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Innovative activity and gender dynamics

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Abstract We explore the innovative performance of firms resulting from their Phase II Small Business Innovation Research (SBIR) research-funded projects in terms of the gender dynamics of the firms. Using commercialization as the relevant performance metric, we find that Phase II projects led by a female principal investigator (PI) have greater probability of being commercialized in female-owned firms than in male-owned firms. This result is consistent with the findings from other settings that females tend to perform better when working under a female supervisor.

Keywords Innovation · SBIR program · Gender gap · Principle investigator

JEL classifications J16 · L26 · O31 · O38

> Byrdes of on kynde and color flok and flye allwayes together
>
> — William Turner (*The Rescuing of Romish Fox*, 1545)

1 Introduction

Much has been written about the so-called gender gap in terms of the availability of third-party financial resources for women-owned firms (Gicheva and Link, 2013, 2015; OECD, 2019). Regarding the implications of this gender gap, the evidence in the literature on firm performance, in terms of survival rates and growth rates, is mixed (Szerb et al., 2007; Link and Strong, 2016; Brush et al., 2017). An important aspect of the gender gap literature that has rarely been studied is the relationship between gender and the innovative performance of firms. This paper addresses that topic.

Furthermore, gender congruence between individuals at different levels in a power structure has been shown to be an important factor for female advancement in many settings, including labor markets and educational organizations. Conspicuously absent from this literature is an emphasis on successful innovative activity by females in a homophilic relationship.[1]

In this paper, we explore the innovative performance of firms resulting from their Phase II Small Business Innovation Research (SBIR) research-funded projects in terms of what we call the gender dynamics of the firms. In

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[1] Lazarsfeld and Merton (1954, p. 23) wrote: "Perhaps we shall be allowed, therefore, to summarize the fifteen-word phrase, 'a tendency for friendships to form between those who are alike in some designated respect' by the single word *homophily* …".

particular, we take into consideration the gender of the owner of the firm as well as the gender of the principal investigator (PI) involved in the SBIR project in our study of whether or not the Phase II project was successful as measured by whether or not it resulted in a commercialized innovation.

In Section II, we briefly describe the U.S. SBIR program and we introduce the National Institutes of Health (NIH) data that we use in our empirical analyses. In Section III, we summarize the relevant literature on economic performance in general and the homophily among females. Based on that literature, we posit a hypothesis about differences in the innovative performance of female PIs involved in Phase II research depending on the gender of the firm owner. In Section IV we present descriptive evidence based on the NIH data, and we discuss our empirical findings. Section V concludes the paper with summary remarks and our view of an agenda for future research.

2 The U.S. SBIR program

Briefly, the SBIR program was established through the U.S. Small Business Innovation Development Act of the 1982, Public Law 97–219.[2] This act was passed by Congress as an amendment to the Small Business Act of 1953 which established the Small Business Administration. Congress motivated the passage of 1982 Act by stating as a preamble that small businesses have been the principal source of significant innovations in the nation and they are among the most cost-effective performers of research and development (R&D) that results in new products.

The purposes of the SBIR program, when established in 1982, were as stated[3]:

(1) to stimulate technological innovation;
(2) to use small business to meet Federal research and development needs;
(3) to foster and encourage participation by minority and disadvantaged persons in technological innovation; and[4]
(4) to increase private sector commercialization of innovations derived from Federal research and development.

SBIR funding to a small firm (less than 500 employees) is first given as a Phase I award. These are small awards that are intended to assist the firm assess the feasibility of an idea's scientific and commercial potential in response to the funding agency's objectives.[5] Firms that complete their Phase I research can apply for a follow-on Phase II award. These awards are given on the basis of a several criteria, one of which is the potential for the funded technology to results in a commercialized product or process.[6]

As part of Congress' due diligence, it authorized as part of the SBIR program's reauthorization in 2000 the National Research Council (NRC) within the National Academies to study the SBIR program and to offer to Congress suggestions for program improvements. These suggestions for the program would be taken into account when Congress considered the 2008 reauthorization of the program.

As part of the NRC's efforts, in 2005 it conducted a survey of a representative sample of Phase II projects funded by the five largest agencies with SBIR programs: the Department of Defense (DoD), NIH, the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Science Foundation (NSF). After the reauthorization of the SBIR program,[7] Congress authorized additional surveys of

[2] More detailed discussions of the history of the SBIR program are in Link and Scott (2012) and Leyden and Link (2015).

[3] To be eligible for an SBIR award, the firm must be: organized and operated for profit, with a place of business in the United States, which operates primarily within the United States or which makes a significant contribution to the U.S. economy through payment of taxes or use of American products, materials, or labor; more than 50% owned and controlled by one or more individuals who are citizens or permanent resident aliens of the United States; and has not more than 500 employees, including affiliates. Eleven agencies currently participate in the SBIR program: the Environmental Protection Agency, the National Aeronautics and Space Administration, the National Science Foundation, and the Departments of Agriculture, Commerce, Defense, Education, Energy, Health and Human Services (which includes the National Institutes of Health), Transportation, and, most recently, Homeland Security.

[4] When the SBIR program was reauthorized in 1992, this purpose statement was changed to read: "to provide for enhanced outreach efforts to increase the participation of socially and economically disadvantaged small business concerns, and the participation of small businesses that are 51% owned and controlled by women." The data that we analyze below are for the years 1992 through 2010. There is not, however, and increasing trend in the percent of Phase II awards to women-owned firms over this time period. These results are available from the authors on request.

[5] Currently, Phase I awards generally do not exceed $150,000 for six months.

[6] Currently, Phase II awards generally do not exceed $1,000,000 for two years.

[7] See Leyden and Link (2015) for a chronological history of the reauthorization of the SBIR program.

representative samples of both SBIR-funded and STTR-funded Phase II projects.[8] In 2011, DoD, NASA, and NSF Phase II projects were surveyed; NIH and DOE Phase II projects were surveyed in 2014.

In this paper, we focus on commercialization from the Phase II research as the relevant performance variable as was stated in the 1982 Act, and we examine data on NIH funded Phase II projects.[9] The DoD SBIR program is the largest program measured in terms of number of Phase II awards and allocated research dollars. Second to the DoD program in these dimensions is the NIH program. The other three agency programs are much smaller.[10] We chose to examine the data from the NIH from both the 2005 and the 2014 survey not only because of the program's size, but also because the survey measures of commercialization are more market-based than in the DoD data.[11] Many of the technologies developed through DoD funded Phase II awards are in fact purchased directly by the DoD.

Figure 1 shows the NIH sample of projects by the year the project was funded ($n = 966$). The only overlap between the 2005 and 2014 surveys is in 2001; all projects awarded prior to that were surveyed in 2005, while all subsequent awards enter the 2014 sample. The number of projects awarded in a given year ranges from 19 in 1992 (which is also the first year in the data) to 101 in 2001.

3 Gender and firm performance

There is a small literature related to the non-homophilic success of females in small innovation-intensive firms. For example, Weber and Zulehner (2010) study the gender composition of the initial hires of start-up firms in Austria and show that firms that start off with more female employees have higher survival rates. Joshi, Inouye, and Robinson (2018) find that SBIR-funded projects with female PIs are more likely to succeed if the funding agency is comprised of more females; this finding complements the earlier finding of Andersen, Bray, and Link (2017). Ding, Murray, and Stuart (2006) identify a gender gap in commercialization and patenting to which they link women scientists' low exposure to the commercial sector and the perception that commercialization activities detract from academic pursuits. Link and Ruhm (2009), who also use SBIR data, find that women-owned businesses are less successful in commercializing their technology from Phase II projects. Shane et al. (2012) find evidence of bias against women inventors among university technology transfer officers, which play a significant role in directing resources for commercialization, and a predisposition to inventions by Asian inventors with previous industry experience. Finally, Dohse, Goel, and Nelson (2019) show that female owners are more likely than female managers to introduce new innovations to the market.

There is evidence in the literature that female-led firms (e.g., female-owned firms) tend to hire and retain more females at lower levels. Matsa and Miller (2011) show that in a sample of publicly traded U.S. companies, higher female representation on the board of directors leads to more female top executives at the company. Kurtulus and Tomaskovic-Devey (2012) find a strong positive correlation between the share of female top- and mid-level managers in a large sample of U.S. firms. Hensvik (2014) also finds that among firms in Sweden, those with more female managers also tend to hire more female workers at lower levels.

Several recent studies find evidence that having women in top management is associated with better labor market outcomes for lower-ranked females at a firm. Examples include Tate and Yang (2015), who use plant- and firm-level data on non-farm establishments with paid employees from the U.S. Census Bureau's Longitudinal Business Database, and Flabbi, Macis, and Schivardi (2019), who use data on Italian manufacturing firms. Cardoso and Winter-Ebmer (2010) obtain similar results for Portugal, showing that female employees benefit more from female firm leadership in small (100 or fewer employees) firms. See also, Fox et al. (2017) and Shane et al. (2015) for additional examples.

Educational settings provide further evidence that females perform better under female supervisors. Carrell, Page, and West (2010) show that when high-

[8] The Small Business Technology Transfer Act of 1992 established the STTR program. The STTR program is modeled after the SBIR program, and it has the following goal, as stated in the 1992 Act: "[T]o facilitate the transfer of technology developed by a research institution through the entrepreneurship of a small business concern."

[9] The data from the 2005 NIH survey are fully described in National Research Council (2009), and the data from the 2014 NIH survey are fully described in National Academies of Sciences, Engineering, and Medicine (2015).

[10] See, https://www.sbir.gov/

[11] To the best of our knowledge, ours is the first paper to examine statistically any of the 2014 data collected by the NRC.

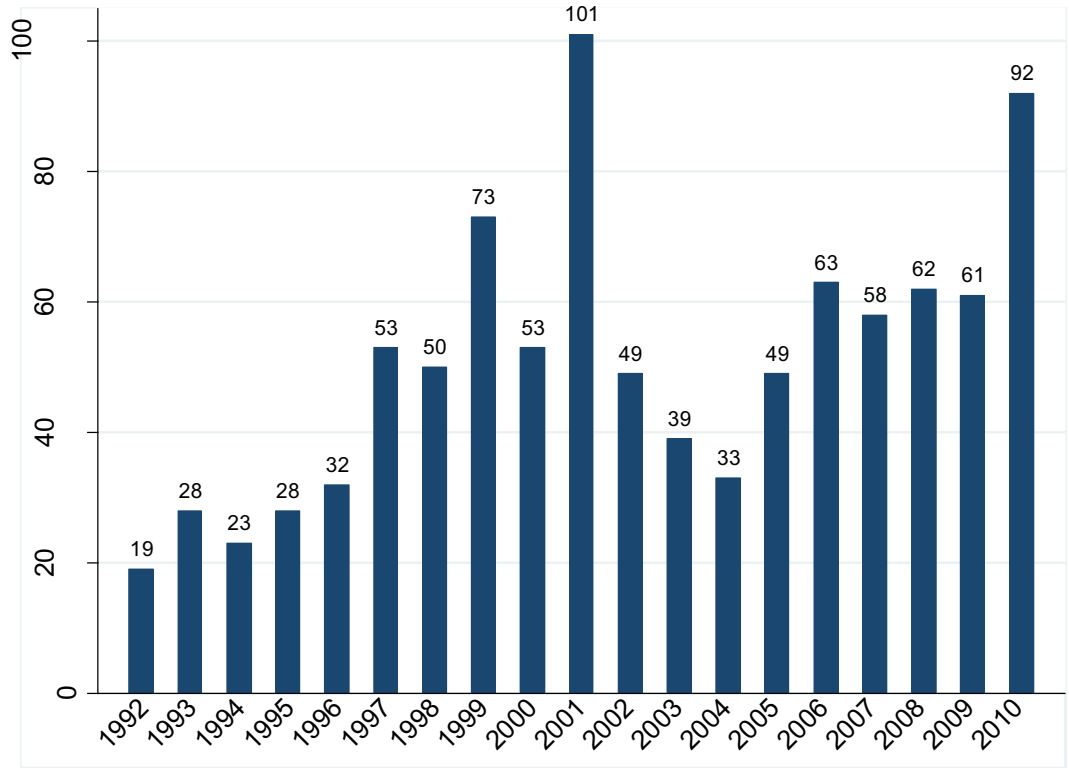

Fig. 1 Distribution of Phase II Projects by Year of Funding ($n = 966$). Note: The 2005 survey includes projects funded in 1992—2001; the 2014 survey includes projects funded in 2001—2010

achieving female students take an introductory math or science course with a female professor, they are more likely to take more math and science and to major in a STEM field. Dee (2007) finds positive impacts for eighth-grade students of having a teacher of the same gender. Bednar and Gicheva (2014, 2018) show that in collegiate athletics, female head coaches perform better and have lower turnover rates when working under an athletic director who is generally supportive of females.

Several explanations have been proposed in the literature for why female workers may be more productive when female representation in upper levels of the firm is higher. Athey, Avery, and Zemsky (2000) offer a theoretical model underscoring the importance for firm performance of same-sex mentorship between workers in upper and lower levels of a company. Flabbi et al. (2019) present a model, consistent with Cornell and Welch's (1996) seminal work, based on the assumption that CEOs derive more accurate signals about the productivity of workers of their own gender, so female CEOs are better able to allocate female workers to the most appropriate tasks.

Based on this literature, we hypothesize that the relationships uncovered by prior studies will carry over to the small innovative firms that comprise our sample, making Phase II research projects with a female PI more successful when the owner of the firm is also female. If females are more productive in homophilic relationships, we also hypothesize that among female-owned firms, those with a female PI on their Phase II research project will tend to be more successful. The existing theories do not address the relative success of all-male compared to all-female teams, but we further explore whether the projects conducted by female-owned firms with a female PI tend to outperform projects in male-owned firms with a male PI.

We make several contributions to the literature in this paper. First, we test existing theories positing that females tend to perform better when working under a female supervisor in the context of small innovative firms, where this relationship has not been examined previously. Second, we examine firm performance in homophilic teams using a well-defined and meaningful measure that is aligned closely with the stated goal of the

Table 1 Definition of Variables

Variable	Definition
Commercialization	=1 if the firm commercialized the technology developed during its Phase II research, as measured in terms of sales of a developed product, process, or service; 0 otherwise
FemaleOwner	=1 if the firm is owned by a female; 0 otherwise
FemalePI	=1 if the PI on the Phase II project is female; 0 otherwise
FemaleOwner x FemalePI	=1 if the firm is owned by a female and the PI on the Phase II project is female; 0 otherwise
FirmSize	Equals the number of employees in the firm at the time the firm submitted its proposal for a Phase II award
PreviousAwards	=1 if the firm had previously received any Phase II awards related to the technology of the current Phase II award; 0 otherwise
NumberPreviousAwards	Number of previous Phase II awards the firm received related to the technology of the current Phase II award
PIasFounder	=1 if the PI on the Phase II project is also the firm founder; 0 otherwise
PIasCEO	=1 if the PI on the Phase II project is also the CEO of the firm; 0 otherwise
SBIRAward	=1 if the Phase II project is funded by a SBIR award as opposed to a STTR award; 0 otherwise

SBIR program.[12] Previous studies of the effectiveness of female firm leadership have used other categories of performance measures such as stock prices and firm assets (e.g., Ahern and Dittmar 2012, Wolfers 2006). Flabbi et al. (2019) use sales per worker, value added per worker, and Total Factor Productivity (TFP), while Matsa and Miller (2013) use firm profits. A third contribution of our paper is that it is the first to analyze the 2014 SBIR survey data.

4 Empirical analysis

We estimate the following probit model of the likelihood that firm i commercializes the technology developed with the Phase II award:

$$\Pr(Commercialization_i = 1 | FemaleOwner_i \times FemalePI_i, \boldsymbol{X_i}) = \Phi(\alpha(FemaleOwner_i \times FemalePI_i) + \boldsymbol{X_i}\beta) \quad (1)$$

where *Commercialization* and *FemaleOwner x FemalePI* are defined in Table 1 along with the controls in vector $\boldsymbol{X}$, and $\Phi(\cdot)$ is the standard normal distribution.

Regarding the variable *Commercialization*, the relevant NRC survey question associated with this variable is: "Has your company and/or licensee had any actual sales of products, processes, services or other sales incorporating the technology developed during this project?" If the respondent to the survey answered YES to having actual sales of either a product, a process, or a service, we defined the variable *Commercialization* to equal 1, and 0 otherwise.

Our hypothesis is that the estimated coefficient on

Table 2 Descriptive Statistics on the Variables

Variable	Mean	Standard Deviation	Range
Commercialization	.468	.499	0/1
FemaleOwner	.149	.356	0/1
FemalePI	.178	.383	0/1
FemaleOwner x FemalePI	.084	.277	0/1
FirmSize	22.3	45.4	1/426
PreviousAwards	.543	.498	0/1
NumberPreviousAwards	1.15	2.47	0/28
PIasFounder	.246	.431	0/1
PIasCEO	.164	.37	0/1
SBIRAward	.916	.277	0/1

Source: 2005 and 2014 surveys

[12] Others (e.g., Siegel and Wessner, 2012; Audretsch and Link, 2018) have examined various output measures, such as patents or publications, associated with a SBIR-funded Phase II project using data from the 2005 NRC survey. We refrain from referring to such output measures as *performance measures* or even *success measures* because they are not a legislatively-defined purposeful outputs from a Phase II project. Our performance measure of commercialization is directly related to purpose statement (4) of the SBIR program as noted above.

Table 3 Mean Values by Gender Composition of the Project Team (standard deviation in parentheses, n = 966)

Variable	Project Composition			
	Male Owner and Male PI	Male Owner and Female PI	Female Owner and Male PI	Female Owner and Female PI
Commercialization	0.45	0.46	0.46	0.63
FirmSize	21.25	27.80	18.33	16.23
	(44.67)	(65.83)	(27.28)	(32.72)
PreviousAwards	0.55	0.42	0.48	0.69
NumberPreviousAwards	0.99	0.74	0.92	3.17
	(1.47)	(1.19)	(1.29)	(6.83)
n	731	91	63	81

Source: 2005 and 2014 surveys

FemaleOwner x FemalePI is positive, indicating that Phase II projects led by a female PI are more likely to commercialize in female- than in male-owned firms and that female-owned firms with a female PI working on the Phase II project are more likely to commercialize than female-owned firms with a male PI.

The variables used to test empirically our hypothesis are defined in Table 1 and descriptive statistics are presented in Table 2. Within our sample, 15% of all Phase II projects were awarded to female-owned firms, and 18% of all Phase II projects in our sample were led by female PIs. Only 8.4% of all Phase II projects were awarded to female-owned firms that also had a female PI, but these statistics suggest that, consistent with findings in prior studies from different settings, females tend to be disproportionately more likely to work with other females across different levels within a company.

Regarding our control variables, our argument for holding constant firm size is that larger firms, that is the larger firms among our sample of small firms, have more internal resources to devote to the commercialization of their Phase II project than do smaller firms. Previous Phase II awards that relate to the technology being researched in the current Phase II project are expected to have a positive impact on the efficiency of the current Phase II project, and we assert that the more efficiently the current Phase II project is conducted the more likely the developed technology will have commercial potential. In some cases, generally in the smaller firms, the PI is also either the founder of the firm or the CEO of the firm. Thus, in these firms, there is a dual homophiletic relationship, and we control for such

Table 4 Estimated Results from the Probit Model in Eq. (1) (n = 966)

Variable	(1)	(2)
FemaleOwner	−0.035	−0.045
	(0.172)	(0.173)
FemalePI	−0.005	−0.008
	(0.143)	(0.143)
FemaleOwner x FemalePI	0.506*	0.572**
	(0.265)	(0.270)
FirmSize	0.001	0.002*
	(0.001)	(0.001)
PreviousAwards	0.333***	–
	(0.088)	
NumberPreviousAwards	–	0.190***
		(0.041)
$NumberPreviousAwards^2$	–	−0.007***
		(0.002)
PIasFounder	−0.012	−0.013
	(0.138)	(0.138)
PIasCEO	−0.341**	−0.344**
	(0.154)	(0.154)
SBIRAward	0.058	0.037
	(0.160)	(0.160)
Constant	−0.442	−0.461
	(0.333)	(0.335)
Wald Ratio χ^2	59.30	63.99
Pseudo R^2	0.042	0.049
Log Likelihood	−639.8	−634.8

Source: 2005 and 2014 survey

Notes: Coefficients from probit model that includes indicators for survey and Phase II award year. Heteroscedasticity-robust standard errors reported in parentheses

*** significant at .01-level, ** significant at .05-level, * significant at .1-level

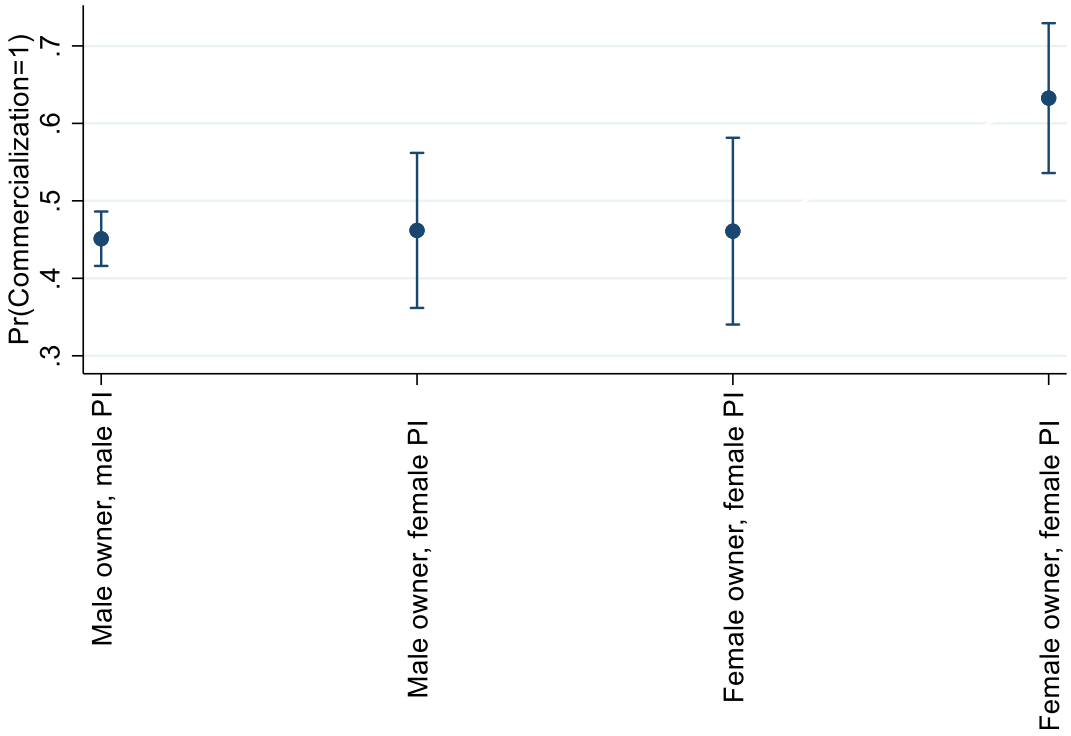

Fig. 2 Predicted Probability of Commercialization. Note: Average marginal effects based on column (2) in Table 4. The error bars show 95% confidence intervals

situations. This information is available only in the 2014 survey, and so we set the variable to equal 0 for all observations from the 2005 data. We control for the cases in which the Phase II project is not funded through a SBIR award but rather through a STTR award. Finally, the specifications include indicators for year when the Phase II project was funded and for survey year (2005 or 2014).

In Table 3, we present the mean value of key variables by what we call project composition. That is, we divide the sample of Phase II projects into the four categories noted in the table. Based on mean values, the likelihood that a Phase II project's technology is commercialized, that is the likelihood that the Phase II project is successful in terms of the main criterion of the SBIR program, is nearly 50% greater in firms with a female owner and a female PI compared to the other three categories of firms, where the probability of commercialization is approximately the same. Also noteworthy in Table 3 is that, on average, firms with both a female owner and a female PI are smaller than any of the other types but they have over 3 times more previous related Phase II awards compared to firms with other gender composition of the owner and PI.[13]

Our econometric findings are presented in Table 4, which shows coefficient estimates from the probit model in eq. (1) and heteroskedasticity-robust standard errors. The specification in column (1) includes an indicator for whether the firm received any Phase II awards in the past that are related to the current technology, while the model in column (2) replaces this indicator with a quadratic in the number of related prior Phase II awards. The findings mirror the unconditional descriptive statistics shown in Table 3. We find that within our sample, the likelihood of commercialization is highest among female-owned firms with a female PI relative to any other category. These results support our hypothesis and are the punchline of our paper. The estimates presented in Table 4 also confirm the observation from Table 3 that male-owned firms with a male or female PI and female-owned firms with a male PI all have similar success rates.

[13] We do not know if there was a female PI involved in any of the previous Phase II awards.

Figure 2 illustrates the marginal effects of the gender variables based on the probit estimates in column (2) of Table 4. Specifically, the plot shows the predicted probability of commercialization for each of the four categories of firms, along with the 95% confidence interval. These results again illustrate that female firm owners (PIs) are more successful when working with a female PI (owner). We also document that in this sample of Phase II projects funded by the NIH, there exists a statistically and economically significant difference in performance between male-owned firms with a male PI and female-owned firms with a female PI.

Finally, regarding the coefficient estimates on control variables in Table 4, the estimated effect of firm size is small and only statistically significant at the 10% level in column (2). The average marginal effect of one standard deviation increase in firm size (45 employees) is a 2.7 percentage point increase in the probability of commercialization. And, previous related Phase II awards, as well as the number of such awards, are a driver of the likelihood that the Phase II project will be commercialized.

5 Concluding statement

We have illustrated empirically in this paper the synergetic effect of what we call gender dynamics, that is of female-owned firms that have a female PI leading their Phase II research project. While our contribution to the economics literature on homophily is unique to only one dimension of innovative behavior, it does, in our view, provide an important starting point for future research on more broadly defined innovation effects of such relationships. Future research might focus on the acquisition of technology-oriented resources, such as venture capital; technology transfer activities, such as patenting behavior, or collaborative research ventures, such as participation in R&D alliances.

To expand the literature more broadly, there might also be other dynamics associated with age, race, ethnicity, orientation, or nationality that have yet to be investigated in general, much less within the innovation literature. Of course, data availability is always a delimiting factor, or even a factor that keeps the research door closed. Creatively designed and executed firm histories over long periods of time might be a relevant vehicle through which to begin.

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