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Translational research: When do public science projects result in real world impact?

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Abstract

We explore the factors that facilitate the generation of products, interventions and practices in public science projects. Previous research has emphasized the role of highly successful star scientists for generating such translational outcomes but has paid less attention to team aspects. We develop hypotheses according to which translational outcomes are a function of principal investigators? scientific quality and their ability to compose teams sporting complementarities across different disciplines and different research orientations. We confirm our hypotheses using a unique multi-source, longitudinal dataset on publicly funded medical projects at Imperial College London. Our study has implications for the study of the antecedents of translational outcomes by emphasizing specifically the role of individual scientific quality is augmented by principal investigators? ability to build and lead suitable teams.

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Abstract

We explore the factors that facilitate the generation of products, interventions and practices in public science projects. Previous research has emphasized the role of highly successful star scientists for generating such translational outcomes but has paid less attention to team aspects. We develop hypotheses according to which translational outcomes are a function of principal investigators' scientific quality and their ability to compose teams sporting complementarities across different disciplines and different research orientations. We confirm our hypotheses using a unique multi-source, longitudinal dataset on publicly funded medical projects at Imperial College London. Our study has implications for the study of the antecedents of translational outcomes by emphasizing specifically the role of individual scientific quality is augmented by principal investigators' ability to build and lead suitable teams.

Introduction

Funders of public science have long sought to promote academic research that generates outcomes with economic and societal impact which can be referred to as translational outcomes. Public research funding organizations all over the world are under increasing pressure to justify their tax-financed allocations to academic research by emphasizing the potential social and economic impacts to be expected from this work. In biomedical research, major research funding organizations dedicate part of their resources to translational research that is specifically aimed at exploiting scientific knowledge for practical applications (Cooksey, 2006; West & Nightingale, 2009; Woolf, 2008). For instance, the largest funder of biomedical research in the world (with a $30b budget), the National Institutes of Health (NIH) emphasizes in its mission statement that beyond the creation of knowledge, it seeks to support the "application of that knowledge to enhance health, lengthen life, and reduce the burdens of illness and disability."

When do publicly funded research projects result in translational outcomes? A large body of research has explored how the characteristics of individual scientists and the local conditions in which they work affects their propensity to generate commercial outcomes or become entrepreneurs (e.g., Azoulay, Ding, & Stuart, 2007, 2009, Lee & Bozeman, 2005; Stephan et al., 2007). By contrast, published work that focuses on projects as unit of analysis and explores the conditions under which they result in economically or socially valuable outcomes is relatively scarce, with some notable exceptions (Ambos et al., 2008; Bercovitz & Feldman, 2011; Cummings & Kiesler, 2005, 2007).

The focus on individuals as a primary unit of analysis is pertinent in that academic scientists have a high degree of autonomy rooted in both the professional culture of public science and typical academic employment relations. However, public science is also characterized by a high degree of inter-individual collaboration both within and across academic institutions (Beaver & Rosen 1978; Wagner & Leydesdorff, 2005). Academic production, including the generation of commercializable inventions and other economically and socially valuable outputs, tends to be pursued by teams of scientists that have become larger with the growth of ever more specialized bodies of knowledge (Wuchty, Jones, & Uzzi, 2007). Independent of the personal characteristics of individual scientists, and the departmental or institutional context in which they operate, the composition and characteristics of the teams in which they work is likely to have a decisive impact on the generation of both academic publications and translational outcomes.

Rather than putting the individual scientist at the center of explaining scientific research outcomes, in this paper we instead investigate projects and their underpinning teams to shed light on the role of collective, organizational factors for both academic and non-academic outcomes. We develop testable hypotheses that combine two aspects which have often been treated separately – the role of scientists' research quality, as indicated by their academic research productivity, and the role of multidisciplinarity and other types of diversity within research teams. On the one hand, we consider how the research quality of the principal investigator affects translational outcomes, given the principal investigator is the initiator and leader of a project and, hence, can be expected to exert a major impact on its direction and outputs. Second, we investigate how differences within the team of investigators affect translational outcomes in order to assess whether team composition provides complementary skills and assets that the principal investigator alone may not possess.

To explore the impact of these factors on translational outcomes, we study the full population of research projects funded by the UK Medical Research Council led by principal investigators at Imperial College London over a five-year period. As translational outcomes we consider whether a project had an impact on policy and clinical guidelines, or the extent to which a project led to new products and therapeutic interventions. Our results suggest that translational research outcomes are positively related to the research quality of the principal investigator, as measured by the academic impact of their published research – suggesting that more successful scientists are more likely to lead projects with translational outcomes. Further predictors of translational research outcomes are represented by the level of diversity in two areas within the research team: multidiscplinarity and differences in research orientation (basicness vs. appliedness). Moreover, we find that the translational output of a project is positively related to the extent to which the co-investigators prove to be experienced in industry-oriented research. Finally, the effect of multisciplinarity is positively moderated by the extent of research orientation diversity within the team, but negatively moderated by the research quality of the principal investigator.

Our findings suggest, on the one hand, that the individual qualities of the principal investigator as academic researcher play a crucial role in determining whether medical and life science oriented publicly funded projects result in translational outcomes. On the other hand, however, we suggest that principal investigators can enhance the propensity of their projects to generate translational outcomes by enlisting co-investigators rooted in other disciplines, and engaging in different types of research (and possibly both simultaneously). In this relationship, the research quality of the principal investigator acts as a partial substitute of multidiscplinarity: The higher the PI's research quality, the lower the multidiscplinarity that is required to achieve a given level of translational outcomes. Importantly, however, enlisting co-investigators who are adept at collaborating with industry via contract research can provide further help in spurring translational outcomes.

Conceptually, our findings provide support for the theory of the superstar scientist who excels at both academic research and commercialization/translation (Zucker & Darby, 1996) but suggest that the mechanism by which this is achieved is partly the result of careful team composition. Principal investigators may choose collaborators from other disciplines, although the benefit of doing so is less pronounced if the principal investigators are high academic performers. More importantly, it appears that by enlisting collaborators with industry-friendly skills that they may not themselves possess, high performing principal investigators may extend their superior vision and energy in the academic field to the production of translational outcomes. Our insights, thus, suggest an inter-individual theory of translational excellence where outcomes are at least partially due to the ability of highly successful scientists to build, inspire and manage high-performing teams.

The paper is structured as follows. The next section will give an overview of the literature. We then describe the empirical setting and data, present the results, and, finally, offer some conclusions.

Theory and hypotheses

A large body of previous research has explored the circumstances under which public science results in economically and social valuable outputs (Salter & Martin, 2000). The bulk of this research has focused on technology transfer and commercialization as the vehicles of this process (Rothaermel, Agung, & Jiang, 2007; Shane, 2002). While some contributions have investigated what determines universities' commercialization output on an organizational level (Adams & Griliches, 1998; Di Gregorio & Shane, 2003; Lach & Schankerman, 2008; Owen-Smith, 2003), most research has considered the individual scientist as primary unit of analysis. Studies have explored individual scientists' involvement in the production of intellectual property, notably via disclosures of valuable inventions to their universities and the subsequent patenting of these inventions (Bercovitz & Feldman, 2008; Owen-Smith & Powell, 2003). Equally, authors have investigated what propels academic scientists to become entrepreneurs and thereby using personal initiative to take their inventions or expertise to market (Louis et al., 1989; Shane, 2004; Stuart & Ding, 2006). This research has yielded interesting results about both the personal characteristics of those individuals who are most effective in driving commercialization, and the role of the social context that facilitates their engagement in this process. In particularly, scholars have highlighted the positive correlation between individuals' research productivity and their involvement in commercialization. "Star scientists" who are individuals with disproportionately high research productivity are also often those who generate patentable inventions, start university-spinoff companies and sit on science-intensive company advisory boards (Buenstorf, 2009; Stuart & Ding, 2006; Zucker & Darby, 1996).

In contrast to individual-focused work, research focusing on public science projects as the unit of analysis is less extensive yet it has yielded some interesting insights. A first stream of this literature considers what determines the research productivity of academic research projects. A study by Averch (1987) of 44 basic research projects in the behavioral and neural sciences funded by the National Science Foundation suggests the number of citations yielded by a project per dollar of NSF funding was positively related to investment in capital equipment and being led by better trained investigators. In a subsequent study, Averch (1989) showed, using data from 93 randomly selected NSF-funded chemistry projects, that the quality of the investigator contributes more to citation efficiency as labor intensity increases and investigator's scientific experience increases. A study by Arora, David and Gambardella (1998) suggests that the number of quality-adjusted publications from 347 biotech projects was positively correlated with collaboration with foreign institutions while the age of the PI and the industrial transferability of the projects had a negative impact. Subsequent studies by Cesaroni and Gambardella (2003) and Arora and Gambardella (2005) point additionally to the importance of the scientific capabilities of the PI and their past publications.

A second stream of the literature specifically addresses the factors facilitating commercial outcomes within academic projects. Bercovitz and Feldman (2011), exploring panel data of 1425 disclosures at two US universities, find that commercial outcomes were positively associated with the team experience and prior social ties among team members. Furthermore, they suggest that larger teams, the presence of star scientists, and grant size are positively related to commercial outcomes. Finally, the presence of medically trained individuals on the team resulted in a higher likelihood of commercialization outcomes. Their study also shows that coordination costs constitute a detriment to achieving outcomes, a result echoed by a study of 62 NSF-funded projects by Cummings and Kiesler (2005). The latter authors show that the number of universities participating in a project is negatively related to generating outcomes even though the use of coordination mechanisms mitigates this effect.

Multidisciplinary projects can be highly successful in producing new ideas and knowledge as well as outreach when they are carried out within one university. A somewhat contrasting picture is painted by Ambos et al. (2008) who analyze 207 public science projects in the physical and engineering sciences at UK universities. They find that the shorter a principal investigators' tenure in academia and the lower their research standing, the more likely a project will result in a commercial output. This result leads the authors to conclude that the ability to generate both academic and translational outcomes is rooted in organization-level ambidexterity, rather than emanating from the ambidextrous qualities of individuals.

Though interesting in their own right, previous studies have paid little attention to the question of how the quality of the principal investigator is related to the question of "optimal diversity" of academic research teams that maximizes translational research outcomes from publicly funded projects. In other words, how can principal investigators compose academic teams that extend and amplify their scientific talent and accumulated expertise in a way that results in translational outcomes? Below we develop hypotheses regarding the effects of different types of diversity on translational outcomes.

We first consider the effect of the research quality of the principal investigator acting as the team leader of a public science project. Previous research has suggested that past performance is a strong predictor for future academic productivity as scientists' earlier success in the research community provides them with advantages that in turn enable further success (Merton, 1968). Furthermore, extant studies also suggest that high performing scientists not only excel at generating further academic outputs but are also adept at commercializing their research (Van Looy, Callaert, & Debackere, 2006). This is the case even though the activities of generating academic publications and producing impact via disclosures, patents or university-spinout companies are at least partially rooted in different motivations and different skill sets (Jain, George, & Maltarich, 2009), and are produced within different trajectories of work (Gittelman & Kogut, 2003).

Why should the research quality of principal investigators, as indicated by the academic impact of their previous research, positively impact the generation of translational outcomes from projects they are leading? The novelty contained in impactful science often provides technological opportunities for successful commercialization. The analysis of the paper-patents pair suggests that both academic and commercially relevant outcomes often arise from the same research programs (Breschi & Catalini, 2010; Murray, 2002). Macro-level analyses of the quality of academic outputs and the quality of intellectual property generated by universities have over time become correlated, suggesting there are positive feedback loops between both realms (Owen-Smith, 2003). The mechanism underlying this effect may stem from the natural scarcity that is a characteristic of novel knowledge and the tacit expertise associated with its utilization (Agrawal, 2005). The convention of priority instituted in science (Merton, 1973) will ensure that novel scientific discoveries are highly publishable and are likely to spark a trajectory of follow-on research. Simultaneously, the initial privileged nature of novel knowledge will enable scientists to ensure priority also with respect to the technological utilization of this knowledge via the filing of patents or other types of intellectual property. Investigators with a successful previous track record of academic publications will therefore be in a better position to lead projects which result in outcomes that are either commercializable or have other types of practical impact.

H1: The extent of translational research output from public science projects is positively related to the research quality of the principal investigator.

We next consider the effect of multidisciplinarity on translational outcomes. Policy makers and science funding organizations often emphasize the importance of multidisciplinarity in achieving transnational research outcomes (Disis & Slattery, 2010). More so than academic publication output, translational outcomes such as novel products or practices are dependent on the combination of knowledge from different disciplines. While for the production of academic publications, diversity within specific disciplines may suffice for generating novelty that lends itself to publication within the disciplinary "silos", for translational outcomes broader diversity may be necessary requiring the collaboration of several disciplines. For instance, in order to develop a new drug, a large number of disciplinary specialties is required, ranging from microbiology, medical biology to medicinal chemistry, toxicology and pharmacology to bioinformatics (Pisano, 2006).

Previous research on teams in academic and other organizational settings has highlighted the central importance of diversity within teams for generating novelty in project outcomes. The recombination of different bodies of knowledge in the course of collaboration that transcends multiple disciplinary boundaries represents a fundamental mechanism through which novelty is created (Schumpeter, 1939). By recruiting team members with a background in different scientific disciplines, technological or clinical problems can be approached from a position where more possible cognitive frames of a problem exist and more possible solutions can be imagined. Each discipline or field of expertise is characterized by the existence of specific operating procedures and methodologies that are taken for granted in routine situations and that constitute both the power of a body of knowledge, as well as its limitations. When different such 'taken-for-granted' procedures collide within team situations, teams will have to be reflexive to which procedures are appropriate and how they should be applied, which in turn offers the opportunity for novelty and innovation.

H2: The extent of translational research outputs from public science projects is positively related to the number of scientific disciplines represented among the investigator team.

We next explore the role of the co-investigators and how they may contribute to the generation of translational outcomes from public science projects. The kind of public science projects supported by a government research funding organization that we explore in this paper will be primarily designed by the principal investigators to generate outcomes relevant for making contributions to the relevant bodies of public science knowledge. While the principal investigator can therefore be assumed to lead the academic aspects of the project, other investigators may bring different visions to the table regarding the objectives and desired outcomes of the project. In particular, these other project team members may differ from the principal investigator by having a stronger taste for application and problem-solving. This would imply that within project teams, a specific division of labor may develop regarding who is in charge of more academic or translational aspects of the project. If such a division of labor exists, we would postulate a higher likelihood of a project team developing translational outcomes.

An indication for the existence of such a division of labor may be that the co-investigators have stronger links to industry, and spend more time working with practical applications than the principal investigator.

H3: The extent of translational research outputs from public science projects is positively related to the amount of industry funding acquired by the co-investigators in public science projects.

We now move to consider what moderates the positive effects of multidisciplinarity on the production of translational outcomes. We first hypothesize how differences in terms of research orientation influence the effects of multidisciplinarity. By research orientation we mean the extent to which the content of a scientist's research is basic or applied. Academic research varies to the extent that it seeks answers to fundamental questions, or whether knowledge is deployed to solve practical or technical problems (Weingart, 1997; Cockburn, Henderson, & Stern, 1999). Researchers, even within the same disciplines, vary in the extent to which they pursue basic or more applied research programs. Collaboration within public science projects involving both basic and applied researchers represents a specific type of variety within project teams that is likely to result in effects that are similar to those of multidisciplinarity.

The presence of research direction diversity within a public science project team is likely to amplify the positive effects of multidisciplinarity on translational outcomes. If project members were rooted in different disciplines but all had, for instance, a strong interest in resolving basic science problems within the confines of their disciplines, goal setting within the project may be difficult and collaboration may become problematic specifically with respect to producing translational outcomes. If, in an alternative scenario, project members vary both in terms of disciplinary orientation as well as research orientation, one may expect a higher likelihood of some discipline representatives refraining from insisting on basic disciplinary contributions and instead offer their expertise to applied problem solving.

> H4: The effect of multidisciplinarity on the extent of translational research outputs from public science projects is positively moderated by the degree of difference in research orientation among the investigators.

Above we argued that principal investigators may enhance the incidence of translational outcomes by introducing diversity into the team. How does specific interdisciplinarity relate to their own research quality? We argue that interdiscplinarity represents a mechanism that represents a substitute for principal investigator research quality, rather than reinforcing the positive effects of the latter on translational outcomes. Highly talented principal investigators may have sufficient vision and leadership to develop translational outcomes from their academic research programs while having to rely on the combinatory input from other disciplines to a lesser extent, compared to individuals with a less stellar track record. The knowledge underpinning the high impact research generated by more successful individuals may be sufficiently novel and disruptive in its own right, without requiring the combination with elements from other disciplines.

> H5: The effect of multidisciplinarity on the extent of translational research output from public science projects is negatively moderated by the research quality of the principal investigator.

Data and Methodology

Data

We compiled a unique longitudinal dataset containing information on the full population of projects pursued by scientists at Imperial College London between 2001 and 2011 funded by the UK Medical Research Council (MRC). Since our theoretical framework contains different constructs of diversity we selected only projects which were awarded to more than one investigator. Our sample includes 127 MRC-funded projects.

With over 700 research-active faculty members and annual research expenditure of over £140m ($225m), Imperial's faculty of medicine is one of Europe's largest medical research institutions. Imperial College London is the 4th largest recipient of MRC funding and received about 3% of the yearly MRC funding budget. The projects the MRC funds range across the spectrum of medical research from basic research to clinical research, and cover a large variety of different subjects. Information was drawn from several sources.

First, we gathered information on all research projects at Imperial College London that were recorded through its internal information system during the period in question. These records included information on all types of projects, including those funded by research grants from governmental sources as well as via contracts with industrial or government organizations. The records also contained individual-level information on all the individuals involved in projects as principal investigators or co-investigators, including their full publication records, invention and patents, and details on their career and demographic status.

Second, we accessed records held by the MRC that included detailed information on research outputs recorded via its e-val system. This information stems from the detailed reports that each grant recipient is required to provide to MRC on an annual basis both over the grant duration and after its termination.

Third, we collected data on directorship positions held by Imperial College London academics from the Bureau Van Dijk's FAME, which provides financial information on 7 million public and private U.K. and Irish companies.

Variables

Dependent variable: Translational outcome. To capture translational outcomes of a biomedical research project, we use different constructs: We use information on whether a project had an impact on policy and clinical guidelines, or the extent to which a project led to new products and therapeutic interventions. New medical treatments and therapeutical strategies provide an important translational outcome since they are developed to improve health. Those outcomes are one of the core goals of translational research (Mankoff et al., 2004; Littman et al., 2007). The establishment of guidelines for application or practice is an additional important characteristic of translational outcomes. They link basic science discoveries and practice, and are shown to be worthy of being treated as outcome indicators of biomedical research impact (Grant et al., 2000; Lewison & Sullivan, 2008). Policies that use new insights from biomedical research support the dissemination of newly created knowledge along the translational continuum from discovery to adoption (Dankwa-Mullan et al., 2010). We operationalize our dependent variable by counting the number of each outcome and aggregated them into one variable for each year since the start of the project.

Independent variables

Research quality (PI). We follow prior work that uses impact-factor-weighted articles to measure the quality of a principal investigator's publication output (e.g., McFadyen &

Cannella, 2004; Arora & Gambardella, 2005). We weighted the stock of publications by the ISI impact factors and adjusted the value for the academic age of the principal investigator in each focal year.

Complementary resources (Co-I). Previous studies have argued that additional research money from industrial partners may influence the research direction of publicly-funded research projects (Ambos et al., 2008). To measure the complementary resources of the projects that were received by the co-Investigators parallel funding opportunities, we use the internal information system on all funded projects. We selected awards received from industrial or government organizations and related them to the co-Investigators in our sample. We averaged the total funding of an award over its duration and cumulated these yearly values (£ 1000') if the respective award was active in the focal year or ended in the year before.

Multidisciplinarity. To capture the degree of multidisciplinarity within the team of investigators, we used the departments the investigators were employed in. Variety in expertise within a biomedical research team can lead to greater creativity and innovation (Harrison & Klein, 2007). We followed the suggestions of Harrison & Klein (2007) and used Teachman's index to measure the diversity of different disciplines involved in the team.

Control variables. We included several control variables that may affect translational research outcomes of the projects. The first variable controls for basic research which is likely to create knowledge rather than apply or translate it. Similar to previous research (Lavie & Drori, 2012), we coded the variable as 1 if the project was basic, 0 if it was an applied project. If the biomedical research project was a combination of both, the value was 0.5. The UKCRC health research classification system codes research activities into seven categories from 'Underpinning Research' to 'Health and Social Care Service Research'. The MRC Programme Managers, trained in the coding scheme, categorize the projects based on the abstract and title of the award. We defined projects that are ‘Underpinning Research’ as basic and all other categories as applied. If the project was categorized by the MRC as ‘Underpinning Research’ and simultaneously in at least a second other category, we defined the project as a combination of basic and applied research. A second control variable controls for the fact that an award might be a fellowship. Fellowships often have training and career development in the focus. The MRC groups awards such as ‘Clinical Scientist Fellowship’, ‘Career Establishment Grant’, or ‘Career Development Award’ into the category fellowship. We created a dummy variable that takes the value 1 if the award is a fellowship and 0 otherwise.

Second, MRC-funded biomedical research projects which are located in departments that are closely related to public health improvements are more likely to produce outcomes that are at the end of the translation continuum. The School of Public Health at Imperial College London aims to ‘strengthening the public health science base, training the next generation of public health leaders and influencing health policies’. We therefore control for Public health and define a dummy variable that is coded as 1 if the principal investigator of the project is located in the School of Public Health and 0 otherwise.

Third, previous research studying outcomes of publicly-funded projects has shown that the academic experience of the principal investigator is related to the likelihood of commercial outcomes (Ambos et al., 2008). We measured academic age as the number of years since the principal investigator’s first publication. Fourth, we controlled for the salary the principal investigator receives in a focal year. The income of a principal investigator proxies the status he may hold within the organization. We used the yearly salary bands of the principal investigator in £1000 to calculate the variable. Fifth, studies have pointed out the importance of academic and industry collaborations for knowledge creation and knowledge application outcomes of applied research programs (Lavie & Drori, 2012). Those collaborations may offer valuable benefits to the projects, such as resources, infrastructure, or tools. We use self-reported information by the principal investigator about their collaborations with academics and private organizations. We created two dummy variables to control whether the biomedical research project had an academic collaboration and whether it had a private collaboration.

Sixth, translational research is supposed to be fruitful if clinicians, laboratory scientists, and physician scientists work together in a collaborative team (Pober, Neuhauser, & Pober, 2001). However, the academic cultures between clinical and basic research is often an inherent antipathy that can inhibit collaborative interactions to support translational research (Feldman, 2008). Hence, different attitudes to different research paradigms in medical research teams can reduce the task performance (Harrison & Klein, 2007). In order to control for this type of separation among the investigators of the biomedical research project, we calculated the research-direction diversity. We operationalized this construct by measuring the standard deviation of the research level (RL) of all the investigators. The RL is based on a method that uses a list of title words to classify biomedical publications along the continuum from clinical to basic (Lewison & Paraje, 2004). The method was developed for bibliometric analysis to show how the RL of journals changes over time or how biomedical subfields emerge. The developer of the method provided technical support to calculate the RL of each investigator in our sample in a given year. The RL is a continuous variable that takes in its extremes the value 1.00 (i.e., clinical) to 4.00 (i.e., basic). The method allows changes of the RL over time and therefore shows advantages over measures that are more static (Lewison & Paraje, 2004). We calculated a standard deviation of the investigator's yearly RL in order to proxy differences in their research fields. Finally, we created a dummy to control for Co-Investigators' directorship. Those who have built experience through membership in a board may influence the likelihood of research outcomes with practical value. The variable is coded as 1 if at least one of the Co-Investigators has been (or is) a member of a board in the focal year.

Results

Table 1 provides the means, standard deviations, and correlations for the variables used in our analysis. We examined the data for multicollinearity and violations of normality assumptions. The dependent variable translational outcome follows a negative binomial distribution. Examining the pairwise correlations of the variables suggested that correlations were fairly low. Few variables have a correlation greater than 0.2 and the highest correlation value is 0.45, between the complementary resources and the directorship of the co-investigators. Moreover, the variance inflation factors (VIFs) are all below the critical value of 10. Both types of indicators suggest that the results are unlikely to be affected by multicollinearity.

Table 1

Because our dependent variable is a non-negative count variable affected by overdispersion, we used pooled negative binomial regression models and control for time (in years) passed since the project started. Results are reported in Table 2. Model 1 shows the result of a baseline model that includes the control variables and the main effects of the moderating variables. The variable time control shows a positive effect suggesting that projects which are in a later stage are more likely to produce translational outcomes. Fellowships are negatively related to the dependent variable while academic collaboration and private collaboration are positively related. Projects led by principal investigators affiliated with the School of Public

Health are more likely to produce translational outcomes. Finally, the presence of co-investigators who held at least one directorship positively influence translational outcomes, suggesting that these individuals contribute to the research project with their practical experience.

Table 2

Model 2 includes the explanatory variables research quality of the principal investigator, multidisciplinarity, and complementary resources acquired by co-investigators from industry and government organizations to test the effects proposed in hypotheses 1-3. Hypothesis 1 predicts a positive effect of the principal investigator’s research quality on translational outcomes. The effect is positive and significant (at 5 %), providing support for Hypothesis 1. Hypothesis 2 predicts a positive relationship between multidisciplinarity and the dependent variable. The effect is significant (at 1 %) and positive. This result provides strong support for Hypothesis 2. Model 2 also shows that the relationship between complementary resources and translational outcomes is positive and significant (at 10 %). This result was expected in Hypothesis 3 and therefore supports the hypothesis. Model 2 shows an improved fit when compared to the base model (Model 1).

Model 3 includes the moderating effects proposed in Hypotheses 4 according to which research-direction diversity positively moderates the relationship between multidisciplinarity and translational outcomes. The effect is positive and significant (at 1%), suggesting strong support for Hypothesis 4. The fit of the model improves when compared to the model with the main effects only (Model 2) and remains stable in the full model (Model 5). Model 4 tests Hypothesis 5 postulating that the research quality of the principal investigator negatively moderates the relationship between the multidisciplinarity of the team and translational outcomes. While the main effect of research quality stays positive and significant, the moderated effect is negative and significant (at 5 %), as expected. We support Hypothesis 5. Overall our models improve the log-likelihood and show an improvement over the base model.

Discussion and conclusion

Our study has implications for the 'great person' theory proposed in existing work on the commercialization of academic science. Extant studies find that the production of valuable intellectual property, commercialization outcomes or other translational outcomes stem from the work of high achievers in science (Zucker & Darby, 1996; Buenstorf, 2009). However, we know less about how individuals achieve these outcomes. On the one hand, high scientific achievers may be highly ambidextrous (Mom, Van Den Bosch, & Volberda, 2009; Ambos et al., 2009) hold all the required skills themselves and also have the motivation to engage in several types of activity. On the other, high achievers may be clever social organizers and build teams through which they complement their own motivations and skills in order to achieve impact that goes beyond the contributions to the academic literature.

In this study, we have provided theory and evidence to support the latter scenario. Instead of addressing the determinants of individuals' productivity, we explored what factors may facilitate the generation of products, interventions and practices within publicly funded academic research projects. We found that the scientific track record of the principal investigator has indeed considerable impact on the generation of such translational outcomes, providing support for the 'great person' theory that emphasize the vision and talent of star scientists. However, we found further that the way in which project teams were composed also contributed to the translational project outcomes. In particular, the presence of co-investigators who have a track record of collaborating closely with industrial partners has a positive impact on translational outcomes, indicating that principal investigators can augment the likelihood of generating such outcomes by complementing their own skills with those of more industry-aware collaborators. A further way of augmenting the likelihood of translational outcome is to compose multidisciplinary teams but the benefit of multidisciplinarity declines the higher the research quality of the principal investigator. The latter insight again supports the theory according to which highly talented and highly visionary individuals may have to rely less on complementary skills then mere mortals.

Our study has also implications for managerial practice within universities and research funding organizations. The findings suggest a dynamic of translational outcomes that is built around a specific project team configuration. In this configuration, high scientific achievers act as principal investigators, and compose teams characterized by diversity both with respect to multidisciplinarity and experience of working with industry whereby the latter applies to the co-investigators but not necessarily the principal investigators themselves. Our results therefore suggest a specific pattern of complementarity between the investigators of public science projects that lead more likely to translational outcomes.

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Table 1: Descriptive Statistics and Correlation Matrix

	Variable	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	VIF
	Translational outcome	0.10	0.54	0	7														
1	Time control	2.72	1.47	1	8	..1.00													1.06
2	Basic	0.27	0.41	0	1	0.07	1.00												1.12
3	Fellowship	0.36	0.48	0	1	–0.01	0.23	1.00											1.17
4	Public health	0.08	0.28	0	1	–0.01	–0.08	–0.12	1.00										1.07
5	Academic age (PI)	18.67	9.24	0	40	0.02	0.10	–0.08	–0.07	1.00									1.08
6	Salary (PI)	78.68	30.46	0	300	–0.06	–0.09	–0.20	0.17	0.14	1.00								1.21
7	Research quality (PI)	3.41	4.39	0	31.76	–0.10	–0.10	–0.06	0.15	–0.08	0.17	1.00							1.10
8	Academic collaboration	0.42	0.49	0	1	0.08	–0.01	0.10	0.01	0.02	0.02	–0.00	1.00						1.08
9	Private collaboration	0.16	0.37	0	1	0.01	–0.04	0.08	0.05	–0.08	–0.01	0.05	0.07	1.00					1.06
10	Research-direction diversity	0.38	0.48	0	2.12	–0.14	–0.12	–0.13	0.01	0.07	0.16	0.02	–0.03	0.02	1.00				1.25
11	Directorship (Co-Is)	0.28	0.45	0	1	–0.13	–0.14	–0.14	0.01	0.01	0.19	–0.01	–0.19	0.11	0.30	1.00			1.40
12	Complementary resources (Co-I)	283.75	671.27	0	4597	–0.09	–0.19	–0.12	0.07	–0.05	0.26	0.05	–0.07	0.02	0.33	0.45	1.00		1.41
13	Multidisciplinarity	0.17	0.28	0	1.35	0.04	–0.09	–0.14	–0.04	–0.02	0.06	–0.10	0.09	0.08	0.27	0.13	0.19	1.00	1.16

Table 2: Results of Negative Binomial Regression for Translational Outcomes

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	–6.228***	–6.290***	–6.001***	–6.386***	–6.164***
	(0.884)	(0.851)	(0.815)	(0.846)	(0.825)
Time control	0.358***	0.389***	0.370***	0.404***	0.387***
	(0.529)	(0.118)	(0.117)	(0.119)	(0.117)
Basic	0.154	0.440	0.248	0.548	0.369
	(0.529)	(0.509)	(0.502)	(0.519)	(0.511)
Fellowship	–1.404**	–1.065**	–1.107**	–1.007**	–1.103**
	(0.564)	(0.521)	(0.495)	(0.521)	(0.493)
Public health	1.647***	1.390***	1.193***	1.347**	1.104***
	(0.498)	(0.517)	(0.395)	(0.570)	(0.400)
Academic age (PI)	0.014	0.011	0.006	0.003	0.002
	(0.023)	(0.023)	(0.023)	(0.024)	(0.023)
Salary (PI)	0.007*	0.004	0.007*	0.006	0.008**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Academic collaboration	1.527***	1.349***	1.225***	1.318***	1.216***
	(0.440)	(0.413)	(0.407)	(0.412)	(0.404)
Private collaboration	1.614***	1.464***	1.290***	1.448***	1.282***
	(0.417)	(0.379)	(0.385)	(0.388)	(0.391)
Research-direction diversity	0.025	–0.545	–1.436**	–0.640	–1.484**
	(0.437)	(0.557)	(0.641)	(0.561)	(0.663)
Directorship (Co-Is)	0.945**	0.605	0.434	0.331	0.255
	(0.480)	(0.524)	(0.543)	(0555)	(0.559)
Research quality (PI)		0.060**	0.060**	0.115***	0.108
		(0.029)	(0.029)	(0.038)	(0.035)
Multidisciplinarity		1.461***	–0.199	–0.139***	–0.037
		(0.482)	(0.796)	(0.505)	(0.776)
Complementary resources (Co-I)		0.001*	0.001*	0.001**	0.001**
		(2.81e-04)	(2.84e-04)	(2.91e-04)	(2.94e-04)
Multidisciplinarity ×			2.843***		2.621***
Research-direction diversity			(0.979)		(0.983)
Multidisciplinarity ×				–0.272**	–0.184
Research quality (PI)				(0.134)	(0.114)
Observations	506	506	506	506	506
Number of projects	127	127	127	127	127
Chi2	66.15***	78.17***	87.54***	82.32***	89.88***
ΔChi2		12.02***	9.37***	4.15**	23.73***
Pseudo R^2	0.225	0.266	0.298	0.280	0.3062

Standard errors in parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$