# Public R&D subsidies, outside private support, and employment growth

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Albert N. Link & John T. Scott (2013) Public R&D subsidies, outside private support, and employment growth, *Economics of Innovation and New Technology*, 22:6, 537-550, DOI: 10.1080/10438599.2013.776744



**Abstract:**

In the aftermath of the passage of the American Recovery and Reinvestment Act of 2009, the employment effects of public subsidies have been scrutinized because of new emphasis on public accountability and transparency. In this paper, we investigate conditions in which public subsidies of research and development (R&D) in small firms stimulate employment growth. We find, based on an empirical analysis of employment growth induced by US Department of Defense Small Business Innovation Research program awards, that the stimulated employment growth is greater under two conditions: one, the presence of outside investors providing additional funding for the R&D and, two, when an exceptional amount of intellectual property is created by the publicly subsidized R&D. In addition to outside investors, other firms that make commercial agreements with the subsidized firm appear important for the employment growth of the subsidized firm. Cooperation between the small business doing the R&D and other firms is an important determinant of the commercial success of the technologies created with the support of public funds.

**Keywords:** public subsidy of R&D | intellectual property | employment growth | entrepreneurship | cooperation

**Article:**

## 1. Introduction

In the aftermath of the passage of the American Recovery and Reinvestment Act of 2009, the employment effects of public subsidies have been scrutinized in a policy environment that places new emphasis on public accountability and transparency. In this paper, we extend our earlier analysis in this journal (Link and Scott 2012d) to investigate conditions in which public subsidies of research and development (R&D) in small entrepreneurial firms stimulate employment growth.[1]

The public program providing the R&D subsidies that we study herein is the US Department of Defense (DoD) Small Business Innovation Research (SBIR) program.[2] The SBIR program was created by the US Congress through the Small Business Innovation Development Act of 1982. Its mission is to provide public funds to support R&D investment by small firms and thereby to stimulate technological innovation, to use small businesses of 500 or fewer employees to meet federal R&D needs, to foster and encourage participation of minority and disadvantaged persons in technological innovation, and to increase private sector commercialization of innovations derived from this federal R&D. DoD's SBIR program is the largest SBIR program, and it accounts for more than 50% of awards (Link and Scott 2010, 2012a).

After multiple multi-month extensions of the program because the US Congress failed to reauthorize it in 2008, the program was reauthorized for six years through the National Defense Authorization Act of 2012. That legislation introduced a number of controversial changes, including for the first time the provision that small firms that are majority-owned by venture capital (VC) operating companies, hedge funds, or private equity firms (hereafter collectively referred to as VCs) are eligible to participate in the program. The new legislated provision about VCs, and also the goal of extending our prior work in this journal by using instrumental variables to identify the coefficients of key endogenous explanatory variables, motivates this paper. To anticipate our findings, which are relevant for the new participation of VCs to the extent that they are able to supplement funding for R&D in promising SBIR projects, the legislated change regarding participation of VCs will have economic benefits in terms of improvements in the employment growth of SBIR-funded firms.

We present herein evidence about the effects of cooperation. In particular, we identify the benefits of combining the SBIR-supported R&D efforts of small firms with the expertise of firms providing outside finance and of firms entering commercial agreements with the small firms.

Lerner and Kegler (2000), in their review of the literature about the SBIR program, explain how the firms providing outside finance help to ensure the commercial success of the small businesses with research supported by the SBIR program. Lerner and Kegler (2000, 311) explain how VC organizations carefully study a firm's business plan, and if the decision is made to invest in the firm, the funds are often disbursed in stages so that the small firm must return to its source of outside financial support repeatedly allowing review of the use of the funds as the R&D project progresses. Lerner and Kegler observe that during this process, VCs monitor the

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[1] Zúñiga-Vicente et al. (2013) survey the large empirical literature about the relationship between public R&D subsidies and private R&D investment. The literature about the relationship between public R&D subsidies and the *employment effects* of the subsidized research is still nascent. We have surveyed what literature that there is in Link and Scott (2009, 2010, 2012a, 2012c, 2012d). Zúñiga-Vicente et al. (2013) emphasize the need for research about the dynamics of the relationship between public subsidies and private R&D investment, about the composition of the subsidized R&D, and about the financial constraints faced by the subsidized firms and the sources of the funding they obtain. In this paper, as well as in Link and Scott (2012a, 2012b, 2012c, 2012d), we address many of these issues in the context of the relation between public R&D subsidies and induced employment growth.

[2] Detailed discussion of the institutional history and the economic motivations for the SBIR program are provided in Link and Scott (2010, 2012a).

managers of the firm they are supporting. It is not surprising then that we find that VC support for a firm's SBIR project has a positive effect on the SBIR-induced employment growth of the firm.

There are statements by the principals of the firms with SBIR projects from case studies of DoD SBIR projects (Wessner 2000) explaining that collaboration through commercial agreements with other firms helps to ensure the commercial success of the SBIR projects. For example, one entrepreneurial SBIR-supported company's founder said that he did the technical work, but that the success of his company depended importantly on his willingness to obtain outside help with the business aspects of innovation (Wessner 2000, 125). This founder said, 'The SBIR program could encourage small businesses to bring in outside expertise to ensure competence in business administration to go along with the competence in the scientific work'. Another DoD-SBIR-supported company's founder said, when discussing the second phase (Phase II described in Section 2) of SBIR support (Wessner 2000, 127):

> The prospects for commercialization could be improved if the SBIR program provided funding for a Mentor/Consultant as a part of Phase II. The SBIR firm would identify in the Phase II proposal a large corporation or marketing consulting firm that would work with the SBIR firm during Phase II and provide expertise about commercializing the technology. The small firm knows the technology, but the larger firm would act as a mentor during Phase II and would be able to help the small firm understand how to market the technology. The big company with the marketing channels and capabilities needed would look at the small company's innovative device and advise it on how to proceed ….A cross section of the mentoring company would be needed. Someone from marketing, someone from engineering, someone from administration, finance, and management… Providing the opportunity of mentoring from and consulting with a large corporation could improve the prospects for commercialization of SBIR results.

Again, given the perceptions of small SBIR-supported firms that outside business expertise is often important for commercial success, it is not surprising that we identify a positive effect on the SBIR-induced employment growth of SBIR-supported firms. This is especially the case when those firms have entered into commercial agreements for the use of the technologies created with their SBIR projects.

In the foregoing discussion, there are explanations of why, in addition to the public support for small business research, outside financial support and managerial support from other firms and organizations can improve the commercialization success of the R&D projects of the small firms supported by the SBIR program. In this paper, we provide evidence that the successful commercialization of small business research is stimulated by the combination of public support and cooperative outside private support.

The remainder of the paper is outlined as follows. In Section 2, we describe our sample of SBIR projects, and in Section 3, we define the relevant variables used in our empirical analyses. In Section 4, we present the findings from our empirical model. Finally, in Section 5, we discuss our findings and offer concluding observations.

## 2. The sample of SBIR-funded projects

Firms in our sample received DoD SBIR support between 1992 and 2001 in the form of a SBIR Phase II project award that was funded after each of the firms had successfully completed a SBIR Phase I project award. Phase I awards were during that time period relatively small (capped at $100,000) and of relatively short duration (typically six months); they were used in response to the funding agency's objectives to assess the feasibility of an idea's scientific and commercial potential. Phase II awards were much larger and of longer duration (typically capped at $750,000 and lasting for two years). One criterion for receipt of a Phase II award is the commercial potential of the R&D project;[3] however, in the current US economic environment, employment growth associated with this public subsidy is of topical importance.

Each firm's current (i.e. 2005) employment was observed as part of a National Research Council (NRC) study mandated by the US Congress. In 2000, the US Congress commissioned the NRC to conduct an evaluation of the economic benefits achieved by the SBIR program and to make recommendations to Congress for improvements in the program. Part of that evaluation exercise involved an extensive NRC survey in 2005 of slightly more than 3000 completed Phase II projects funded by DoD during the 1992–2001 period.[4]

## 3. SBIR-induced employment and covariates of interest

Link and Scott (2012d) proffered in this journal a measure of SBIR-induced employment growth. That growth was calculated econometrically as the difference between a firm's actual employment performance after completion of its Phase II SBIR project and its predicted employment performance in the absence of the award. For purposes of estimating and interpreting the effects of various variables on the SBIR-induced employment growth, that growth is measured with the variable diff:

$$\begin{aligned} \text{diff} &= \ln\left(employment_{\text{actual}}/employment_{\text{predicted}}\right) \\ &= \ln\left(employment_{\text{actual}}\right) - \ln\left(employment_{\text{predicted}}\right) \end{aligned} \quad (1)$$

Thus, diff measures the overall net effect of an SBIR award on a firm's long-run employment.[5]

[3] We have previously found that outside financing is important for commercialization of SBIR technologies (Link and Scott 2009, 2010), and that finding too, depending on the way that VC participation evolves, may support the expectation that the change in the legislation will improve dimensions of the performance of the SBIR program.

[4] Although the NRC survey also focused on awards from the National Institutes of Health, the National Aeronautics and Space Administration, the Department of Energy, and the National Science Foundation, using the largest sample available is, in our opinion, a step in the right direction given that our empirical estimation below relies on an instrumental variables estimator which is discussed in terms of its asymptotic distribution; see Greene (2012, 225–227). Link and Scott (2012a, 2012d) provide detailed descriptions of the NRC's random samples for all five agencies surveyed.

[5] Elsewhere, the NRC (Wessner 2009) and Link and Scott (2012a, 2012c) focused on the short-run project-specific employment gains associated with SBIR funding. Funding for a sampled SBIR project might, or might not, have enabled the small firm to meet research challenges and thrive at a critical juncture in its history. Without the SBIR award, those challenges might not have been met successfully. With the award, the firm might have been able to retain employees to work not only on the funded project but also on other research activities unrelated to the project. Our dependent variable, diff, is thus a measure of the net effect of an SBIR award on a firm's employment.

Table 1 lists the average values for the actual and predicted employment used to create diff in the 755 observation sample available for the growth model and also in the 562 observation sample that contains all of the variables needed for the analysis in the present paper (Link and Scott 2012d). For what follows, it is important to emphasize that for $employment_{\text{predicted}}$ we estimated, with control for selection into our sample, a model of the firm's growth if it had not received an SBIR award. The specification and estimation of the growth model is in Link and Scott (2012d).

**Table 1.** Mean actual and predicted employment in 2005 for DoD Phase II SBIR award recipients

| *N* | **Actual** | **Predicted** |
|---|---|---|
| 755 | 59.93 | 31.38 |
| 562[a] | 53.67 | 28.61 |

[a]We used 562 projects in the empirical analysis below. These are the projects for which all relevant information was reported.

Herein, we ask: What characteristics of firms and their SBIR projects explain the differences across the awards in their SBIR-induced employment impacts? The explanatory variables considered are variables that were not used to estimate $employment_{\text{predicted}}$. Those variables that were considered are defined in Table 2.

**Table 2.** Definitions of the explanatory variables

| | |
|---|---|
| Firm characteristics | |
| *spinoffs* | Number of spinoff companies that the firm has established as a result of the SBIR program |
| *percrevssbir* | Percentage of firm's revenues, during its last fiscal year, from federal SBIR and/or Small Business Technology Transfer (STTR) funding (Phase I and/or Phase II) |
| SBIR research | |
| *rltdphII* | Number of the firm's Phase II awards that are related to the Phase II project as of the time of that project |
| Market | |
| *fedacq* | 0/1, with 1 indicating that a federal system or acquisition program is using the technology from the Phase II project |
| Intellectual property | |
| *patents+sigma1* | For the technology developed as a result of the Phase II project, 0/1, with 1 indicating that the number of patents applied for is a standard deviation or more above the mean for the entire sample of Phase II projects |
| *sbirpatents* | For the firm as a whole (considering the patents granted from all of its research projects over the firm's lifetime) rather than for the individual Phase II project sampled, the number of patents that have resulted, at least in part, from the firm's SBIR and/or STTR awards from the firm's founding up to 2005 |
| Funding | |
| *outfintoinv* | The amount of outside finance (i.e. other than the funding provided by the SBIR program or provided by the firm itself or its principals or provided by colleges and universities) during the Phase II project relative to total investment (including the SBIR Phase II award) in the Phase II project (note that outside financing variable does not include the funding from colleges and universities; funding from these sources is controlled separately as *univtoinv* because the funding from academia is arguably more analogous to direct research support rather than being simply generic funding for the operation of the project) |

| | |
|---|---|
| *univtoinv* | Ratio of additional developmental funding during the Phase II project from colleges or universities to total investment (including the SBIR Phase II award) in the Phase II project |
| *perstoinv* | Ratio of additional developmental funding during the Phase II project from the principals' investment of personal funds to total investment (including the SBIR Phase II award) in the Phase II project |
| Commercial agreement | |
| *dmnftgagr* | 0/1 with 1 indicating that as a result of the technology developed during the Phase II project, the company had one or more manufacturing agreements finalized or in ongoing negotiations with US companies/investors or with foreign companies/investors |
| *drdagr* | 0/1 with 1 indicating that as a result of the technology developed during the Phase II project, the company had one or more R&D agreements finalized or in ongoing negotiations with US companies/investors or with foreign companies/investors |
| Commercial type[a] | |
| *nocom* | 0/1 with 1 indicating no planned commercial use for project's results |
| *software* | 0/1 with 1 indicating the project planned to commercialize software |
| *hardware* | 0/1 with 1 indicating the project planned to commercialize hardware |
| *process* | 0/1 with 1 indicating the project planned to commercialize process technology |
| *service* | 0/1 with 1 indicating the project planned to commercialize a service |
| *research* | 0/1 with 1 indicating the project planned to commercialize a research tool |
| *education* | 0/1 with 1 indicating the project planned to commercialize educational materials |
| *other* | 0/1 with 1 indicating the project planned commercialization not covered in the other categories |

[a]Projects for which the respondent did not provide a particular qualitative assessment of commercialization type are subsumed in the intercept term in the estimated models.

In addition to the dependent variable diff, we model as endogenous variables the explanatory variables describing intellectual property created by the sampled Phase II project's publicly subsidized R&D, the project's funding other than the funding from the SBIR Phase II award, commercial agreements with other firms for using the technology created by the project, and the use of that technology by a federal acquisition program. These endogenous explanatory variables are variables that we expect might have an influence on the long-run trajectory of the firm's employment growth, yet they are also affected by the outcome of the Phase II SBIR project's subsidized research.

The intellectual property variable associated with the SBIR Phase II project, *patents+sigma1*, captures exceptional performance among the sampled DoD projects in creating intellectual property. It equals 1 when the number of patents applied for is a standard deviation or more above the mean for the entire sample of Phase II projects, and 0 otherwise. Among the 562 observations with the entire set of variables used in this paper, there are just 15 observations with *patents+sigma1* =1, and those observations each have 6 or more patents applied for from the sampled project's research results.[6]

The presence of outside funding for the Phase II project, commercial agreements with other firms, federal acquisitions, and intellectual property protection for the project's results are all expected to improve the possibility that the project will support employment growth; yet, all of

[6] The average number of patent applications for the 562 observation sample was 1.1 with a range from 0 to 100. For the 15 cases with *patents+sigma1* =1, the average number of applications was 20.4 with a standard deviation of 32.4 and a range from 6 to 100.

those explanatory factors are likely to be influenced by the results developed from the project itself. Absent specifying a functional form for each of these endogenous explanatory variables, we fit the one equation, for long-run SBIR-induced employment through publicly subsidized R&D, of such a multiple-equation system, and we instrumented the endogenous explanatory variables.

For instruments, we use the variables describing prior funding (i.e. funding for the research that was obtained before the Phase II SBIR award), and we also use a set of qualitative variables for the US states in which the firms receiving the SBIR awards are located. Table 3 provides a list with definitions of the prior funding variables used as instruments.

**Table 3.** Prior funding variables used as instruments

| | |
|---|---|
| *priorsbirfndg* | 0/1 with 1 indicating that (*excluding the Phase I, which proceeded this Phase II*) prior to the Phase II award, the firm received funds from the SBIR for research or development of the technology in the Phase II project |
| *priornonsbirfed* | 0/1 with 1 indicating that prior to the Phase II award, the firm received funds from non-SBIR federal R&D for research or development of the technology in the Phase II project |
| *priorventcap* | 0/1 with 1 indicating that prior to the Phase II award, the firm received funds from VC for research or development of the technology in the Phase II project |
| *priorotherpriv* | 0/1 with 1 indicating that prior to the Phase II award, the firm received funds from another private firm for research or development of the technology in the Phase II project |
| *priorprivinv* | 0/1 with 1 indicating that prior to the Phase II award, the firm received funds from a private investor for research or development of the technology in the Phase II project |
| *priorintrnlco* | 0/1 with 1 indicating that prior to the Phase II award, the firm received funds from internal company investment (including borrowed money) for research or development of the technology in the Phase II project |
| *priorstateorlocal* | 0/1 with 1 indicating that prior to the Phase II award, the firm received funds from state or local government for research or development of the technology in the Phase II project |
| *priorunivfndg* | 0/1 with 1 indicating that prior to the Phase II award, the firm received funds from a college or university for research or development of the technology in the Phase II project |
| *priorother* | 0/1 with 1 indicating that prior to the Phase II award, the firm received funds from other sources than those specified in the foregoing qualitative variables for research or development of the technology in the Phase II project |

Because past is prologue, meaning that past experience is expected to be a good predictor of future capabilities and outcomes, a firm's prior funding will logically be correlated with the provision of outside financing for the Phase II project itself and also will be correlated with the ability to develop intellectual property and make commercial agreements; yet, the prior funding would be predetermined rather than resulting endogenously with the evolution and success of the Phase II project after it has begun. Also, the availability of VC and other sources of funding, as well as economic conditions, will vary from one state to another. Logically, then, the state variables will be correlated with other funding and intellectual property and commercial agreement capabilities; yet, the variance in the qualitative indicators of the states would not be endogenously determined by the SBIR Phase II project.

Descriptive statistics for the dependent variable diff, for the explanatory variables, and for the prior-funding variables used as instruments are given in Table 4. Appendix 1 provides the correlation matrix for the dependent and explanatory variables.

**Table 4.** Descriptive statistics ($n$=562)

| | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|
| Firm characteristics | | | | |
| diff | 0.132 | 1.10 | −2.63 | 4.24 |
| *spinoffs* | 0.463 | 1.20 | 0 | 6 |
| *percrevssbir* | 38.0 | 31.9 | 0 | 100 |
| SBIR research | | | | |
| *rltdphII* | 2.05 | 1.79 | 1 | 29 |
| Market | | | | |
| *fedacq* | 0.162 | 0.369 | 0 | 1 |
| Intellectual property | | | | |
| *patents+sigma1* | 0.0267 | 0.161 | 0 | 1 |
| *sbirpatents* | 7.86 | 20.0 | 0 | 125 |
| Funding | | | | |
| *outfintoinv* | 0.194 | 0.275 | 0 | 0.987 |
| *univtoinv* | 0.00140 | 0.0196 | 0 | 0.400 |
| *perstoinv* | 0.00939 | 0.0435 | 0 | 0.455 |
| Commercial agreement | | | | |
| *dmnftgagr* | 0.151 | 0.359 | 0 | 1 |
| *drdagr* | 0.285 | 0.452 | 0 | 1 |
| Commercial type[a] | | | | |
| *nocom* | 0.0285 | 0.166 | 0 | 1 |
| *software* | 0.290 | 0.454 | 0 | 1 |
| *hardware* | 0.534 | 0.499 | 0 | 1 |
| *process* | 0.210 | 0.408 | 0 | 1 |
| *service* | 0.162 | 0.369 | 0 | 1 |
| *research* | 0.141 | 0.348 | 0 | 1 |
| *education* | 0.0196 | 0.139 | 0 | 1 |
| *other* | 0.0836 | 0.277 | 0 | 1 |
| Prior funding instruments | | | | |
| *priorsbirfndg* | 0.212 | 0.409 | 0 | 1 |
| *priornonsbirfed* | 0.126 | 0.333 | 0 | 1 |
| *priorventcap* | 0.0231 | 0.150 | 0 | 1 |
| *priorotherpriv* | 0.0943 | 0.293 | 0 | 1 |
| *priorprivinv* | 0.0747 | 0.263 | 0 | 1 |
| *priorintrnlco* | 0.310 | 0.463 | 0 | 1 |
| *priorstateorlocal* | 0.0178 | 0.132 | 0 | 1 |
| *priorunivfndg* | 0.0160 | 0.126 | 0 | 1 |
| *priorother* | 0.0391 | 0.194 | 0 | 1 |

[a]Projects for which the respondent did not provide a particular qualitative assessment of commercialization type are subsumed in the intercept term in the estimated models.

## 4. Estimation of model of diff with endogenous explanatory variables

Table 5 presents the results of estimating both the ordinary regression and instrumental variables models of diff for the sample of DoD Phase II projects.[7] Because some of the firms with sampled Phase II SBIR awards have multiple sampled awards, we have clustered the errors by firm.[8,9]

**Table 5.** Coefficients from the models of diff for the DoD sample (robust standard error, errors clustered by firm in all specifications)[a]

| Variable | Ordinary regression (1)[b] | Instrumental variables (2)[b] |
|---|---|---|
| Firm characteristics | | |
| *spinoffs* | 0.0990 (0.0359)*** | 0.0802 (0.0656) |
| *percrevssbir* | −0.00977 (0.00174)**** | −0.00782 (0.00235)**** |
| SBIR research | | |
| *rltdphII* | 0.0401 (0.0216)* | 0.0247 (0.0281) |
| Market | | |
| *fedacq* [d] | 0.157 (0.130) | −0.293 (0.428) |
| Intellectual property | | |
| *patents+sigma1* [d] | 0.790 (0.233)**** | 2.99 (1.37)** |
| *sbirpatents* | 0.00501 (0.00127)**** | 0.00816 (0.00270)*** |
| Funding | | |
| *outfintoinv* [d] | 0.416 (0.190)** | 1.04 (0.597)* |
| *univtoinv* [d] | −1.57 (0.502)*** | −2.73 (2.63) |
| *perstoinv* [d] | −4.40 (1.18)**** | −4.12 (7.91) |
| Commercial agreement | | |
| *dmnftgagr* [d] | 0.0797 (0.141) | 1.51 (0.695)** |
| *drdagr* [d] | 0.00167 (0.114) | −0.941 (0.534)* |
| Commercial type[e] | | |
| *nocom* | 0.244 (0.286) | 0.162 (0.316) |
| *software* | 0.0772 (0.121) | 0.263 (0.174) |

[7] The estimation and post estimation work is performed with 'ivregress' using StataCorp (2011b) as described in StataCorp (2011a, 810–842).

[8] Hence, as explained in StataCorp (2011a, 831), the usual tests (due to Durbin, Wu, and Hausman) for endogeneity discussed by Greene (2012, 234–237) are not appropriate because they assume that the error term is identically and independently distributed. Among the available tests for endogeneity, we used a regression-based test for endogeneity (implemented with StataCorp (2011b) and described completely in StataCorp (2011a, 839)) that is appropriate with clustering of the errors. The null hypothesis that the instrumented explanatory variables are actually exogenous is rejected at a significance level better than 0.001 whether the regression-based test for endogeneity is done for the instrumental variables specification reported in Table 5 (with the probability weights and clustered errors) and using the 'forceweights' option to compute the test for endogeneity or for the specification (which gives very similar results to what is reported in Table 5) with the clustered errors but without the probability weights (which are appropriate given our survey data). For the model reported in column 2 of Table 5, with the null hypothesis being that the variables are exogenous, using the 'forceweights' option, the robust regression test of endogeneity gives $F(7, 399) = 4.18$ ($p=0.0002$) adjusted for 400 clusters by firm. For the same model with the clustered errors but without the probability weights, the robust regression test gives $F(7, 399) = 3.76$ ($p=0.0006$).

[9] Keep in mind that the employment growth studied is the long-run growth for the firm, and the determinants of such growth do differ in general from those for project-specific employment effects. For example, Link and Scott (2012a) show that the use by a federal acquisition program of the technology resulting from the DoD-funded project has an important positive effect on the number of employees retained in a small firm directly because of the technology created with its SBIR Phase II award. For the direct effect on employment associated with the subsidized research project, the government's provision of a market for the commercial results from the project appears important. However, as Table 5 shows, the use by a federal acquisition program is not an important determinant of the long-run employment trajectory of the firms that we are examining in this paper.

| Variable | Ordinary regression (1)[b] | Instrumental variables (2)[b] |
|---|---|---|
| *hardware* | −0.120 (0.100) | −0.310 (0.144)** |
| *process* | −0.134 (0.121) | −0.102 (0.172) |
| *service* | 0.0401 (0.119) | 0.0189 (0.156) |
| *research* | −0.149 (0.135) | −0.127 (0.186) |
| *education* | −1.00 (0.349)*** | −0.880 (0.404)** |
| *other* | −0.0356 (0.179) | −0.0867 (0.244) |
| Constant | 0.385 (0.142)*** | 0.317 (0.184)* |
| *n* | 562 | 562 |
| $F$ [c] | 12.2 (19,399)**** | |
| Wald $\psi^2$(df) | | 94.9 (19)**** |
| $R^2$ | 0.221 | |

[a] Significance levels (two-tails): ****=0.001, ***=0.01, **=0.05, *=0.10.
[b] Estimation with probability weights (also called sampling weights) and standard errors adjusted for 400 clusters by firm. The sampling weights used here are described in Link and Scott (2012a, Table B1, 128–130). StataCorp (2011c, '20.22.3 Sampling weights', 301–303) describes the logic and methods for sampling weights.
[c] In parentheses are the degrees of freedom for the numerator followed by the degrees of freedom for the denominator=the number of clusters −1.
[d] Treated as endogenous in the instrumental variables estimation. Thus, the instrumented variables are *fedacq, patents+sigma1, outfintoinv, univtoinv, perstoinv, dmnftgagr*, and *drdagr*. In addition to the predetermined explanatory variables, the instruments were *priorsbirfndg, priorventcap, prioruniv fndg, priornonsbirfed, priorotherpriv, priorprivinv, priorintrnlco, priorstateorlocal, priorother*, and qualitative variables for the 39 states (with one left in the intercept) for the location of the small firms receiving the sampled Phase II SBIR awards.
[e] Projects for which the respondent did not provide a particular qualitative assessment of commercialization type are subsumed in the intercept term in the estimated models.

The findings support our expectation that outside finance to relax finance constraints is important for a successful small firm's R&D project and is associated with greater long-run employment growth for the firm. Employment growth is also greater for firms that have been exceptionally successful in creating and protecting their intellectual property as indicated, for the technology generated by their sampled subsidized project, by having exceeded by at least a standard deviation the mean number of patent applications (i.e. the project is among the top 15 performers in the 562 observations of DoD Phase II SBIR projects). Employment growth is also greater when the firm has a larger portfolio of patents from its entire history of performing SBIR-related research, perhaps because of the protection of intellectual property that is provided by a web of complementary patents. The higher the percentage of a firm's revenues that is taken by awarded funds, the lower is the firm's employment growth, and that may signal that a firm is still largely at a pre-commercial R&D stage and has not yet begun growing employment to support commercial sales. Among the commercial type variables, only hardware and education are significant, and they are both associated with lower long-run employment growth.

Link and Scott (2012a) provide the descriptive relations that do not attempt to identify the coefficients using instrumental variables. In those descriptive relations, prior spin-off companies from SBIR funding, previous Phase II SBIR awards related to the sampled award, funding support from academia, and the use of personal funding in financing the sampled research project all have statistically significant relations (of differing directions) with employment growth resulting from the publicly subsidized research. In the instrumental variables specification, these effects are no longer statistically significant, although their estimated coefficients are in some cases quite similar and on the whole their magnitudes tell the same story as the descriptive statistics. The directions of these effects that do not appear significant in the new instrumental variables specification are discussed in Link and Scott (2012a).

Finally, it is expected that commercial agreements (about the technology created with the publicly subsidized R&D) with other firms might affect the long-run trajectory for the firm's employment, with an increase or decrease in employment growth anticipated depending on the circumstances. There are a large number of types of commercial agreements described in the NRC data and in Link and Scott (2012a). Our regression strategy for the model reported in Table 5 was first to estimate the instrumental variables model with all of the types of commercial agreements entered, and then to drop the insignificant ones. The story for the other variables is essentially the same with or without the insignificant commercial agreement variables, so we have presented in Table 5 just the parsimonious model with the only two significant commercial agreement variables in this sample.

As given in Table 5, firms that have manufacturing agreements with other firms have greater long-run employment growth, while firms with R&D agreements have lesser employment growth. Perhaps, the former are so successful that they cannot grow employment fast enough to handle the demand created by their new technology and reach agreements with other firms to do some of the manufacturing, while the latter may focus on creating intellectual property that is then sold or licensed to others. As reported in Link and Scott (2012a), in the descriptive statistics for the DoD sample, overall there is a negative effect of commercial agreements on employment growth. Here, with the additional insight from the instrumental variables model, that overall effect is not statistically significant by conventional standards, but we can see that the effects of the manufacturing agreements (present for 15% of the sample) and R&D agreements (present for 28% of the sample) do have significant effects.

**5. Conclusions and discussion**

In this paper, we identified systematic relations between employment growth induced by publicly subsidized R&D and variables that influence that growth. Because our model prominently includes several variables – intellectual property, outside finance, and commercial agreements – that are themselves endogenously determined by the success of the subsidized R&D, we have identified the relations by estimating a model of the R&D-subsidy-induced employment growth using instruments for the endogenous variables among the variables explaining the induced growth.

Table 6 simulates the effects for the key variables in the model. First, for a typical baseline case, the net gain in employment induced by the publicly subsidized R&D is 34% of the employment predicted for the firm in the counterfactual case without the public subsidy of its Phase II SBIR R&D project. Keeping all other variables at their baseline level, increasing *sbirpatents* to a standard deviation above its mean increases the net employment gain from the subsidized research to 58% of the counterfactual predicted employment without the public subsidy. An increase, other things held at the baseline level, in outside finance to a standard deviation above its mean increases the net employment gain to 80% of the counterfactual employment. A DoD-funded firm that has achieved manufacturing agreements using the technology created with its subsidized research, other things being at the baseline level, has an expected net gain in employment that is five times the counterfactual predicted employment. *Ceteris paribus*, the presence of R&D agreements is associated with less than predicted employment, with the shortfall being 48% of the predicted employment. We expect that scenario corresponds to a small firm that focuses on R&D and then sells technology to other firms rather than itself producing products using the technology.

**Table 6.** Net employment gain induced by publicly subsidized R&D relative to the predicted employment without the SBIR Phase II award[a]

| Scenario | Expected value | 95% Confidence interval |
|---|---|---|
| Typical/baseline case | 0.340 | −0.0531 to 0.897 |
| *sbirpatents* high | 0.578 | 0.0891–1.29 |
| *patents+sigma1* high | 25.6 | 0.901–371 |
| *outfintoinv* high | 0.795 | 0.0376–2.11 |
| *dmnftgagr* high | 5.09 | 0.363–26.2 |
| *drdagr* high | −0.477 | −0.776 to 0.222 |

[a] The figures shown are ($e^{\text{diff}}-1$) for each scenario. The baseline case uses the following scenario: *sbirpatents* =8, *spinoffs* =0, *percrevssbir* =38, *reltdphii* =2, *patents+sigma1* =0, *outfintoinv*$ =0.19$, *univtoinv* =0.001, *perstoinv* =0. 009, *dmnftgagr* =0, *drdagr* =0, *fedacq* =0, *nocom*$ =0$, *software*$ =0$, *hardware* =0, *process* =0, *service* =0, *resear ch* =0, *education* =0, and *other* =0. For each of the other scenarios in turn, with all other variables kept at their levels in the baseline case, changing just the one indicated variable for the scenario, the continuous variables *sbirpatents* and *outfintoinv* are set to be a standard deviation higher than their sample means, and the dichotomous variables *patents+sigma1, dmnftgagr*, and *drdagr* are set to equal 1.

In this DoD sample of Phase II SBIR projects, the largest employment effect by far is for firms that have been exceptionally successful in obtaining intellectual property to protect the results of their Phase II SBIR project. *Ceteris paribus*, if *patents+sigma1* exceeds its mean by a standard deviation or more, the expected value of the net employment induced by the publicly subsidized R&D is 26 times the prediction for employment in the counterfactual case without the public subsidy. Thus, we see that the truly spectacular successes for publicly subsidized R&D are the cases with especially successful creation and protection of intellectual property.

Two points about the effect of intellectual property are worth highlighting. Importantly, as we have emphasized, the creation and protection of intellectual property is endogenous to the evolution of the R&D projects, and for that reason, the identification of its effect has required the use of instrumental variables. Also, in a separate equation, of the complete system of equations, for the endogenous explanatory variable *patents+sigma1*, the presence of exceptional success in creating and protecting intellectual property would be related to the endogenous explanatory variable *outfintoinv* that describes the presence of outside finance. The set of instrumental variables allow us to identify the relation between employment growth and both the intellectual property and the outside finance, but all are endogenously determined and related to one another as the publicly subsidized R&D project evolves.

We find that the employment growth from the public support of a small firm's R&D varies with the outside, third-party support for the firm and with the intellectual property created by the publicly subsidized R&D. Other things being the same, a firm with outside finance or intellectual property experiences employment growth beyond what would have been predicted for the firm in the absence of the public R&D subsidy. Commercial agreements may be associated with employment gains for the subsidized firm, but in some cases, they are also associated with lower employment growth for the small firm. We expect that occurs when such agreements can allow the small firm to earn returns on the new technology developed with the subsidized R&D; yet, employment growth induced by the innovation is experienced in other firms that license the technology or purchase the rights to it.

For example, the president of a very successful DoD SBIR-award recipient firm explained that his firm was not interested in growing, saying (Wessner 2000, 225): 'We remain an engineering service company that commercializes its product opportunities through licensing or the creation of separate product companies'.

We conclude with five interpretative points about our findings.[10] First, our findings complement the literature about the determinants of cooperation by exploring the effects of cooperation in the particular context of collaboration between outside firms and small businesses to help commercialize the publicly supported research of the small businesses. Our analysis of the effects provides understanding about the causes.

Second, our results support the inference that cooperating firms can better appropriate the value of knowledge spillovers than non-cooperating firms. A contractual commercial agreement between another firm and a small firm with an SBIR-award can allow more effective transfer of knowledge created with the small firm's publicly supported research because both parties to the agreement have better access to the knowledge resources of the other. The agreements allow the dedication of resources and organizational efforts necessary for the commercially successful access to and use of external knowledge.

Third, both the presence of outside financial support beyond the public support and the presence of commercial agreements are arguably reliable signals of the quality of the technological knowledge generated and the potential commercial success of the small firms with publicly supported R&D projects. The small firms with good research projects attract more attention from outside investors and from incumbents expecting to realize benefits from the knowledge generated by the research.

Fourth, the descriptive evidence about the types of cooperative agreements (Link and Scott 2012b) and the types of outside finance (Link and Scott 2010) could usefully be augmented in future research with more description about the cooperating firms and the outside investors. With the information about exactly which firms and investors are the outside supporters of the publicly supported small business research, the location and characteristics of the outside organizations would be available. It would be possible to develop a greater understanding of why the outside support increases the successful commercialization of the technologies created with small business research.

Fifth, our findings suggest that the search for cooperating partners and outside investors might be a useful condition for the provision of public support once the small business research has proceeded beyond the initial stage Phase I award that establishes the potential and feasibility of the research and has reached Phase II when the technology will be developed to achieve its commercial potential.

[10] We are indebted to the editor and the anonymous referees for this interpretative framework for our study.

**Acknowledgements**

We are grateful to the editor and anonymous referees for insightful comments that greatly improved the interpretation of this paper.

**References**

William, Greene H. 2012. *Econometric Analysis*, 7, Upper Saddle River, NJ: Prentice Hall.

Lerner, Josh and Colin, Kegler. 2000. “Evaluating the Small Business Innovation Research Program: A Literature Review.”. In *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, Edited by: Wessner, Charles W. 307–324. Washington, DC: National Academy Press.

Link, Albert N. and Scott, John T. 2009. Private Investor Participation and Commercialization Rates for Government-Sponsored Research and Development: Would a Prediction Market Improve the Performance of the SBIR Programme?. *Economica*, 76(302): 264–281. (doi:10.1111/j.1468-0335.2008.00740.x)

Link, Albert N. and Scott, John T. 2010. Government as Entrepreneur: Evaluating the Commercialization Success of SBIR Projects.. *Research Policy*, 39(5): 589–601. (doi:10.1016/j.respol.2010.02.006)

Link, Albert N. and Scott, John T. 2012a. *Employment Growth from Public Support of Innovation in Small Firms*, Kalamazoo, MI: W. E. Upjohn Institute for Employment Research.

Link, Albert N. and Scott, John T. 2012b. The Exploitation of Publicly Funded Technology. *Journal of Technology Transfer*, 37(3): 375–383. (doi:10.1007/s10961-012-9255-x)

Link, Albert N. and Scott, John T. 2012c. Employment Growth from the Small Business Innovation Research Program.. *Small Business Economics*, 39(2): 265–287. (doi:10.1007/s11187-010-9303-6)

Link, Albert N. and Scott, John T. 2012d. Employment Growth from Public Support of Innovation in Small Firms.. *Economics of Innovation and New Technology*, 21(7): 655–678. (doi:10.1080/10438599.2011.638190)

StataCorp. 2011a. *Stata Base Reference Manual: Release 12*, College Station, TX: StataCorp LP.

StataCorp. 2011b. *Stata Release 12 Statistical Software*, College Station, TX: StataCorp LP.

StataCorp. 2011c. *Stata User's Guide: Release 12*, College Station, TX: StataCorp LP.

Wessner, Charles W. 2000. *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, Edited by: Wessner, Charles W. Washington, DC: National Academy Press.

Wessner, Charles W. 2009. *An Assessment of the SBIR Program at the Department of Defense*, Washington, DC: National Academy Press.

Zúñiga-Vicente, José Ángel, César Alonso-Borrego, Francisco J. Forcadell, and José I. Galán. 2013. "Assessing the Effect of Public Subsidies on Firm R&D Investment: A Survey." *Journal of Economic Surveys*, forthcoming. doi: 10.1111/j.1467-6419.2012.00738.x

## Appendix 1. Simple correlation matrix

| | diff | sbirpa~s | spinoffs | percre~r | reltd~ii | patent~1 | outfin~v | univto~v | persto~v | dmnftg~r | drdagr | fedacq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| diff | 1.0000 | | | | | | | | | | | |
| sbirpatents | 0.1681 | 1.0000 | | | | | | | | | | |
| spinoffs | 0.1465 | 0.4153 | 1.0000 | | | | | | | | | |
| percrevssbir | -0.2563 | 0.0052 | 0.1332 | 1.0000 | | | | | | | | |
| reltdphii | 0.0518 | 0.0480 | -0.0265 | 0.1144 | 1.0000 | | | | | | | |
| patents+sigma1 | 0.1279 | 0.0017 | 0.0189 | -0.0640 | 0.0328 | 1.0000 | | | | | | |
| outfintoinv | 0.2000 | 0.1125 | 0.0971 | -0.0756 | 0.0608 | 0.2254 | 1.0000 | | | | | |
| univtoinv | -0.0288 | -0.0072 | 0.0071 | 0.0100 | 0.0106 | -0.0082 | -0.0012 | 1.0000 | | | | |
| perstoinv | -0.1345 | -0.0608 | -0.0731 | -0.0252 | 0.0009 | 0.0008 | 0.0086 | -0.0052 | 1.0000 | | | |
| dmnftgagr | 0.0212 | -0.0705 | -0.0013 | 0.0014 | 0.0197 | 0.1766 | 0.1775 | -0.0186 | 0.0768 | 1.0000 | | |
| drdagr | -0.0185 | 0.0345 | 0.0196 | 0.0755 | 0.0388 | 0.0668 | 0.1588 | -0.0270 | -0.0438 | 0.3060 | 1.0000 | |
| fedacq | 0.0989 | -0.0176 | 0.0116 | -0.0437 | 0.0319 | -0.0129 | 0.0929 | -0.0313 | 0.0475 | 0.0436 | -0.0525 | 1.0000 |
| nocom | 0.0191 | -0.0310 | 0.0320 | -0.0030 | -0.0763 | -0.0283 | -0.0656 | -0.0122 | -0.0370 | -0.0125 | -0.0606 | -0.0462 |
| software | 0.0015 | -0.1576 | -0.1089 | -0.0578 | 0.0449 | -0.0572 | -0.0903 | -0.0455 | 0.0614 | -0.1056 | -0.0730 | 0.2087 |
| hardware | 0.0232 | 0.0799 | 0.0925 | 0.0364 | 0.0761 | 0.1105 | 0.1745 | 0.0139 | 0.0042 | 0.2053 | 0.0995 | 0.0331 |
| process | -0.0271 | -0.0009 | -0.0094 | 0.0458 | 0.1065 | -0.0041 | 0.0326 | 0.0234 | -0.0536 | 0.1726 | 0.1976 | 0.0106 |
| service | 0.0040 | -0.0833 | -0.0405 | -0.0334 | 0.0481 | 0.0171 | 0.0517 | -0.0189 | -0.0364 | 0.0571 | 0.0652 | 0.0821 |
| research | -0.1213 | -0.1082 | -0.0959 | 0.0434 | -0.0133 | 0.0601 | -0.0438 | 0.0025 | -0.0293 | 0.1008 | 0.1192 | 0.0863 |
| education | -0.1233 | -0.0524 | -0.0223 | -0.0139 | -0.0109 | -0.0234 | -0.0112 | -0.0101 | 0.0115 | 0.0121 | 0.0816 | 0.0774 |
| other | -0.0243 | -0.0099 | 0.0174 | 0.0167 | -0.0150 | -0.0500 | 0.0461 | -0.0215 | 0.0371 | 0.0339 | 0.0658 | 0.0417 |

| | nocom | software | hardware | process | service | research | educat~n | other |
|---|---|---|---|---|---|---|---|---|
| nocom | 1.0000 | | | | | | | |
| software | -0.1094 | 1.0000 | | | | | | |
| hardware | -0.1832 | -0.3066 | 1.0000 | | | | | |
| process | -0.0882 | -0.0407 | 0.0001 | 1.0000 | | | | |
| service | -0.0752 | 0.0597 | -0.0056 | 0.2122 | 1.0000 | | | |
| research | -0.0692 | 0.1025 | 0.0393 | 0.1183 | 0.2530 | 1.0000 | | |
| education | -0.0242 | 0.1928 | -0.0997 | 0.0848 | 0.2168 | 0.2385 | 1.0000 | |
| other | -0.0517 | -0.0231 | -0.1429 | -0.0137 | -0.0281 | 0.0443 | 0.0501 | 1.0000 |