J Knowl Econ (2010) 1:48–66
DOI 10.1007/s13132-009-0004-9

Assessing the Value of Regional Innovation Networks

Mary G. Schoonmaker · Elias G. Carayannis

Received: 20 May 2009 / Accepted: 20 December 2009 /
Published online: 13 February 2010

Abstract This paper investigates how regional innovation networks can assist the development of innovations to commercialization. We argue that the inventors and innovating firms who engage in these regional innovation networks are more likely to have advanced toward a commercialized product than if they did not engage with the network. Building upon regional cluster and innovation network theories, we plan to develop an evaluative model in order to examine how the dynamics among factors have punctuated innovation and regional economic growth. The benefits to be gained from this project are insights into innovation investment, policy, and business strategies. We will focus on the innovation network in the State of Maryland as it exhibits a combination of academia, government, and industry factors in a regional cluster. The key research questions to be addressed are: what regional innovation networks factors contribute to sector innovation and commercialization, defined as the first stage of diffusion, which regional factors are the best predictors of innovation success, and what is the definition of success.

Keywords Biotechnology · Information and communication technologies · Regional innovation networks · Technology transfer and commercialization · Intangible assets · Risk capital

Background

Regions depend on innovation as a source of economic sustainability and growth. Innovations must be commercialized to contribute to the local economy. As such, regions need to create processes that foster innovation and shepherd the early stages of an innovation's diffusion. In this context, we will research empirically how "value", defined as increased sector revenues and jobs, is created through regional innovation networks. Regional innovation networks are best characterized by

M. G. Schoonmaker · E. G. Carayannis (✉)
The George Washington University, School of Business, Washington, DC, USA
e-mail: caraye@gwu.edu

collaboration among academia, government, and industry for the purposes of fostering and accelerating innovation. The focus and purpose of these networks is to drive economic development through increased commercialized innovation, derived from internal or external research and development (R&D), financial resources, and other support programs. Typically, regional clusters/innovation networks represent competitive environments and market concentration.

Different types of regional innovation networks have been deployed. Ranging from technology parks, learning cities, regional systems, and national ecosystems, each of these types of networks includes regional actors and a sponsoring mechanism that drives the innovation processes toward success, which is defined as has been above, increased revenues and jobs. In addition to the diversity of styles of regional innovation networks, what is not evident from the literature on regional cluster/innovation networks is an evaluative model.

Building upon regional cluster and innovation network theories, we plan to develop a quantitative model in order to examine how the dynamics among factors have punctuated innovation and economic growth. The specific focus will be on meso-level factors as these will serve as the foundation for the model. We selected to research the state of Maryland as it exhibits the theoretical factors we wish to model. This region tends to be a source of extensive research and development, has access to public and private funding, and engages with technology transfer networks and academia. We will primarily focus on incubator participants in the Biotech and information communication and technology (ICT) sectors, as these industries generally exemplify characteristics that include intellectual property (IP) and start-up funding.

This project will elucidate the network competency factors and their associated weights and combinations for regional innovation network actors—academia, government, and industry. The benefits to be gained from this project are insights into innovation investment, policy, and business strategies.

The paper begins with a literature review that covers regional innovation network theories. We will include in this review incubator research as incubators can be characterized as having regional innovation networks elements. Then, we will propose a regional innovation network value framework. After an explanation about the methods and procedures employed in the study, we will discuss the findings. In the final section, we will present the implications for theory, limitations, and potential future empirical work.

Literature review

Atkinson and Castro [2] reported that economists see technological innovation as the key to higher standards of living as well as maintaining a nation's comparative advantages in the global economy. The Organisation for Economic Co-operation and Development [OECD] [29] explained that innovation of technology was one of the key drivers of productivity growth across the "new" economy in the USA. Even dating back to Schumpeter [35], sources of innovation activity, both major and incremental, are found in competitive environments and market concentration. The economic challenge is how to foster national and regional innovation and its ultimate success—product commercialization and diffusion. As stated by Clark and Li [11], the new economy requires government to "provide guidance…to stimulate business and economic growth through investment" (p. 1). Government policies are needed to foster both invention and innovation, simultaneously acting as supply and demand market forces.

Regional clusters/innovation networks represent competitive environments and market concentration. According to OECD [27, 28], many governments have embraced regional clusters as a method for developing regional innovation, growth, and global competiveness. Porter et al. [30] defined a regional network as "an agglomeration of companies, suppliers, service providers, and associated institutions in a particular field...linked by externalities and complementarities…usually located near each other" (p. 1). Carayannis and Wang [8] stated that "the features of a cluster are shaped by the cluster's organizational structure, geographic scope, density, breadth and depth as well as the special characteristics of population, culture, and technology" (p. 3). At the most elemental level, the basic component for success is a regional economic development plan, created by the local network actors, namely academia, enterprises, and government. Dzisah and Etzkowitz [13] proclaimed that the triple helix interaction of academia, business/industry, and government drives regional development. "The triple helix model...[defines] a more prominent role for the university in innovation…[and the] movement towards collaborative relationships among the three major institutional spheres (Dzisah and Etzkowitz, p. 103). Carayannis and Campbell [9] extended the triple helix to a quadruple helix, which theorizes that local culture impacts knowledge sharing and innovation. This is an important network dimension to be included when evaluating the dynamics of collaboration among the three actors—academia, business/industry, and government. "Networks emphasize interaction, connectivity, and mutual complementarity and reinforcement" (Carayannis and Campbell, p. 204). The rationale and relationships between elements of the system are what comprises innovation networks (Carayannis and Campbell).

Christensen and Rosenbloom [10] argued a similar point, by advancing the traditional studies about the characteristics of the technological changes, material processes, and organizational dynamics with a third factor—the value network. "A key determinant of the probability of commercial success of an innovative effort is the degree to which it addresses the well-understood needs of known actors within the value network in which an organization is positioned" (Christensen and Rosenbloom, p. 255). A network is interaction and linkages.

Regional clusters represent a dynamic system, comprised of factors that facilitate innovation. The challenge for a regional innovation network is how to optimize fostering and accelerating innovation. Komninos [19] wrote that a regional cluster system of innovation includes the following components: (1) technology transfer organization, (2) innovation financing, (3) public/private R&D and universities research institutes, and (4) technological information system. This model demonstrates the interaction among industry and institutions, which is managed by a technology transfer organization. When researching Silicon Valley's success, Cooke [12] explained the critical regional cluster elements found are: (1) basic research, knowledge generation, and application capabilities, (2) venture capital funding and other support services, and (3) a local value chain. This model utilizes market efficiency dynamics among the financial resources and the inventors/innovators. Campbell [5] noted that competitive regions typically operate within knowledge networks, where "local knowledge, learning, and creativity are accepted as parts of the software infrastructure of city regions" (p. 8). This model invokes more of a knowledge sharing and virtual infrastructure that can be built within a metropolis. These different types of regional innovation networks have created something greater than the sum of the parts, which, in essence, is the value of the system.

All of the above theories and studies point to several factors and interactions among factors that comprise regional innovation networks, which will be explored in the proposed study. According to Arthurs et al. [1], "Despite the fascination with clusters in both academic and policy circles, key aspects of the concept remain highly disputed. The rush to employ clusters has run ahead of many conceptual, theoretical, and empirical issues" (p. 265). In addition to the models mentioned above, additional models have emerged based upon different geographic and industry deployments. For example, Komninos [20] discussed several different models that have evolved over the past two decades: technology parks and districts, learning regions and regional innovation systems, and intelligent cities and regions. Another example of the differences is explained by Dzisah and Etzkowitz [13], who wrote that in developed countries the regional innovation networks are empirical; in developing countries the networks are normative.

In addition to the diversity of styles of regional innovation networks, what is not evident from literature on regional cluster/innovation networks is a quantitative, evaluative model. Many of the theoretical models are qualitative. For example, Rogers et al. [33] researched regional innovation networks via case studies. The goal of these case studies was to qualitatively describe the mechanisms for technology transfer between federal R&D laboratories and private companies. In addition, successful models in Japan and Germany were discussed. One of the key findings from this study was the identification of knowledge transfer support as a mechanism to take the innovation toward commercialization (Rogers et al.). Komninos [20] has used empirical case studies to depict the different modes of regional innovation networks. Each of the case studies depicts the key actors and attributes that are the essential ingredients in the particular network. Another example is Porter et al. [30], who have extended their regional cluster theory into a regional development consulting practice. The learnings from these regional deployments have been captured in case studies and success stories as well as a business competitive evaluation tool. The case studies elucidate the findings from successful regional cluster economic development models. Each of the examples follows the Porter et al. cluster for competitiveness model, which is a derivative of Porter's competitive and comparative theories. The Business Competitive Index (BCI) ranks the quality of a nation's business environment, company operations and strategy ranking, and GDP per capita (Porter et al.). The analysis that supported the BCI included 127 countries and provided an assessment of, through econometric techniques, the value of the particular country's economic development network.

What we did find was an array of studies on business incubators that outlined factors and models that encompass the innovation processes that are a subset of regional innovation networks. In particular, incubator programs typically include the key actors in a regional innovation network: academia, government, and industry.

Unique to incubators are the micro-network elements that function among the actors during the initial product development phases. These elements can be codified and modeled using quantitative and qualitative information. Bergek and Norrman [4] proposed a framework to evaluate incubators. This framework includes four categorical inputs: "shared office space, a pool of shared support services, profession business support or advice, and network provisions, internal and/or external" (Bergek and Norrman, p. 21). Hackett and Dilts [17] outlined a similar model that encompassed five elements: selection, infrastructure, business support, mediation, and graduation. What is important about the above two models is that "the primary valued-added feature of networked incubators is the set of institutionalized processes that carefully structure and transfer knowledge throughout the incubator network in order to create condition that facilitate the development of incubates and the commercialization of their innovations" (Hackett and Dilts, p. 70). Within the diverse set of regional innovation models that have been developed to date, there is theoretical acknowledgement by practitioners and scholars that the combinations leading to success are difficult to model and predict.

Research hypotheses

The research questions of interest are as follows:

- What regional innovation networks factors contribute to sector innovation and commercialization, defined as the first stage of diffusion?
- Which regional factors are the best predictors of innovation success?
- What is the definition of success?

We have captured the main elements in the regional innovation network. The predictor factors are the incubator programs, the financing options, and the source of IP. The dependent factor is the network value as measured by increased jobs, increased payroll, and positive revenues all of which amount to tax revenues for the region.

Value of incubator programs

According to the National Business Incubator Association (NBIA) [25], incubator program services have delivered $17 billion in revenues and supported 100,000 jobs for 27,000 companies in 2005 in the U.S.A. The average revenue per participant is $645,824 (NBIA). In this study, the highest value and return on investment programs are linkages to academia, linkages to strategic partners, funding, technology commercialization assistance, and management team identification. In terms of quantitative results, as measured by NBIA, there is an indication of positive association between the incubator programs and the creation of revenues and jobs.

The importance of access to low-cost or free resources alleviates start-up fixed and/or variable costs. The incubator adds resources to the organization without incurring costs and provides access to the latest knowledge in order to develop an innovation [23]. What this translates to for incubator participating firms is the possibility of generating positive revenues quickly without a portion of the traditional overhead costs. McAdam and McAdam demonstrated in their qualitative study on support programs for start-ups that engagement with resources and support increases as the firm advances through the early lifecycle phases.

The third research contribution comes from Cooperative Research and Development Agreements (CRADAs) technology transfer case studies conducted by Rogers et al. [33]. The survey focused on communication and education transfer activities as well as source of invention. As these studies were qualitative, they would be difficult to replicate and also, generalize. However, the communication and education variables helped reinforce the predictor variables included in our model.

Bergek and Norrman [4] concluded that among the best practices by incubators, if there was alignment between goals and outcomes, there was a higher probability of success. Also, an important finding was that programs varied by sector and region (Bergek and Norrman). This means that the incubator programs are customized or designed to fit the regional context.

The research hypothesis is to understand the positive relationship between the incubator program and its clients' contributions to the regional economic growth. It is expected to be positive even with some fairly high attrition rates. The key discovery will be the understanding of the weights for each of the programs. This will help us understand the combination of incubator programs that help predict success.

Hypothesis 1a: Regional/sector growth is positively attributed to regional incubator infrastructure programs.

Hypothesis 1b: Regional/sector growth is positively attributed to regional incubator professional support programs.

Hypothesis 1c: Regional/sector growth is positively attributed to regional incubator linkages programs.

Value of financing

During the initial stages of a company's life cycle, securing capital and talent is critical to survival. Cash flow is critical during the product development stage, often being called "the valley of death" ([6], p. 10). As exhibited by Maryland's incubator clients, obtaining financing was one of their highest priorities (The Maryland Technology Development Corporation (TEDCO) [36, 37]). Public and private financing options exist in many forms, such as federal or state grants, angel funding, and venture capital funding. The challenge for a start-up is how to discover and secure the financial resources. The Silicon Valley regional innovation network model demonstrates efficient access to working capital and talent [12]. In this particular and somewhat unique model, government was less involved (Cooke). In the late 1990s up through 2001, the venture capital financiers of Sand Hill/Silicon Valley had an abundance of funds along with an abundant supply of probable innovations. The network was well connected in terms of market demand and supply forces (Cooke).

This hypothesis seeks to understand the role of other non-incubator activities, namely financing options that are complementary to the incubator program. While these are somewhat intuitive, we are attempting to understand the contribution from non-incubator activities and the interaction between non-incubator activities and incubator activities.

Hypothesis 2: Regional/sector growth is positively attributed to financial resources that are complementary to the regional incubator program.

Value of technology R&D

Mowery and Rosenberg [24] provided a critical review of several empirical studies that focused on market demand and innovation. The most helpful study to our research is Project Scientific Activity Predictor from Patterns with Heuristic Origins (SAPPHO), which was conducted by the University of Sussex, England. This project compared 43 pairs of companies in the chemical and scientific sectors. The goal of the study was to understand the variables involved with successful innovators and innovations. One of the key items that differentiated successful companies was use of outside technology and scientific advice in a specific area (Mowery and Rosenberg). In a similar review study, Freeman and Soete [14] proclaimed that one of Project SAPPHO's success factors for innovating firms was strong R&D and use of patents.

Mansfield [22] found that "one-tenth of the new products and processes commercialized during 1975 through 1985 in the information processing, electrical equipment, chemicals, instruments, drugs, metals, and oil industries could not have been developed without academic research" (p.11). In addition to these findings, Mansfield investigated the time lag for innovations that used academic research as compared to those innovations that did not. The finding was that those innovations that were engaged with academic research had a 10% faster development to commercialization cycle (Mansfield). Thus, the collaboration between academia and private enterprises that seek to incorporate academic IP into their innovation is purported to accelerate development timelines.

Similar to hypothesis two, this hypothesis seeks to understand the role of other non-incubator activities, namely sources of IP that are complementary to the incubator program. While these are somewhat intuitive, we are attempting to understand the contribution from non-incubator activities and the interaction between non-incubator activities and incubator activities.

Hypothesis 3: Regional/sector growth is positively attributed to the access to and acquisition of IP.

Combinatorial effect

A network effect can be described as the impact resulting from a combination of network nodes, which is larger than the summation individual network nodes. Network theory helps us understand the combination of regional innovation network factors. As reported by Schilling and Phelps [34], alliance clusters exhibit "network effect" density and reach properties. Hackett and Dilts [17] asserted that "the incubation process includes and transcends the incubator" (p. 70). Thus, the incubator program is part of a much larger network. Product commercialization usually occurs within an innovation community and that community usually exhibits patterns described by conventional network theory [21, 26].

The regional innovation network is expected to exhibit utility properties similar to Reed's Law, which describes the network effect as the utility value generated from the exponential scaling of its members [31]. Mowery and Rosenberg [24] argued that the model of innovation is a "very complex interactive process" and concluded that the process is multi-directional with different factors and weights depending on the market context (p. 118). This network effect reflects the dynamics among technology, channels, communication, and context [32]. Porter et al. [30] incorporated in their BCI, a combination of academia, industry, and governmental inputs as evidence of impact on GDP, the dependent variable. Graf and Margull [15] wrote that in technology and innovation incubator parks, the interaction is most important, which in essence is the network.

This final hypothesis is again, based upon theory, but also is intuitive. Working in combination, the five factors are expected to be the most predictive in terms of explaining regional innovation growth. The critical element of this particular hypothesis is in the understanding the network impact of the inputs to the model.

Hypothesis 4: The highest predictive network value is represented by the combination of factors—incubator programs, funding, and IP.

Methods

The methods to be deployed in this study are both qualitative and quantitative in order to provide as much data as is pragmatically possible on the regional model. The rationale for this is that regional innovation network theories to date have been predominately studied at the macro-level, meaning country level, and to some degree, at the micro-level, with firm case studies. We seek to gather an aggregate of information by capturing cross-sectional data through sample surveys and will model the results in a regression. This study is non-experimental as we are not randomly selecting participants and are not manipulating variables.

Procedures

We began the *first phase* of our study by working with the president of the MBIA to position the project and gain agreement for the study. Then, as shown in Appendix A, we proceeded to interview the three Incubator Directors from Baltimore, Frederick, and Rockville as part of our survey development process. These three regions have the highest concentration of funding and Biotech and ICT incubator participants. These were semi-structured interviews. A draft survey was included as part of this interview process. Our survey items were developed from reviewing incubator studies from Hackett and Dilts [17, 18] and prior projects conducted by NBIA [25] and TEDCO [36, 37].

For the *second phase* of our project, we tested our survey with two methods—survey and a face-to-face format with a pilot group of four incubator participants from two incubators—Frederick and Rockville as Baltimore did not want to participate in the pilot study. We used an introductory letter packet, which included the researcher's CV and a non-disclosure form, to announce the survey to the pilot group. This is shown in Appendix B. Participants were executive officers of the companies in the study group. The survey, shown in Appendix C, used questions that are related to the measures and constructs. Basic demographics, such as founding date, incubator site details, and primary industry were collected. Source of IP and sources and amounts of funding were gathered. The dependent variables were tracked by obtaining the difference in both FTE and payroll and the sum of revenues from 2007 to 2009. A five-point Likert scale was used to assess the incubator programs. The results of this indicated that the Internet format was not as effective as the interview format. Additionally, the non-disclosure that was used in the interview format was a complete necessity in order to get financial information from the participants.

Based upon the pilot results, for the *third phase* of our project, we proceeded to interview 2007–2009 incubator participants from the two locations, using a semi-structured interview format. The interview format was identical to the one used in the pilot phase. As in the case of the pilot interviews, the information being sought required proprietary information, we used the pilot interview non-disclosure form. For the third location, Baltimore, we used a shorter version of the survey and associated respondents with proxies from the secondary data base, which had the financial information. The purpose of this was to have complete information that could not be captured from the Baltimore participants.

Our sample was 25 current incubator participants and three graduates. The Incubator site demographics were 14 from Rockville, ten from Frederick, and four from Baltimore. Industries represented were predominately from Biotech (17) and ICT (8). The overall timeline, which ran from June–September, for the project is shown in Appendix D.

Measures

We derived our measures from an incubator measurement scale, developed by Hackett and Dilts [18]. Their incubator measurement research design and sample was a non-experimental cross-sectional method. Content, construct, and unidimensionality were assessed. Reliability was assessed and achieved with scales performing above the prior set alpha level of 0.6. First, we ran a correlation procedure to understand the correlations among the variables we tested. This is shown in Fig. 1. Then, we used Cronbach's coefficient alpha to determine the unidimensionality of our scales. The other measures are objective. For the financial factor, we used public and private funding information. For the IP factor, we used the sources of IP: university, federal, and/or internal R&D, as these have been shown to correlate well with new product introductions [3, 16, 34, 38]. The dependent variables were self-reported information (increase in full-time equivalents, increase in payroll, and positive revenues) collected through the survey respondents.

Statistical analysis

The analysis was focused on two steps. We placed each of these constructs into a fixed-effects regression equation in order to investigate the positive attribution of the independent variable on the predictive variables—increase in FTE, increase in

	ipu	ipf	ipp	ft3	py3	st	fed	prv	rev	cg	lgl	con	tr	cnsl	acs	nw	so	se	sf	iptt
ipf	-0.17																			
ipp	-0.49	-0.78																		
ft3	-0.09	0.31	-0.21																	
py3	-0.04	0.29	-0.23	0.90																
st	0.02	-0.11	0.09	-0.21	-0.15															
fed	-0.14	0.29	-0.17	0.36	0.38	-0.01														
prv	0.30	-0.11	-0.10	0.27	0.46	-0.10	-0.09													
rev	-0.20	0.47	-0.29	0.72	0.69	0.00	0.42	-0.15												
cg	-0.11	0.31	-0.20	0.82	0.66	-0.08	0.45	-0.07	0.65											
lgl	0.05	0.08	-0.10	-0.18	-0.26	0.28	0.16	-0.17	-0.23	0.10										
con	0.06	0.04	-0.08	-0.44	-0.41	0.39	0.14	-0.18	-0.43	-0.25	0.58									
tr	0.22	0.03	-0.17	-0.01	0.09	0.23	0.17	0.13	-0.01	0.02	0.24	0.16								
cnsl	0.02	0.23	-0.21	-0.02	-0.07	0.25	0.21	-0.24	0.12	0.27	0.55	0.35	0.55							
acs	0.07	0.17	-0.20	-0.03	-0.06	0.16	-0.08	-0.26	0.19	0.03	0.33	0.13	0.47	0.77						
nw	0.09	0.32	-0.34	0.04	-0.06	0.20	0.04	-0.09	0.10	0.06	-0.02	0.11	-0.04	0.10	0.15					
so	0.14	-0.18	0.08	0.41	0.38	0.04	0.01	0.20	0.03	0.23	-0.21	-0.02	0.34	-0.15	-0.09	-0.08				
se	0.23	-0.14	-0.03	0.34	0.31	0.08	-0.01	0.12	0.08	0.18	0.00	0.16	0.03	-0.04	0.10	-0.13	0.67			
sf	-0.13	0.16	-0.06	0.33	0.31	-0.12	0.04	0.15	-0.01	0.17	0.02	0.23	0.28	0.04	0.04	-0.08	0.61	0.36		
iptt	0.10	-0.04	-0.03	-0.25	-0.26	0.62	0.15	-0.21	-0.13	-0.09	0.56	0.64	0.18	0.34	0.24	0.12	-0.03	0.26	0.05	
dis	0.29	-0.04	-0.15	-0.20	-0.13	0.15	-0.04	0.10	-0.17	-0.25	0.25	0.45	0.40	0.34	0.37	0.18	-0.01	0.04	0.27	0.34

***Significance <.01 marked in green.

**Significance <.05 marked in light orange.

*Significance <.10 marked in gray.

Independent Variables
IPU = IP sourced from university
IPF = IP sourced from federal government
IPP = IP sourced internally
ST = State funding
FED = Federal funding
PRV = Private funding
LGL = Legal advice/workshops
CON = Connections to funding
TR = Training
CNSL = Counseling
ACS = Access to mentors
SO = Shared office facilities
SE = Shared equipment
SF = Space with flexible terms
IPTT = Access to IP and tech transfer
DIS = Access to discounts/free memberships

Dependent Variables
FTE3 = Difference between entry and current full-time employees (greater than or equal to 32 hours)
PY3 = Difference between entry payroll and current payroll
Rev = Sum of revenues from 2007 through June 2009

Fig. 1 Correlation matrix.

payroll, and positive revenues. These procedures assisted us in understanding each of the hypotheses in terms of positive relationships. Next, we placed all factors into regression model to test the value of the combination of the variables as predictors of the dependent variables. We assumed normality, linearity, and homoskedasticity as the sample size is slightly under 30.

Discussion

Results

As shown in Table 1, the dependent variables demonstrated increases in each category—employees, payroll, and revenues. For all sectors, the average

Table 1 Dependent variables—means by industry.

Dependent variable	All (median)	Biotech	ICT	Other
Change in employees	5.68 (3)	5.53	7.63	1.34
Change in payroll (000s)	$401.32 ($120)	$506.05	$315.75	$36.00
Revenues (000s)	$541.61 ($100)	$566.94	$440.88	$666.67

increase was 5.68 with a median of 3. Increases in payroll were $401.320 with a median of $120,000. Positive revenue was $541,610 with a median of $100,000.

The secondary data from the ETC-Baltimore demonstrated similar aggregate means to the sample in this study. Employees increased by a lower average amount of two and positive revenues were $574,520. From this secondary data, we could not derive change in payroll.

Additionally, the average salary increased from $60,994 to $83,054. When we compared this with the TEDCO study conducted in 2007, the average salary was $75,000 for incubator participants.

Hypothesis 1a: Regional/sector growth is positively attributed to regional incubator infrastructure programs.

The regional incubator infrastructure programs had a standardized Cronbach's coefficient alpha of 0.78. The variables included with this construct are shared facilities, shared equipment, and flexible terms. We tested this construct independently with each of the dependent variables—increase in FTE, increase in payroll, and positive revenues. The results are shown in Table 2.

None of the results are significant. Thus, this hypothesis is not supported. However, from a descriptive stand-point, we evaluated the infrastructure programs to have means shown in Table 3.

Qualitative comments demonstrated that these set of variables are highly valuable to the incubator participants and graduates. "The flexible rates are very good," was a comment from several participants. "We would like to see a lower rent rate that scales faster as times goes forward. Also, we would like additional Biotech equipment," was stated by one Biotech participant. This may account for the slightly lower Biotech mean of 3.94. Some participants wanted more MIS support. A few comments were made about leveraging the website to get access to conference rooms and reduce emails. Nevertheless, this is a valued area by the majority of participants.

Table 2 Infrastructure program statistical results.

Dependent variable	*r*-square	*F* value	Pr>*F*
Increase FTE	0.1873	1.84	0.1161
Increase payroll	0.1603	1.53	0.2330
Positive revenues	0.0082	0.07	0.9774

Table 3 Infrastructure program means by industry.

Variable	All	Biotech	ICT	Other
Shared facilities	3.93	3.94	4.75	1.67
Shared equipment	3.39	3.29	4.25	1.67
Flexible terms	4.36	4.37	4.75	3.34

Hypothesis 1b: Regional/sector growth is positively attributed to regional incubator professional support programs.

The incubator professional support programs had a Cronbach's coefficient alpha of 0.79. The variables included with this construct are legal advice, counseling, access to mentors, and training. We tested this construct independently with each of the dependent variables—increase in FTE, increase in payroll, and positive revenues. The results are shown in Table 4.

None of the results are significant. Thus, this hypothesis is not supported. However, from a descriptive stand-point, we evaluated the incubator support programs to have means as shown in Table 5. These means are all close to three, indicating a medium–high valuation of these programs.

Several Frederick participants said that the counseling from the Incubator Director is par excellence. One participant said "We decided on this location because of the Incubator Director." Another participant expressed the need for patent advice. Many participants wanted marketing and strategy assistance for their products. Another wanted tax advice. Many participants valued the training events and wanted this to continue. One participant said a business syllabus about how to structure benefits and support services would be helpful for the non-business technical founders.

Hypothesis 1c: Regional/sector growth is positively attributed to regional incubator linkages programs.

The incubator program linkages program had a standardized Cronbach's coefficient alpha of 0.64. The variables included with this construct are networking, discounts/free memberships, connections to funding, and access to IP and tech transfer. We tested this construct independently with each of the dependent variables—increase in FTE, increase in payroll, and positive revenues. The results are shown in Table 6.

None of the results are significant. Thus, this hypothesis is not supported. However, from a descriptive stand-point, we evaluated the incubator linkages programs to have means as shown in Table 7. This set of means has a wider range,

Table 4 Professional support program statistical results.

Dependent variable	r-square	F value	Pr > F
Increase FTE	0.0420	0.25	0.9055
Increase payroll	0.0923	0.58	0.6770
Positive revenues	0.1658	1.14	0.3613

Table 5 Professional support variable means by industry.

Variable	All	Biotech	ICT	Other
Legal advice	3.00	2.76	3.50	3.00
Counseling	3.14	3.24	3.00	3.00
Access to mentors	3.36	3.35	3.38	3.34
Training	2.93	3.47	3.38	2.67

with access to IP and tech transfer as not being valuable to the participants to networking as being of extreme importance.

Networking comments included the desire to have connections to clinics and hospitals for drug trials. While this is offered by the incubators, the participant that made this comment said that his company would be willing to pay a commission for these introductions. Others wanted advice on how to get on the GSA schedule or introductions to a government prime. Another expressed interest was participating in a regional trade show as a group or allowing for a discounted registration.

Hypothesis 2: Regional/sector growth is positively attributed to financial resources that are complementary to the regional incubator program.

The financial funding sources had a Cronbach's coefficient alpha of −0.220. Additionally, when the sources of funding were tested in the regression model, the results were not meaningful. Thus, this hypothesis is not supported. However, as shown in Table 8, from a descriptive stand-point, we evaluated the state/local, federal, and private funding sources to have means of $45.5k, $280.96k, and $1,500.37k, respectively. The larger private funding amounts came from more mature Biotech companies that had received venture capital funding. More importantly, the medians were all zero, which indicates the lack of presence of funds.

While funding is a challenge for these participants, there was minimal commentary about expectations for funding assistance. One participant said she would have like to have understood how to get access to federal stimulus funds. Another participant would like to see help with grant writing. Others asked for assistance with information about credit and loan applications. Most of the participants that received funding from the state or federal government expressed awareness of the funding sources.

Hypothesis 3: Regional/sector growth is positively attributed to the access to and acquisition of IP.

Table 6 Linkages program statistical results.

Dependent variable	*r*-square	*F* value	Pr>*F*
Increase FTE	0.2052	1.48	0.2394
Increase payroll	0.1768	1.23	0.3239
Positive revenues	0.2359	1.78	0.1682

Table 7 Linkages variable means by industry.

Variable	All	Biotech	ICT	Other
Networking	3.71	4.05	3.38	2.67
Discounts	2.75	2.88	2.63	2.33
Connections to Funding	3.36	3.47	3.38	2.67
Access to IP/TT	1.54	1.53	1.38	2.00

The IP construct had a Cronbach's coefficient alpha of −33.207. Additionally, when the sources of IP were tested in the regression model, the results were not meaningful. Thus, the hypothesis is not supported. However, as shown in Table 9, from a descriptive stand-point, we are able to see a pattern of low-tech transfer among the participants in the study.

Specifically, 19 companies had 100% of their IP sourced internally, three companies had 100% of their IP sourced from the federal government, and one company had 100% of its IP sourced from a university. Two companies had mixed federal and internal IP and three companies had mixed university and internal IP. Of the mixed IP firms, four were Biotech and one was ICT. The low rate of tech transfer was a surprise, especially in Biotech. However, having some form of IP is a condition for entry into the incubator program.

Hypothesis 4: The highest predictive network value is represented by a combination of factors—incubator programs, funding, and IP.

The regression model used the five sets of variables with each of the dependent variables. The results are shown in Table 10. The set of variables predicts all three dependent variables, with the notation that revenue has a higher p value.

Thus, this hypothesis is supported. As the FTE had the highest r-square, we ran a stepwise regression and monitored the VIF, but the r-square of the model decreased to 0.7009 and the variables included—shared equipment, flexible terms, connections to funding, federal funding, and government IP—were not meaningful based upon theory. The FTE model parameter results are reported in Table 11. The majority of the parameter estimates are not significant.

Many participants indicated that the program operated well under constrained resources. One of the Biotech graduates stated, "We would not have started the company without the incubator support even though we had the funding and the IP in place." Another expressed, "This is a great learning resource for the early stages."

We ran a regression with the control variable called time, which is the total time from entry to exit. The results had an r-square value of 0.843 with an F value of

Table 8 Funding means by industry (000s).

Type of Funding	All (Median)	Biotech	ICT	Other
State/local funding	$45.64 (0)	$51.18	$51.00	–0–
Federal funding	$280.96 (0)	$459.71	$6.50	–0–
Private funding	$1,500.37 (0)	$2405.59	$114.38	$66.67

Table 9 IP percentages by industry.

IP Source	All	Biotech	ICT	Other
University IP	9%	11.76%	6.25%	–0–
Public IP	14%	20.59%	6.25%	–0–
Internal IP	77%	67.65%	87.50%	100%

3.16, and a p value of 0.0344. The results from this are shown in Table 12. The control variable time contributes less than 2% to the model and is not significant. Many of the parameters did not change materially when we compared this to the results shown in Table 11. The most notable change was the intercept value. As in the prior model, the majority of the variables are not significant.

Contributions

The contribution to theory from this research study is the beginning development of a quantitative model from which to build enhanced models for other regions and/or sectors. Of particular importance is that none of the independent variables alone could predict a positive outcome for any of the dependent variables. We will treat this as a preliminary indication that these cannot stand alone and instead, work most optimally in combination. The information from this study can supplement the prior TEDCO 2007 study. The most important practical finding is the FTE and payroll increases, which can be converted to tax revenues for the respective counties.

Limitations

Limitations of the study are that the sector of interest, the three Incubators from the state of Maryland, could be deemed as too successful. Although it was not evident based upon the small sample size, high levels of state and federal funding and a rich concentration of universities and other institutions, the conditions could be viewed as too optimal. This might make it hard to generalize as these conditions could be too unique to Maryland and not other regional examples. Additionally, by focusing exclusively on the incubators, other regional innovation network factors have been excluded. For example, technology councils, which typically are comprised of existing businesses, often act as sources of innovation exchange and collaboration. Additionally, we did not evaluate the management dimension, which could cause success or failure.

Table 10 Combinatorial statistical results.

Dependent variable	r-square	F value	Pr>F
Increase FTE	0.8274	3.30	0.0252**
Increase payroll	0.8184	3.10	0.0314**
Positive revenues	0.7784	2.42	0.0713*

**p<0.05, *p<0.10

Table 11 Parameter estimates for FTE model.

Parameter	Estimate	Standard error	*T* value	Pr>|*t*|
Intercept	−4.554	6.593	−0.69	0.5040
Shared facilities	2.260	2.210	1.02	0.3283
Shared equipment	0.862	1.310	0.66	0.5239
Flexible terms	1.621	1.833	0.88	0.3954
Legal advice	1.150	1.061	1.08	0.3013
Counseling	1.781	1.516	1.17	0.2649
Access to mentors	−0.070	1.582	−0.04	0.9654
Training	−3.133	1.807	−1.73	0.1109
Networking	0.347	1.060	0.33	0.7499
Discounts	0.615	1.102	0.56	0.5881
Connections to funding	−4.042	1.333	−3.57	0.0044
IP/tech transfer	−0.279	1.118	−0.25	0.8077
IP-university	−0.012	0.056	−0.22	0.8334
IP-federal	0.057	0.426	1.33	0.2118
IP-private	0.000	0.000	0.00	0.0000
State funds	0.009	0.015	0.63	0.5420
Federal funds	0.004	0.002	2.56	0.0268
Private funds	0.000	0.000	1.48	0.1666

Directions for future research

Suggestions for future research are modeling other regional sectors, either by industry and/or by geography. The original goal for this research project was a structural equation model (SEM), as shown in Fig. 2. Expanding the sample size to hundreds would allow the SEM to perform. This might be a good comparison model that could alter a few factor weights and pathways in the model. Also, the model could be modified to a product life cycle context, where other factors could be incorporated as the product advances toward the final stages of commercialization. Additionally, the current regional economic tools could be further enhanced with this model in terms of determining regional innovation network resource allocation and predictive modeling of network economic output, defined as incremental revenues and employment.

Conclusion

In this paper, we reviewed a range of theories and research studies involving regional innovation networks. Acknowledging that the prior research was qualitative and focused on the macro and micro aspects of regional innovation, we used this as our foundation. While much attention has been devoted to the description of regional innovation networks, less attention has been focused on assessing the value of the network. The results of our study indicate that the value created by the regional

Table 12 Parameter estimates for FTE model, controlling for time.

Parameter	Estimate	Standard error	*T* value	Pr>|*t*|
Intercept	−12.15	10.072	−1.21	0.2600
Time	1.131	1.135	1.00	0.3421
Shared facilities	1.996	2.226	0.90	0.3910
Shared equipment	1.109	1.333	0.83	0.4248
Flexible terms	2.269	1.945	1.17	0.2704
Legal advice	1.165	1.061	1.10	0.2980
Counseling	2.234	1.583	1.41	0.1886
Access to mentors	−0.729	1.715	−0.42	0.6799
Training	−2.637	1.875	−1.41	0.1899
Networking	0.515	1.074	0.48	0.6420
Discounts	1.138	1.220	0.93	0.3732
Connections to Funding	−4.333	1.170	−3.70	0.0041
IP/Tech Transfer	−0.349	1.121	−0.31	0.7617
IP-University	−0.015	0.056	−0.26	0.7990
IP-Federal	0.060	0.427	1.40	0.1930
IP-Private	0.000	0.000	0.00	0.0000
State Funds	0.011	0.015	0.76	0.4653
Federal Funds	0.004	0.002	2.18	0.0542
Private Funds	0.000	0.000	0.56	0.5865

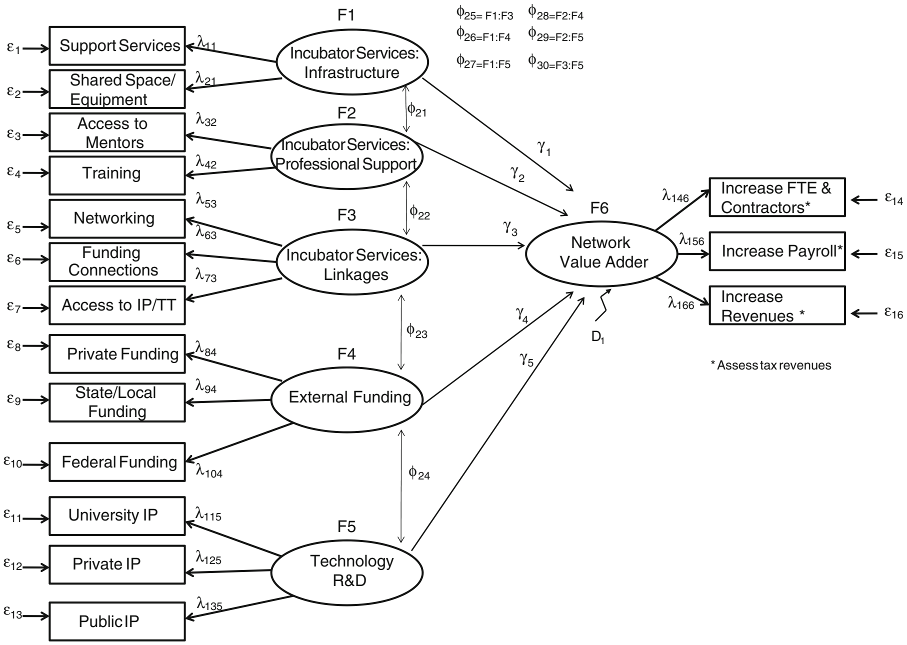

Fig. 2 SEM proposed diagram.

innovation network is found in the combination of inputs from IP, funding, and programmatic support. These innovation systems “consist of a critical mass of local knowledge, expertise, personnel, and resources grouped together by related technologies” ([7], p. 345).

As interest in regional economic development and innovation continues to grow, new research efforts should focus on extending the model to include new sectors and new variables. This research effort can also begin to advance modeling the different types of regional innovation networks. Twenty-first century global/local economies and associated innovation systems represent ecosystems that are dynamic and complex, which adds to the opportunity for further investigation.

References

1. Arthurs D, Cassidy E, Davis C, Wolfe D (2009) Indicators to support innovation cluster policy. Int J Technol Manag 46(3–4):263–279
2. Atkinson R, Castro D (2009) A national technology agenda for the new administration. Yale J.L & Tech, 190-208
3. Basberg B (1987) Patents and the measurement of technological change: a survey of the literature. Res Policy 16:131–141
4. Bergek A, Norrman C (2007) Incubator best practice: a framework. Technovation 28:20–28
5. Campbell T (2008) Learning cities: converting discovery to knowledge in complex systems. Retrieved from www.urbanage.org on March 7, 2009
6. Carayannis E (2007) Missing vital signs and bridging the valley of death: emerging view. Astra Vital Signs Conference
7. Carayannis E (2008) Knowledge-driven creative destruction, or leveraging knowledge for competitive advantage. Ind High Educ 22(6):343–353
8. Carayannis E, Wang V (2008) The role of the firm in innovation networks and knowledge clusters. Innovation networks and knowledge clusters. Palgrave MacMillan, New York
9. Carayannis E, Campbell D (2009) ‘Mode 3 and ‘Quadruple Helix’: toward a 21st century fractal innovation ecosystem. Int J Technol Manag 46(3–4):201–234
10. Christensen C, Rosenbloom R (1993) Explaining the attacker’s advantage: technological paradigms, organizational dynamics, and the value network. Res Policy 24:233–257
11. Clark W, Li X (2004) Social capitalism: an economic paradigm for the transfer and commercialisation of technology. International Journal of Technology Transfer and Commercialisation 3(1)
12. Cooke P (2003) Economic globalization and its future challenges for regional development. Int J Technol Manag 26(2–4):401–420
13. Dzisah J, Etzkowitz H (2008) Triple helix circulation: the heart of innovation and development. International Journal of Technology Management and Sustainable Development 7(2):101–115
14. Freeman C, Soete L (1997) The economics of industrial innovation, 3rd edn. The MIT Press, Cambridge
15. Graf H, Margull R (2008) A model of an innovation system with a position regulation of science and technology parks within innovation networks. Knowledge Matters. Palgrave Macmillan, New York
16. Griliches Z (1990) Patent statistics as economic indicators: a survey. J Econ Lit 28:1661–1707
17. Hackett S, Dilts D (2004) A systematic review of business incubation research. J Technol Transfer 29 (1):55–82
18. Hackett S, Dilts D (2007) Inside the black box of business incubation: study B-scale assessment, model refinement, and incubation outcomes. J Technol Transfer 33:439–471
19. Komninos N (2004) Regional intelligence: distributed localized information systems for innovation and development. Int J Technol Manag 28(3–6):483–506
20. Komninos N (2005) Regional innovation in Europe. 2nd National Innovation Forum
21. Lynn L, Reddy R, Aram J (1996) Linking technology and institutions: the innovation community framework. Res Policy 25:91–106
22. Mansfield E (1990) Academic research and industrial innovation. Res Policy 20:1–12

23. McAdam M, McAdam R (2008) High tech start-ups in university science park incubators: the relationship between the start-ups lifecycle progression and use of the incubator's resources. Technovation 28:277–290
24. Mowery D, Rosenberg N (1979) The influence of market demand upon innovation: a critical review of some recent empirical studies. Res Policy 8:102–153
25. National Business Incubator Association (2006) 2006 state of business incubation industry
26. Nohria N, Eccles RG (1992) Networks and organizations. Harvard Business School Press, Boston
27. Organisation for Economic Co-operation and Development (1999) Boosting innovation: The cluster approach. Retrieved on April 29, 2009 from http://www.oecd.org/document/23/0,3343,en_2649_34273_1894871_1_1_1_1,00.html
28. Organisation for Economic Co-operation and Development (2002) Dynamising national systems of innovation. Retrieved on April 29, 2009 from http://www.oecdbookshop.org/oecd/display.asp?K=5LMQCR2K7FWD&DS=Dynamising-National-Innovation-Systems
29. Organisation for Economic Co-operation and Development (2004) Science and innovation policy. Retrieved on February 23, 2009 from www.oecd.org/dataoecd/18/17/23706075.pdf
30. Porter M, Ketels C, Delgado M (2007) The microeconomic foundations of prosperity: findings from the business competitive index. World Economic Forum - The Global Competitiveness Report 2007-2008
31. Reed D (2000) The law of the pack. Harvard Bus Rev 79(2):23–24
32. Rogers E (2003) Diffusion of innovations, 5th edn. Free Press, New York
33. Rogers E, Carayannis E, Kurihara K, Allbritton M (1998) Cooperative research and development agreements (CRADAs) as technology transfer mechanisms. R&D Management 28(2):79–88
34. Schilling M, Phelps C (2007) Interfirm collaboration networks: the impact of large-scale network structure on firm innovation. Manag Sci 53(7):1113–1126
35. Schumpeter J (1942) Capitalism, socialism, and democracy. Harper, New York
36. The Maryland Technology Development Corporation (2000) Best practices in business incubation
37. The Maryland Technology Development Corporation (2007) Maryland incubator impact analysis and evaluation of additional incubator capacity
38. Trajtenberg M (1987) Patents, citations, and innovations: tracing the links. Working Paper 2457. National Bureau of Economic Research