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# A policy mix experiment to promote start-up success: exploratory evaluation of the NSF Small Business Innovation Research (SBIR)/Industry University Cooperative Research Center (IUCRC) membership supplement

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## Abstract

This paper investigates the outcomes of a policy experiment, the NSF SBIR/IUCRC Membership Supplement, designed to promote the success of small high-tech entrepreneurial ventures by providing subsidized memberships in university-based cooperative research centers (IUCRCs). Data collected via semi-structured interviews with representatives of 61 Small Business Innovation Research (SBIR) firms indicated that SBIR firms who used the supplement to join an IUCRC reported multiple R&D benefits including research cost avoidance, research savings, and access to expensive equipment. A vast majority of SBIR firms also reported realizing or anticipated realizing commercial benefits (e.g., new investors, new products, and improvements to existing products). As suggested by social capital theory, SBIR firms reported that the policy mix experiment helped them make new connections with faculty and industry. Following our qualitative results, a structural equation model was applied to test the effect of social capital as an antecedent of SBIR firm R&D and commercialization outcomes. Results suggested that the SBIR firms who developed more social capital through interactions with faculty and industry members realized significantly more R&D and commercialization benefits. Further, commercialization benefits mediated the relationship between social capital and the SBIR firm's perceived return on investment. Overall, this study demonstrates the feasibility of subjecting mixed policy interventions to evaluative scrutiny and provides evidence that such instruments can have substantive and positive effects on small high-tech entrepreneurial ventures. We discuss implications for social capital theory, policy mix initiatives and entrepreneurship policy.

**Keywords** Entrepreneur · SBIR · Cooperative research center · Policy mix · Social capital theory

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## 1 Introduction

Over the past decade, Science, Technology and Innovation (STI) policy community has demonstrated increased interest in embracing a policy mix framework which explicitly acknowledges that policy is more frequently than not a messy, complex, multi-level and multi-actor phenomenon that involves multiple policy instruments (Flanagan et al. 2011). Unfortunately, a number of factors including the complexity of types of “mixes” one can consider, uncertainty surrounding the outcomes of these mixes have limited both theory development and empirical research.

Given this background, the next several sections our paper will attempt to make a contribution to this promising area of policy analysis by: (1) highlighting some of the key concepts and challenges discussed by policy mix scholars; (2) highlighting some of the barriers to conducting empirical research in this area; (3) describing a “designed” policy mix experiment undertaken by the National Science Foundation (NSF) that targets high technology Small Business Innovation Research (SBIR) firms that lends itself to empirical evaluation; (4) highlighting a theory of change that would explain how and why this particular mix would be beneficial; and finally (5) describing a study which attempted to assess the effectiveness of this initiative.

### 1.1 SBIR/IUCRC Membership Supplement

In 2007, NSF issued a Dear Colleague Letter (DCL), a mechanism used to alert currently funded principal investigators (PIs) about a supplemental funding opportunity, labeled “Supplemental Opportunity for SBIR/STTR Memberships in IUCRCs” (hereafter referred to as the SBIR/IUCRC Membership Supplement).<sup>1</sup> The DCL invited Phase II NSF SBIR and STTR awardees to request supplemental funding that could be used to purchase a subsidized membership in one of NSF’s IUCRCs.<sup>2</sup> The announcement indicated that the goal of the supplement was to “accelerate the innovation process by partnering industry-relevant academic research with commercialization focused small business research.” For those not familiar with these long-standing NSF programs, a SBIR is a relatively straight forward financial award given to a small technology-focused firm to help advance its technology to commercialization (Cooper 2003). IUCRCs are NSF-sponsored, university-based cooperative research centers or “organization(s) or unit(s) within a larger organization that performs research and also has an explicit mission (and related activities) to promote, directly or indirectly, cross-sector collaboration, knowledge and technology transfer, and ultimately innovation” (Gray et al. 2013, p. 9).

While a comprehensive description of the SBIR and IUCRC programs is beyond the scope of this paper, Table 1 highlights some of the characteristics they have in common

<sup>1</sup> An archived version of the updated 2009 announcement can be found here: <https://www.nsf.gov/pubs/2009/nsf09065/nsf09065.jsp>.

<sup>2</sup> Although both SBIR and STTR awardees were eligible for the supplement, for simplicity we will refer to SBIRs in the remainder of the paper.

**Table 1** Comparison of IUCRC and SBIR/STTR programs

	IUCRC program	SBIR/STTR program
Founded	1979	1977
Objective	“Perform cutting-edge pre-competitive fundamental research in science, engineering, technology area(s) of interest to industry and that can drive innovation and the U.S. economy”	“Support scientific excellence and technological innovation ... to build a strong national economy; Increase private-sector commercialization of innovations derived from Federal research and development funding”
Target Audience	R&D intensive firms and organizations (primarily large)	Domestic small businesses engaged in R&D
TRL-Level	Precompetitive research; TRL 1–3	Commercialization; TRL 4 and up
Mode of Operation	Consortium of firms supporting pre-competitive research at universities (10–15 years of funding)	Multi-phase (I–III) funding to individual small firms for commercialization (1–3 years of funding)

Program objectives quoted from program websites

Various agencies use TRL levels to categorize their research efforts. In this case we used the following: *National Research Council (US) Committee on Capitalizing on Science, Technology, and Innovation*; Wessner CW, editor. Washington (DC): National Academies Press (US); 2007

and others on which they differ.<sup>3</sup> Specifically, both programs are “legacy” programs tracing their creation back to the late 1970s and both programs list innovation and economic payoff/development as their primary goals. However, they differ substantially in both target audiences and methods. The IUCRC program attempts to achieve its innovation and economic goals by inducing R&D intensive firms to join a university-based industrial consortia which focuses on conducting pre-competitive research aimed at solving technical challenges and filling knowledge gaps shared across an industrial sector (rather than on the needs of just one firm), while the SBIR program attempts to achieve its objectives by providing financial support to small technology-focused businesses in order to accelerate their specific commercialization efforts. Clearly, each operates at very different stages of the innovation process/TRL-levels (Mankins 1995). Importantly, both programs have demonstrated their effectiveness in promoting innovation and related outcomes, albeit for very different populations and using very different approaches (Gray et al. 2013; Lerner 1999).

From a conceptual standpoint, the SBIR/IUCRC Membership Supplement appears to be an example of a “policy mix” experiment, in this case a deliberate attempt to combine two hopefully complementary policies/programs to produce a desired outcome—accelerate the innovation process. In the next section we discuss the policy mix movement within the science, technology and innovation (STI) policy community, highlight how this DCL fits within this framework, highlight some literature that suggests why such an initiative might be beneficial and describe our attempt to evaluate this experiment. Although the supplement was intended to benefit stakeholders in both the IUCRC and SBIR programs, and our comprehensive evaluation study examined both sides, this paper will focus on the impacts of this policy experiment on SBIRs (and STTRs).

## 2 Policy mix movement in STI

While NSF did not articulate a conceptual framework when it released the DCL for the SBIR/IUCRC Membership Supplement, this initiative appears to be consistent with the recent movement away from isolated policies and programs and toward a “policy mix” framework within the STI policy community. Policy mix is a concept borrowed from the economic policy community that explicitly acknowledges that policy is more frequently than not a messy, complex, multi-level and multi-actor phenomenon (Flanagan et al. 2011). While there is no universally accepted definition of policy mix Flanagan and his colleagues suggest it “implies a focus on the interactions and interdependencies between different policies as they affect the extent to which intended policy outcomes are achieved” (Flanagan et al. 2011, p. 702). In short, it asserts most targets of STI policy, like strengthening R&D investments by firms, supporting start-ups and entrepreneurship development, are influenced by a “system of policy instruments” emanating from a variety of agencies, levels of government and jurisdictions that involve a myriad of institutions and infrastructures. At the same time, it also highlights the potential value of deliberately combining ‘tools from the STI toolbox’ rather than focusing exclusively on tweaking old policy instruments or inventing new ones. While a complete explication of policy mix is beyond the scope of this paper, a couple of points seem relevant to our current discussion.

<sup>3</sup> More detailed descriptions of the IUCRC and SBIR programs can be found at <https://www.nsf.gov/eng/iip/iucrc/> and <https://seedfund.nsf.gov/>, respectively.

First, the number and complexity of factors that can be considered under this conceptual framework is daunting to say the least. A number of emergent typologies of relevant factors or dimensions have been offered. For instance, two primary mixing factors are the *policy instruments* used and the *dimensions of the STI ecosystem* on which they act. Wolfe (2019) suggests the *instruments* involved could range from economy-wide efforts to stimulate higher levels of R&D, to skills and training policies, to policies to link actors in the R&D domain and promote collaborative research. Conversely, starting with the same instrument one can have a mix *across various dimensions* (e.g., level of governance, time, geography, institution/agency, intentionality). Flanagan et al. (2011), also suggest four *types of interaction*: different instruments targeting the same actor/group (within/across dimensions); different instruments targeting different actors/groups involved in the same process (within/across dimensions); different instruments targeting different processes in a broader system (within/across dimensions); the same instruments (across different dimensions). These are only a partial list of factors/dimensions one could consider.

A second point involves the anticipated *outcomes* of a particular mix. One should not expect every mix to produce beneficial synergies. Various mixes can have conflicts or tensions between the policy rationale, its goals and implementation strategies (Wolfe 2019). As a consequence, according to Gunningham and Sinclair (1999), mixes can be: inherently complementary; inherently incompatible; complementary if sequenced; or complementary or otherwise depending on the context. Arnold (2004) expands on this issue by highlighting the potential to create input, output and behavioral (changed behavior by the recipients of state support, based on learning they do in the course of receiving subsidies or other state support) additionalities via policy mixes. Since issues of conflicts/compatibility related to policy goals and related issues will undoubtedly translate into either synergistic or unintended (or null) effects, one would be wise to ground experiments like the SBIR/IUCRC Membership Supplement on a well-considered theory of change.

Finally, in spite of growing enthusiasm for applying a policy mix framework within the STI community, empirical research and evaluation has not kept pace. In truth, the challenge posed by policy mix research varies depending on the complexity of the “mixes” one is trying to evaluate. At one end of the continuum, we have discrete designed mixes involving a limited number of instruments and at the other end larger portfolio or “whole system” mixes (Arnold 2004). While emphasizing the need for a mix of research methods, others acknowledge relatively straight forward evaluation methods can be used for simple designed mixes (Magro and Wilson 2013; Arnold 2004). For instance, Lanahan and Feldman (2015) used traditional OLS econometric analyses to examine the motivations for a state and federal mix that involved matching support for the SBIR program. For portfolio or whole system mixes various authors suggest we engage in broad conceptual analysis, meta analyses (Magro and Wilson 2013) and/or empirical innovation policy histories (Flanagan et al. 2011). Nonetheless, Cunningham et al. (2013) conclude “evaluation practice does not undertake sufficient systematic efforts to tackle the challenge of the interplay of instruments and policies, at both levels” (p. 28).

In summary, given the explosive growth of STI-related policies and programs over the past several decades and the likelihood that the outcomes and impacts of these initiatives are affected by multiple rather than isolated policies and instruments, the STI-policy community has begun to embrace a policy mix perspective. However, to date, the payoffs from applying this perspective have been disappointing due to a number of factors: the large number of policies and instruments deployed across different dimensions and contexts; the heterogeneity of the ‘types’ of mixes and contexts one can examine; challenges in matching



**Table 2** SBIR/IUCRC membership supplement as policy mix

Policy mix category	SBIR/IUCRC membership supplement
Objective	Accelerate the innovation process by partnering industry-relevant academic research with commercialization focused small business research
Mix type	Designed mix of two discrete STI programs
Interaction type	Targeting different actors/groups involved in a sector-specific innovation process
Dimensions	Implemented within a single national STI agency
Timing	Sequenced interaction between earlier and later actors in innovation process
Instruments	Combination of direct fiscal support augmented by access to consortial research and stakeholders

research/evaluation methods to specific types of mixes; and uncertainty about which mixes may be complementary or incompatible.

In our view, in order to continue to make progress in this domain, future research and analysis needs to build on at least three building blocks: a clear and unambiguous understanding of the type of policy mix one is examining, an understanding of *why* and *how* a particular mix should be complementary, and an attempt to match one's evaluation methods to type of mix and anticipated benefits under consideration. In the following section we attempt to provide such a framework for our evaluation of the SBIR/IUCRC Membership Supplement.

### 3 SBIR/IUCRC supplement as policy mix

In our view, the SBIR/IUCRC Membership Supplement represents a relatively straightforward example of policy mix (See Table 2). First, it involves a deliberate or designed attempt to achieve a STI-related objective (e.g., accelerate the innovation process) by the integration of two specific programmatic instruments as opposed to a more ambitious attempt to examine organically created systems of policies. Consistent with Flanagan's second type of interaction, it involves an attempt to *target different actors/groups involved in the same process*. As previously stated, IUCRCs involve university-based researchers and primarily large firms and focus on pre-competitive research in a consortial environment, while SBIR firms are small entrepreneurial ventures working to commercialize technologies supported by federal R&D funding and are focused on product/process development and therefore reside downstream from IUCRCs in the innovation process. Thus, these programs are *sequenced* (Gunningham and Sinclair 1999) involving earlier and later actors in the innovation process. The initiative was deployed within a single national STI program. Drawing from Wolfe's (2019) categorization it appears to represent a *combination* of an instrument that primarily provides *direct fiscal support* (SBIR) combined with an instrument that provides *indirect support* in the form of access to a portfolio of precompetitive research projects and the network of faculty, students and industrial sponsors involved in a consortia (IUCRC).

In summary, an emergent typology of policy mix efforts suggests the SBIR/IUCRC Membership Supplement represents a relatively simple 'designed or intentional' mix that attempts to bring together different programs (and actors) within the same federal agency at different points in the innovation process, with the intention of accelerating the



commercialization of publicly-funded technologies by encouraging a partnership between entrepreneurial ventures and university-based industrial research consortia.

## 4 Theory of change

Our ability to articulate a research-based or theoretical perspective to explain the synergistic interactions that might be created by the SBIR/IUCRC Membership Supplement is limited by at least two challenges. First, the DCL that established the supplement, related supporting documents and staff we had access to did not reference a supporting theory and/or explain *how* and *why* the partnership that was created would help contribute to superior performance for either program. This is not particularly surprising since a number of scholars have noted that policy makers often do not draw from, at least directly, academic research and theories to develop and justify various policy mix experiments (Magro and Wilson 2013; Flanagan et al. 2011). More typically, they draw on some combination of experience, intuition and a filtered understanding of relevant theory (Kuhlmann et al. 2010). As a consequence, we are left to infer what relevant theories *might* and *might not* have supported this experiment.

Given that we are dealing with a hybrid instrument that includes features of two government programs, operating at different stages of the innovation process the second challenge involves identifying theories that make sense at the intersection of these two programs. As we highlighted in Sect. 2, a given policy mix may be complementary or incompatible (contingent on sequencing and/or context) (Gunningham and Sinclair 1999). As a consequence, we need to identify research and theory that is consistent with the goals, operations, timelines and expected outcomes of two programs that, as we have highlighted above (Sect. 1.1), are very different and perhaps conflicting in a number of respects.

### 4.1 Research support

Although Cunningham et al. (2013) concluded, “A systematic search in both literature databases and specialized evaluation and innovation policy databases reveals a rather thin base of evidence regarding deliberate policy mix design and intended or unintended interactions between instruments” (pg. 1), they note some exceptions. Not surprisingly, these have come from analyses of relatively simple and targeted designed STI policy mix, like the SBIR/IUCRC Membership Supplement. At a high level of analysis they found successful initiatives centered around the combination of direct and indirect R&D support. More specifically, they conclude: “First, direct financial support, which is mostly targeted to small and/or young firms, is more fruitful if it is complemented by non-financial support both for internal management (often around HR and production) and for market access (from classical participation in trade fairs, to more sophisticated networking with ‘key’ suppliers, often provided through geographical or sectoral structures—clusters or technical centers).” (pg. 30).

Since the SBIR IUCRC Membership Supplement involves exactly this combination of features: small and/or young firms; direct financial support from the SBIR program to these firms combined with access to a sector-specific IUCRC’s research projects and network of research performing faculty and students and sponsoring member firms, this finding appears to provide some support for *why* the SBIR/IUCRC Membership Supplement

might be both complementary and productive. In the next section we examine *how* this type of partnership might affect innovation-related outcomes.

## 4.2 Social capital theory

At a fundamental level, the SBIR/IUCRC Membership Supplement is an inter-organizational partnership between an SBIR firm and a consortial IUCRC, brokered and financed by the NSF. As a consequence, many of the theories that might explain the instrumental mechanisms that might derive from such an arrangement come from inter-organizational relationship (IOR) theories which explore why organizations enter into various and diverse types of formal and informal inter-organizational arrangements (e.g., Kale et al. 2000; Mowery et al. 1996; Ring and Van De Ven 1994; Hamel 1991; Oliver 1990) including cooperative R&D (Hagedoorn et al. 2000; Dill 1990).

Social Capital theory (SCT) has often been used in IOR and alliance research to explain how organizations can effectively and efficiently extract value from networks (Inkpen and Tsang 2005; Burt 2000; Dyer and Nobeoka 2000). Social capital has been defined as any valuable asset that stems from access to resources made available through social relationships (Granovetter 1992; Nahapiet and Ghoshal 1998). SCT recognizes both formal and informal interpersonal processes established by networked organizations can lead to the accumulation of social capital.

In the context of the SBIR/IUCRC Membership Supplement, we believe membership represents a formal partnership or contractual relationship, while networking during and between meetings and casual introductions represent informal interactions. Simply becoming aware of another's role in the IUCRC and the disciplinary expertise available to them as a member of the IUCRC, may serve as a bridge for SBIR firms to resources that can advance their commercialization agenda. SCT suggests that when SBIR firms gain membership into IUCRCs that perform research and promote cross-sector collaboration, knowledge and technology transfer, and ultimately innovation, these formal and informal links to social capital may serve as valuable resources SBIR firms can use to advance their commercialization objectives (Bozeman et al. 2001). In short, SCT provides a theoretical basis for hypothesizing why SBIR firms might benefit from participation in IUCRCs.

## 4.3 Summary

The SBIR IUCRC Membership Supplement appears to constitute a relatively simple and straight forward 'designed or intentional' policy mix of different programs (and actors) within the same federal agency at different points in the innovation process. Both research and theory appear to provide some justification for why and how such a combination might be both complementary and beneficial. In the next sections, we describe our research goals that the methods we used to evaluate this experiment.

## 4.4 Goals

Although the evaluation challenges posed by the SBIR IUCRC Membership Supplement are more tractable than many policy mix analyses our assessment goals were modest and exploratory for two reasons. First, the initiative is novel and prior research and theory provides limited guidance on how to assess the interactive effects of combining two such

programs. Second, by necessity, our research was conducted *ex post facto*—data were collected after the supplemental awards were made and in most cases completed—which limited our research options.

Given this background our research had two goals. First, *To explore the effectiveness of the SBIR/IUCRC Membership Supplement for accelerating the innovation process.* Secondly, assuming our findings supported the supplement's effectiveness, *To evaluate whether SCT could explain the observed innovation-related effects.* Our first research goal will be addressed under Part 1 (below) and our second research goal will be addressed in Part 2 (Sect. 7).

## 5 Part 1: Program effectiveness

Related to our first goal our research questions include:

1. Does the SBIR/IUCRC Membership Supplement appear to achieve its stated goal to “accelerate the innovation process by partnering industry-relevant academic research with commercialization focused small business research.” Specifically,
  - a. Do SBIR firms report realizing increased innovation-related R&D and commercialization benefits?
  - b. Do SBIR firms report any significant costs or unintended consequences due to their participation in the initiative?
  - c. Do SBIR firms consider their involvement to be worth the time and money they invested? Why?

### 5.1 Methodology

Given the exploratory nature of our research questions, we utilized a descriptive *ex-post facto* mixed methods design. Around the time the supplement was ending or sometime after that time, the PI (or designee) was interviewed about subjective and objective outcomes of the project. Specifically, respondents were asked to provide forced choice ratings about a variety of issues including specific R&D and commercialization benefits. Since we did not have the luxury of a comparison group or more direct counterfactual, we relied on qualitative data in the form of benefit vignettes provided by the informants to document and support the validity of their benefit rating (Creswell and Creswell 2017).

### 5.2 Policy intervention

As described in Sect. 1.1, the SBIR/IUCRC Membership Supplement was announced via a DCL in 2007 in order to “accelerate the innovation process by partnering industry-relevant academic research with commercialization focused small business research.” The DCL can accurately be called a mixed policy “experiment” since it did not have a discrete budget (e.g., it was funded by slack resources within the IUCRC and SBIR programs) and could

**Table 3** IUCRC program statistics on a typical IUCRC

Variable	IUCRC national mean
Total Budget	\$2.3 M
N of University Sites	2.77
N of Members	17.83
N of Faculty	15.12
N of PhD Students	16.56
N of MS Students	8.05
N of BS Students	7.64

For more information see the report on National Science Foundation Industry/University Cooperative Research Centers: FY2014 Center Director Structural Information Report (Gray et al. 2014)

be ended simply by withdrawing the DCL.<sup>4</sup> On the SBIR side of this partnership, the initiative targets innovative and technologically advanced firms that have an active Phase II or Phase IIB SBIR (or STTR) award from NSF. These firms were offered an opportunity to obtain a membership in an IUCRC of their choice by paying just \$5,000 towards a membership (or 10% of the fee for fees above \$50 k); NSF pays for the balance of the membership fee.<sup>5</sup> In this way, the SBIR pays a modest fee but receives the same privileges as large member firms that are paying the full membership. IUCRC member privileges include: *a seat on the center's Industrial Advisory Board (IAB)*,<sup>6</sup> *attendance at semi-annual meetings, ability to influence the research agenda and vote on new projects, access to all center research results, and non-exclusive royalty-free rights to all center intellectual property.*

IUCRCs can vary significantly in their size, scope and technological focus. As Table 3 details, the average IUCRC had a budget of about \$1.4 M, includes about three universities, 17 industry members, 13 faculty and 28 students. The technical focus of the IUCRC's SBIR firms joined were quite diverse and included centers with a focus in advanced electronics and photonics; advanced manufacturing; advanced materials; biotechnology; civil infrastructure systems; safety and health; information, communication, and computing; and system design and simulation. Consistent with NSF policy these IUCRCs focused on performing pre-competitive research that consortia members shared.

### 5.3 Sample

Several processes led to an SBIR firm becoming involved in the initiative and subsequently our study which are relevant to our interpretation of our findings. First, NSF released the DCL and distributed it to eligible Phase II SBIRs and to IUCRCs. This was followed by an

<sup>4</sup> In fact, after 4 years of operation NSF decided to end the experiment by withdrawing the DCL.

<sup>5</sup> SBIR members could receive two one-year memberships in different IUCRCs or one two-year membership in a single center.

<sup>6</sup> The Industrial Advisory Board (IAB) of an IUCRC is made up of representatives from member firms. Each member firm is entitled to one seat on the IAB, per membership held by that firm. Members' rights and obligations are codified in a legally binding membership agreement.

ad hoc marketing or dissemination effort that involved: some IUCRCs cold calling specific SBIR firms; IUCRC faculty reaching out to individuals they knew possessed a relevant SBIR; and NSF staff strategically encouraging SBIRs to pursue this opportunity. Because of its limited budget and the ad hoc way the supplement was implemented, according to data we received from NSF, we estimate that about 14% of eligible SBIR/STTR firms took advantage of this supplemental opportunity.<sup>7</sup> Thus, SBIR firms that participated in the initiative were a self-selecting group.

The sampling frame for our study was SBIR firms that received a *SBIR/IUCRC Membership Supplement* between 2008 and 2013. According to the database provided by NSF, 74 firms met this criterion.<sup>8</sup> Sixty one firms or 82% participated in our interviews.<sup>9</sup>

At the time of data collection, SBIR-member firms had the following average characteristics: annual sales, \$3.1 M; number of employees, 22.0; women/minority owned, 29.8%. It would probably be more accurate to call this sample “SBIR/IUCRC membership supplement graduates” since they were on average 2.9 years beyond the end of their membership supplement when the interviews were conducted; by the time they were interviewed, 80% were no longer covered by their membership supplement.

Using data obtained from D&B Hoover’s and the IUCRC Evaluation Database we were able to compare the SBIR supplement sample with a random sample of small businesses that participate in IUCRCs as regular members ( $N=60$ ).<sup>10</sup> SBIR-members that participated in the membership supplement were significantly younger (Founded on average in 1999 vs 1993 ( $t=-1.87$  ( $p=.05$ )), smaller (\$3.1 M vs \$10.8 M in annual sales,  $t=2.66$  ( $p<.01$ )), employed fewer employees (22 vs 63,  $t=1.90$  ( $p=.05$ )), and were more likely to be women/minority owned (19% vs 9%,  $X^2=3.7$  ( $p<.05$ )) than the average SBIR firm.<sup>11</sup> In essence SBIR supplement members appeared to be microenterprises compared to regular small business IUCRC members.

## 5.4 Procedures and assessment instrument

Data were collected from a SBIR firm representative (usually the SBIR PI, firm CEO) who was actively involved in the membership supplement via a structured telephone interview

<sup>7</sup> To calculate the percentage of eligible SBIR/STTR firms that received a membership supplement, we took the number of unique firms listed by NSF as receiving a membership supplement ( $N=72$ ) divided by the total number of NSF SBIR/STTR Phase II awards made during the supplement period, 2008–2013 ( $N=508$ ) (<http://sbir.gov/past-awards?agency=138&phase=2&period=6>).

<sup>8</sup> NSF’s list included 72 members. However, some members had memberships in more than one center. If that was the case, we attempted to conduct the interview separately for each center. The  $N$  of targeted interviews was 74.

<sup>9</sup> The response rate was 87% if firms no longer in business were excluded.

<sup>10</sup> The  $N$  of IUCRC small business members was based on the  $N$  of current and past SBIR members in active IUCRCs. SBIR members of graduated IUCRCs were excluded from the sample because graduated centers do not submit membership data to the master IUCRC database and therefore their members could not be included in the comparison population ( $N=5$ ). An additional seven SBIR/STTR firms on the NSF list were not on the master IUCRC membership list and were therefore not included in comparative analysis.

<sup>11</sup> Data on the SBIR/STTR members and comparison group of small business IUCRC members were obtained from D&B Hoover’s Online (2013). D&B Hoover’s continuously updates their database with the most current information as they receive it from listed firms. Therefore, these data represent the status of these firms at the time of data collection, not necessarily their status at the time they became IUCRC members.

guide. The interview was scheduled at a time convenient for the respondent and usually lasted about 20–25 min.<sup>12</sup> Firms were told their identity would be confidential but in some cases we might ask their permission to share some “success stories”. In a number of cases at the end of the interview some firm representatives volunteered their willingness to be identified with the outcomes they reported.

The interview included a combination of forced choice and open-ended questions (described in more detail in Sect. 5.6). In order to quantify the benefits received, we asked firm representatives to indicate whether they had received a variety of specific benefits (response categories: no, realized, anticipate) (Hsieh and Shannon 2005). When a respondent reported a benefit, interviewers were instructed to prompt them to provide sufficient details to be able to prepare a vignette or mini case describing that benefit.<sup>13</sup>

## 5.5 Analyses

Most analyses reported below involve simple descriptive statistics (frequency counts, means, medians). In cases where respondents provided qualitative descriptions of benefits, we conducted a directed content analysis to apply codes based on existing theory to the data. Data that did not fit any of the theory-derived codes was analyzed to identify a new code (Hsieh and Shannon 2005). Another member of the team repeated the coding process until we achieved an inter-rater agreement of 70% or better. We then calculated frequency counts that indicated how many and what percentage of the respondents provided an answer in each category. Coded data were then reviewed to select representative quotes reported in the results section. Finally, qualitative data were used to prepare mini-cases for several firms that helped illustrate how participants benefitted from their participation.

## 5.6 Measures

Data collection from interviews and archival sources involved variables in four domains: (1) benefits (R&D, commercialization, social capital) and costs of membership, (2) subjective overall evaluation of value of membership; (3) SBIR firm and center characteristics; (4) interactions with the center and its other participants. Variables in the last two domains will be addressed under Part 2 results.

### 5.6.1 Benefits and costs of membership

SBIR-members were asked about both the benefits and costs of their membership in an IUCRC. Benefits measured include R&D benefits, commercialization benefits, and social capital benefits. Respondents were asked about benefits in general, and then asked about a series of specific benefits in each of the categories listed. For the specific benefits items,

<sup>12</sup> In order to familiarize ourselves with the case, before we began the interviews, we reviewed the abstract of the SBIR/STTR firm’s proposal and their website and developed a summary of their technology and commercialization goals and confirmed our understanding of the technology at the beginning of the interview.

<sup>13</sup> Since we believed recording the interviews might seem overly intrusive to our respondents, interviewers simply entered as close to a verbatim account of the respondents’ answers as possible. If the interviewer was uncertain about the accuracy of their record, they were instructed to double check what they recorded with the respondent.

respondents were asked to indicate if they had not gotten the benefit, anticipated realizing the benefit, or had realized the benefit in question. Conflicts or costs were measured via an open-ended question.

### 5.6.2 R&D benefits

Because IUCRCs engage primarily in precompetitive research and the most frequently cited benefits/outcomes of participation in an IUCRC is most likely to involve changes or improvements in their R&D activity (Gray and Steenhuis 2003) that one might observe during TRL 1–3, respondents were asked to indicate whether they had realized any of the following benefits: avoided internal R&D costs; saved time or money on internal research projects; initiated new lines of research internally; used center's equipment or facilities that your firm would not otherwise have access to.<sup>14</sup>

### 5.6.3 Commercialization benefits

SBIRs tend to focus on nearer-term commercialization of some research and/or technology they possess that focus on TRL 4 and above. As a consequence, respondents were asked to indicate whether they had realized any of the following development/commercialization-related benefits: accessed IUCRC's IP or other technology; produced their own IP related to research at the center; launched new products or services; improved existing products or services; improved operational or manufacturing processes; added new jobs; helped us identify new applications for the technology that we are trying to develop; helped find an investor; and identified a partner with whom they can apply for a Phase IIB SBIR supplement to accelerate commercialization of their Phase II project.

### 5.6.4 Social capital benefits

Social capital theory suggests that one of the major benefits SBIR stakeholders might receive by joining and becoming engaged in an IUCRC are social capital in nature (Leonchuk and Gray 2017). As a consequence, respondents were asked to indicate whether they had realized any of the following benefits/connections: valuable connections to university researchers and students; valuable connections to other IUCRC members (for example, as customers, suppliers, partners, or investors); identified parties that might invest in or otherwise support our commercialization efforts; made valuable connections to government agencies; hired or contracted with any students or faculty from the IUCRC; collaborated with or received support from faculty and/or firms on developing new SBIR or other research proposals.

<sup>14</sup> It should be noted that it is difficult to unambiguously differentiate these benefits. These questions were based on prior research that showed members report *cost avoidance* benefits from not needing to do research and *acceleration* of their R&D based on research findings producing cost or time savings (Rivers and Gray 2013).



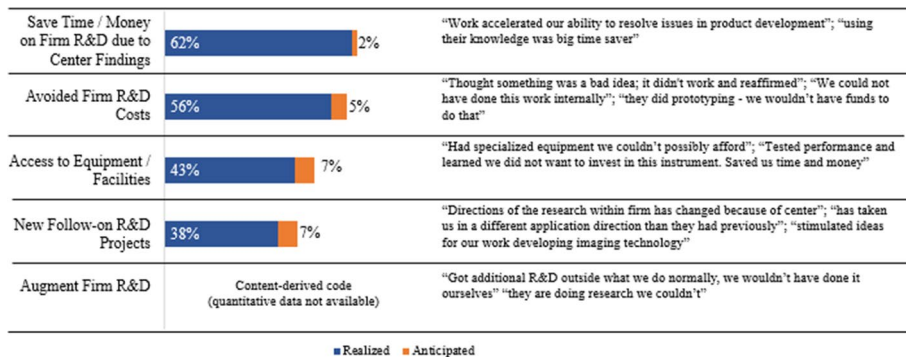


Fig. 1 Percentage of R&D benefits reported by SBIR/STTR firm representatives

### 5.6.5 Costs of participation

As described earlier, policy mix interventions may cause conflicts which result in less than optimal or even negative outcomes. In addition, firm investments of any kind can be expected to have both costs and benefits. Thus, in the context of involvement by an SBIR firm in an IUCRC, we can expect firms to have benefits and costs. Costs would include their financial investment (\$5000) as well as potentially negative consequences. Therefore, SBIR respondents were asked to describe anything "negative" that had happened to their firm based on their participation in their IUCRC.

### 5.6.6 Overall evaluation

In order to obtain a summary evaluation of their participation in the IUCRC program, respondents were asked to make a subjective assessment, a perceived return on investment (ROI), of whether the membership was worth the time and money invested (Definitely yes, Probably yes Probably not, Definitely not).

## 6 Results

### 6.1 Benefits and costs

#### 6.1.1 Research and development benefits

Firm representatives were asked about the R&D benefits described above. As Fig. 1 demonstrates, a substantial percentage (between nearly 40% to over 60%) of firm representatives indicated that they had realized a variety of R&D-related benefits (with an additional 2–7% reporting they anticipated these benefits in the near future); open-ended comments that accompany these ratings document the benefit and the respondent's attribution to participation in their IUCRC. On average, firms reported receiving 2.2 of the 4 R&D benefits surveyed, or 55%. Additional respondent comments

describing how firms benefited from these R&D opportunities are provided in “Appendix 1”.

Over sixty percent of firm representatives reported they saved time or money on internal research projects because center research accelerated their own research. For instance, firm representatives reported: “center’s work accelerated our ability to resolve issues in product development.” Over half of firm representatives also indicated they had *avoided* internal R&D costs as a result of the center’s research results. For instance, firm representatives reported: “thought something was a bad idea; it didn’t work and reaffirmed”; “they did prototyping—we wouldn’t have funds to do that.”

Almost half reported that they benefited specifically from use of equipment/facilities that they would not have had access to otherwise. For instance, firm representatives reported: “got to access all the equipment we needed”; “had specialized equipment we couldn’t possibly afford.”

While most of the benefits affected current R&D efforts, nearly forty percent of firm representatives reported they initiated or anticipated initiating new lines of research due to center findings. For instance, one firm representative reported: “directions of the research within my firm has changed because of the center”; “the center has helped to confirm new directions in sensors—influenced our research strategy.”

Based on open-ended comments provided by respondents, we also identified an additional R&D benefit that was not explicitly included on our forced choice list: *augmented R&D*. In other words, in their mind the center was performing research activities that they were neither planning to do or capable of doing. Typical descriptions of this benefit include: “got additional R&D outside what we do normally, we wouldn’t have done it ourselves;” “we could not have done this work internally.”

Mini Case 1 describes how one firm capitalized on center research activities and inputs as well as other advice and assistance from center stakeholders to advance their commercialization plans that suggests SCT processes may have been at work.

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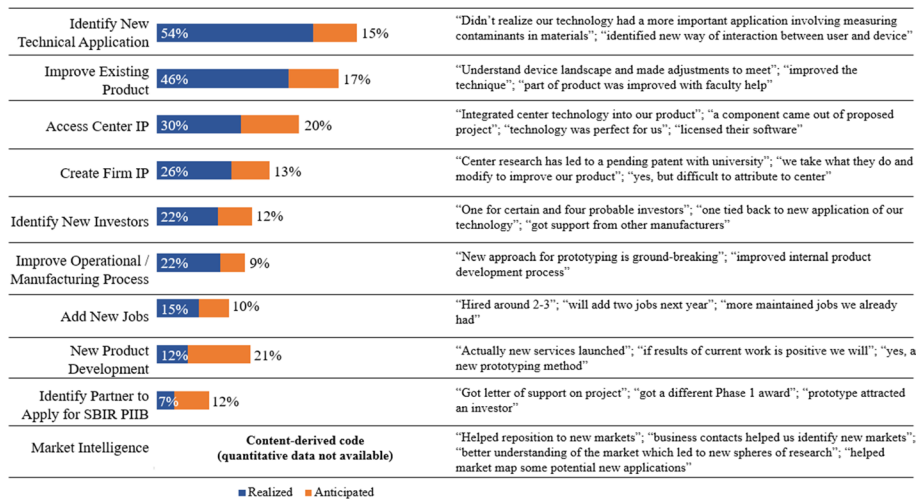
#### Mini Case 1: SBIR firm benefits from testing services and IP support

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Firm L focused on developing hardware and software solutions for wireless communication systems.

They needed access to advanced testing facilities and expertise for a sophisticated integrated circuit technology they developed and to see if it could fit into wireless systems. They also felt their technology might have capabilities that went beyond the applications they currently considered. By taking a membership in the center the firm was able to meet both of these needs and gain expertise that helped them secure investors. The firm reported that the research and testing performed by the center helped them avoid R&D costs, accelerated their R&D plan, improved the product and ultimately validated the IP that was embedded in their technology. The center’s research and testing also identified some new applications for the technology. As the respondent reported, “We had laundry list of things we wanted to apply our technology to. By testing it we found it was more powerful than we initially thought.” Besides the obvious direct research benefits, the firm reported the center personnel went out of their way to provide advice and evidence that helped the firm get funding from a VC firm. As the respondent indicated, “Director was extremely helpful in terms of helping us do our due diligence in working with VC firms. We’ve talked to lots of VC firms who would come in and bring a specialist with questions about our technology. Several times this prof helped us prepare responses to VC firms. He was really very very helpful. We did not have a specialist in high level systems. So when we were challenged by these VC specialists, we wanted to make sure we had the correct response.” As the firm began to expand operations the center helped them identify and hire employees including one of the center’s former students. In the words of the respondent, “Without the NSF grant it none of this would have been possible”

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**Fig. 2** Percentage of commercialization benefits reported by SBIR/STTR firm representatives

### 6.1.2 Commercialization benefits

As Fig. 2 demonstrates, a substantial percentage of SBIR firm representatives, ranging from 20% to nearly 70% reported they had realized or anticipated realizing one or more of a spectrum of commercialization-related benefits. Not surprisingly, given the amount of time commercialization-related impacts take to reach fruition, a higher percentage of firm representatives indicated they anticipated (rather than realized) various benefits than was reported on the R&D questions. On average, firms reported realizing 3.6 of 9 commercialization benefits measured, or 40%. Open-ended comments that accompany these ratings document the benefit and the respondent's attribution to participation in their IUCRC; additional comments describing how they benefited from these commercialization opportunities are provided in "Appendix 2".

Surprisingly, given the laser focus most small business start-ups have on their existing product, center membership appears to have had its largest impact on the identification of "new applications for the technology we are trying to develop" or what is often referred to as 'pivoting' in the entrepreneurship literature; i.e., "a change in a firm's strategy that reorients the firm's strategic direction through a reallocation or restructuring of activities, resources, and attention" (Kirtley and O'Mahony 2019, p. 4). Almost seventy percent of firm representatives reported they had realized or anticipated realizing this benefit (realized, 54%; anticipated, 14%). Firm representatives offered a wide range of descriptions for this benefit, including: "didn't realize our technology had a more important application involving measuring contaminants in materials"; "translated our technology to another sector". Interestingly, in many of these cases it appears that the interaction with other IAB members, not university research performers, was the factor that opened their eyes to a new application. As one member put it, "two IAB members can use our technology in a way we didn't anticipate."

This is not to say that firms had lost focus on the technology that they were funded to develop and commercialize under their SBIR award. Over sixty percent of firm representatives reported that participation in their center had an impact on improving existing

products or services (realized, 46%; anticipated, 17%). Typical descriptions offered by respondents include: “improved the technique”; “part of product was improved with faculty help.” Another thirty percent reported improved manufacturing processes (realized, 22%; anticipated, 9%) with one respondent reporting: “new approach for prototyping is ground-breaking.”

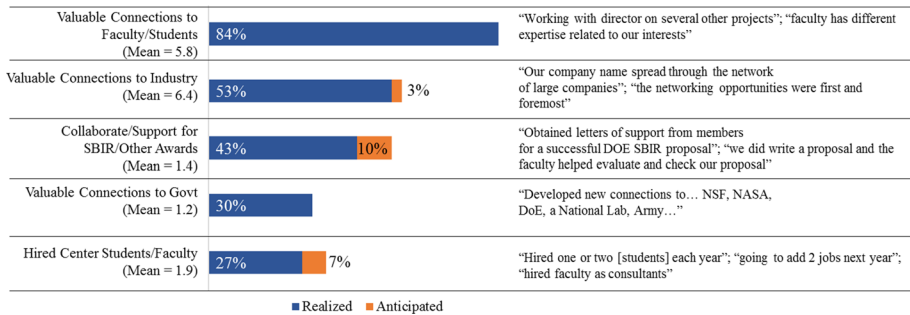
Firm representatives also reported IP-related benefits. Almost fifty percent reported accessing center IP and almost forty percent mentioned creating IP within the firm. In both cases about one-third of those reporting the benefit indicated they anticipated rather than realized the benefit (center IP; realized, 30%; anticipated, 20%; Firm IP; realized, 26%; anticipated, 13%). Typical descriptions include: “integrated center technology into our product”; “a component came out of proposed project”; “technology was perfect for us”; Typical descriptions of firm IP benefits include: “center research has led to a pending patent with university”.

Given the relatively brief membership of SBIR firms in centers, it is noteworthy that a significant percentage of firm representatives report very concrete commercialization-related outcomes. For instance, over one-third of firm representatives mentioned launching new products or services (12% realized; 21% anticipated). Another one-third mentioned help finding new investors (realized, 22%; anticipated, 12%). Almost twenty percent reported finding an investor for their Phase IIB SBIR application (realized, 7%; anticipated, 12%). Finally, nearly one-quarter reported adding new jobs (realized, 15%; anticipated, 10%).<sup>15</sup> Typical descriptions of this benefit include: “got exposed to student we hired”; “hired two new interns per year.” While probably a very generous attribution, one firm representative reported, “yes, all people here are a result of fact they [center] helped us get VC support.”

Based on open-ended comments provided by respondents, we identified an additional commercialization-related benefit that was not explicitly included on our forced choice list: *market intelligence*. Respondents reported a more nuanced understanding of the customers or markets they would be trying to access. Generally, these insights appeared to derive from discussions and interactions they had with other center industry members. Typical descriptions of this benefit include: “got information about the market potential of our technology”; “helped reposition to new markets”; “business contacts helped us identify new markets.”

Mini Cases 2 describes how different member firms realized both direct and indirect commercialization benefits from participating in their IUCRC.

<sup>15</sup> It is worth noting that this benefit probably overlaps with the “hired or contracted with faculty and students” benefit described under networking and human capital benefits in Sect. 6.4.1.



**Fig. 3** Percentage realizing human and social capital benefits reported by SBIR/STTR firm representatives

#### Mini Case 2: R&D and commercialization benefits networking links them together

Company D is involved in plasma engineering for defense, energy, and manufacturing industries. In an interesting variation on what we heard from other firms, they started with the center as an observer before they officially began their membership via a supplement. They indicated they were looking for three types of benefits: potential new customers, new avenues for their products and research the firm could leverage for their own goals. According to their reports they realized all of these benefits and some additional benefits they had not anticipated. The respondent indicated that involvement in the center accelerated and augmented their internal research capability. In the words of the respondent, "we got additional R&D related to laser welding that we would not have done ourselves." Much of the benefit from this research has been applied to their manufacturing process. The firm reports that the center's research and advice has resulted in improved products, new applications of these products and has promise of leading to a new product. Improved products were derived from ideas and understandings derived from the center and involved technology that was outside the firm's expertise. The center's research helped them pivot from applications targeted at a declining technology area to other sectors that showed more promise. The new product is a sensor technology for manufacturing oil wells used for fracking and involves partnering with two current IAB members. Another product is beyond the prototype stage and being built for a member company in a different area. In the words of the respondent, "because the center is multidisciplinary, we gained exposure and knowledge. We had a benefit in our process as a result. Beyond what we expected because the center dual mission." Firm also anticipates it may realize some IP from center research and reported hiring one center student as a full-time employee and another part-time. In spite of the very concrete commercialization-related benefits that the firm has realized, the respondent was vocal about the role networking played in obtaining these benefits. "The biggest benefit is relationship building with member companies. We were able to build lasting relationships with companies. You meet two times in person, talk on phone more, get comfortable. With those relationships, then come opportunities. From a small business perspective, the IUCRC gives us that access to potential partners we need for product sales, RD, services, partnering. There's an immense value to that." In this vein, the respondent indicated they had developed new relationships with eight firms, developed contacts with three new investors and developed a DoE proposal to conduct additional research. The respondent reported that the time they invested in the membership was worth a lot more than the money they invested but they left no doubt that their involvement in the center was well worth both.

## 6.2 Social capital benefits

In addition to asking about R&D and commercialization benefits, we asked firm representatives to indicate whether they have "realized", "anticipated realizing" or had "not realized" a list of five social capital benefits. As Fig. 3 demonstrates, the majority of SBIR members indicated they had realized a variety of the social capital benefits. On average,

firms reported realizing 2.5 of the 5 social capital benefits measured, or 50%. Additional illustrative comments describing specifically how firms benefited from these networking opportunities are provided in “Appendix 3”.

For instance, over eighty percent of firms reported they had “made valuable connections to university researchers and students.” The average number of such “new” connections reported by a firm with university researchers and students was 5.8. In explaining this benefit, one respondent reported: “expanding to a dozen researchers I got to know through the center from other universities & centers.”

The majority of firm representatives (53%) also indicated they had realized “valuable new connections to other center members (for example, as customers, suppliers, partners, or investors).” Interestingly, although SBIRs reported more frequent interactions with university personnel, the average number of new industry connections (Mean  $N=6.4$ ) exceeded the number of new faculty/student contacts. What appears to be important about these member networking benefits is how regularly and quickly they seem to translate into resource-related business advantages for a small company. For instance, firm representatives reported the following: “I met a lot of people, learned how the big firms do business”; “we bought raw materials from a member”; “director introduced us to some investors”. In short, firms are reporting networking which is already translating into access to valuable tacit knowledge and useful resources. About thirty percent reported making valuable connections to government agencies (Mean  $N=1.2$ ). In addition, over thirty percent of firm representatives reported they had hired or contracted with students or faculty (26%) or anticipated doing so (7%). The kinds of hires firms made ranged from student internships, to faculty consulting or subcontracting to full-time employee hires. Even more concretely, the majority of firm representatives indicated they had realized (43%) (or anticipated realizing 9%), “collaborated with or received support from faculty and firms on developing new SBIR/STTR or other research proposals.”

It seems that social capital that was developed from the interactions with the IUCRC for the SBIR firms in our sample contributed to realized R&D and technology commercialization benefits. We further explore the relationship between Center interactions, social capital formation, and the realization of R&D and commercialization benefits in Part 2.

### 6.3 Conflicts or costs of memberships

Given that firms typically make a cost–benefit analysis of any investment they make (Cyert and March 1963) combined with concerns about policy mix compatibility and unintended consequences, SBIR firm representatives were also asked to highlight whether there was anything negative about their experiences with the SBIR/IUCRC membership.

While some members reported what would be best characterized as obstacles to achieving their goals, relatively few cited specific costs. Over half of the firm representatives (62%) indicated there was nothing negative or unproductive about the experience. The balance of firm representatives mentioned issues that seemed to range from minor annoyances to what might be considered major obstacles to their ability to achieve various benefits. Eighteen percent of firm representatives mentioned challenges related to operational issues. For instance, 6.6% of all respondents highlighted informal agreements or promises they received from centers that were not fulfilled. As one respondent put it, “they promised to have the equipment ready...they didn’t have it and had to borrow it...very frustrating.” Other firm representatives (9.8%) mentioned poor communications/meetings (“we felt like outsiders”) or shortcomings in the member agreement (3.2%) (“IP language was overly

**Table 4** Reported frequencies of negative IUCRC membership experiences

	N	%	Illustrative comments
Nothing	38	62.3	"No negative experiences"; "Nothing negative"
Problematic Operational Issues	14	23.0	"agreements promised not fulfilled on time"; "membership/IP agreement too restrictive"; "communication problems"; "less project selection influence than I would like"; "challenging to attend all meetings"
Supplement Shortcomings	7	11.5	"time frame too short"; "they couldn't afford to keep going"
Research Problems	8	13.1	"it is just little off course. We are too narrow for them [center]"; "so there was a long start up time...for a small firm, this is detrimental"

restrictive for small firm"). Approximately twelve percent of comments referred to shortcomings inherent in the supplement itself including the short time frame or limited funding provided. For detailed examples, see Mini Case 3.

Interestingly, only thirteen percent mentioned issues related to the research that was being done including its quality/relevance/timeliness ("it is just little off course. We are too narrow for them [center]."), or slow or unpredictable progress ("so there was a long start up time...for a small firm, this is detrimental"). These issues seem much more serious and could cause major delays to time-sensitive small firms. See Table 4 for details.

#### Mini Case 3: Overpromising and underdelivering

Firm X develops products for the wireless sector and focuses on developing PCB for circuit boards.

They hoped the center would help them evaluate the IP they held. Center indicated they had all this equipment ready and they were going to develop and evaluate for a PCB (circuit board). But they didn't actually own the equipment and had to make arrangement to borrow it for 2 days and then they had to send it back. While they eventually did the work, the process was very frustrating and time consuming. They over promised on having the equipment. we were able to do a little bit but then we were out. In the firm's opinion, they did not deliver what they promised. So it put the whole project at risk. It happened toward the end of the year so the actual testing was done in some local labs. In the firm's opinion there was a long start up time. for a small firm, this is detrimental. a small firm doesn't have the resources to hang around like that needed to see the return on investment from the money and the time.

## 6.4 Overall evaluation

In order to provide an overall evaluation of the supplement, we used a subjective measure—a self-report evaluation of the value provided by the subsidized membership.

### 6.4.1 Perceived Return on Investment (ROI) of membership

We asked firm representatives to make a summary judgment about the value of the supplement. Specifically, they were asked: "Given your experience being a member of the center to date, do you think your participation was worth the time and money your firm invested in the membership?" They could respond with one of four answers: definitely yes, probably yes, probably not, definitely not (See Table 5).



**Table 5** Reported frequencies of Perceived Return on Investment (Worth Time and Money Invested)

Response	N	%	Illustrative comments
Definitely Yes	42	68.9	"I would tell almost any small business to do it. This center is great. A small business would be foolish not to take advantage"; "Have received some very tangible benefits. They developed connections that they would not be able to achieve... The nature of the center and meetings, people were sharing the research." It definitely shortened the time to connect and have opportunities to interact. The density of networking opportunities was a big benefit"
Probably Yes	11	18.0	"we haven't gotten the results yet, but it looks like it's going to work out"
Probably Not	4	6.6	"they dropped the ball on us"; "I do see potential value in the IUCRC program; this particular case just did not work out well"
Definitely Not	4	6.6	"Lost money from membership and traveling associated with it"; "The faculty members don't like to log time and don't like to be restricted by deliverables and time"

The overwhelming majority of participants (86.9%) answered in the affirmative with 68.9% saying “definitely yes” and another 18% saying “probably yes.” Firm representatives who said it was definitely worth their time and money appeared to receive tangible benefits that they valued. For instance, firm representatives reported: “I would tell almost any small business to do it. This center is great. A small business would be foolish not to take advantage”; “Have received some very tangible benefits”; “The density of networking opportunities was a big benefit.” When explaining why they answered “probably” worth their time and money, firm representatives tended to hedge their judgment based on anticipated but as yet unrealized benefits. For instance, one firm representative reported, “we haven’t gotten the results yet, but it looks like it’s going to work out.” About thirteen percent of firm representatives reported “probably not” (6.6%) or “definitely not” (6.6%) worth the time and money invested. Those that reported that the membership was not worth their time and money, appeared to be the same firm representatives that reported poor alignment with the center’s technical program, bad or negative experiences and few benefits. In some cases, these firm representatives reported a failure on the part of the center to deliver on promises and poorly aligned goals and timelines (See Mini Case 4). These findings suggest that 13% of the SBIR firms either were not well aligned with the center they were a member of or that IUCRC and its members were not willing and effective partners.

In summary, the vast majority of the firms who participated in the supplement believe what they got out of it was worth the time and money they invested in their membership. These findings would appear to be a very strong endorsement of the value of the supplemental membership mechanism by the SBIR firm representatives.

## 6.5 Summary

At the program-level of analysis, the SBIR IUCRC Membership Supplement appears to have had an impact on a variety innovation-related outcomes. A high percentage of SBIR members report realizing a variety of concrete benefits ranging from, research progress, R&D cost avoidance and savings to more commercially relevant outcomes including identifying new applications for their product to the introduction of a product or service. The overwhelming majority believed their participation was worth the time and money they invested (perceived ROI). While it is difficult to say with certainty whether some of these benefits might have been realized by simply sponsoring an individual project at a university, the diversity of benefits reported including access to venture support, identification of new applications and market insights and attributions by respondents about the role played by university and industry stakeholders in securing those benefits suggest more complex and additive processes are at work in this policy mix experiment (Arnold 2004). In addition, most SBIR members did not report significant negative effects or costs. Most of the issues raised appear to constitute inefficiencies in the partnership that perhaps could be ironed out over time. However, about 13% of these firms report significant mismatches between needs and center capabilities or delays in getting research underway and completed. This probably represents a significant cost for firms under extreme time pressure. The spontaneous attribution about networking mechanisms contributing to these benefits and the high rate of social capital benefits reported appear to reinforce the possibility that a connection may exist between these variables. We attempt to examine this connection empirically in the next section.

## 7 Part 2: Social capital processes

In Sect. 4.2, we indicated that SCT might provide a theory of change to support how the mixed policy initiative embodied in the SBIR IUCRC Membership Supplement could have a beneficial impact on R&D and commercialization outcomes. Specifically, SCT would hypothesize that expanded formal and informal networking between SBIR members with various IUCRC stakeholders would enhance their social capital and provide access to valuable innovation-related resources. Findings from Part 1 appear to support the beneficial effect of the supplement on R&D and commercialization (and social capital outcomes). At least some of the comments provided by respondents appears to connect these benefits to the networking-based social capital they also acquired. In this section, we attempt to address our second research goal, *To evaluate whether SCT could explain the observed innovation related outcomes*, empirically.

Related to our second goal our hypotheses include:

Hypothesis 1a: SBIR firms with higher amounts of IUCRC meeting attendance will demonstrate higher levels of social capital.

Hypothesis 1b: SBIR firms with higher levels of student and faculty interactions between meetings will demonstrate higher levels of social capital.

Hypothesis 1c: SBIR firms with higher levels of Industry Advisory Board (IAB) member interactions between meetings will demonstrate higher levels of social capital.

Hypothesis 2a: Higher levels of social capital will positively relate to higher amounts of realized technology commercialization benefits for SBIR firms.

Hypothesis 2b: Higher levels of social capital will positively relate to higher amounts of realized R&D benefits for SBIR firms.

Hypothesis 3a: Higher amounts of realized commercialization benefits will be positively related to the SBIR firm's perceived ROI.

Hypothesis 3b: Higher amounts of realized R&D benefits will be positively related to the SBIR firm's perceived ROI.

Hypothesis 4a: Realized commercialization benefits will mediate the relationship between social capital and SBIR firm's perceived ROI.

Hypothesis 4b: Realized R&D benefits will mediate the relationship between social capital and SBIR firm's perceived ROI.

### 7.1 Methods

#### 7.1.1 Sample and instrument

Part 2 utilized the same sample and questionnaire used to address Part 1 questions. Analyses in Part 2 include some additional variables and a number of transformations in the variables we examined. First we also examine SBIR member characteristics, IUCRC center characteristics, and data on the frequency of interactions reported between SBIR members and other IUCRC stakeholders. In addition, the benefit variables examined in Part 1 were combined to create summary scales for Part 2 hypotheses.

## 7.1.2 Measures

**7.1.2.1 SBIR characteristics** As we have discussed earlier (Sect. 5.3), all policy instruments and particularly policy mix instrument's effectiveness are dependent on contextual factors including the type of participants, and the circumstances or conditions in the local environment. In order to determine if such variables affected outcomes, we assessed a series of SBIR firm characteristics, as well as Center characteristics. Firm characteristics included firm age, firm age when they got their SBIR award, time since their SBIR award ended, total years as an IUCRC member, N of employees, and previous university collaboration experience (none, a fair amount, a great deal). Center characteristics included in the analysis were N of members, Center total budget, and Center age. However, since none of the Center characteristics were significantly correlated with our outcome measures, they are not discussed in results.

**7.1.2.2 Member interactions** SCT asserts that organizations benefit by accessing and mobilizing resources while interacting with their partners or networks. Within the context of an IUCRC, much of the formal and informal interactions associated with an IUCRC occur at semi-annual center meetings. Members must participate in various center activities like attending semi-annual meetings, voting on projects, making suggestions for project improvement, interacting with PIs, students and other members in order to influence the center's research agenda, to gain tacit knowledge and ultimately to extract value from their center membership. As SCT would predict, participating in these activities also creates an opportunity to expand their social capital which can increase access to various resources. In order to measure these formal and informal interactions, respondents were asked about their meeting attendance (attended all meetings, attended some meetings, participated remotely, did not attend), the frequency of their between meeting interactions with Center faculty and students (none, a little, a moderate amount, a lot), and their between meeting interactions with other Center IAB members (none, a little, a moderate amount, a lot).

Although there was some variability in attendance at IAB meetings, SBIR firms appear to be actively engaged in this central aspect of center operations. Almost half (44%) of the firm representatives reported they attended all of the IAB meetings during their term of membership, while the balance attended some (38%), attended some remotely (10%), or not at all (8%). Those SBIR firm respondents that regularly attended IAB meetings would have a much greater opportunity to have established relational capital with IUCRC member representatives, which should enhance openness and promote collaboration.

Almost all the firm representatives (97%) reported interacting with faculty/students in between these meetings, with 29% reporting "a lot" of such contacts, and about half (58%) reporting a "moderate amount" of between meeting contacts. These interactions were typically project related. Some firm representatives also reported working with center faculty and students on outside projects. Between meeting interactions with other firms were reported by about half (48%) of all SBIR members, with only 7% reporting a lot of contact, and 26% reporting a moderate amount of between meeting interactions. SBIR-members reported that these interactions ranged from general networking, to exploring business opportunities, developing joint proposals for contracts and grants, doing collaborative work with other members, and buying or selling products and services with center members.

**7.1.2.3 R&D, commercialization and social capital indices** Descriptive statistics for R&D, commercialization and social capital benefits were reported in Part 1. In order to address

our Part 2 research hypotheses we created summary scales for each of these constructs. As the purpose of our analyses is to determine if technology commercialization outcomes occurred for SBIR firms, count variables were created in order to represent the number of realized benefits. Latent variables were not created as we did not have a theoretical reason to suspect the realized benefits represented one unique construct, but rather represented a formative index (Edwards and Bagozzi 2000). Indices were created by counting the number of benefits realized (anticipated was not counted) by a respondent for each outcome category. Our benefit indices had the following ranges: R&D 0–4, commercialization 0–9 and social capital 0–6.

**7.1.2.4 Perceived return on investment (ROI)** As described in Part 1, perceived ROI was measured by asking SBIR firm representatives to make a summary judgment about the value of the IUCRC membership supplement. Specifically, SBIR firms were asked: “*Given your experience being a member of the center to date, do you think your participation was worth the time and money your firm invested in the membership?*” Perceived ROI was measured on a 1 to 4 Likert scale with the following response options, (1) definitely not, (2) probably not, (3) probably yes, and (4) definitely yes. See Table 5 and Sect. 6.4.1 for details.

## 7.2 Analytical technique

Path analysis, also referred to as simultaneous equation modeling or structural equation modeling (SEM), was used to assess the direct and indirect effects of the focal variables used in our study hypothesis (e.g., see Bollen 1989; James et al. 1984). Path analysis was used as it provides a means to assess all theoretically hypothesized relationships among study variables in a single model (e.g., see Ahn et al. 2018; Bilimoria et al. 2006; Bellini et al. 2019). All analyses were conducted using the R programming language version 3.5.2 (R Core Team 2018) and the package lavaan for estimating the SEM model (Rosseel 2012). To avoid parametric assumptions with regard to model estimation and improve our model estimates of indirect effects following best practice (e.g., see Cheung and Lau 2008), the path model was estimated with 1000 bootstrapped samples (Bollen and Stine 1990; West et al. 1995). In addition to all model estimates, the standard errors were calculated with 1,000 bootstrapped samples. Model fit was assessed following Hu and Bentler’s (1999) recommendations.

## 7.3 Results

Before estimating the path model, we examined the correlations between our focal study variables to assess if a conducting a structural model was appropriate. Based upon SCT, we expect to higher levels of interactions will relate to higher levels of social capital benefits realized. Correlations supported this assumption (see Table 6), highlighting that higher levels of meeting attendance, university interaction, and industry interactions related to higher levels of social capital benefits realized by SBIR firms, respectively. Following, we see that social capital is positively correlated with both R&D and commercialization benefits realized by SBIR firms. Last, we find positive correlations between R&D benefits and commercialization benefits realized by SBIR firms and their perceived ROI regarding the IUCRC membership supplement.

Overall, we see that covariation held across all focal variables in our path model, which is a requirement for establishing causality (Shadish et al. 2002). Next, following SCT, we

**Table 6** Correlations and descriptive statistics

	Variable	N	Mean	SD	1	2	3	4	5	6
1	Meeting Attendance	61	2.18	0.92						
2	University Interaction	59	2.12	0.72	0.07					
3	Industry Interaction	61	0.89	1.02	0.34**	0.15				
4	Social Capital Index	61	2.33	1.50	0.40**	0.29*	0.65**			
5	R&D Benefits Index	61	1.98	1.10	0.23	−0.05	0.13	0.44**		
6	Commercialization Benefits Index	61	2.08	1.67	0.25	0.25	0.44**	0.56**	0.20	
7	Perceived ROI	61	2.49	0.89	0.16	0.18	0.32*	0.43**	0.33**	0.33**

ROI Return on investment

$p < .05^*$ ,  $p < .01^{**}$ . Correlation is significant at the 0.01 level (2-tailed)

expect that interactions with IUCRC members must precede the social capital benefits realized (i.e., working closely with industry and academic members of the IUCRC) and that this work must logically precede any realized benefits of R&D or new technology being commercialized. By establishing covariation and the logic of temporal precedence, we are confident that a path model is an appropriate analysis for the current study.

Based on SCT we hypothesized that SBIR firm interactions will lead to social capital development (H1a–c), that social capital would predict commercial (H2a) and R&D (H2b) outcomes, which would predict subjective ROI outcomes (H3a–b) for SBIR firms. Finally, we hypothesized that commercialization and R&D benefits would mediate the relationship between social capital and perceived ROI (H4a–b). The model likelihood-ratio test and associated fit statistics suggested our hypothesized model provided good fit with the data ( $\chi^2(11) = 11.21$ , Bollen-Stine  $p = .833$ , CFI = .997, TLI = .996, IFI = .997, RMSEA = .018).

The first set of hypotheses focused on assessing the relationship between SBIR firm interactions with IUCRC stakeholders in the form of (H1a) formal meetings attended, (H1b) faculty and student interactions, and (H1c) industrial advisory board (IAB) interactions. Following SCT, we tested the hypothesis that SBIR firm interactions led to higher levels of social capital benefits for SBIR firms. Results supported our hypotheses, that the amount of IUCRC meetings attendance by SBIR firms ( $b = .49$ ,  $t = 3.05$ ,  $p = .002$ ), faculty and student interaction ( $b = .40$ ,  $t = 2.02$ ,  $p = .044$ ), and interactions with the IAB members ( $b = .73$ ,  $t = 4.68$ ,  $p < .001$ ) were all positively related to the SBIR firm's social capital realized, respectively.

Second, we tested the hypotheses that the level of SBIR firm social capital contributed to higher amounts of (H2a) realized technology commercialization benefits and (H2b) realized R&D benefits. Results supported our hypotheses that higher amounts of SBIR firm social capital positively related to higher amounts of commercialization benefits ( $b = .62$ ,  $t = 5.97$ ,  $p < .001$ ) and also higher amounts of R&D benefits ( $b = .29$ ,  $t = 3.47$ ,  $p = .001$ ). The empirical results from the path analysis confirmed results from the qualitative data suggesting that formal and informal interactions with IUCRC's and their members contributed positively to SBIR firm technology commercialization as well as helping to supplement and enhance internal firm R&D.

Our third set of hypotheses assessed whether the policy mix experiment was perceived as worthwhile for the SBIR firms. Here, we hypothesized, that due to the mission of the SBIR program and the SBIR firms being focused primarily on technology commercialization, that the SBIR firms would deem their membership in IUCRCs favorably if commercialization benefits were realized during their interactions and time spent working with the IUCRCs (H3a). Given that STC does not specify the types of benefits that social capital may leverage, we also tested the hypothesis that realized R&D benefits predicted perceived ROI (H3b). Results supported the hypothesis that SBIR firm's subjective assessment of the program was positive if they received commercialization benefits (H3a) ( $b = .13$ ,  $t = 2.07$ ,  $p = .038$ ) but did not reach statistical significance for R&D benefits realized (H3b) ( $b = .17$ ,  $t = 1.80$ ,  $p = .073$ ).

Finally, we assessed the role of social capital on SBIR firms' subjective perceptions of whether participation in IUCRCs was worthwhile (i.e., perceived ROI). We tested the indirect effect from social capital to the SBIR's perceived ROI (H4a) and found that social capital had a positive indirect effect on perceived ROI through commercialization benefits realized ( $a*b = .09$ ,  $p = .054$ ), but no significant indirect effect through R&D benefits (H4b) realized ( $a*b = .05$ ,  $p = .136$ ). Here, the results suggest that the SBIR firms who participated in the policy mix experiment perceived their time and effort spent building social capital with IUCRCs as worthwhile only if commercialization



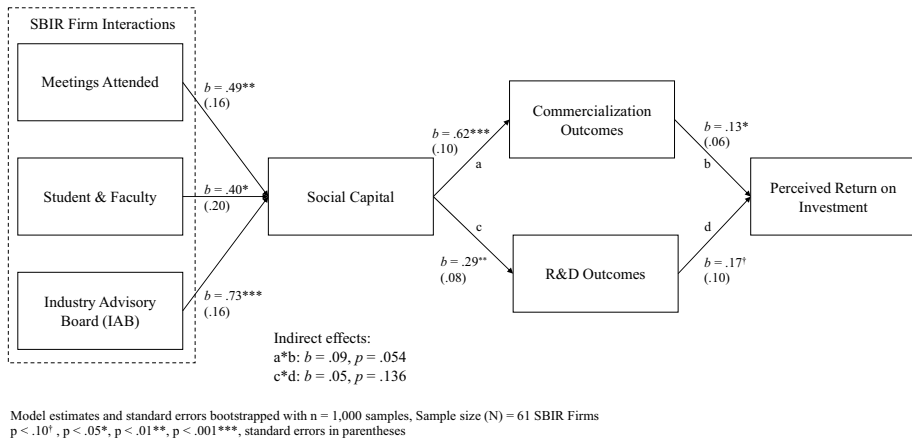


Fig. 4 Path model

benefits were realized. The overall model  $R^2$  for each focal dependent variable is as follows: social capital  $R^2 = .53$ , commercialization benefits  $R^2 = .30$ , R&D benefits  $R^2 = .16$ , and perceived ROI  $R^2 = .14$ . For detailed model results, please refer to Fig. 4.

As a post hoc model test, to better understand the magnitude of the effect of SBIR firm's social capital on commercialization benefits realized and R&D benefits realized, we tested the difference in the path estimates (a) from social capital to commercialization benefits realized (i.e.,  $b = .62$ ,  $p < .001$ ) and (b) from social capital to R&D benefits realized (i.e.,  $b = .29$ ,  $p < .001$ ). Results suggested that the path estimate from social capital to commercial benefits realized was significantly higher in magnitude of effect than the path estimate of social capital to R&D benefits realized (Wald test (1) = 5.40,  $p = .020$ ). Thus, we can conclude that the influence of social capital is significantly larger for SBIR firm's commercialization benefits in comparison to their R&D benefits realized. Overall, the results seem to support that the SBIR firms had significant and positive experiences from the policy mix experiment.

## 7.4 Part 2 Summary

Overall, study 2 results supported our theoretical propositions that interactions between SBIRs and other IUCRC stakeholders played an important role in contributing to higher levels of social capital and also to the R&D and commercialization benefits realized by the SBIR firms. We find that those firms with higher levels of interactions with IUCRC members, students, faculty, and industry develop higher amounts of social capital, and this in turn relates to greater amounts of realized R&D and commercialization outcomes for the SBIR firms (e.g., developing new products or improving existing products). Significantly, these effects are significantly greater for commercialization benefits which also contribute to greater perceived ROI. The empirical results in Part 2 map very well with the qualitative results from study 1, thus providing mixed-methods support of our focal study hypotheses, that social capital has an additive effect for SBIR firms, especially for the commercialization of new technologies.

## 8 Overall discussion

### 8.1 Evaluation of the SBIR/IUCRC Membership Experiment

The SBIR/IUCRC Membership Supplement was an intentional combination of two long-standing NSF STI initiatives that focused on earlier and later stages of the innovation process. The stated objective of the DCL which created this experimental policy mix initiative, “accelerate the innovation process by partnering industry-relevant academic research with commercialization focused small business research”, appears to have two components: creating a viable partnership between industry-relevant academic research and commercialization focused small business research and accelerating the innovation process.

With respect to the first component of that objective, the initiative appears to have been very successful in creating an intentional mix of two federal programs that incorporate university, industry and government. Over a couple of years it helped introduce and integrate 70-plus SBIR firms as fully-participating members of a series of nationally prominent IUCRCs. This success appears to have come about due to a series of instrumental program implementation processes: firms foray into the world of multi-partner collaborative research was heavily subsidized; firms were able to choose the center they joined; and based on participation data almost all SBIRs report engaging with the centers and their stakeholders to varying degrees via their official meetings and informally outside of meetings. Importantly, at the end of their involvement over 85% of respondents reported participating in the partnership was worth their time and money.

Addressing the second component of the DCL’s objective, “accelerating the innovation process”, is obviously more challenging for two reasons. First, the innovation process is very complex, involving a number of steps and processes. It is also contextual. That is the process can differ depending on a variety of national innovation system, sector, organizational and local contextual factors, and the type of technology being developed (Fagerberg 2006), that may not be reflected in this particular study. Second, the design and methods used in this exploratory study fall short of the type of counterfactually-supported causal inferences one could make with a quasi-experiment or a tightly controlled multiple case study (Rideout and Gray 2013). Nonetheless, we believe our mixed-method assessment strategy provides adequate information given our exploratory research questions.

The most distinguishing goal of the SBIR program is to “increase private-sector commercialization of innovations derived from Federal research and development funding.” Given the short time they were involved in this policy experiment, the commercialization-related findings reported in Sect. 6.1 are quite encouraging. The majority of SBIR-members report realizing or anticipate realizing the following: new technology applications for their technology; improved existing products; and access to center IP. Over 25% report: creating firm IP; identifying new investors; improving operational/manufacturing processes; new product development; and adding new jobs. Importantly, these ratings are supported by specific and convincing explanatory comments by the respondents. As one respondent put it “center research has led to a pending patent with university” while another anticipated that “collaboration with another member company will lead to new sensor technology with huge benefit.” Thus, a relatively sizeable percentage of firms have made progress or appear to be making progress toward the end-game of the innovation process—commercialization. While the benefits the firms reported varied, only a small minority of firms reported participation in the program produced negative outcomes and/or was not worth the time and money they invested.

## 8.2 The additive effect of social capital in producing benefits

It is important to remember that there is no assurance that all mixed policy initiatives will be productive. As Gunningham and Sinclair (1999) point out, mixes can be inherently complementary; inherently incompatible; complementary if sequenced; or complementary depending on context. As a consequence, we believe it is important for policy mixes to be built with respect to a strong research framework and theory-based theory of change. In our introduction we reported that other researchers have found that mixed policy initiatives that included direct fiscal support (e.g., SBIR) and an instrument that provides indirect support (including management assistance, access to markets, etc.) had yielded positive effects (Cunningham et al. 2013). In our case we hypothesized that additive effects could be explained by SCT processes involving increased interactions and expanded social networks which provided access to valuable resources. Both qualitative and quantitative results appear to support this connection. Many of the R&D and commercialization benefit Mini Cases provided mentioned the key role played by faculty/student and/or industry intermediaries in producing those benefits. In addition, our empirical data support the hypothesized connection between networking interactions, social capital, realized benefits and subjective evaluation of ROI, especially via commercial benefits.

## 8.3 Implications for research evaluation

The policy mix movement promises to provide a much more nuanced and realistic lens to view the collection of STI programs we have created over the past several decades. However, it can only achieve this goal if its emerging conceptual framework is married with a robust program of evaluation research and policy analysis. Research on whole system mixes and even portfolio-sized mixes will continue to pose serious methodological challenges. However, STI ecosystem is replete with a large collection of designed, programmatic combinations, like the SBIR IUCRC Membership Supplement, which involve integrating or combining multiple program instruments. A quick review of the DCLs released on by NSF on an annual basis—many of which involve supplemental funding for extra research or training—would confirm this assertion. Unfortunately, few are viewed as policy mix initiatives and almost none are subjected to evaluative scrutiny to see if they are truly complimentary. We hope our study demonstrates the feasibility and desirability of beginning a more rigorous assessment of these promising experiments.

While we believe our exploratory study has demonstrated that there is an opportunity to conduct meaningful evaluation research on the benefits and costs of relatively straight forward design mixes like the SBIR/IUCRC Membership Supplement, we believe future research can go further in a number of respects.<sup>16</sup>

- Attempts should be made to use designs with stronger counterfactuals and larger sample sizes. For instance, in the case at hand, if budgets permitted, one could have created a matched control group of supplement-eligible SBIRs who chose not to participate in

<sup>16</sup> Finally, shortly after we completed our data collection efforts NSF decided to withdraw the DCL. The opportunity to secure a subsidized SBIR/IUCRC Membership Supplement no longer exists. No explanation was given by NSF for the decision to discontinue the supplement.

the program as a control group. Since most technologies were still under development during our study, using longer follow up periods would also be recommended.

- We have acknowledged contextual factors (e.g., program, agency, region, sector, national innovation system) may affect the outcomes of various policy mix efforts. The SBIR program is deployed across all federal research-funding agencies nationally, it would be useful to understand what moderating effects these and other factors introduce.
- Our analysis was based on highlighting the importance of several policy mix dimensions. Scholarship in this area would benefit from development of more comprehensive typology of factors and dimensions.
- The policy mix literature talks about the potential for various “additionalities” when various instruments are combined. In order to capitalize on the potential synergy involved in these combinations, we need to be able to communicate a research and theory based ‘theory of change’ that helps identify and document these additionalities. In the case at hand we found substantial support for SCT processes being instrumental in the benefits SBIR firms reported. Based upon our study results, we also recommend that future research take a more nuanced view of social capital that examines cognitive, relational and structural social capital (Inkpen and Tsang 2005; Dyer and Singh 1998; Nahapiet and Ghoshal 1998). Research on partnership-based policy mix experiments should also examine the value of other interorganizational theories and the resourced-based view (RBV) of the firm (Barney 1991, 2001). Understanding the potential competitive advantage that policy mix provides for small high-tech entrepreneurial ventures is important to advance theory on both policy mix and RBV.
- While the innovation process is very messy, complex and interactive process, it would be helpful to utilize more nuanced outcomes measures, perhaps building on one of several TRL scales that are available.

## 9 Conclusion

Our research has several implications for contemporary STI policy. Consistent with the growing interest in a policy mix orientation, it demonstrates feasibility of launching small scale policy experiments based on the combination of existing programs without making an expensive and perhaps irreversible commitment to a particular intervention. We estimate this policy experiment cost about \$4 million over the 4 years it was in operation. Second, although the supplement is no longer in effect, our findings should be encouraging for those interested in partnering individuals and organizations operating at earlier and later stages of the innovation process. Finally, we hope it demonstrates how research and theory can and should be used to inform the growing discussion on policy mix in STI.

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of many SBIR/STTR firms as well as efforts of the on-site evaluators who have been collecting data that contributes to our national IUCRC evaluation database. Any conclusions, findings, or recommendations are those of the authors and do not necessarily reflect those of the National Science Foundation or the U.S. government.

## Appendix 1

### R&D benefits illustrative examples

Benefit	Illustrative comments
Accelerated R&D/Save Time Money	"We were investigating membranes and they helped us along—might not have looked at it without this collaboration"; "feasibility studies very useful to reduce risk of early ideas"; "work accelerated our ability to resolve issues in product development"; "using their knowledge was big time saver"; "new testing methods—saved lots of time—and did it better"
Avoided Firm R&D Costs	"Center was able to help identify the problem which helped the us to prevent extra costs"; "thought something was a bad idea; it didn't work and reaffirmed"; "We could not have done this work internally"; "they did prototyping—we wouldn't have funds to do that"; "avoided unproductive research lines based on what we learned"; "they are doing research we couldn't"
Access to Equipment	"Tested performance and learned we did not want to invest in this instrument. Saved us time and money"; "had specialized equipment we couldn't possibly afford"; "helped center acquire some equipment we were using"; "a device designed for us would have cost too much to do ourselves—the R&D opportunities we've seen that we wouldn't have addressed"
New Lines of Research	"Far more important than saving \$ on R&D—growth of the company"; "has taken us in a different application direction than they had previously"; "stimulated ideas for our work developing imaging technology"; "now that we know this is possible [new direction], we are trying to explore on our own"; "directions of the research within firm has changed because of center"; "Center has helped to confirm new directions in sensors- influenced research strategy"
Augmented/extended our R&D	"More augmented our R&D"; "we augmented rather than avoided costs"; "would not have been able to evaluate technology without their resources and knowledge"; "we did not have R&D without this"; "they are doing research we couldn't"; "they are doing the software development we couldn't do"; "exploring projects internally we would never have explored otherwise"; "got additional R&D outside what we do normally, we wouldn't have done it ourselves"

## Appendix 2

### Commercialization benefits illustrative examples

A policy mix experiment to promote start-up success: exploratory...

Benefit	Illustrative comments
Identify new technical application	"Possibility of new factory related chemistry process"; "didn't realize our technology had a more important application involving measuring contaminants in materials"; "translated our technology to another sector"; "their technology allow us to access broader market"; "identified new way of interaction between user and device"; "found our technology was more powerful than we initially thought (for new application)"; "may allow technology to work under different conditions"; "two IAB members can use our technology (in a way we didn't anticipate)"; "applicability of our additives to a new different type of material"
Improve existing product	"Improved the technique"; "part of product was improved with faculty help"; "understand device landscape and made adjustments to meet"; "indirectly helped to improve products"; "upgrade their product"; "characterization allowed improvement"; "using laser welding based advice and expertise of center"
Access Center IP	"It showed improvement but we didn't use it"; "integrated center technology into our product"; "a component came out of proposed project"; "technology was perfect for us"; "licensed their software"; "now in our software product"; "IP filed that we hope to use"; "their IP developed and improved testing methods"; "IP related to additives in a material"
Create Firm IP	"Center research has led to a pending patent with university"; "we take what they do and modify to improve our product"; "yes, but difficult to attribute to center"; "filled for some patents"; "our IP enhanced by center research"; "validated our IP in their lab"; "anticipate some disclosures"; "may influence our IP"; "provisional patent filed"
Identify new investors for firm	"One for certain and four probable investors"; "one tied back to new application of our technology"; "got support from other manufacturers"; "member firm will act as our distributor"; "military group funded us"; "two potential investors"; "promising but too soon to tell"; "no investment yet but interest"
Improve operational/mfg. process	"Improved internal product development process"; "new approach for prototyping is ground-breaking"; "collaboration with company will lead to new sensor technology with huge benefit"; "on hardware side we are improving manufacturing"; "testing and lab work helped work more effectively with manufacturers"; "yes, through new test method"
Add new jobs	"Got exposed to student we hired"; "hired two new interns per year"; "hired around 2–3"; "will add two jobs next year"; "more maintained jobs we already had"; "new Army project will result in five new hires"; "yes, all people here result of fact they helped us get VC support"
Launch new product/service	"Actually new services launched"; "if results of current work is positive we will"; "yes, a new prototyping method"; "attempted to launch a new product"
Identify investor to apply for SBIR PIIB	"Got letter of support on project"; "got a different Phase 1 award"; "prototype attracted an investor"; "in the talking stage"; "yes but after the grant was over"; "in process but not realized yet"; "tried but ran out of time to apply"

Benefit	Illustrative comments
Market intelligence	"[Advice] expanded market"; "good suggestions for transferring product to market"; "helped market map some potential new applications"; "translated technology into other markets"; "got information about the market potential of our technology"; "helped reposition to new markets"; "better understanding of the market which led to new spheres of research"; "changed marketing to new target"; "business contacts helped us identify new markets"

#### Mini Case 3: SBIR firm with multiple synergistic benefits

This firm focuses on energy and emissions related technology research and development. They had a very high regard for the center director and wanted to get involved in the research he was working on and thought it overlapped nicely with the kind of problems they were working on. They were very adamant that without the supplement they wouldn't have joined the center. They indicate that they have received a number of very concrete R&D and commercialization benefits from participation in the center. First, involvement has produced a lot of R&D cost avoidance and savings and accelerated their ability to do product development. As a consequence they have been able to deploy their limited R&D resources more effectively. They report that they have gotten a lot of free expert consulting from the center and characterize the experience of the faculty as "astounding." A device designed for them would have cost too much for them to do themselves—and this R&D opportunity would never have been addressed.

According to the company a project they proposed made a lot of progress solving a tech issue. As a consequence, they pulled this work into their own R&D because: "You only get so far in the center because it's precompetitive and then have to take it the rest of the way on your own." This work has been incorporated into an existing product component they are currently refining and using. Although they haven't licensed any center IP, they "take what the center does and modify it and improve for their own issues." In addition, in the course of working with the center they realized they had a technology and that had another more important application -measuring contaminants in materials. They are in the process of commercializing this application. In another case one of their research projects was dormant due to a technical issue they couldn't overcome. With the center's help they were able to get through the issue. Based on this work they are designing a new technology for a new customer.

They also anticipate a new product may come from their work that will be targeted at a DoE project. They report winning a number of federal and private grants as a result of the work they have done with the center which has produced additional income for the firm. They report they have already attracted one new investor and a possible four additional investors in part due to these center-related commercialization developments. This work has resulted in them hiring two summer interns, subcontracting a project with a professor, are a subcontractor on a project funded through the center. They anticipate adding two jobs next year that are related to the center's work. The impact of getting involved in the center on their social capital is impressive with them reporting relationships with 18 new faculty or students and 30 IAB members. Not surprisingly they report, "I would tell almost any small business to do it. This center is great. A small business would be foolish not to take advantage of it."

## Appendix 3

### Human and social capital benefits illustrative examples



Benefit	Illustrative comments
Valuable Connections to Faculty/Students	“Made great connections with several faculty and students”; “working with director on several other projects”; “faculty has different expertise related to our interests”; “networking with faculty helped us win a number of fed and private grants -income as a result of that”
Valuable Connections to Industry	“I met a lot of people, learned how the big firms do business”; “The networking opportunities were first and foremost”; “We were also able to contract with a key service provider. We also bought raw materials from a member” “our company name spread through the network of large companies”; “established a partnership with another member”; “director introduced us to some investors”
Collaboration/Support for SBIR/Other Awards	“We did write a proposal and the faculty helped evaluate and check our proposal”; “actively working on some new proposals with some of the faculty associated with the center”; “Obtained letters of support from members for a successful DOE SBIR proposal”
Valuable Connections to Gov’t	“Developed new connections to... NSF, NASA, DoE, a National Lab, Army...”
Hired Center Students/Faculty	“Around 2 or 3 employees hired”; “hired one or two [students] each year”; “hired faculty as consultants”; “professor is a subcontractor”; “projects with faculty that involve supporting students”; “eight students hired”; “going to add 2 jobs next year”

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