industries. Hence, there is a strong likelihood that the smaller universities may be prohibited from reaching the research trough. Though there are some indications--which were deemed insignificant in the study--that the smaller universities are seeking a niche in these under used areas of interaction, there seemed to be a herd mentality within the surveys that quality institutions are based upon quantitative factors that can be assigned to teaching, research, and service--the rule of accountability.

Recommendations

In order to diverge from the typical research philosophy adopted by many universities, it is the recommendation of this researcher that each university should adopt a semi-publicly supported Department of Industrial Cooperation similar to MIT. The department would operate in some ways like a high-tech equivalent of the agricultural extension centers described in the literature and in other ways like the not-for-profit research organizations--Batelle, Southwest Research Institute, etc. Some operating funds would be supplied by the state and federal governments through various grants. Other operating funds would come from user fees. Additionally, spin-off companies could be developed.

The Department of Industrial Cooperation would coordinate university-industry activities and could be divided along functional lines: Office of Grants, Office of Consulting, Office of Technical Training, and Office of Facility and Equipment Coordination. The Office of Grants would establish the policies and develop the contracts associated with formal research grants and contracts. The office would maintain a database of faculty and faculty expertise and would aggressively seek research grants and contracts. The overhead would be supported with the direct cost fee associated with the research. The Office of Consulting would share the database of faculty expertise and would actively promote institutional consulting. Like research, overhead would be supported with the direct cost fee associated with the project. The Office for Technical Training would develop short-courses, workshops, and seminars. These training activities would be supported by user fees and federal and state funds. The Office of Facility and Equipment Coordination would coordinate excess university and firm facilities to maximize their use and minimize costs. Expensive equipment could be borrowed, rented, or shared between universities and industries for reasonable intervals of time rather than be bought. Innovative sale-leaseback arrangements could be worked out among universities and industries along with accompanying state and federal tax breaks.

Some proponents in the literature proposed that the major mission of the university is to extend knowledge through research. Other proponents in the literature proposed that the major mission of the university is to educate through teaching. These proposed options may be too narrowly focused. A broader mission of the university in the new world order of technological competition may be to provide opportunity. Presently, the research and teaching mission provide opportunity to a few. A goal of the Department of Industrial Cooperation would be to expand the often underrepresented service mission of the university and provide opportunity to more.

The goal of an educated and civilized society should be the maximization of opportunities provided to society. This equates to more, better, and higher paying jobs, which equate to more and better cooperation among the societal structures such as government, industry, and higher education.

Further Studies

A logical extension of this study would be the examination of the so-called industrial and research parks throughout the nation and examination of the similarities and differences between regions based upon interactions. Through sufficient analysis, the researcher could see which interactions seem to correlate with the development of various disciplines. The data would additionally concentrate the focus upon those interactions that do make a difference in economic development.

Another logical extension of the study would be to separate the universities based upon their responses and perform a statistical analysis on industries that have entered, remained, and left the region in the last five years. Such a study could be politically invaluable during budget times.

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APPENDICES

APPENDIX A

East Tennessee State University
College of Education
Department of Educational Leadership and Policy Analysis • Box 19000A • Johnson City, Tennessee 37614-0002 • (615) 929-4415, 4430

January 13, 1992

«name»
«company»«IF box»
«box»«ENDIF»«IF street»
«street»«ENDIF»
«city», «state» «zip»

Dear Manager:

Your firm is invited to participate in a study concerning the interactions between higher education and high-tech industries in East Tennessee and Southwest Virginia. Firms, such as yours, were selected from the Tennessee and Virginia Directories of Manufacturers for inclusion in the study based upon documented Standard Industrial Classification (SIC) codes for high-tech industries. Responses to the enclosed questionnaire should be provided by the person(s) most knowledgeable about university-industry affairs--research grants, consulting, facility use, technical training and transfer, etc.--in your organization, such as a research manager, engineering manager, or senior engineer.

This study is being conducted as partial fulfillment of my Ed. D. degree in Educational Leadership and Policy Analysis at East Tennessee State University and, more importantly, to add to the knowledge about regional university-industry interactions. The questionnaire was developed based upon an examination of the existing literature and a pilot study conducted during the summer. I would like for the responder to use the enclosed pre-addressed envelope so that I can maintain a record of returned surveys.

Because the survey is being sent to a small, representative sample, it is extremely important that your responses be included in order to develop an accurate characterization of the region's university-industry interactions. Your assistance in furnishing this information will be important to the continued growth in our region. Thank you for your cooperation.

Sincerely,

Wm. Hugh Blanton
Doctoral Candidate
Educational Leadership
and Policy Analysis
East Tennessee State University

INDUSTRIAL SURVEY

Return to:
Hugh Blanton
304 Harbour View Dr.
Johnson City, TN 37615

CONFIDENTIAL

About this project:

Your company has been selected for participation in a questionnaire survey on the interactions between higher education and high-tech industries in East Tennessee and Southwest Virginia. The following questionnaire is designed to provide information on factors that constitute and permit interactions between higher education and high-tech industries. Summary information from the survey will be used to review educational and industrial policies that influence university-industry interactions.

Your company's participation in this study is vital to its success. Please assign the task of completing this questionnaire to the person(s) such as a research manager, scientist, or engineer in your organization most knowledgeable about university-industry affairs. I am keenly aware of the value of your time and have tried to construct the questionnaire in such a way as to minimize your time and effort.

Your responses will remain strictly confidential.

Thank you for your assistance, and be assured that all information on your response will be held strictly confidential. Only aggregate results will be published, and no responses will be directly attributed to you or your institution.

Thank you for your help!

I. Personal Information. A business card may be attached to answer the personal information.

Name of Person Completing Survey ____________________

Position ____________________

Name of Company ____________________

Address ____________________

City__________ State _____ Zip_______ Telephone (   )__________

II. Firm Characteristics. Based upon your best estimates, complete the following entries.

Firm's annual sales__________ Firm's total number of employees__________

Approximately what percentage of the total number of employees are technically skilled (Engineers, Scientists, Programmers, technicians, etc.) ____________________

How much money is allocated annually to R&D by your firm? ____________________

Principle Products or Services____________________

____

III. General Data. Based upon your best estimates, complete the following entries.

1. Approximately what percentage of the employees at your firm annually receive advanced training through university workshops, seminars, or continuing education ? ____________________

2. What percentage of the personnel at your firm would you estimate utilize university research facilities such as laboratories, computer centers, information centers, or research facilities each month?

____

3. How many university personnel per month would you estimate utilize your firm's research facilities such as laboratories, computer centers, information centers, research facilities, or technical libraries?

____

4. On average, how many miles must employees travel between the firm and the university to attend classes, workshops, etc., or utilize university research facilities as described in questions 1 and 2?

____

A. If your firm participates in research grants and contracts with universities, answer questions 5 through 8. Otherwise you may proceed to question 9.

5. In how many research grants and contracts does your firm normally participate with universities in a year? ____________________

6. What would you consider to be the average dollar amount of a research grant? ____________________

7. What is the average distance between your firm and the universities used most often for research grants and contracts? ______________________________

8. Of the following faculty ranks, which faculty rank would you seek to conduct your firm's R&D contracts?

Professor	Associate Professor	Assistant Professor	No Preference
☐	☐	☐	☐

B. If your firm utilizes faculty consultants or student interns, answer questions 9 through 12. Otherwise you may proceed to question 13.

9. How many consulting projects does your firm participate in annually? ______________

10. Of the following faculty ranks, which faculty rank would you seek as a consultant?

Professor	Associate Professor	Assistant Professor	No Preference
☐	☐	☐	☐

11. How many university student co-ops or interns does your firm normally enlist annually? ________

12. On average, what is the distance between your firm and the universities from which you choose most of your consultants or student interns? ______________________

13. If your firm has a surplus capacity of laboratory space and lab equipment which can be shared with university personnel, how many university personnel per week can your firm accommodate in your firm's facilities without disturbing the use by the firm scientist and engineers? ____________

14. When your firm seeks interaction with universities, does your firm work through formal organizational channels (the vice president for research, continuing education, office of research and sponsored programs, or departmental dean) or does the firm work through informal channels (individual faculty)?

Formal Organizational Channels	Informal Organizational Channels	Both Formal & Informal
☐	☐	☐

IV. Policy Considerations. This section provides you an opportunity to comment on ways in which the universities can be of assistance to the private sector in fostering university-industry interactions.

16. What are the most important ways in which the universities can be of assistance to your firm?

____

____

____

____

____

17. What are some important ways in which you believe your company can be of assistance to university research and education programs?

____

____

____

____

____

18. What do you regard as the three most significant barriers to university-industry interaction?

(1) ____

____

(2) ____

____

(3) ____

____

Thank you for your cooperation. If you would like to receive a summary of the results, mark the box. ☐

East Tennessee State University
College of Education
Department of Educational Leadership and Policy Analysis • Box 19000A • Johnson City, Tennessee 37614-0002 • (615) 929-4415, 4430

November 12, 1991

«name1» «name2»
«department»
«university»«IF box»
«box»«ENDIF»«IF street»
«street»«ENDIF»
«city», «state» «zip»

Dear Dr. «name2»:

You are invited to participate in a study concerning the interactions between higher education and high-tech industries in East Tennessee and Southwest Virginia. You were selected for inclusion in the study based upon your institution's recognized role in the region.

This study is being conducted as partial fulfillment of my Ed. D. degree in Educational Leadership and Policy Analysis at East Tennessee State University and, more importantly, to add to the knowledge about regional university-industry interactions. The enclosed questionnaire was developed based upon an examination of the existing literature and a pilot study conducted during the summer. I would like for you to use the enclosed pre-addressed envelope so that I can maintain a record of returned surveys.

Because the survey is being sent to a small, representative sample, it is extremely important that your responses be included in order to develop an accurate characterization of the region's university-industry interactions. Your assistance in furnishing this information will be important to the continued growth in our region. Thank you for your cooperation.

Sincerely,

Wm. Hugh Blanton
Doctoral Candidate
Educational Leadership
and Policy Analysis
East Tennessee State University

ACADEMIC SURVEY

Return to:
Hugh Blanton
304 Harbour View Dr.
Johnson City, TN 37615

CONFIDENTIAL

About this project:

You have been selected for participation in a survey on the interactions between higher education and high-tech industries in East Tennessee and Southwest Virginia. The enclosed questionnaire is designed to provide information on factors that constitute and permit interactions between higher education and high-tech industries. Summary information from the survey will be used to review educational and industrial policies that influence university-industry interactions.

Your participation in this study is vital to its success. I am keenly aware of the value of your time and have tried to construct the questionnaire in such a way as to minimize your time and effort.

Your responses will remain strictly confidential.

Thank you for your assistance, and be assured that all responses will be held strictly confidential. Only aggregate results will be published.

Thank you for your help!

I. Individual Characteristics. Based upon your best estimates, complete the following questions.

Your faculty rank: ☐ Lecturer ☐ Asst. Prof. ☐ Assoc. Prof. ☐ Professor

Number of days normally spent performing industry-supported contract research each week. __________

Number of days normally spent performing government-supported contract research each week. ______

Number of days normally spent performing industrial consulting each week. ____________________

Number of academic courses normally taught each semester/quarter. ______________________

Area(s) of Expertise. ____

____

What percentage of your research and/or consulting effort is spent in:

Basic Research (the development of new knowledge). ______

Applied Research (the application of existing knowledge). ______

Developmental Research (the development of new products or processes). ______

What is the percentage increase in your annual income (as compared to your annual academic salary) due to your involvement in industry-supported research contracts or industrial consulting? ______

II. General Data. Based upon your best estimates, complete the following entries.

1. Approximately how many employees are in the firm that you most frequently contact? ______

2. What percentage of total employees in this firm are skilled labor (such as engineers and scientists)? ______

3. How many technology transfer events (workshops, seminars, or continuing education classes) do you perform <u>annually</u> for industry? ______

4. On <u>average</u>, how many industry personnel attend these technology transfer events? ______

5. How many persons per <u>month</u>, if any, from industry use your department's research facilities or equipment? ______

6. What would you estimate to be the distance between those firms which attend your technology transfer events or take advantage of your research facilities? ______

7. How often do you visit a firm per <u>month</u> to use equipment or facilities not available at your university? ______

A. <u>Research Contracts</u>. If you or your department participates in research grants and contracts with industry, answer questions 8 through 11. Otherwise you may proceed to section B.

8. How many industrially-supported research grants or contracts do you <u>annually</u> participate in with industry? ______________________________

9. Which type of firm normally contacts you or your department concerning research contracts?

________ 01 Electronics or electrical equipment
________ 02 Biotechnology
________ 03 Computer hardware
________ 04 Computer software
________ 05 Communication equipment
________ 06 Material science
________ 07 Laboratory instruments, scientific instruments, and medical equipment
________ 08 Management
________ 09 Industrial organic chemicals
________ 10 Manufacturing
________ 11 Machine design

________ 12 Others: specify ____________________________________

10. What would you estimate to be the <u>average</u> dollar amount of each industrially-supported research grant that you are involved in? ___________________________________

11. What is the <u>average</u> distance between your university and the firms with which you have research contracts? ______________________________

B. <u>Consulting</u>. If you participate in industrial consulting, answer questions 12 through 15. Otherwise you may proceed to section C.

12. How many industrial consulting projects do you <u>annually</u> participate in? _________________________

13. On <u>average</u>, what is the distance between those firms with which you consult? ____________________

14. How frequently do you visit firms for consultation? ____________________________________

15. What is the average length in <u>hours</u> of each session when you meet for consulting? ________________

C. Departmental Data. .

16. Approximately how many students in your department are annually involved in student co-ops or internships? ____________________________

17. If your department has surplus capacity of laboratory space and equipment which can be shared with firm scientists or engineers, how many industry personnel could your department accommodate weekly without disturbing the use by professors and students? ____________________________

18. When firms seek interaction with your university, do the firms seem to work through formal organizational channels (the vice-president for research, continuing education, the departmental dean, or the office of research and sponsored programs) or does the firm work through informal channels (individual faculty)?

Formal Organizational Channels	Informal Organizational Channels
☐	☐

III. Policy Considerations. This section provides you an opportunity to comment on ways in which universities can be of assistance to the private sector in fostering university-industry interactions.

19. What are the most important ways in which industry can be of assistance to you and your department?

____

____

____

20. What are some important ways in which you believe you and your department can be of assistance to industry?

____

____

____

21. What do you regard as the three most significant barriers to university-industry interaction?

(1) ____

____

____

(2) ____

____

____

(3) ____

____

____

Thank you for your cooperation. If you would like to receive a summary of the results, check the box.

☐

APPENDIX B

East Tennessee State University
College of Education
Department of Educational Leadership and Policy Analysis • Box 19000A • Johnson City, Tennessee 37614-0002 • (615) 929-4415, 4430

February 3, 1992

«name»
«company»«IF box»
«box»«ENDIF»«IF street»
«street»«ENDIF»
«city», «state» «zip»

Dear Manager:

Recently a questionnaire was mailed to you seeking your responses concerning university-industry interactions. If you have already completed and returned it, please accept my sincere thanks. If not, please do so today. Because your firm is among the few high-tech industries in East Tennessee and Southwest Virginia, it is extremely important that your responses also be included in the study if the results are to be accurate.

If by some chance you did not receive the questionnaire, or it was misplaced, I have enclosed an additional questionnaire for your convenience.

Thank you for your help.

Sincerely,

Wm. Hugh Blanton
Doctoral Candidate
Educational Leadership
and Policy Analysis
East Tennessee State University

East Tennessee State University
College of Education
Department of Educational Leadership and Policy Analysis • Box 19000A • Johnson City, Tennessee 37614-0002 • (615) 929-4415, 4430

December 1, 1991

«name1» «name2»
«department»
«university»«IF box»
«box»«ENDIF»«IF street»
«street»«ENDIF»
«city», «state» «zip»

Dear Dr. «name2»:

Recently a questionnaire seeking your responses concerning university-industry interactions was mailed to you. If you have already completed and returned it, please accept my sincere thanks. If not, please do so today. Because it has been sent to only a small, representative sample, it is extremely important that yours also be included in the study if the results are to be accurate.

If by some chance you did not receive the questionnaire, or it got misplaced, please call me right now (615-282-0800 ext. 374), and I will put another one in the mail to you.

Thank you for your help.

Sincerely,

Wm. Hugh Blanton
Doctoral Candidate
Educational Leadership
and Policy Analysis
East Tennessee State University

APPENDIX C

Academic Data Tables

Table 16.

Model-building data for size of research grants and contracts

Survey	Dollar	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
4	50000	1	1	2	1000	50	500	3	0
6	25000	1	1	2	5000	10	200	0	0
8	15000	1	1	2	400	4	40	5	0
12	50000	1	1	2	1000	50	270	2	1
14	30000	1	0	3	400	75	20	12	1
16	100000	1	1	3	2000	50	25	0	0
18	200000	1	1	2	71000	20	30	0	1
20	50000	0	1	2	25000	40	350	0	0
24	50000	1	1	3	1000	50	30	5	0
26	70000	0	1	2	10000	*	200	0	0
28	50000	1	1	2	10000	60	800	0	0
32	35000	1	1	2	1000	10	1000	0	0
34	20	0	1	2	*	*	*	0	0
36	5000	1	1	2	2000	50	150	0	0
40	50000	1	0	3	100	2	350	5	1
42	30000	1	0	2	100	10	70	5	0

*missing or unclear data

Table 16.

Continued

Survey	Dollar	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
46	15000	1	0	1	8000	20	100	0	1
52	20000	1	1	2	*	*	1500	0	0
56	50000	1	0	3	100	20	125	0	0
58	4000	1	1	2	10000	50	1500	0	0
60	10000	1	1	2	*	*	400	0	0
60	10000	1	1	2	*	*	400	0	0
62	65000	0	1	2	25	80	150	0	1
66	28000	0	0	3	*	*	2	0	1
68	100000	1	1	1	2	100	250	3	1
70	25000	1	1	2	100	10	500	0	0
78	70000	1	1	2	100	90	25	25	1
80	70000	0	1	2	300	10	450	0	0
84	200000	0	1	1	2000	10	350	0	0
88	40000	0	1	1	5000	20	1000	0	0
92	800000	1	1	3	7000	15	250	0	1
96	75000	0	1	2	*	*	200	5	1
102	15000	1	1	2	2000	10	500	4	0
106	200000	0	1	2	*	*	2000	*	0

*missing or unclear data

Table 16.

Continued

	Dollar	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
Survey									
108	25000	0	1	1	1000	50	10	10	0
112	70000	1	1	1	100	90	300		0
114	30000	1	1	2		80	300	0	0
116	50000	1	0	1	20	90	200	0	0
120	100000	0	1	1	3000	20	800	0	0

*missing or unclear data

Table 17.

Correlation analysis of model-building data related to the size of research grants and contracts

	Dollar	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Dollar	1.0000								
Prof.	.0241	1.0000							
Un. Size	.1695	–.0422	1.0000						
Classes	.2293	.4545*	–.1553	1.0000					
Fir. Size	.1907	.0051	.1482	-.0120	1.0000				
Skill	-.1458	.1046	.0346	–.1093	–.1564	1.0000			
Distan.	–.0553	–.2043	.2726	–.2431	–.0556	–.1193	1.0000		
Capac.	–.1390	.1520	–.0834	.1172	–.1893	.3664	–.3411	1.0000	
Formal	.3254	.2208	–.1997	.1485	.2242	.2906	–.3264	.3122	1.0000

Table 18.

Validation data for the size of research grants and contracts

Survey	Dollar	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
11	75000	1	1	1	8000	25	2000	0	0
13	250000	1	1	2	20000	5	200	5	1
15	50000	1	1	2	5000	50	*	0	1
17	100000	0	0	4	*	*	30	5	1
19	120000	1	1	3	4000	10	800	4	0
21	3000	1	0	3	1000	*	*	3	1
25	250000	1	1	1	25000	20	2000	0	1
29	6000	0	0	2	100	20	100	0	1
41	50000	1	0	2	*	10	250	0	1
43	20000	1	0	3	600	20	600	5	1
45	55000	1	1	2	8	50	280	0	1
51	25000	0	1	2	5000	10	30	0	0
53	25000	0	0	3	*	*	30	0	0
59	100000	1	1	1	*	30	200	5	0
61	25000	0	1	1	*	*	40	0	1
63	65000	1	1	1	3000	10	500	2	0
67	60000	1	1	3	800	20	8	0	0
71	800000	0	1	1	2500	25	200	0	1

*missing or unclear data

Table 18.

Continued

Survey	Dollar	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
73	20000	1	1	2	20	20	150	0	9
75	190000	0	1	1	100	80	7000	20	0
81	65000	1	1	1	*	*	2500	*	0
87	20000	1	0	3	300	20	100	0	0
91	20000	0	0	3	22000	33	*	*	*
93	20000	1	0	1	1000	20	200	0	1
95	18000	0	1	2	*	*	600	0	0
99	5000	1	0	3	300	20	40	*	0
101	35000	1	1	2	200	10	120	10	0
103	30000	0	1	2	1000	70	1500	0	1
109	50000	1	0	3	2	50	5	0	1

*missing or unclear data

Table 19.

Correlation analysis of validation data related to the size of research grants and contracts

	Dollar	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Dollar	1.0000								
Prof.	–.3191	1.0000							
Un. Size	.3192	–.1077	1.0000						
Classes	–.3974	.2740	–.3623	1.0000					
Fir. Size	.2784	.2119	.3327	–.3088	1.0000				
Skill	–.0427	–.3613	.0761	–.1052	–.3370	1.0000			
Distan.	.0849	–.3134	.2894	–.4175	–.0556	.6400	1.0000		
Capac.	.0452	–.1787	.1924	–.1484	–.0952	.2964	.7267	1.0000	
Formal	.2633	–.1240	–.3721	–.0712	.2166	.1176	–.2406	–.2881	1.0000

Table 20.

Model-building data for consulting activity

Survey	Conslt.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
2	2	0	0	4	500	10	10	1	0
6	1	1	1	2	5000	10	200	0	0
10	1	0	0	4	*	*	*	0	0
14	2	1	0	3	400	75	20	12	1
16	6	1	1	3	2000	50	25	0	0
18	2	1	1	2	71000	20	30	0	1
24	2	1	1	3	1000	50	30	5	0
26	1	0	1	2	10000	*	200	0	0
28	2	1	1	2	10000	60	800	0	0
30	6	0	0	3	400	10	50	0	0
32	4	1	1	2	1000	10	1000	0	0
40	5	1	0	3	100	2	350	5	1
42	4	1	0	2	100	10	70	5	0
46	6	1	0	1	8000	20	100	0	1
54	3	0	0	3	100	20	1500	0	0
56	4	1	0	3	100	20	125	0	0

*missing or unclear data

Table 20.

Continued

Survey	Conslt.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
58	3	1	1	2	10000	50	1500	0	0
62	2	0	1	2	25	80	150	0	1
64	10	1	0	3	150	1	15	0	1
68	2	1	1	1	2	100	250	3	1
70	3	1	1	2	100	10	500	0	0
72	2	1	1	0	10000	10	850	0	0
74	1	1	1	2	10	80	7000	0	1
76	1	0	1	0	100	2	75	5	0
78	1	1	1	2	100	90	25	25	1
82	3	1	1	1	1000	40	100	0	0
84	3	0	1	1	2000	10	350	0	0
88	1	0	1	1	5000	20	1000	0	0
92	3	1	1	3	7000	15	250	0	1
96	1	0	1	2	*	*	200	5	1
98	3	1	1	2	4	100	10	2	0
100	2	1	0	1	200	5	20	3	0
102	4	1	1	2	2000	10	500	4	0
104	2	0	1	3	250	80	250	0	0

*missing or unclear data

Table 20.

Continued

Survey	Conslt.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
108	1	0	1	1	1000	50	10	10	0
112	5	1	1	1	100	90	300	*	0
114	5	1	1	2	*	80	200	0	0
116	1	1	0	1	20	90	3	0	0
118	2	0	0	4	280	5	30	0	1

*missing or unclear data

Table 21.

Correlation analysis of the model-building data associated with consulting activities

	Conslt.	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Conslt.	1.0000								
Prof.	.1633	1.0000							
Un. Size	–.3481	.0798	1.0000						
Classes	.2747	–.1512	–.3923	1.0000					
Fir. Size	–.0503	.1670	.1814	-.0779	1.0000				
Skill	-.3077	.1423	.2574	–.0037	–.1637	1.0000			
Distan.	–.0547	.2206	.0938	–.0684	–.0536	.1519	1.0000		
Capac.	–..2431	.1208	.0196	–.0411	–.1451	.2774	–.1685	1.0000	
Formal	–.0098	.0621	–.1688	.2680	.2269	.2283	.2002	.2291	1.0000

Table 22.

Validation data for consulting activity

Survey	Conslt.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
5	1	0	0	3	2500	*	400	5	0
7	15	1	0	3	300	*	15	0	0
9	2	0	1	1	*	*	400	0	0
11	1	1	1	1	8000	25	2000	0	0
13	2	1	1	2	20000	5	150	5	1
15	5	1	1	2	5000	50	50	0	1
19	6	1	1	3	4000	10	300	4	0
21	3	1	0	3	1000	*	100	3	1
25	3	1	1	1	25000	20	800	0	1
33	6	0	0	3	4	100	30	0	1
41	6	1	0	2	*	10	250	0	1
43	5	1	0	3	600	20	200	5	1
51	20	0	1	2	5000	10	45	0	0
53	20	0	0	3	*	*	45	0	0

*missing or unclear data

Table 22.

Continued

Survey	Conslt.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
55	10	1	1	1	*	30	1500	5	0
57	2	1	1	2	40	25	300	4	0
59	2	1	1	2	2000	50	1500	0	0
63	2	1	1	1	3000	10	100	2	0
67	2	1	1	3	800	20	200	0	0
71	2	0	1	1	2500	25	200	0	1
81	10	1	1	1	*	*	500	*	0
89	20	0	1	2	50000	*	3000	*	0
95	2	0	1	2	*	*	40	0	0
97	1	1	0	3	4000	75	80	0	1
99	2	1	0	3	300	20	40	*	0
103	12	0	1	2	1000	70	1000	0	1
107	25	1	1	0	10	0	3000	2	0
109	3	1	0	3	2	50	5	0	1

*missing or unclear data

Table 23.

Correlation analysis of validation data as related to consulting

	Conslt.	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Conslt.	1.0000								
Prof.	–.3468	1.0000							
Un. Size	.1722	.0192	1.0000						
Classes	–.3397	.0000	–.6112	1.0000					
Fir. Size	–.2090	.2123	.2907	-.2740	1.0000				
Skill	-.2132	–.3664	–.5697	.4634	–.3001	1.0000			
Distan.	.4573	.1810	.3435	–.6558	–.0137	–.2175	1.0000		
Capac.	–.0329	.3773	.0129	.1022	.0916	–.5058	–.0959	1.0000	
Formal	–.2366	–.2451	–.5230	.2597	.2608	.5007	–.3969	–.1020	1.0000

Table 24.

Model-building data for student co-ops

Survey	Co-ops	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
2	20	0	0	4	500	10	10	1	0
4	10	1	1	2	1000	50	*	3	0
6	60	1	1	2	5000	10	200	0	0
8	3	1	1	2	400	4	*	5	0
10	29	0	0	4	*	*	*	0	0
12	6	1	1	2	1000	50	*	2	1
14	36	1	0	3	400	75	20	12	1
16	20	1	1	3	2000	50	75	0	0
18	300	1	1	2	71000	20	30	0	1
20	200	0	1	2	25000	40	*	0	0
24	20	1	1	3	1000	50	500	5	0
26	4	0	1	2	10000	*	200	0	0
30	9	0	0	3	400	10	50	0	0
32	25	1	1	2	*	10	2000	0	0
36	30	1	1	2	2000	50	*	0	0
38	10	1	1	2	5000	*	*	4	1
40	15	1	0	3	100	2	100	5	1
42	10	1	0	2	100	10	80	5	0
44	15	0	4	2	*	*	*	0	1

*missing or unclear data

Table 24.

Continued

Survey	Co-ops	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
46	30	1	0	1	8000	20	2000	0	1
48	15	1	0	4	*	*	*	2	1
54	10	0	0	4	2	50	70	0	1
56	100	1	0	3	100	20	1500	0	0
58	4	1	1	2	10000	50	750	0	0
60	5	1	1	2	*	*	*	0	0
64	40	1	0	3	150	1	15	0	1
66	125	0	0	3	*	*	*	0	1
70	10	1	1	2	100	10	500	0	0
72	10	1	1	0	10000	10	850	0	0
76	50	0	1	0	100	2	75	5	0
78	100	1	1	2	100	90	25	25	1
80	2	0	1	2	300	10	*	0	0
84	25	0	1	1	2000	10	500	0	0
90	100	0	1	2	*	*	*	0	0
92	125	1	1	3	4000	15	50	0	1

*missing or unclear data

Table 24.

Continued

	Co-ops	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
Survey									
96	25	0	1	2	*	*	20	5	1
98	30	1	1	2	4	100	10	2	0
100	5	1	0	1	200	5	20	3	0
104	50	0	1	3	250	80	250	0	0
106	20	0	1	2	*	*	*	*	0
108	100	0	1	1	1000	50	20	10	0
110	30	1	0	2	*	*	*	0	1
112	30	1	1	1	100	90	300		0
116	40	1	0	1	20	90	3	0	0
118	40	0	0	4	280	5	30	0	1

*missing or unclear data

Table 25.

Correlation analysis of validation data as related to student co-ops

	Co-ops	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Co-ops	1.0000								
Prof.	.1157	1.0000							
Un. Size	.2905	.0514	1.0000						
Classes	–.0318	–.1603	–.3603	1.0000					
Fir. Size	.8149	.1975	.2548	-.1161	1.0000				
Skill	.0285	.1145	.2269	.0428	–.1137	1.0000			
Distan.	–.0914	.2359	–.0523	–.2403	.0108	–.1562	1.0000		
Capac.	.1133	.0984	.1085	–.0995	–.1605	.4096	–.2403	1.0000	
Formal	.3503	.1347	–.2994	.3554	.2700	–.0375	–.0561	.2473	1.0000

Table 26.

Validation data for student co-ops

Survey	Co-ops	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
2	20	0	0	4	500	10	10	1	0
4	10	1	1	2	1000	50	*	3	0
6	60	1	1	2	5000	10	200	0	0
8	3	1	1	2	400	4	*	5	0
10	29	0	0	4	*	*	*	0	0
12	6	1	1	2	1000	50	*	2	1
14	36	1	0	3	400	75	20	12	1
16	20	1	1	3	2000	50	75	0	0
18	300	1	1	2	71000	20	30	0	1
20	200	0	1	2	25000	40	*	0	0
24	20	1	1	3	1000	50	500	5	0
26	4	0	1	2	10000	*	200	0	0
30	9	0	0	3	400	10	50	0	0
32	25	1	1	2	*	10	2000	0	0
36	30	1	1	2	2000	50	*	0	0
38	10	1	1	2	5000	*	*	4	1
40	15	1	0	3	100	2	100	5	1
42	10	1	0	2	100	10	80	5	0
44	15	0	4	2	*	*	*	0	1

*missing or unclear data

Table 26.

Continued

Survey	Co-ops	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
46	30	1	0	1	8000	20	2000	0	1
48	15	1	0	4	*	*	*	2	1
54	10	0	0	4	2	50	70	0	1
56	100	1	0	3	100	20	1500	0	0
58	4	1	1	2	10000	50	750	0	0
60	5	1	1	2	*	*	*	0	0
64	40	1	0	3	150	1	15	0	1
66	125	0	0	3	*	*	*	0	1
70	10	1	1	2	100	10	500	0	0
72	10	1	1	0	10000	10	850	0	0
76	50	0	1	0	100	2	75	5	0
78	100	1	1	2	100	90	25	25	1
80	2	0	1	2	300	10	*	0	0
84	25	0	1	1	2000	10	500	0	0
90	100	0	1	2	*	*	*	0	0
92	125	1	1	3	4000	15	50	0	1
96	25	0	1	2	*	*	20	5	1
98	30	1	1	2	4	100	10	2	0

*missing or unclear data

Table 26.

Continued

	Co-ops	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
Survey									
100	5	1	0	1	200	5	20	3	0
104	50	0	1	3	250	80	250	0	0
106	20	0	1	2	*	*	*	*	0
108	100	0	1	1	1000	50	20	10	0
110	30	1	0	2	*	*	*	0	1
112	30	1	1	1	100	90	300	*	0
116	40	1	0	1	20	90	3	0	0
118	40	0	0	4	280	5	30	0	1

*missing or unclear data

Table 27.

Correlation analysis of validation data related to student co-ops

	Co-ops	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Co-ops	1.0000								
Prof.	.1157	1.0000							
Un. Size	.2905	.0514	1.0000						
Classes	–.0318	–.1603	–.3603	1.0000					
Fir. Size	.8149	.1975	.2548	-.1161	1.0000				
Skill	.0285	.1145	.2269	.0428	–.1137	1.0000			
Distan.	–.0914	.2359	–.0523	–.2403	.0108	–.1562	1.0000		
Capac.	.1133	.0984	.1085	–.0995	–.1605	.4096	–.2403	1.0000	
Formal	.3503	.1347	–.2994	.3554	.2700	–.0375	–.0561	.2473	1.0000

Table 28.

Model-building data for employee training activities

Survey	Employ. Train.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
6	1	1	1	2	5000	10	250	0	0
10	5	0	0	4	*	*	250	0	0
12	3	1	1	2	1000	50	500	2	1
14	2	1	0	3	400	75	20	12	1
16	1	1	1	3	2000	50	250	0	0
18	2	1	1	2	71000	20	250	0	1
20	1	0	1	2	25000	40	2500	0	0
24	10	1	1	3	1000	50	200	5	0
28	2	1	1	2	1000	60	*	0	0
32	12	1	1	2	*	10	2000	0	0
38	3	1	1	2	5000	*	2000	4	1
52	10	1	1	2	*	*	1500	0	0
56	2	1	0	3	100	20	120	0	0
58	20	1	1	2	10000	50	1500	0	0
64	1	1	0	3	150	1	50	0	1
68	2	1	1	1	2	100	300	3	1
76	2	0	1	0	100	2	50	5	0
78	1	1	1	2	100	90	25	25	1

*missing or unclear data

Table 28.

Continued

Survey	Employ. Train.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
80	1	0	1	2	300	10	50	0	0
82	4	1	1	1	1000	40	20	0	0
84	3	0	1	1	2000	10	500	0	0
86	2	1	1	2	50	50	*	*	*
88	1	0	1	1	5000	20	500	0	0
92	2	1	1	3	7000	15	30	0	1
94	2	0	1	1	24	20	300	*	*
98	3	1	1	2	4	100	300	2	0
100	2	1	0	1	200	5	5	3	0
102	2	1	1	2	2000	10	3000	4	0
108	1	0	1	1	1000	50	10	10	0
112	6	1	1	1	100	90	*	*	0
116	1	1	0	1	20	90	3	0	0
118	4	0	0	4	280	5	30	0	1
120	5	0	1	1	3000	20	3000	0	0

*missing or unclear data

Table 29.

Correlation analysis of model-building data related to employee training

	Employ. Train.	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Employ.	1.0000								
Prof.	.1157	1.0000							
Un. Size	.2905	.0514	1.0000						
Classes	–.0318	–.1603	–.3603	1.0000					
Fir. Size	.8149	.1975	.2548	-.1161	1.0000				
Skill	.0285	.1145	.2269	.0428	–.1137	1.0000			
Distan.	–.0914	.2359	–.0523	–.2403	.0108	–.1562	1.0000		
Capac.	.1133	.0984	.1085	–.0995	–.1605	.4096	–.2403	1.0000	
Formal	.3503	.1347	–.2994	.3554	.2700	–.0375	–.0561	.2473	1.0000

Table 30.

Validation data for employee training activities

Survey	Employ. Train.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
5	2	0	0	3	2500	*	2000	5	0
7	2	1	0	3	300	*	3	0	0
9	3	0	1	1	*	*	*	0	0
15	6	1	1	2	5000	50	25	0	1
17	2	0	0	4	*	*	*	5	1
25	2	1	1	1	25000	20	*	0	1
29	1	0	0	2	100	20	100	0	1
33	1	0	0	3	4	100	*	0	1
41	15	1	0	2	*	10	500	0	1
43	2	1	0	3	600	20	2000	5	1
55	2	1	1	1	*	30	1500	0	0
57	3	1	1	2	40	25	500	4	0
59	1	1	1	2	2000	50	1000	0	0
63	3	1	1	1	3000	10	300	2	0
65	2	0	1	1	*	*	*	0	0
71	10	0	1	1	2500	25	200	0	1
73	1	1	1	2	20	20	*	0	*
75	4	0	1	1	100	80	7000	20	0

*missing or unclear data

Table 30.

Continued

Survey	Employ. Train.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
81	4	1	1	1	1000	40	20	0	0
87	2	1	0	3	300	20	100	0	0
89	6	0	1	2	50000	*	5000	*	0
91	2	0	0	3	22000	33	40	*	*
93	1	1	0	1	1000	20	200	0	1
95	1	0	1	2	*	*	600	0	0
107	1	1	1	0	10	0	3000	2	0
113	5	0	1	1	4500	50	*	*	*

*missing or unclear data

Table 31.

Model-building data for university facility use

Survey	Univ. Facil.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
6	1	1	1	2	5000	10	250	0	0
14	12	1	0	3	400	75	20	12	1
18	10	1	1	2	5000	10	250	0	1
20	3	0	1	2	25000	40	2500	0	0
24	2	1	1	3	1000	50	200	5	0
36	3	1	1	2	2000	50	200	0	0
40	3	1	0	3	100	2	30	5	1
44	2	0	1	2	*	*	*	0	1
58	10	1	1	2	10000	50	1500	0	0
64	50	1	0	3	150	1	50	0	1
80	2	0	1	2	300	10	50	0	0
92	20	1	1	3	7000	15	30	0	1
94	1	0	1	1	25	20	300	*	*
98	6	1	1	2	5	100	300	2	0
100	1	1	0	1	200	5	5	3	0
102	1	1	1	2	2000	10	3000	4	0
108	10	0	1	1	1000	50	10	10	0
116	2	1	0	1	20	90	3	0	0
118	2	0	0	4	280	5	30	0	1

*missing or unclear data

Table 32.

Correlation analysis of model-building data related to university facility use

	Univ. Facil.	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Facil.	1.0000								
Prof.	.1842	1.0000							
Un. Size	−.2251	−.1195	1.0000						
Classes	.2851	−.0101	−.2424	1.0000					
Fir. Size	.0135	.0239	.3119	-.0923	1.0000				
Skill	−.1747	.1441	.1103	−.3041	−.1082	1.0000			
Distan.	−.1866	−.0974	.3842	−.1290	.1606	−.0520	1.0000		
Capac.	−.0624	−.0135	−.1875	−.0130	−.2605	.2662	−.1079	1.0000	
Formal	.5104	.1195	−.4848	.7002	.2506	−.3488	−.3469	.0875	1.0000

Table 33.

Validation data for university facility use

Survey	Univ Facil.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
3	2	1	0	4	*	*	25	0	0
7	2	1	0	3	300	*	3	0	0
11	2	1	1	1	8000	25	*	0	0
15	1	1	1	2	5000	50	25	0	1
21	5	1	0	3	1000	0	0	3	1
33	1	0	0	3	4	100	*	0	1
49	1	1	0	2	*	*	*	0	0
57	2	1	1	2	40	25	500	4	0
63	6	1	1	1	3000	10	300	2	0
71	2	0	1	1	2500	25	200	0	1
75	1	0	1	1	100	80	7000	20	0
81	3	1	1	1	*	*	500	*	0
93	1	1	0	1	1000	20	200	0	1
101	2	1	1	2	200	10	*	10	0
103	5	0	1	2	1000	40	1500	0	1
107	2	1	1	0	10	0	3000	2	0

*missing or unclear data

Table 34.

Correlation analysis of validation data related to university facility use

	Univ. Facil.	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Facil.	1.0000								
Prof.	.1157	1.0000							
Un. Size	.2905	.0514	1.0000						
Classes	–.0318	–.1603	–.3603	1.0000					
Fir. Size	.8149	.1975	.2548	-.1161	1.0000				
Skill	.0285	.1145	.2269	.0428	–.1137	1.0000			
Distan.	–.0914	.2359	–.0523	–.2403	.0108	–.1562	1.0000		
Capac.	.1133	.0984	.1085	–.0995	–.1605	.4096	–.2403	1.0000	
Formal	.3503	.1347	–.2994	.3554	.2700	–.0375	–.0561	.2473	1.0000

Table 35.

Model-building data for industry facilities use

Survey	Firm Facil.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
12	4	1	1	2	1000	50	500	2	1
14	1	1	0	3	400	75	20	12	1
18	48	1	1	2	71000	20	250	0	1
24	6	1	1	3	1000	50	200	5	0
28	1	1	1	2	1000	60	*	0	0
56	1	1	0	3	100	20	120	0	0
58	1	1	1	2	10000	50	1500	0	0
78	1	1	1	2	100	90	25	25	1
82	4	1	1	1	1000	40	20	0	0
100	1	1	0	1	200	5	5	3	0
108	2	0	1	1	1000	50	10	10	0
112	2	1	1	1	100	90			0

*missing or unclear data

Table 36.

<u>Correlation analysis of model-building data related to industry facilities use</u>

	Firm Facil.	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Visits	1.0000								
Prof.	.1183	1.0000							
Un. Size	.2799	–.2182	1.0000						
Classes	.0094	.4303	–.2817	1.0000					
Fir. Size	.9809	.1203	.2602	-.0043	1.0000				
Skill	–.3415	–.0686	.3144	..2657	–.3351	1.0000			
Distan.	–.0218	.1942	.3240	.0900	.1171	.0303	1.0000		
Capac.	–.2804	–.1879	.0601	.0677	–.2879	.7824	–.3630	1.0000	
Formal	.3904	..2722	.0891	..2635	.3712	.4622	–.1236	.4334	1.0000

Table 37.

Validation data for firm facilities use

Survey	Firm Facil.	Prof.	Univ. Size	Classes	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
15	12	1	1	2	5000	50	25	0	1
29	2	0	0	2	100	20	100	0	1
43	1	1	0	3	600	20	2000	5	1
63	6	1	1	1	3000	10	300	2	0
81	1	1	1	2	*	*	*	0	0
85	15	1	1	2	*	*	*	0	0
101	1	1	1	2	200	10	*	10	0

*missing or unclear data

Table 38.

Correlation analysis of validation data related to industry facility use

	Firm Facil.	Prof.	Univ. Size	Classes Taught	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Facil.	1.0000								
Prof.	.4341	1.0000							
Un. Size	.8675	.5774	1.0000						
Classes	–.4089	–.0000	–.7071	1.0000					
Fir. Size	.9748	.6096	.9287	-.4318	1.0000				
Skill	.7518	.1925	.3333	.2357	.6488	1.0000			
Distan.	–.6013	.3604	–.5472	.7412	–.4768	–.2954	1.0000		
Capac.	–.5582	.4937	–.3665	.5183	–.3870	–.4480	.9576	1.0000	
Formal	–.1002	–.3333	–.5774	.8165	–.2424	.5774	.2180	–.0705	1.0000

APPENDIX D

INDUSTRY DATA TABLES

Table 39.

Industry aggregate data for size of research grants and contracts

Survey	Dollar	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
3	50000	0	0	25	150	10	150	0	0
23	25000	0	1	13	200	35	40	1	1
26	50000	0	1	50	5600	65	60	50	1
33	500000	0	1	50	5600	65	60	50	1
37	20000	0	1	1	625	10	20	0	1
60	25000	1	0	10	180	25	500	10	1

Table 40.

Correlation analysis of industry aggregate data related to the size of research grants and contracts

	Dollar	Prof.	Univ. Size	R&D	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Dollar	1.0000								
Prof.	–.2629	1.0000							
Un. Size	.3751	–.6124	1.0000						
R&D	.9135	–2893	.1109	1.0000					
Fir. Size	.9925	–.2747	.4543	.8586	1.0000				
Skill	.8728	–.0983	.4615	.7799	.8639	1.0000			
Distan.	–.2621	.9686	–.7817	–.1954	–.3001	–.1557	1.0000		
Capac.	.9762	–.0571	.3051	.8609	.9717	.9008	–.0787	1.0000	
Formal	.1965	.2500	.6124	–.1535	.2817	.4669	.0112	.3165	1.0000

Table 41.

Industry aggregate data for consultations

Survey	Consult.	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
1	4	0	0	10	6	50	10	0	1
3	1	0	0	25	150	10	150	0	0
6	2	0	1	*	2	100	25	0	0
8	2	0	1	10	15	90	12	0	0
10	5	0	1	17	260	80	15	3	0
14	10	0	1	3	500	0	25	5	1
15	10	1	1	10	21	80	5	0	1
16	2	0	1	20	10	50	5	0	0
19	6	0	1	5	250	3	25	0	1
21	1	1	0	*	1000	10	20	0	1
22	4	0	0	2	2	100	4	0	0
23	1	0	1	13	200	35	20	1	1
24	5	1	1	40	5	80	95	1	1
28	3	1	1	6	30	10	50	0	1
29	100	0	1	0	15	80	15	0	0
30	5	1	1	15	20	70	*	2	1
33	1200	0	1	50	5600	65	30	50	1
35	2	1	1	*	5	60	35	0	0

*missing or unclear data

Table 41.

Continued

Survey	Consult.	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
37	2	1	1	1	625	10	*	0	1
43	2	0	1	1	35	50	*	0	1
44	4	1	1	0	2	100	*	0	*
45	5	0	1	*	170	7	25	0	1
46	2	0	1	4	237	67	75	0	1
48	2	1	0	*	140	25	5	0	1
49	15	1	1	*	8000	7	15	0	1
50	2	*	1	*	2000	35	25	0	1
52	5	0	0	0	250	4	3	3	1
54	4	0	1	1	1100	5	700	0	1
56	15	1	1	*	5	80	*	0	0
57	10	0	0	3	5	40	1	2	1
60	2	1	0	10	180	25	500	10	1
61	3	0	1	18	200	30	20	0	0

*missing or unclear data

Table 42.

Correlation analysis of industry aggregate data related to consultations

	Consult	Prof.	Univ. Size	R&D	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Consult	1.0000								
Prof.	–.1228	1.0000							
Un. Size	.1625	.0546	1.0000						
R&D	.6478	.1602	.2030	1.0000					
Fir. Size	.9733	–.1576	.1848	.6128	1.0000				
Skill	.1592	.0546	.1416	.2384	.0246	1.0000			
Distan.	–.0850	.2101	–.0862	–.1073	.0726	–.3514	1.0000		
Capac.	.9701	–.0460	.0752	.6381	.9610	.0787	.0051	1.0000	
Formal	.1472	.3669	–.0229	–.0449	.2123	–.3984	.2336	.2240	1.0000

Table 43.

Industry aggregate data related to student co-ops

Survey	Co-ops	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
1	2	*	0	10	6	50	*	0	1
3	2	0	0	25	150	10	150	0	0
6	2	*	1	*	2	100	*	0	0
8	2	0	1	10	15	90	*	0	0
10	6	*	1	17	240	80	*	3	0
14	15	0	1	3	500	0	*	5	1
16	1	*	1	20	10	50	*	0	0
17	1	*	0	0	850	3	*	0	0
19	2	*	1	5	250	3	*	0	1
21	2	1	0	*	1000	10	*	0	1
22	1	*	0	2	2	100	*	0	0
23	1	0	1	13	200	25	40	1	1
33	100	0	1	50	5600	65	60	50	1
42	10	1	1	*	*	*	*	0	1
45	2	*	1	*	170	7	*	0	1
48	*	*	0	*	140	25	*	0	1
49	12	1	1	*	8000	7	*	0	1

*missing or unclear data

Table 43.

Continued

	Co-ops	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
Survey									
50	10	*	1	*	2000	35	*	0	1
52	3	*	0	0	250	4	*	3	1
54	6	*	1	1	1100	5	*	0	1
60	7	1	0	10	180	25	500	10	1
61	10	0	1	18	200	30	*	0	0
62	3	*	0	*	206	25	*	*	1

*missing or unclear data

Table 44.

Correlation analysis of industry aggregate data related to student coops

	Co-ops	Prof.	Univ. Size	R&D	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Co-ops	1.0000								
Prof.	–.2823	1.0000							
Un. Size	.5487	–.5774	1.0000						
R&D	.9228	–.5313	.4443	1.0000					
Fir. Size	.9985	–.3325	.5823	.9321	1.0000				
Skill	.8946	–.2511	.8078	.7079	.9002	1.0000			
Distan.	–.3475	.9746	–.7428	–.5233	–.3984	–.4036	1.0000		
Capac.	.9903	–.1483	.5015	.8684	.9819	.8977	–.2245	1.0000	
Formal	.3512	.3333	.5774	–.0183	.3399	.6816	.1170	.4308	1.0000

Table 45.

Industry aggregate data related to employee training

Survey	Employ. Train.	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
1	2	0	0	10	6	50	10	0	1
3	10	0	0	25	150	10	150	0	0
6	0	0	1	*	2	100	25	0	0
8	25	0	1	10	15	90	12	0	0
10	10	0	1	17	240	80	15	3	0
14	20	0	1	3	500	0	25	5	1
16	10	0	1	20	10	50	5	0	0
17	25	*	0	0	850	3	40	0	0
19	3	0	1	5	250	3	25	0	1
21	15	1	0	*	1000	10	20	0	1
22	98	0	0	2	2	100	4	0	0
23	2	0	1	13	200	35	20	1	1
33	75	0	1	50	5600	65	30	50	1
42	0	1	1	*	*	*	1	0	1
45	7	0	1	*	170	7	25	0	1
48	20	1	0	*	140	25	5	0	1
49	15	1	1	*	8000	7	15	0	1

*missing or unclear data

Table 45.

Continued

Survey	Employ. Train.	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
50	2	*	1	*	2000	35	25	0	1
52	5	0	0	0	250	4	3	3	1
54	1	0	1	1	1100	5	700	0	1
60	8	1	0	10	180	25	500	10	1
61	10	0	1	18	200	30	20	0	0
62	2	0	0	*	206	25	*	*	1

*missing or unclear data

Table 46.

Correlation analysis of industry aggregate data related to technical training

	Employ. Train.	Prof.	Univ. Size	R&D	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Employ.	1.0000								
Prof.	–.1170	1.0000							
Un. Size	–.1231	–.3721	1.0000						
R&D	.3065	–.0691	.2212	1.0000					
Fir. Size	.4810	–..0870	.2670	.7472	1.0000				
Skill	.6218	–.1182	.0287	.2635	.1103	1.0000			
Distan.	–.2447	.5240	–.0896	–.2080	.0337	–.3664	1.0000		
Capac.	.5037	.1057	.1487	.7699	.9607	.1654	–.0301	1.0000	
Formal	–.2216	.2402	–.0430	–.1504	.3193	–.5491	.3100	.3155	1.0000

Table 47.

Industry aggregate data related to university facility use

Survey	Univ. Facil.	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
2	10	*	1	*	12	90	*	0	1
3	10	0	0	25	150	10	150	0	0
5	25	0	1	*	4	75	6	0	1
8	10	0	1	10	15	90	12	0	0
9	2	*	1	20	60	25	*	5	1
11	10	*	1	8	5	75	*	1	1
12	1	*	0	20	34	24	*	0	1
13	1	*	1	*	85	25	*	0	0
14	10	0	1	3	500	0	25	5	1
15	10	1	1	10	21	80	5	0	0
16	10	0	1	20	10	50	5	0	0
21	1	1	0	*	1000	10	20	0	1
22	98	0	0	2	2	100	4	0	0
23	1	0	1	13	200	35	20	1	1
28	2	1	1	6	30	10	50	0	1
30	10	1	1	15	20	80	*	2	1

*missing or unclear data

Table 47.

Continued

	Univ. Facil.	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
Survey									
32	25	*	0	1	8	90	*	0	1
33	15	0	1	50	5600	65	30	50	1
35	20	1	1	*	5	60	35	0	0
37	2	1	1	1	625	10	*	0	1
38	1	*	1	*	1000	5	*	*	0
39	1	*	0	1	900	10	*	0	1
41	1	*	1	0	60	20	*	0	0
42	2	1	1	*	*	*	1	0	1
43	10	0	1	1	35	50	*	0	1
45	25	0	1	*	170	7	25	0	1
46	4	0	1	4	27	67	75	0	1
47	1	*	0	2	200	10	*	0	1
48	5	1	0	*	140	25	5	0	1
50	1	*	1	*	2000	35	25	0	1
52	2	0	0	0	250	4	3	3	1
54	1	0	1	1	1100	5	700	0	1

*missing or unclear data

Table 47.

Continued

Survey	Univ. Facil.	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
55	1	*	0	0	60	20	*	0	0
56	20	1	1	*	5	80	*	0	0
58	40	1	0	*	5	60	*	0	0
59	1	0	0	0	35	20	100	0	*
60	5	1	0	10	180	25	500	10	1
61	1	0	1	18	200	30	20	0	0
62	2	0	0	*	206	25	*	*	1

*missing or unclear data

Table 48.

Correlation analysis of industry aggregate data related to university facility use

	Univ. Facil.	Prof.	Univ. Size	R&D	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Facil.	1.0000								
Prof.	–.1546	1.0000							
Un. Size	–.4200	–.0550	1.0000						
R&D	–.1080	–.1484	.1508	1.0000					
Fir. Size	–.0245	–.1897	.1992	.7654	1.0000				
Skill	.5609	–.0386	.1150	.1627	.0872	1.0000			
Distan.	–.2023	.1800	–.1541	–.1945	.0317	–.3857	1.0000		
Capac.	–.0059	–.0651	.0829	.7798	.9622	.1232	–.0333	1.0000	
Formal	–.4035	.3892	.1886	–.1589	.2716	–.3417	.2759	.2869	1.0000

Table 49.

Industry aggregate data for firm facility use

Survey	Firm Facil.	Prof.	Univ. Size	R&D	Firm Size	Prop. of Skilled	Dist.	Capac.	Form
1	3	0	0	10	6	50	10	0	1
4	5	*	0	*	30	50	*	*	0
12	1	*	0	20	34	24	*	0	1
14	50	0	1	3	500	0	25	5	1
22	4	0	0	2	2	100	4	0	0
33	98	0	1	50	5600	65	60	50	1
52	2	0	0	0	250	4	3	3	1
54	1	0	1	1	1100	5	700	0	1

*missing or unclear data

Table 50.

Correlation analysis of industry aggregate data related to industry facility use

	Firm Facil.	Prof.	Univ. Size	R&D	Size of Firm	Prop. of Skilled	Dist.	Capac.	Formal
Firm	1.0000								
Prof.	*	1.0000							
Un. Size	.6401	*	1.0000						
R&D	.8637	*	3946	1.0000					
Fir. Size	.8735	*	.5832	9502	1.0000				
Skill	.1264	*	–.3741	.3743	.2078	1.0000			
Distan.	–.2751	*	.4810	–.2245	–.0027	–.3912	1.0000		
Capac.	.9148	*	.4779	.9724	.9782	.2693	–.2095	1.0000	
Formal	.2740	*	.4472	.2269	.2798	–.7489	.2180	.2384	1.0000

* no variance in the variable

VITA

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