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PRIVATE EQUITY AND THE INNOVATION STRATEGIES OF ENTREPRENEURIAL FIRMS: EMPIRICAL EVIDENCE FROM THE SMALL BUSINESS INNOVATION RESEARCH PROGRAM

Albert N. Link
Christopher J. Ruhm
Donald S. Siegel

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ABSTRACT

There is great interest in evaluating the impact of private equity investments on innovation and economic growth. However, there is no direct empirical evidence on the effects of such transactions on the innovation strategies of entrepreneurial firms. We fill this gap by examining a rich project-level data set consisting of entrepreneurial firms receiving Small Business Innovation Research (SBIR) program research awards. We find that SBIR firms attracting private equity investments are significantly more likely to license and sell their technology rights and engage in collaborative research and development agreements. Our results suggest that private equity investments accelerate the development and commercialization of research-based technologies, thus contributing to economic growth. We conclude that both public investments and private investments are key to innovation performance.

Albert N. Link
Department of Economics
University of North Carolina at Greensboro
P.O. Box 26165
Greensboro NC 27402-6165
anlink@uncg.edu

Donald S. Siegel
School of Business
University at Albany, SUNY
1400 Washington Avenue
Albany, NY 12222
dsiegel@albany.edu

Christopher J. Ruhm
Frank Batten School of
Leadership and Public Policy
University of Virginia
235 McCormick Rd.
P.O. Box 400893
Charlottesville, VA 22904-40893
and NBER
ruhm@virginia.edu

Private Equity and the Innovation Strategies of Entrepreneurial Firms:

Empirical Evidence from the Small Business Innovation Research Program

I. Introduction

There is considerable interest in assessing the antecedents and consequences of private equity investments (Cumming, Siegel, and Wright (2007); Bloom, Sadun, and van Reenen (2009)). A key research question is whether these transactions improve performance. Most empirical studies of the performance effects of private equity investments report evidence on their impact on short-run stock prices (i.e., event studies), long-run stock prices, financial returns to private equity investors, or accounting profits of publicly-traded firms. Such approaches focus on firm-level financial returns to private equity investments.

An emphasis on firm financial performance suffers from several limitations. First, from a policy perspective, it is more important to evaluate the impact of private equity investments on key economic variables, such as innovation and total factor productivity (TFP). Regulatory decisions regarding private equity investments should be based on their impact on economic efficiency and innovation or R&D—which we call real effects—and not exclusively on their financial effects.[1]

Another drawback of most empirical studies, as noted in Lichtenberg and Siegel (1990), is that the firm is not always the appropriate unit of analysis because many private equity investments occur below the firm level. That is, the majority of private equity transactions do not involve a transfer of ownership of an entire publicly-traded firm. Instead, most private equity deals or buyouts are divestments of a unit of a large firm, or a transaction that affects only a few establishments. The end result is that full-firm transactions involving publicly-traded companies constitute only a very small percentage of aggregate private equity activity. As a result, several studies of the real effects of private equity transactions have been based on plant or establishment level data (e.g., Lichtenberg and Siegel (1990); Harris, Siegel, and Wright (2005); Davis, Lerner, Haltiwanger, Miranda, and Jarmin (2011)). In the case of R&D and

[1] Cumming, Siegel, and Wright (2007) first introduced the term *real effects* with respect to innovation and productivity related performance.

innovation, it is more desirable to have data at the project level because that is the appropriate unit of analysis for specific research investments.

Table 1 summarizes key studies of the effects of private equity investments on innovation and TFP. Note that the unit of analysis has been the firm, division, or plant (establishment) but none of these investigations has been based on project-level data. In addition to the aggregation issue, these studies have been based on incomplete measures of a firm's innovation strategies. More specifically, they rely on input and output measures associated with the innovation process, such as R&D expenditure and new product development, but not on the underlying innovation strategy to use inputs to generate outputs.

The purpose of this study is to extend analyses of the real effects of private equity investments by assessing their impact on the innovation strategies of entrepreneurial firms. Specifically, we examine a rich and unique project-level data set containing comprehensive measures of dimensions of the innovation strategies of entrepreneurial firms and associated private equity investments.

II. Empirical Analysis

A. Analytical Framework

As noted in the previous section, there have been no project-level studies of the relationship between private equity investments and innovation strategies. We begin to fill this void by estimating variants of the following model:

(1) *innovation strategy* = F (*private equity*, **X**)

where, from our empirical vantage, *innovation strategy* refers to four dimensions of a firm's innovation strategy, *private equity* refers to four sources or types of private equity investments, and **X** is a vector of project- and firm-specific characteristics.

We view this model as a starting point to investigate the underlying relationship between private equity investments and innovation strategies. It explicitly assumes that success in attracting financial investors influences the firm's pursuit of an innovation strategy to further develop and commercialize its technology. However, we recognize that this relationship will often be simultaneous; a firm's ability to attract private equity investments might be influenced by the innovation strategy that it has already adopted. Pursuit of a focused innovation strategy might therefore send a positive signal to potential investors, as might indications of success during early stages of the development endeavor.[2] Thus, the empirical analyses that follow are descriptive and exploratory in nature, and our findings should be interpreted in that light.

B. The Data Set

The data analyzed in this paper relate to projects funded through the Small Business Innovation Research (SBIR) program of the National Institutes of Health (NIH), within the Department of Health and Human Services. The SBIR program is a set aside program established through the Small Business Innovation Development Act of 1982.[3] The objectives of the program were and still are to use small businesses with 500 or fewer employees to stimulate technological innovation, to meet federal research and development (R&D) needs, to foster participation by minority and disadvantaged persons in innovation, and to increase private sector commercialization of innovation from federal R&D. The Act initially required agencies with greater than $100 million in extramural research to set aside 0.20 percent of their external research budget for small firms. That percentage has increased over time, and it is now 2.5 percent.[4]

The Small Business Reauthorization Act of 2000 mandated that the National Research Council (NRC) within the National Academies evaluate the economic benefits associated with the SBIR program. In 2005, as part of its study, the NRC conducted an extensive survey of projects completed from Phase II awards made by five agencies between 1992 and 2001.[5] NIH was one of these five agencies.[6] NIH was selected for this study because it maintains a large

[2] As discussed below, the data analyzed are not sufficient to model the timing of receipt of private equity investments or the timing of the adoption of an innovation strategy.
[3] SBIR is the largest public program that subsidizes small firms in the United States. Lerner (1999) has referred to it as an example of government acting as venture capitalist. Link and Scott (2010) have referred to the SBIR program as an example of government acting as entrepreneur.
[4] See Link and Scott (2012a), and references therein, for a legislative history of the SBIR program.
[5] Phase I awards are to establish the technical merit and feasibility of potential for commercialization of the proposed R&D. Phase II awards are to continue Phase I R&D. Generally, Phase I awards lasted for 6 months and in 2005 were capped at $100,000; and Phase II awards lasted for 2 years and were capped at $750,000. These award guidelines were increased when the SBIR program was reauthorized at the end of 2011.
[6] The other agencies were the Department of Defense (DoD), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Science Foundation (NSF). DoD is the largest SBIR-sponsoring agency accounting for about 57% of Phase II projects funded in 2005; NIH ranks second at 19%.

SBIR program—second only to the Department of Defense (DoD)—and because the lion's share of the technologies resulting from the SBIR-funded research are competed in the marketplace.[7]

Table 2 shows the data reduction process to arrive at the population of 495 randomly sampled Phase II projects funded by NIH between 1992 and 2001. Thirty-four of these project had not been completed at the time of the survey and information was missing for 32 additional projects, resulting in a final analysis sample of 419 projects.[8]

C. Discussion of the Variables

The two categories of variables of interest in this study are the innovation strategies adopted by the firms conducting the Phase II research, and the private equity investments received to support further development and commercialization of the technology resulting from the funded research. Measures of these variables are defined in Table 3 along with the covariates included in vector **X** in at least some specifications of equation (1). Descriptive statistics on these variables are presented in Table 4.

Data are available in the NRC data set on four innovation strategies undertaken with another firm(s) to commercialize the technology developed through the SBIR project: a licensing agreement for the technology (*lic*), a sale of technology rights (*tech*), a joint venture agreement which includes the collaborative development of the technology (*joint*), and an R&D agreement which includes collaborative research (*r&d*).[9]

In the analyses that follow we examine the adoption of each of these innovation strategies individually. We also consider two aggregated or combined measures based on these innovation strategies. The first is a binary variable equaling 1 if the firm adopted at least one of these defined strategies, and 0 otherwise (*commdv*). The second is a count of the number of innovation strategies—0 to 4—that the firm pursued (*comm*).

Following Wessner (2009), four sources or types of private equity investments are considered: U.S. venture capital funding (*vc*), foreign investments (*for*), other (non-venture capital) domestic private equity investments (*odpe*), and other domestic private company

[7] The primary mission of NIH's SBIR program is the development of fundamental knowledge and its application for improving health. Over 12 percent of DoD's awards through 2005 resulted in technologies purchased and used by the federal government compared to less than 2 percent for NIH.

[8] In 31 of 32 cases, information was missing on the alternative investments. We were not able to ascertain why these questions had not been responded to in these cases.

[9] A preliminary analysis of these innovation strategies, and other marketing and manufacturing strategies, is in Link and Scott (2012b).

investments (*odpc*).[10] The presence of each source is measured dichotomously in some specifications and in dollar (*$*) terms in others. As with innovation strategies, we also considered two aggregated or combined measures of private equity investments. The first measure is binary equaling 1 if the firm received any form of private equity investment to support its project, and 0 otherwise (*priv*). The second measure is the dollar amount of such aggregated investments (*priv$*).

Four variables are subsumed in vector **X** in equation (1). First, the gender of the owner of the small business is held constant (*female*). It has been shown by Gicheva and Link (forthcoming) that women-owned entrepreneurial companies are disadvantaged in private equity investment markets. Thus we control for gender to obtain estimates of the marginal impact of the private equity investment variables on innovation strategies.

Second, the amount of time since receiving the Phase II award is held constant (*years*). We posit that years will enter negatively in equation (1). The longer the time since receiving the award the more likely the firm will have discontinued a project and thus the less likely that any particular innovation strategy would have been adopted.

Third, we control for the scale of the project by the log of the number of employees in the firm at the time of the Phase II award submission (ln*emp*). To the extent that larger firms have more experience and resources to devote to the commercialization of technology, they might be less likely to pursue an innovation strategy with another company(ies) to develop further or commercialize their technology. Thus, we predict that ln*emp* will enter negatively in equation (1).

Finally, we control for whether a university was involved in the SBIR-funded research. Baldwin and Link (1998) have shown that universities act as honest brokers when involved with a firm(s) in research. That is, university involvement increases the likelihood that the research results will not remain proprietary. Thus, other firms or investors might be less likely to participate in an innovation strategy for concern that their returns will be diminished. Therefore, we predict that *univ* will also enter negatively in equation (1).

D. Empirical Results

[10] This category includes angel investors. See Wessner (2008).

Alternative specifications of equation (1) are considered, and the estimated results are presented in Tables 5 through 10.[11] When the dependent variable is dichotomous (i.e., a particular innovation strategy is adopted, or not) we estimate equation (1) as a probit model and report marginal effects with other regressors evaluated at their sample means. When the dependent variable is a count variable (i.e., the number of innovation strategies adopted), we estimate (1) as a negative binomial model and report the estimated coefficients. In all cases, we report robust standard errors that are clustered at the company level (the 419 projects in our data set were conducted by 313 firms).

Regardless of the specification, we find that firms receiving private equity investments to support the development and commercialization of their SBIR technology are more likely to enter into an innovation strategy with another firm(s).[12]

Tables 5 and 6 show the empirical results for equation (1) when the two aggregate measures of innovation strategy are the dependent variables and the aggregate measures of private equity investments are the independent variables of key interest. In all cases, the presence of private equity investments (columns (1) and (2)) or the amount of these investments (column (3) and (4)) are positively related to the likelihood that an innovation strategy will be pursued. Moreover, the estimated effects are large. For example, the receipt of private equity investments is predicted to increase the probability that a company follows at least one of the innovation strategies by 40 percentage points—from 35 to 75 percent—and to raise the number of innovation strategies by over 200 percent—from 0.5 to 1.6. See rows (1) and (2) in Table 7.

Also, the adoption of an innovation strategy is more likely to occur sooner rather than later. In all of the specifications in Tables 5 and 6, the estimated coefficient on *years* is negative, as predicted, and statistically significant at least at the .10 level.

Firm size at the time of the Phase II submission, ln*emp*, is consistently negative as predicted, but its estimated coefficient is not always significant at a conventional level.

[11] With reference to Table 1, an important econometric issue is possible selection into the survey sample of 495 projects. Link and Ruhm (2009, 2011) and Link and Scott (2010) have examined the NIH SBIR data in various contexts and have found no empirical evidence of selection bias. Thus, the issue is not reconsidered herein.

[12] Here and throughout the analysis, we examined whether the results are sensitive to changes in the econometric specifications such as measuring private investment dollars in logs rather than levels, or including a quadratic term for the dollar investment. We also estimated models with the number of employees at Phase II submission measured in levels (rather than logs) or with a quadratic term included. The results were not materially affected by these changes.

University involvement in the SBIR-funded research, *univ*, is consistently negative, as anticipated, and its estimated coefficient is always significant at least at the .15 level in Table 5 and it is close to that level of significance in Table 6.

In columns (1) and (3) of Tables 5 and 6, we controlled for the type of technology (e.g., product, process, or service) resulting from the SBIR-sponsored research that will be commercialized by including covariates for the Institute within NIH that funded the research.[13] However, these Institute effects are not significant, and these variables are not considered in subsequent regressions.

The results in Tables 8 through 11 correspond to an analysis of each of the innovation strategies separately. In column (1) of each of these tables, the estimated coefficient on the binary measure of private equity investments (*priv*) is positive, significant, and of large size (15 to 37 percentage points, compared to sample averages ranging between 10 and 30 percent). We interpret this finding to suggest that, other things held constant, the presence of private equity investments in any amount and from any source is sufficient to incentivize the company to pursue in an innovation strategy with another firm(s). See rows (3) through (6) in Table 7. When the dollar amount of these private investments is considered (*priv$*)—column (3) in Tables 8 through 11—the same conclusion follows for all of the strategies except involvement in a joint venture, where the estimates fail to indicate a relationship.

The estimated results in columns (2) and (4) of Tables 8 through 11 disaggregate the private equity investments by source or type. In the specifications reported in column (2) of each table the disaggregation is dichotomous, while in column (4) of each table the disaggregation is in dollar terms. The empirical results vary by type of innovation strategy.

Comparing the results in column (2) of each table, other (non-venture capital) private equity investments (*odpe*) are positively and strongly correlated with all four innovation strategies, as

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[13] These specifications included separate controls for the following Institutes: National Institute on Aging; National Institute of Allergy and Infectious Diseases; National Cancer Institute; National Institute on Drug Abuse; National Institute on Deafness and Other Communication Disorders; National Institute of Diabetes and Digestive and Kidney Diseases; National Institute of General Medical Sciences; National Institute of Child Health and Human Development, National Heart, Lung and Blood Institute; National Institute of Mental Health; National Institute of Neurological Disorders and Stroke; and National Center for Research Resources. We also included an "other" institute variable for the following Institutes that had small numbers of projects: National Institute on Alcohol Abuse and Alcoholism; National Institute of Arthritis and Musculoskeletal and Skin Diseases; National Institute of Dental and Craniofacial Research; National Institute of Environmental Health Sciences; National Eye Institute; National Library of Medicine; National Human Genome Research Institute; and National Institute of Nursing Research.

are other private company investments (*odpc*) for all cases except joint ventures. Conversely, the presence of foreign investment (*for*) only affects, in a statistical sense, the likelihood of a licensing strategy being pursued, and the presence of U.S. venture capital (*vc*) only affects the likelihood of a R&D strategy being pursued. However, the venture capital effect on R&D is the strongest of any of the four investment types. A similar picture emerges when other (non-venture capital) private equity investments are measured in dollar terms in column (4) of each table, although the coefficients are measured with less precision. Particularly noteworthy is the positive relationship between venture capital funding and the adoption of a R&D strategy in Table 11. This finding is robust regardless of whether venture capital funding is measured dichotomously (*vc*) or in dollar terms (*vc$*).

The predicted relationships in Table 12 summarize the impacts of private equity investments by source on each innovation strategy.

The predicted effect of gender on a company's innovation strategy varies by type of strategy, although it is never statistically significant when innovation strategy was measured collectively in Tables 5 and 6. Conversely, the gender effect is positive in all of the licensing specifications in Table 8, although only significant when private equity investment is measured dichotomously. But, the effect of gender on innovation strategy is insignificant when related to a joint venture strategy, and negative and significant when related to the adoption of a R&D strategy or sale of technology.

Finally, in all of the specifications in Tables 8 through 11, university involvement is negatively related to the adoption of any specific innovation strategy. The effect is significant with regard to licensing and R&D, and marginally so with respect to the sale of technology and engagement in a joint venture.

III. Concluding Observations

There is great interest in evaluating the impact of private equity investments on innovation and economic growth. However, there is no direct empirical evidence on the effects of such transactions on the innovation strategies of entrepreneurial firms. The purpose of this paper was to fill this gap by examining a rich project-level data set consisting of firms receiving SBIR awards. One-sixth of these entrepreneurial firms attracted private equity investments.

Our analysis reveals that firms attracting private equity investments are significantly more likely to adopt innovation strategies such as entering into licensing agreements and selling their technology rights, and engaging in collaborative R&D agreements. However, these relationships differ across types of investment activities. For example, where the presence of non-venture capital private equity investments are positively associated with all of the innovation strategies studied, the effects of venture capital investments are particularly strong on for one innovation strategy, engagement in a collaborative R&D agreements. Understanding these disparate effects, and the reasons for them, is clearly an important topic for future research.

Our findings can be interpreted to suggest that private equity investments accelerate commercialization of publicly funded research and the diffusion of knowledge by becoming an integral part of the entrepreneurial firm's innovation strategy. This interpretation thus underscores the importance of both public and private investments in the development and commercialization of research that firms would not have undertaken on their own.[14]

Several caveats must be noted. For example, Link and Ruhm (2009) have shown that firms receiving Phase II NIH SBIR awards are far more likely to commercialize these innovations if they receive additional investment funding from outside sources than if they do not. However, our analysis here has not determined the degree to which these effects are causal, with the outside investments directly leading to adoption of the innovation strategies that we study, and to what extent promising technologies attract these sources of funding but would (eventually) be commercialized even without it. Our suspicion is that both factors are at play and that there are also interactive and complementary effects, whereby promising technologies are more likely to receive outside funding which, in turn, accelerates and expands the commercialization of these innovations.

[14] See Link and Scott (2010, 2012a) for an understanding of the economics of the SBIR program.

Table 1
Studies of the Effects of Private Equity on R&D-Related Variables and Total Factor Productivity

Authors	Country	Unit of Analysis	Nature of Transactions	Findings
Lichtenberg and Siegel (1990)	U.S.	Plant	Divisional and full-firm LBOs and MBOs of public and private companies	Plants involved in LBOs and MBOs are more productive than comparable plants before the buyout; LBOs and especially MBO plants experience a substantial increase in productivity after a buyout; employment and wages of non-production workers at plants (but not production workers) declines after an LBO or MBO; no decline in R&D investment
Wright, Thompson and Robbie (1992)	U.K.	Firm	Divisional, and full-firm MBOs of private companies	MBOs enhance new product development
Long and Ravenscraft (1993)	U.S.	Division	LBOs and MBOs	LBOs result in a reduction in R&D expenditures
Zahra (1995)	U.S.	Firm	MBOs	MBOs result in more effective use of R&D expenditure and new product development
Bruining and Wright (2002)	Holland	Firm	Divisional MBOs	MBOs result in more entrepreneurial activities such as new product and market development
Harris, Siegel, and Wright (2005)	U.K.	Plant	Divisional and full-firm LBOs and MBOs of public and private companies	Plants involved in MBOs are less productive than comparable plants before the buyout; they experience a substantial increase in TFP after a buyout
Lerner, Sørensen, and Strömberg (2011)	Worldwide	Firm	Private equity backed LBOs	Patent citations increase in the aftermath of buyouts, but the quantity of patenting is unchanged; patent portfolios appear to be become more focused after private equity investment

Table 2
Construction of the Random Sample of NIH Projects

Data Reduction	Number of Projects
Population of NIH-funded Phase II projects, 1992-2001	2,497
Survey population*	1,680
Random survey population**	1,679
Survey respondents***	495
Respondents with completed Phase II projects	461
Projects with complete data	419

Notes:
* We thank Dr. Charles Wessner for the NRC for making these data available for this study.
** The NRC surveyed a number of non-randomly selected projects. These were projects that resulted in significant commercialization success, and the NRC wanted to highlight them in their final report to Congress (Wessner 2009).
*** These 419 projects were undertaken by 313 different firms.

Table 3
Definition of Variables

Variable Name	**Definition**
Innovation Strategy Measures	
commdv	=1 if company finalized or is negotiating any of the following innovation strategies (*lic, tech, joint, r&d* – see below) with another company(ies) to commercialize the technology developed during the Phase II project, 0 otherwise
comm	number of innovation strategies finalized or being negotiated with another company(ies) to commercialize the technology developed during the Phase II project
lic	=1 if a licensing agreement has been finalized or is being negotiated with another company(ies), 0 otherwise
tech	=1 if a sale of technology rights agreement has been finalized or is being negotiated with another company(ies), 0 otherwise
joint	=1 if a joint venture agreement has been finalized or is being negotiated with another company(ies), 0 otherwise
r&d	=1 if a R&D agreement has been finalized or is being negotiated with another company(ies), 0 otherwise
Alternative Investment Measures	
priv	=1 if any form of private investment in the project, 0 otherwise
priv$	amount of any form of private investment in the project ($)
vc	=1 if U.S. venture capital investment in the project, 0 otherwise
vc$	amount of U.S. venture capital investment in the project ($)
for	=1 if foreign investment in the project, 0 otherwise
for$	amount of foreign investment in the project ($)
odpe	=1 if other private equity investment in the project, 0 otherwise
odpe$	amount of other private equity investment in the project ($)
odpc	=1 if other domestic company private investment in the project, 0 otherwise
odpc$	amount of other domestic company private investment in the project ($)
Other Covariates	
female	=1 if female owned company, 0 otherwise
years	number of years since receiving Phase II award
emp	number of employees at the time of Phase II submission
ln*emp*	log of the number of employees at the time of Phase II submission
univ	=1 if a university involved in executing Phase II award, 0 otherwise

Table 4
Descriptive Statistics, n=419

Variable Name	Mean	Standard Deviation	Range
Innovation Strategy Measures			
commdv	0.4153	0.4934	0/1
*comm**	0.7232	1.0489	0 – 4
lic	0.2959	0.4570	0/1
tech	0.1050	0.3069	0/1
joint	0.1002	0.3007	0/1
r&d	0.2220	0.4161	0/1
Alternative Investment Measures			
priv	0.1647	0.3713	0/1
priv$	841551.8	6357233	0 – 7.99e+07
vc	0.0334	0.1800	0/1
vc$	366627.8	3954432	0 – 5.99e+07
for	0.0263	0.1661	0/1
for$	87389.2	751907	0 – 1.00e+07
odpe	0.0883	0.2841	0/1
odpe$	338489.8	3098637	0 – 5.00e+07
odpc	0.0692	0.2541	0/1
odpc$	49045.0	377317	0 – 5.60e+06
Other Covariates			
female	0.1790	0.3838	0/1
years	7.4057	2.6498	4 – 13
emp	21.7613	49.4857	1 – 422
ln*emp*	2.0083	1.3236	0 – 6.0450
univ	0.5227	0.5001	0/1

Note:
* 59% of respondents reported on the survey that they had not adopted any innovation strategy, 22% reported 1 strategy, 11% 2 strategies, 5% 3 strategies, and 3% 4 strategies.

Table 5
Probit Analyses of the Adoption of Any Innovation Strategy
Marginal Effects (robust standard errors), n=419
Dependent variable *commdv*

Variable	**(1)**	**(2)**	**(3)**	**(4)**
priv	0.4049	0.4026	—	—
	(0.0637)****	(0.0630)****		
priv$	—	—	1.16e-08	1.02e-08
			(5.71e-09)***	(5.62e-09)**
years	-0.0253	-0.0225	-0.0269	-0.0249
	(0.0095)****	(0.0094)***	(0.0095)****	(0.0093)****
female	0.0341	0.0223	0.0083	-0.0062
	(0.0830)	(0.0845)	(0.0786)	(-0.0818)
ln*emp*	-0.0255	-0.01679	-0.0393	-0.0318
	(0.0220)	(0.0219)	(0.0216)**	(0.0217)*
univ	-0.0794	-0.0800	-0.0875	-0.0829
	(0.0544)*	(0.0533)*	(0.0540)*	(0.0528)*
Institute dummies	†	—	††	—
Chi^2(df)	51.24	40.15	25.29	13.54
pseudo R^2	0.1030	0.0853	0.0511	0.0303
log pseudolikelihood	-255.086	-260.118	-269.852	-275.769

Notes:
**** significant at the 0.01-level
*** significant at the 0.05-level
** significant at the 0.10-level
* significant at the 0.15-level
Marginal effects show the predicted impact of a one-unit change in the explanatory variable and are calculated with the other covariates evaluated at their sample means.
Standard errors are adjusted for 313 clusters by firm
† Institute dummy variables as a group are not significant, $Chi^2(12)=9.58$
†† Institute dummy variables as a group are not significant, $Chi^2(12)=11.23$

Table 6
Negative Binominal Analysis of the Adoption of Multiple Innovation Strategies (robust standard errors), n=419
Dependent variable *comm*

Variable	(1)	(2)	(3)	(4)
priv	1.0841	1.1103	—	—
	(0.1368)****	(0.1366)****		
priv$	—	—	2.19e-08	2.24e-08
			(4.30e-09)****	(5.47e-09)****
years	-0.0495	-0.0482	-0.0587	-0.0590
	(0.0271)**	(0.0265)**	(0.0280)***	(0.0272)***
female	-0.1048	-0.1287	-0.1790	-0.2197
	(0.1907)	(0.1979)	(0.2013)	(0.2141)
ln*emp*	-0.0887	-0.0744	-0.1503	-0.1408
	(0.0568)*	(0.0556)	(0.0583)****	(0.0586)***
univ	-0.1739	-0.1968	-0.2152	-0.2216
	(0.1425)	(0.1399)	(0.1504)	(0.1506)*
constant	0.0435	-0.0093	0.5635	0.4859
	(0.3116)	(0.2381)	(0.3145)**	(0.2412)***
Institute dummies	†	—	††	—
alpha	0.3000	0.3820	0.6516	0.7593
	(0.1556)	(0.1601)	(0.1756)	(0.1783)
Chi^2(df)	105.04	83.07	51.40	24.72
log pseudolikelihood	-456.025	-460.547	-476.953	-482.257

Notes:
**** significant at the 0.01-level
*** significant at the 0.05-level
** significant at the 0.10-level
* significant at the 0.15-level
Standard errors are adjusted for 313 clusters by firm
† Institute dummy variables as a group are not significant, $Chi^2(12)=7.17$
†† Institute dummy variables as a group are not significant, $Chi^2(12)=10.19$

Table 7
Predicted Relationship between Private Equity Investments and Innovation Strategies

	Outcome	No Private Equity Investment (*priv* = 0)	Private Equity Investment (*priv* = 1)
(1)	≥1 Innovation Strategy (*commdv*)	0.3504	0.7460
(2)	# of Innovation Strategies (*comm*)	0.5358	1.6262
(3)	Licensing Agreement (*lic*)	0.2352	0.6036
(4)	Sale of Technology Rights (*tech*)	0.0612	0.3086
(5)	Joint Venture (*joint*)	0.0732	0.2261
(6)	R&D Agreement (*r&d*)	0.1663	0.4907

Note:
Table shows predicted values averaged across all projects from the estimates of the specifications in column (2) of Tables 5 and 6, and column (1) of Tables 8 through 11.

Table 8
Probit Analyses of the Adoption of a Licensing Strategy
Marginal Effects (robust standard errors), n=419
Dependent variable *lic*

Variable	**(1)**	**(2)**	**(3)**	**(4)**
priv	0.3725	—	—	—
	(0.0669)****			
vc	—	-0.0469	—	—
		(0.1320)		
for	—	0.2496	—	—
		(0.1809)*		
odpe	—	0.3854	—	—
		(0.0989)****		
odpc	—	0.3582	—	—
		(0.0954)****		
priv$	—	—	1.06e-08	—
			(5.19e-09)***	
vc$	—	—	—	3.29e-08
				(4.65e-08)
for$	—	—	—	1.34e-07
				(1.06e-07)
odpe$	—	—	—	-1.40e-08
				(1.68e-08)
odpc$	—	—	—	2.32e-07
				(1.06e-07)***
years	-0.0028	-0.0023	-0.0062	-0.0070
	(0.0086)	(0.0086)	(0.0085)	(0.0091)
female	0.1117	0.1131	0.0819	0.0950
	(0.0784)*	(0.0783)*	(0.0756)	(0.0777)
ln*emp*	-0.0002	0.0003	-0.0152	-0.0208
	(0.0195)	(0.0199)	(0.0196)	(0.0207)
univ	-0.0602	-0.0713	-0.0648	-0.0803
	(0.0494)	(0.0493)*	(0.0494)	(0.0510)*
Chi^2(df)	34.70	41.22	7.48	12.29
pseudo R^2	0.0748	0.0872	0.0239	0.0470
log pseudolikelihood	-235.447	-232.301	-248.412	-242.541

Notes:
**** significant at the 0.01-level
*** significant at the 0.05-level
** significant at the 0.10-level
* significant at the 0.15-level
Marginal effects show the predicted impact of a one-unit change in the explanatory variable and are calculated with the other covariates evaluated at their sample means.
Standard errors are adjusted for 313 clusters by firm

Table 9
Probit Analyses of the Adoption of a Sale of Technology Rights Strategy
Marginal Effects (robust standard errors), n=419
Dependent variable *tech*

Variable	**(1)**	**(2)**	**(3)**	**(4)**
priv	0.2471	—	—	—
	(0.0612)****			
vc	—	0.0462	—	—
		(0.0951)		
for	—	-0.0109	—	—
		(0.0619)		
odpe	—	0.1758	—	—
		(0.0971)***		
odpc	—	0.3029	—	—
		(0.0995)****		
priv$	—	—	2.61e-09	—
			(1.68e-09)*	
vc$	—	—	—	4.75e-09
				(2.43e-09)***
for$	—	—	—	1.07e-08
				(1.58e-08)
odpe$	—	—	—	-4.30e-09
				(5.47e-09)
odpc$	—	—	—	1.11e-07
				(3.70e-08)****
years	-0.0039	-0.0048	-0.0069	-0.0082
	(0.0052)	(0.0052)	(0.0054)	(0.0057)
female	-0.0495	-0.0550	-0.0609	-0.0549
	(0.0276)*	(0.0273)*	(0.0301)**	(0.0301)*
ln*emp*	-0.0157	-0.0167	-0.0260	-0.0293
	(0.0103)*	(0.0102)*	(0.0110)***	(0.0113)****
univ	-0.0075	-0.0152	-0.0146	-0.0235
	(0.0278)	(0.0278)	(0.0308)	(0.0302)
Chi^2(df)	37.83	33.64	12.00	24.80
pseudo R^2	0.1402	0.1373	0.0385	0.0811
log pseudolikelihood	-121.037	-121.444	-135.344	-129.353

Notes:
**** significant at the 0.01-level
*** significant at the 0.05-level
** significant at the 0.10-level
* significant at the 0.15-level
Marginal effects show the predicted impact of a one-unit change in the explanatory variable and are calculated with the other covariates evaluated at their sample means.
Standard errors are adjusted for 313 clusters by firm

Table 10
Probit Analyses of the Adoption of a Joint Venture Strategy
Marginal Effects (robust standard errors), n=419
Dependent variable *joint*

Variable	**(1)**	**(2)**	**(3)**	**(4)**
priv	0.1521	—	—	—
	(0.0518)****			
vc	—	0.0797	—	—
		(0.1191)		
for	—	-0.0780	—	—
		(0.0253)		
odpe	—	0.2224	—	—
		(0.0878)****		
odpc	—	0.0487	—	—
		(0.0673)		
priv$	—	—	-4.94e-10	—
			(1.23e-09)	
vc$	—	—	—	-2.06e-10
				(4.94e-09)
for$	—	—	—	-5.76e-08
				(1.09e-07)
odpe$	—	—	—	5.31e-09
				(1.24e-08)
odpc$	—	—	—	2.99e-08
				(3.93e-08)
years	-0.0033	-0.0034	-0.0040	-0.0047
	(0.0055)	(0.0055)	(0.0057)	(0.0056)
female	-0.0320	-0.0269	-0.0424	-0.0409
	(0.0325)	(0.0335)	(0.0322)	(0.0317)
ln*emp*	-0.0220	-0.0181	-0.0276	-0.0272
	(0.0115)**	(0.0115)*	(0.0122)***	(0.0121)***
univ	-0.0092	-0.0053	-0.0113	-0.0108
	(0.0279)	(0.0284)	(0.0292)	(0.0287)
Chi^2(df)	21.26	25.45	7.15	7.96
pseudo R^2	0.0763	0.0856	0.0292	0.0336
log pseudolikelihood	-126.020	-124.758	-132.439	-131.851

Notes:
**** significant at the 0.01-level
*** significant at the 0.05-level
** significant at the 0.10-level
* significant at the 0.15-level
Marginal effects show the predicted impact of a one-unit change in the explanatory variable and are calculated with the other covariates evaluated at their sample means.
Standard errors are adjusted for 313 clusters by firm

Table 11
Probit Analyses of the Adoption of a R&D Agreement Strategy
Marginal Effects (robust standard errors), n=419
Dependent variable *r&d*

Variable	**(1)**	**(2)**	**(3)**	**(4)**
priv	0.3357	—	—	—
	(0.0680)****			
vc	—	0.3689	—	—
		(0.1682)***		
for	—	0.1509	—	—
		(0.1660)		
odpe	—	0.1647	—	—
		(0.0952)**		
odpc	—	0.2716	—	—
		(0.1025)****		
priv$	—	—	8.43e-09	—
			(3.30e-09)***	
vc$	—	—	—	9.38e-08
				(5.78e-08)**
for$	—	—	—	9.13e-08
				(1.27e-07)
ope$	—	—	—	-2.09e-08
				(2.57e-08)
odpc$	—	—	—	1.67e-07
				(6.63e-08)***
years	-0.0251	-0.0266	-0.0279	-0.0315
	(0.0077)****	(0.0077)****	(0.0076)****	(0.0087)****
female	-0.1137	-0.1114	-0.1238	-0.1236
	(0.0480)***	(0.0489)**	(0.0493)***	(0.0553)**
ln*emp*	-0.0170	-0.0211	-0.0320	-0.0410
	(0.0178)	(0.0179)	(0.0175)**	(0.0198)***
univ	-0.0675	-0.0837	-0.0749	-0.0904
	(0.0424)*	(0.0424)***	(0.0432)**	(0.0466)**
Chi^2(df)	49.93	44.22	27.45	34.63
pseudo R^2	0.1255	0.1263	0.0712	0.1075
log pseudolikelihood	-193.977	-193.788	-206.013	-197.959

Notes:
**** significant at the 0.01-level
*** significant at the 0.05-level
** significant at the 0.10-level
* significant at the 0.15-level
Marginal effects show the predicted impact of a one-unit change in the explanatory variable and are calculated with the other covariates evaluated at their sample means.
Standard errors are adjusted for 313 clusters by firm

Table 12
Predicted Relationship between Specific Private Equity Investments and Innovation Strategies

Innovation Strategy	**Type of Investment** No Private Equity (*priv* = 0)	Venture Capital (*vc*)	Foreign (*for*)	Other Private Equity (*odpe*)	Other Company (*odpc*)
Licensing Agreement (*lic*)	0.2352	0.5261	0.8037	0.8871	0.5820
Sale of Technology Rights (*tech*)	0.0612	0.4407	0.3482	0.6398	0.3482
Joint Venture (*joint*)	0.0732	0.1805	0.1161	0.3321	0.1161
R&D Agreement (*r&d*)	0.1663	0.7956	0.4281	0.6455	0.4281

Note:
Table shows predicted values averaged across all projects from the estimates of the specifications in columns (1) and (2) of Tables 8 through 11. Private equity investments types are assumed to be exclusive (e.g., when venture capital is received the other types of private equity are not).

References

Baldwin, William L. and Albert N. Link (1998). "Universities as Research Joint Venture Partners: Does Size of Venture Matter?" *International Journal of Technology Management* 15:895–913.

Bloom, Nicholas, Raffaella Sadun, and John van Reenen (2009). "Do Private Equity-Owned Firms Have Better Management Practices?" in A. Gurung and J. Lerner (eds.), *Globalization of Alternative Investments, The Global Economic Impact of Private Equity Report 2009,* pp. 3–23. Geneva, Switzerland: World Economic Forum.

Bruining, Hans and Mike Wright (2002). "Entrepreneurial Orientation in Management Buyouts and the Contribution of Venture Capital," *Venture Capital: An International Journal of Entrepreneurial Finance* 4:147–168.

Cumming, Douglas, Donald S. Siegel, and Mike Wright (2007). "Evaluating the Financial and Real Effects of Management Buyouts and Private Equity Investments," *Journal of Corporate Finance* 13:439–460.

Davis, Steve, Josh Lerner, John Haltiwanger, Javier Miranda, and Ron Jarmin (2009), "Private Equity, Jobs, and Productivity," in A. Gurung and J. Lerner (eds.), *Globalization of Alternative Investments, The Global Economic Impact of Private Equity Report 2009,* pp. 27–43. Geneva, Switzerland: World Economic Forum.

_____. (2011). "Private Equity and Employment." NBER Working Paper 17399, Cambridge, MA: National Bureau of Economic Research.
Available at http://www.nber.org/papers/w17399.

Gicheva, Dora and Albert N. Link (forthcoming). "Leveraging Entrepreneurship through Private Investments: Does Gender Matter?" *Small Business Economics* (DOI 10.1007/s11187-011-9411-y).

Harris, Richard, Donald S. Siegel, and Mike Wright (2005). "Assessing the Impact of Management Buyouts on Economic Efficiency: Plant-Level Evidence from the United Kingdom, *The Review of Economics and Statistics* 87:148–153.

Lerner, Josh (1999). "The Government as Venture Capitalist: The Long-Run Impact of the SBIR Program," *Journal of Business* 72:285–318.

Lerner, Josh, Morton Sorensen, and Per Strömberg. "Private Equity and Long-Run Investment: The Case of Innovation," *Journal of Finance* 66:445–477.

Lichtenberg, Frank R. and Donald Siegel (1990). "The Effect of Leveraged Buyouts on Productivity and Related Aspects of Firm Behavior," *Journal of Financial Economics* 27:165–194.

Link, Albert N. and Christopher J. Ruhm (2009). "Bringing Science to Market: Commercializing from NIH SBIR Awards," *Economics of Innovation and New Technology* 18:381–402.

Link, Albert N. and Christopher J. Ruhm (2011). "Public Knowledge, Private Knowledge: The Intellectual Capital of Entrepreneurs," *Small Business Economics* 36:1–14.

Link, Albert N. and John T. Scott (2010). "Government as Entrepreneur: Evaluating the Commercialization Success of SBIR Projects," *Research Policy* 39:589–601.

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

Link, Albert N. and John T. Scott (2012b). "The Exploitation of Publicly Funded Technology," *Journal of Technology Transfer* 37:375–383.

Long, William F. and David J. Ravenscraft, D.J. (1993). "LBOs, Debt and R&D Intensity," *Strategic Management Journal* (Summer Special Issue) 14:119–135.

Wessner, Charles W. (2008). *An Assessment of the SBIR Program*, Washington, DC: National Academies Press.

Wessner, Charles W. (2009). *An Assessment of the SBIR Program at the National Institutes of Health*, Washington, DC: National Academies Press.

Wright Mike, Steve Thompson, and Ken Robbie (1992). "Venture Capital and Management-Led Leveraged Buyouts: A European Perspective," *Journal of Business Venturing* 7:47–71.

Zahra, Shaker. (1995). "Corporate Entrepreneurship and Financial Performance: The Case of Management Leveraged Buy-Outs," *Journal of Business Venturing* 10: 225–247.