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How Principal Investigators' Commercial Experience Influences Technology Transfer and Market Impacts

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Overview: Businesses can benefit from university-industry collaborations, yet they rarely take full advantage of them. Scientists who serve as principal investigators (PI) act as the nucleus of university-industry collaborations and partner with industry to co-create value. We conducted a case study of PIs at publicly funded research universities, institutes, and organizations in Ireland to explore how having commercial experience influences how PIs approach technology transfer and how they develop new business models, products, and services. We learned that PIs' prior commercial experience influences how they approach their research, project work, and project selection and affects how they commercialize knowledge and outputs from their scientific research—that is, patents, licences, agreements, etc.—throughout the project's life cycle. In university-industry collaborations, PIs' commercial experience can impact industry partners' attempts to realize technology transfer and market impacts.

Keywords: Principal investigators, Technology transfer, Market impact, University-industry collaboration, Commercial experience

Innovations created by public research organizations such as universities or government research centers benefit industry (Giones 2019; Lehmann and Menter 2016; Tseng et al. 2020). Because the academic sector has proprietary knowledge and unique expertise and capabilities, university-industry collaborations can enhance businesses' innovation and technology development (Schoppe and Chylla 2016). Studies show that most university-industry research partnerships don't fully realize the value created during the collaborative process due mainly to misaligned strategies and objectives (Valentín 2000; Starbuck 2001). Scientific outcomes may be the primary motivator for academic partners, while industry partners aim to exploit scientific outcomes through technology transfer and achieve substantive market impacts. Tensions can arise (Cunningham and Harney 2006) when neither party understands the other's objectives or motivations regarding technology transfer and commercializing knowledge and other outputs.

In university-industry collaborations, principal investigators (PIs) help industry partners achieve technology transfer and realize market impacts. Acting as knowledge creators and brokers, PIs

shape the directions of existing and new scientific research that enable industry partners to exploit new knowledge that results from a university-industry collaboration (Cunningham et al. 2017). The PI leads technology transfer and directs the research that creates market benefits in the form of new products, services, and business models (Cunningham and O'Reilly 2019).

Despite growing expectations that academic research should have tangible results that benefit local, regional, and national economies (McConnell and Cross 2019), the principal investigator's role remains understudied. Existing research about PIs focuses on strategic behaviors, managerial challenges, motivations to become a PI, research output productivity, how PIs identify research and market opportunities, and barriers they experience (Cunningham 2019; Del Giudice et al. 2017; Kastrin et al. 2018; Mangematin et al. 2014; Menter 2016; O'Kane 2018). Here we examine whether PIs' commercial experience—that is, work experience in a non-academic/industry sector—influences how they approach technology transfer and develop market impacts.

Our findings show PIs' prior commercial experience influences their approach to research, their project work, and how they select projects. It also affects the research translation process throughout the project life cycle. Our study highlights that PIs' differing degrees of commercial experience may ultimately affect project outcomes and success. Industry partners should consider commercial experience when selecting PIs to collaborate with. Industry partners should also assess whether the prospective university or research partner has sufficient support mechanisms to ensure more effective collaborations with PIs.

Background

To prepare our survey, we explored existing literature about the principal investigator role and its impact on technology transfer and market shaping.

The Principal Investigator Role

Companies make significant investments annually in university-industry collaborations to advance knowledge and create value through technology and knowledge transfer (Giunta et al. 2016; Freitas et al. 2013). Principal investigators lead large-scale research projects initiated by university-industry partnerships. Different definitions exist regarding who PIs are and what they do (Cunningham et al. 2014). O'Kane et al. (2017, p. 217) describe PIs as "lead researchers on successful programme and project grants," while Cunningham et al. (2016b, p. 72) define PIs as "scientists who orchestrate new research projects, combine resources and competencies, deepen existing scientific trajectories or shape new ones that are transformative in intent, nature and outcome that can be exploited for commercial ends and/or for societal common good." Boehm and Hogan (2014) suggest PIs have an entrepreneurial role in building and shaping networks as well as bridging the gap between science and industry.

Beyond teaching and administrative duties, PIs are influential research leaders who engage with industry partners, facilitate technology transfer, disseminate research, and manage resources (Cunningham et al. 2020; Romano et al. 2017). Casati and Genet (2014) argue that PIs take on more than scientific leadership and that often a disconnect exists between PIs' job descriptions and what they do in practice. According to Kidwell (2014, p. 34), PIs are at "the forefront of new scientific knowledge." Baglieri and Lorenzoni (2014) suggest that PIs play a pivotal role in

technology transfer on the user side. Mangematin et al. (2014) state that PIs act as "linchpins" between science and markets. Hence, successful PIs have to boundary span—that is, collate and exchange information, knowledge, and know-how (Tushman and Scanlan 1981)—between academic, industry, and policy sectors. PIs also have to collaborate with diverse academic and industry partners to realize technology and knowledge transfer outputs. In essence, they have to simultaneously combine academic rigor, commercialization, and value creation (Ambos et al. 2008).

The PIs' Role in Technology Transfer and Market Shaping

To secure research funding with industry partners, PIs must make a compelling business case about the commercial and market potential of their scientific projects. PIs must be able to demonstrate market shaping—that is, use their scientific discoveries or knowledge to create new products, services, and business models that provide competitive advantage (Mangematin et al. 2014). PIs also need to create value by leveraging their networks within and beyond academia through strong reciprocal interpersonal relationships (Cunningham et al. 2018). They must meet industry partners' expectations while concurrently meeting requirements to publish scientific results and pursue technology transfer opportunities (Cunningham et al. 2019b).

Technology transfer is an important part of a PI's role, but they can face barriers and feel unprepared for the commercialization process. According to O'Kane et al. (2017), Technology Transfer Offices (TTOs) lack much-needed market analysis resources to support PIs' commercialization and value creation efforts. This lack of support coupled with the power of industry partners (Cunningham et al. 2015) create managerial challenges that impact the time that PIs allocate to their scientific projects. According to Cunningham et al. (2016a), PIs who allocated more time to research-related activities also allocated more of their time to technology transfer activities such as market research.

The Case Study

We surveyed PIs from publicly funded Irish-based universities, institutes of technology, and public research organizations in the fields of science, engineering, and technology. We identified 1,391 potential survey participants from public data on research projects and lead researchers, gathered from national funding agencies, organizations, and schemes, including Science Foundation Ireland, the Health Research Board, Enterprise Ireland and the Environmental Protection Agency, and European Union Framework 6 and 7 schemes.

Methodology

Using Dillman's (2000) total design method, we emailed the potential PI respondents and asked them to complete an online survey. After three rounds of reminders, we had a response rate of 31.7 percent (441 valid responses).

This survey consisted of 40 predominantly closed-ended multiple choice and ranking questions. The questions focused on PI activities and actions regarding the design, management, and promotion of their scientific projects. For most questions, we asked respondents to choose a publicly funded project on which they acted as a PI and answer in relation to this specific project. Given the exploratory nature of our study, we employed independent sample t-tests to examine

statistically significant differences between PIs with and without previous commercial experience.

Respondents answered questions about industry collaboration and engagement, and motivation and control. We asked respondents about the extent to which they engaged in pre-proposal activities for their selected project, on a seven-point Likert scale, from not at all (1) to a very large extent (7). We also asked PIs about their level of involvement in different collaboration activities over the previous five years using a three-point inverted scale from extensive involvement (1) to never involved (3).

Our survey also included questions about technology transfer and market impacts, and scientific publications and scientific capital impacts. We asked PI respondents to rate the level of importance placed on various impact criteria in their selected projects, on a seven-point Likert scale, from not important (1) to very important (7). Similarly, we asked PIs to assess the impact of their chosen project using a seven-point Likert scale, from no impact (1) to significant impact (7).

Findings

Thirty-three percent (n=145) of respondents stated they had commercial experience (an average of five years of employment), compared to 67 percent (n=296) with no commercial experience. For both groups' selected projects, approximately 30 percent were basic science projects, and approximately 70 percent were applied science projects. We grouped our findings according to collaboration focus and activities, impact focus, and determinants of university-industry project success.

Collaboration Focus and Activities

We found that PIs with commercial experience had higher levels of engagement in seven of the nine queried pre-proposal activities compared to PIs without commercial experience. The most significant differences between PIs with and without commercial experience were in desk research and direct consultation with industry end users as well as patent searches (Table 1).

Table 1.—Project pre-proposal activities

Category	**PIs With Commercial Experience**	**PIs Without Commercial Experience**	**Statistical Significanc**
Patent search	3.3 +/- 2.2	2.5 +/- 2.1	***
Investigation of activity of competitor research groups	5.0 +/- 1.9	4.7 +/- 2.1	ns
Literature search	6.0 +/- 1.2	6.1 +/- 1.4	ns
Direct consultation with industry end users	3.7 +/- 2.2	2.7 +/- 1.9	***
Desk research on industry end users	3.7 +/- 2.1	2.7 +/- 1.9	***
Direct consultation with scientific experts	4.4 +/- 1.8	4.4 +/- 1.8	ns

Direct consultation with technology transfer office	3.0 +/- 2.0	2.5 +/- 2.0	*
Direct consultation with funding agency	4.0 +/- 2.0	3.4 +/- 2.0	**
Direct consultation with own institution scientific specialists	4.2 +/- 2.2	3.7 +/- 2.0	*

Note: The asterisks *, **, and *** indicate statistical significance at 5%, 1%, and 0.1% alpha levels, respectively, using a two-tailed independent sample t-test—that is, *$p<0.05$, **$p<0.01$, and ***$p<0.001$.

PIs with commercial experience ranked their top three factors that stimulated actual or potential technology transfer as strong linkages with industry, clearly defined commercialization opportunities, and institutional provision of technology transfer activities. By contrast, PIs without commercial experience ranked institutional provision of technology transfer activities highest, followed by own department leadership and commitment and strong linkages with industry (Table 2).

Table 2.—Top three factors that facilitate actual or potential technology transfer for selected projects

PIs With Commercial Experience	**PIs Without Commercial Experience**
1) Strong Industry Linkages	1) Institutional Provision of Technology Transfer
2) Clearly Defined Commercialization Opportunities	2) Own Department Leadership & Commitment
3) Institutional Provision of Technology Transfer	3) Strong Industry Linkages

Regarding collaboration, PIs with commercial experience were more likely to be members of industry advisory boards or undertake consultancy or contract assignments with private enterprises. However, we found no statistically significant differences between PIs with and without commercial experience regarding international collaboration.

Queried on a seven-point Likert scale from not at all (1) to a very large extent (7), PIs with commercial experience engaged in more pre-proposal consultation with scientific specialists in their own institution, whereas PIs without commercial experience focused more on academic partnerships and collaborations in general. Regarding their top three motivations for becoming a PI on their selected projects, PIs without commercial experience sought to increase their profile within internal and external research communities, though not to a significant degree (Table 3). By contrast, PIs with commercial experience wanted to become PIs on their selected projects to increase their control over technology transfer and administrative issues. We found that PIs without commercial experience focused more on creating and maintaining connections with internal and external research communities in their respective research field, whereas enhanced decision-making power, particularly with respect to technology transfer, motivated PIs with commercial experience.

Table 3.–Motivations to become project PI

Category	PIs With Commercial Experience	PIs Without Commercial Experience	Statistical Significance
To have greater administrative control of project	16.3%	14.1%	ns
To develop new research area	84.5%	83.9%	ns
To have greater scientific control of the project	56.6%	55.7%	ns
To have greater administrative control of project budget	8.5%	9.8%	ns
To have greater control over the technology transfer	17.8%	8.2%	**
To increase profile within external research community	62.8%	72.2%	*
To increase profile within own institution	31.8%	34.9%	ns
Requirement of my role in my institution	24.8%	25.9%	ns

Note: The asterisks * and** indicate statistical significance at 5% and 1% alpha levels, respectively, using a two-tailed independent sample t-test—that is, *$p<0.05$ and **$p<0.01$.

Impact Focus

In order to examine potential differences between the intended and the actual impact of their research projects, PIs were asked to first indicate the level of importance they placed on particular impact criteria (Table 4), and then assess the actual impact of their project in relation to these impact criteria (Table 5). PIs placed greater importance on scientific publications, scientific capital, and human capital impacts, compared to political and market impact. PIs with commercial experience rated technology transfer impact significantly higher than those without, which suggests they placed more emphasis on technology transfer compared to PIs without commercial experience. Although market impact was one of the least important impacts overall, PIs with commercial experience considered it significantly more important compared to those without commercial experience (Table 4).

Table 4.—Level of importance placed on impact criteria

Category	**PIs With Commercial Experience**	**PIs Without Commercial Experience**	**Statistical Significance**
Scientific publication	5.9 +/- 1.5	6.5 +/- 1.0	***
Technology transfer	4.9 +/- 1.8	4.4 +/- 1.9	**
Political impact	4.1 +/- 1.9	4.1 +/- 1.9	ns
Economic impact	4.4 +/- 1.8	4.5 +/- 1.7	ns
Relationship impact	4.8 +/- 1.7	4.9 +/- 1.7	ns
Scientific capital impact	5.8 +/- 1.2	6.0 +/- 1.2	ns
Human capital impact	5.7 +/- 1.5	5.8 +/- 1.4	ns
Market impact	4.2 +/- 2.1	3.5 +/- 2.1	**
Contract impact	5.6 +/- 1.6	5.6 +/- 1.6	ns

Note: The asterisks *, **, and *** indicate statistical significance at 5%, 1%, and 0.1% alpha levels, respectively, using a two-tailed independent sample t-test—that is, *$p<0.05$, **$p<0.01$, and ***$p<0.001$.

For their selected projects PIs ranked scientific capital and human capital impacts highest. PIs with commercial experience rated technology transfer and market impacts significantly higher, which suggests they focused more on these two elements. On average, PIs with commercial experience had also filed more invention disclosures in the last five years. PIs without commercial experience reported that they focused more on scientific publications and scientific capital impacts. When asked to assess the actual impact of their chosen projects, PIs with commercial experience rated scientific capital impact and scientific publications lower than PIs without commercial experience (Table 5). On average, PIs without commercial experience reported 20 peer-reviewed journal papers published in the last five years, compared to 18 for PIs with commercial experience.

Table 5.–Self-assessment of impacts of selected projects

Category	**PIs With Commercial Experience**	**PIs Without Commercial Experience**	**Statistical Significance**
Scientific publication	5.1 +/- 1.7	5.7 +/- 1.3	***
Technology transfer	4.1 +/- 1.8	3.8 +/- 1.9	ns
Political impact	4.0 +/- 1.7	4.0 +/- 1.8	ns
Economic impact	4.5 +/- 1.6	4.6 +/- 1.7	ns
Relationship impact	4.8 +/- 1.7	5.0 +/- 1.6	ns
Scientific capital impact	5.6 +/- 1.3	5.8 +/- 1.2	*
Human capital impact	5.6 +/- 1.3	5.8 +/- 1.2	ns
Market impact	3.7 +/- 2.0	3.1 +/- 1.9	**
Contract impact	5.4 +/- 1.6	5.5 +/- 1.5	ns

Note: The asterisks *, **, and *** indicate statistical significance at 5%, 1%, and 0.1% alpha levels, respectively, using a two-tailed independent sample t-test—that is, *$p<0.05$, **$p<0.01$, and ***$p<0.001$.

Regarding the most common dissemination and technology transfer activity on the selected projects, peer publication was more important for PIs without commercial experience, while collaborative research with industry was greater for PIs with commercial experience (Table 6). Our findings suggest that when designing their research projects, PIs without commercial experience put more focus on scientific impacts (peer publications), whereas PIs with commercial experience focus more on technology transfer and market impacts.

Table 6.–Most common dissemination and technology transfer activity on selected projects

Category	PIs With Commercial Experience	PIs Without Commercial Experience	Statistical Significance
Industry workshops	7.3%	4.7%	ns
Research symposiums and colloquiums	14.6%	18.6%	ns
Peer publications	38.2%	52.6%	**
End of project reports	12.2%	11.5%	ns
Collaborative research with industry	12.2%	4.3%	**
Contractual research for industry	1.6%	2.0%	ns
Consulting and technical services	4.9%	1.2%	*
Licensing of intellectual property	4.1%	3.2%	ns
Spin-off enterprise	4.9%	2.0%	ns

Note: The asterisks *, **, and *** indicate statistical significance at 5%, 1%, and 0.1% alpha levels, respectively, using a two-tailed independent sample t-test,--that is, *$p<0.05$, **$p<0.01$, and ***$p<0.001$

Determinants of University-Industry Project Success

When asked to rank the top three factors that determined a project's success, all PIs ranked the expertise of the project team first, followed by a strong project leader, and effective project planning. We also asked PIs to rank the top three factors that stimulated actual or potential technology transfer on their selected projects. PIs with commercial experience ranked industry linkages and clearly defined commercialization opportunities significantly higher, while PIs without commercial experience emphasized the role of their own department, the technology transfer office, and perhaps most significantly, institutional provision of technology transfer activities (Table 7). At the same time that PIs without commercial experience sought greater autonomy on their research projects, they relied more heavily on institutional supports for their technology transfer activities.

Table 7.–Factors that facilitate technology transfer

Category	**PIs With Commercial Experience**	**PIs Without Commercial Experience**	**Statistical Significance**
Institutional provision of technology transfer activities	17.0%	26.3%	*
Own department leadership and commitment	8.0%	14.5%	*
Accessibility of technology transfer office support	7.0%	10.1%	ns
Clearly defined and documented technology transfer policies	2.0%	1.1%	ns
Facilitation of researcher involvement in the technology transfer process	5.0%	6.7%	ns
Realistic expectations on commercial returns from technology transfer	4.0%	6.1%	ns
Professional development initiatives to enhance technology transfer knowledge and expertise	2.0%	5.6%	ns
Financial rewards for researchers	5.0%	5.0%	ns
Strong linkages with industry	27.0%	13.4%	***
Positive previous experiences in relation to technology transfer	2.0%	1.1%	ns
Clearly defined commercialisation opportunities	21.0%	11.2%	**

Note: The asterisks *, **, and *** indicate statistical significance at 5%, 1%, and 0.1% alpha levels, respectively, using a two-tailed independent sample t-test—that is, *$p<0.05$, **$p<0.01$, and ***$p<0.001$.

In summary, our results suggest that PIs without commercial experience focused on publications and relied on the technology transfer office for their technology transfer activities. In contrast, PIs with previous commercial experience focused more on knowledge creation and a research idea's commercial potential.

Discussion

We explored whether PIs' prior commercial experience influences their approaches to technology transfer and market impacts in university-industry collaborations. We found that commercial experience influences research approaches, project work, and project selection. We also found that PIs without commercial experience focused on scientific publications and scientific capital, while PIs with prior commercial experience focused more on technology transfer and market impacts.

Our results suggest that PIs with commercial experience engaged more with industry partners from project inception through planning to the dissemination phase. They were more likely to form strong linkages with industry and bring in additional industry partners or industry contributors to their research projects. Overall, PIs with prior commercial experience prioritized matching the project scope with industry demand compared to PIs without commercial experience—this emphasis may mean that projects run by PIs with commercial experience will result in more tangible outcomes and commercial success.

By contrast, PIs without commercial experience prioritized scientific capital impacts as reflected by their focus on scientific publications and their motivation to increase their profile within external research communities. Overall, PIs without prior commercial experience relied more on institutional support structures for their technology transfer activities. Hence, industry partners should consider these dependencies and offer additional support in cases where institutional support structures are insufficient.

Our study offers practical considerations for industry partners looking to engage in university-industry collaborations. Industry partners may favor PIs with commercial experience due to their experience edge—they may believe that these PIs can more adeptly exploit knowledge and technology transfer opportunities because they understand the industry partner's needs and market opportunities better. Industry partners may hesitate to engage with PIs without commercial experience due to their reliance on institutional supports for technology transfer activities. Since the level of technology transfer supports varies between institutions, it can influence the project work of individual academic scientists (Braunerhjelm 2007; Lawson and Sterzi 2014). If PIs do not receive adequate institutional support (mentoring and nurturing) to mitigate their lack of commercial experience (Cunningham et al. 2014), neither the PIs, their institution, nor their industry partners may fully realize opportunities from technology transfer. Therefore, the level of institutional support given to PIs could be a determining factor for industry partners.

Both PIs with and without commercial experience can enhance scientific and technological progress. PIs with commercial experience are not necessarily better collaborators—the best choice for an industry partner depends on which project approach it deems will prove most beneficial. Regardless, the project design stage is the best time for industry partners and project

PIs to agree upon a strategy that will foster the creation of new knowledge and promote optimal technology transfer outcomes.

Industry partners can proactively support PIs without commercial experience by engaging with their institutional supports such as TTOs. If industry partners engage with institutional supports at the project design stage, the collaborators may be able to avoid technology transfer obstacles and maximize value. We recommend that institutional support structures such as technology transfer offices be used irrespective of PIs' commercial experience as the PIs in our study tended to favor knowledge transfer (publications, end-of-project reports) over more formal technology transfer outputs (spin-off firms, licenses). Industry partners should work closely with PIs at every stage of a funded project to ensure they secure their desired outcomes—that is, the transformation of scientific research into commercializable knowledge such as patents, licences, agreements, etc.

PIs and industry partners should align their knowledge and technology transfer strategy to exploit new knowledge. Having mutual, clearly defined commercialization objectives at the outset may spur technology transfer. Industry partners need to recognize that in university-industry collaborations PIs are motivated by creating new knowledge and scientific publications and may be less focused on having control over the technology transfer process. Industry partners' engagement and partnership strategies with PIs should build a common purpose that meets this core motivation of creating new knowledge.

To be effective within university-industry collaborations, PIs need the appropriate skills and capabilities to be successful (Cunningham et al. 2015). Academic and research institutions need to create environments in which PIs can thrive and achieve technology transfer so their industry partners can achieve a dominant market position (Dolan et al. 2019; Kidwell 2014). Industry partners have an explicit expectation that PIs will contribute to technology transfer and market benefits. To make better use of their university-industry collaborations, companies must carefully select their PIs and consider potential barriers to technology and knowledge transfer (Albats et al. 2018).

PIs with commercial experience may understand industry partners' needs, but PIs without commercial experience might challenge status quo thinking and approaches and open up new research paths. For PIs and industry partners, our study reinforces the need for strong institutional support to bring about more effective technology transfer. This support could include having commercialization and sectoral expertise within a TTO, robust technology transfer policies and procedures (invention disclosure processes, standard technology transfer agreements for licensing), and funding to support legal and other professional development support in cases of technology transfer disputes. Inadequate institutional technology transfer supports can hamper technology transfer efforts, destroy value created within university-industry collaborations, and potentially deter or turn off industry partners.

Some limitations of our study are worth noting. As PIs completed this survey based on their own assessments, there is some risk of self-reporting bias. In addition, our sample consisted of PIs in Ireland, which may limit the generalizability of our results; the respective academic context and the country's associated higher education legislation might impact PIs' research activities (Cunningham et al. 2019a).

Conclusion

When selecting a PI for university-industry collaborations, industry partners should consider several factors. PIs with commercial experience may be attractive because they may be more effective at knowledge and technology transfer and creating outputs with market impact. But industry partners shouldn't necessarily disregard PIs without commercial experience because they may challenge the status quo and forge new research opportunities with valuable technology and market potential. The technology transfer support the PI's institution offers is an important consideration because inadequate support can mean loss of knowledge and untapped value creation. Industry partners thereby have an opportunity to create a more fertile environment by providing more dedicated structures and support mechanisms for PIs with and without commercial experience and overcome existing barriers that hinder efficient technology transfer processes.

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