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PIs AS BOUNDARY SPANNERS, SCIENCE AND MARKET SHAPERS

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Abstract

The research program organization has been generalized to implement research policies in OECD countries. Principal investigators are the linchpin of the program based organization as they are developing research project to fit within programs. However, principal investigators are not only project managers but they also enact their environment, shape organization, heterogenous networks, research avenues, research communities and transepistemic arenas. Principal investigators are not only researchers they are also boundary spanners amongst academic and private sectors and amongst subfields and disciplines. Principal investigators, especially serial Principal investigators act as scientific entrepreneurs who enact their environment. It questions the relationship between Principal investigators and their organization. It also questions the efficiency and effectiveness of program based research policy.

Keywords: Scientific entrepreneurs, Principal investigators, enactment, research avenues

INTRODUCTION

Universities have not only witnessed dramatic growth over the last 20 years but, in most countries, their research activities have also undergone radical reorganization led by top-down reforms based on program based organization. The scientific landscape has been changing and different contributions described these evolutions : Tyler (2011) analyses the effects of the Bayh Dole act and how to optimize technology transfer from the tax payer point of view; Laredo(2003) portrayed the change at the European level emphasizing the European research programs as a new way to organize knowledge production and dissemination; the traditional third mission of universities and public sector research (Gibbons, 1994; Nowotny *et al.*, 2003); or its triple helix formulation (Etzkowitz *et al.*, 2000). These approaches are describing the changing missions of public sector research, the evolution of universities and the transformations of the relationships with their environments. However, the mechanismsby which reforms get implemented into public sector research organizations and universities remain unclear and those who are the engine of the changes are unknown.

The Journal of Technology Transfer positions the special issue "***The growing role of PIs as science, technology and market shapers"*** to focus on the actors of the transformation, those who are participatinginand shaping the new organization of science. Research programs have been the key mechanism to orient research and to set up research agendas. Different schemes have been implemented worldwide (Defazio *et al.*, 2009; Jimenez-Saez *et al.*, 2011; Kato *et al.*, 2012; Wu, 2010). Principal investigators are the linchpin of the transformation, shaping research avenues, articulating actors within programs, bridging academia and industry. They play a specific role in the new governance of research as they are the ones who design research projects and manage their implementation. While policy makers and funding agencies specify and prioritize scientific targets, principal investigators interpret public policies and programs; they articulate scientific research avenues, scientific programs and priorities, firms' expectations and their own anticipations of where science is going. These new roles also involve coordinating with multiple organizations, including industry partners, and generallymakingthe job of the principal investigator more important and policy relevant.

The emergence of new roles comes hand with hand with tensions:

- Scientists have been trained to produce science, to write papers and teach. As they are required to provide the bridge between science and industry, PIs become brokers, playing a role not common in decades past. There is typically no formal training for

PIs playing such brokerage and inter-organizational political roles. Are managerial capabilities innate or do they need to be learnt? Nature versus nurture?

- In the new governance of science and universities, principal investigators have increased responsibility as scientific fiduciaries. The legal and the informal responsibilities entailed in the financial management of research pose new administrative challenges for the principal investigator, requiring them to measure carefully the balance of research management and research leadership in their approach to their principal investigator mission.Can they, simultaneously, be entrepreneurs and administrators?
- As most project funding sources require the anticipation of linkages between research and its application, principal investigators are market shapers. Principal investigators will anticipate and envision a range of outputs including the publication targets, the application targets for their research, the collaborative research networks and arrangements, and at a higher level the new trajectory that will drive further their scientific field.At the outsets of their research principal investigators form expectations about future markets, but how do scientists form these projections and expectations?
- Through training and experience a scientist is discipline grounded. To provide policy makers and firms with answers, principal investigators are combining different disciplines, technological platforms or devices to produce solutions, based on multidisciplinaryproject organization. They are required to simultaneously engage in academia to match discipline-based assessment criteria and in problem-based achievements.
- Finally, if a project is a temporary organization structure, the principal investigator is charged with shaping this temporary organization structure and planning for fundingbeyond the defined lifetime of the structure.They are managers, typically without the benefit of professional management development.

Based on existing definitions such as that of the NSF[1], existing contributions on PIs have been emphasizing their role as project managers and administrators (Birnbaum-More *et al.*, 1990;

[1]"the individual designated by the grantee, and approved by the NSF, who will be responsible for the scientific or technical direction of the project"

Frestedt, 2008). More recently, the role of research leaders as boundary spanners to articulate different disciplines, different points of view and logics to solve problems (Adler *et al.*, 2009; Bozeman *et al.*, 2004; Comacchio *et al.*, 2011; Jain *et al.*, 2009). The boundary spanning perspective is very important to introduce three dimensions that are expanded in this special issue. First of all, as boundary spanners principal investigators are bridging different areas, academia, higher education, policy makers and firms. They have a role to articulate different objectives, time frames, logics and cultures. They also have a role within academia to create a dialogue between disciplines, to shape research avenues and to combine different approaches and instruments to propose solutions. Finally, emphasizing the boundary spanner roles obliges scholars to reconsider the definition of PIs, their characteristics and to question their role in academic science, not only in the light of their productivity but also on their ability to implement visions and to share expectations.

This special issue considers the sundry roles of the principal investigator, the changed environment in which they operate, and the managerial challenges they face.It also addresses the role of principal investigators in environment enactment, shaping new organizations(Boardman *et al.*, 2013; Cunningham *et al.*, 2013), engaging with actors outside academia to articulate both scientific and societal/economic (Baglieri *et al.*, 2013; Boehm *et al.*, 2013; Casati *et al.*, 2013; Kidwell, 2013), producing scientific results (Feeney *et al.*, 2013) and shaping the new trajectories in their scientific domain(Casati *et al.*, 2013).The implications of the findings across the papers in this issue for policy makers, including funding agencies, universities and public research centers, and potential scientific leaders or principal investigators are also considered.

The special issue contributes to our understanding of the role of principal investigators as the linchpin of program based science and technology policy. First of all, the special issue emphasizes the diversity of principal investigators. Second, it underlines the entrepreneurship dimensions of PI actions. Third, it questions practices of PIs, the limits of their actions and the potential facilitating conditions. Finally, research avenues and implications for policy makers are explored.

DEFINITIONSAT STAKE

Ambiguities about the PIs' definitions reflect the tensions about their role and functions. Funding agencies like the US National Science Foundation or the European Research Council

define the principal investigator as the individual responsible for the scientific or technical direction of the project. Agencies emphasizethe principal investigator's responsibilities for coordinating work across different teams. University definitions for role of principal investigator emphasize managerial and administrative responsibilities. A review of the research policy documentation in Ivey League universities[2] presents a deliberate internal management focus with some concern for management of external engagement.While there are some mentions of responsibility for the scientific conduct and scientific program, there is no reference to scientific leadership.

Even if it is often implicit, scholars are seeing principal investigators as scientists with a managerial role. They assess the effect of being a principal investigator on their scientific productivity (Defazio *et al.*, 2009; Feeney *et al.*, 2013; Ponomariov *et al.*, 2010) and concentrate on principal investigataors' functions as project managers. Boardman et al (Boardman *et al.*, 2013) and Cunningham et al. (Cunningham *et al.*, 2013)focus specifically on the managerial function of PIs, underlying this very role. Boehm and Hogan (Boehm *et al.*, 2013) deepen the boundary spanning role while Casati and Genet (Casati *et al.*, 2013), Kidwell (Kidwell, 2013)and Baglieri and Lorenzoni(Baglieri *et al.*, 2013)reveal the entrepreneurial dimension of PIs. The three papers see PIs as visionary individuals who mobilize public or private money to implement their vision of science, mobilizing resources, translating interests into technologies or scientific results (Callon, 1986; Callon *et al.*, 1989; Leigh Star *et al.*, 1989), and finally shaping models, representations and new areas (Knorr-Cetina, 1977; Morgan, 2012).

THE PRINCIPAL INVESTIGATOR AS A SCIENTIFIC ENTREPRENEUR

As entrepreneurs, principal investigators are engaging in three actions: ***envisioning*** to propose perspectives, vision of the future and to share expectations; ***creation*** of new organization to organize resources, of new markets by shaping innovations and users or new research avenues or trajectories; and ***resourcing*** to implement their vision and to make things happen. Casati and Genet (Casati *et al.*, 2013)argue that the study of their practices represents a potentially

[2] University of Pennsylvania, Dartmouth University, Columbia University, Brown University, Cornell University, Princeton University, Harvard University, and Yale University.

rich field of study.The manner in which principal investigators undertake to shape their research environment indicates that they have entrepreneurial behaviors and practices in terms of how they acquire and mobilize resources.The entrepreneurial characteristics also extend to how they engage in science and anticipate the outcomes of their research efforts.

Casati and Genet identify four sets of practices for principal investigators:***focusing in scientific discipline***(scientific production); ***innovating and problem solving***(bridging academia and industry to solve problems); ***shaping new paradigms and models***(implement the principal investigator's vision of the evolution of science) and ***brokering science***(implementvision through leveraging new networks and forming new organizations).Principal investigators are engaged in the different practices at different levels and their engagement shapes their roles, from that of project manager (mostly focusing and innovating) to that of scientific entrepreneur (shaping new models and paradigms and brokering science).The scientific entrepreneur links "different worlds and different activities to cross the borders of knowledge", and enacts "their environments by changing the boundaries of their organization and setting up new ones".

The importance of changing the boundaries of their organization is endorsed by Baglieri and Lorenzoni(Baglieri *et al.*, 2013).Their paper tracks five principal investigators who are both scientists in the context of operating as principal investigators in university settings, and users, in the context of being involved in spin-off enterprises that are developing research outcomes for market applications.They develop a scientific template that indicates how principal investigators which are engaged in researching and developing new technological devices benefit from being lead users as this activity positions them closer to the market need and allows them to provide roadmaps that shape market size and customer needs.As principal investigator they invent to solve technical problems, thereby engaging in ***value creation***, and then ***capture value*** through the creation of the new firm.The simultaneous rather than separate arrangements provide for an aggregation of effort through the creation of cognitive and physical conditions that enable the scientist to envision the process from "bench to proof of concept".

How principal investigators work to enact their cognitive and physical research space is developed further in Kidwell (Kidwell, 2013). She describes the principal investigators in her study as "visionaries who mobilized their resources to enact their research agendas.They search for and seek to shape environments where their work is recognized and supported.She

identifies that successful principal investigators will make critical strategic choices at different points as they shape the environment that will most effectively facilitate achievement of their scientific vision.

The first area of strategic choice relating to the principal investigator's environment involvesthe choice of theirplace of work.Each of the principal investigators in her study made purposeful decisions regarding the selection of their institution and their movement between institutions as their research agenda progressed.Their search to find a place to "make it happen" would not just see the principal investigator move from one university to another, but as appropriate to their research agenda, this search for alignment can also see the principal investigator exit the university to private industry, including through the establishment of their own enterprise.Baglieri and Lorenzoni(Baglieri *et al.*, 2013)observe that principal investigators are often motivated to perform both in university laboratories and in spin-off enterprises in order to enlarge their sphere of influence. Their cases studies illustrate that principal investigators consider academic entrepreneurship as a route to shaping their institutional research environment and influence the market boundaries relevant to their scientific outputs.They also note that the scientists engaging in academic entrepreneurship are more likely to be those that are classified as the brilliant scientists within their institutions.

The second area of strategic choice for principal investigators as they shape their research environment involves choices between which boundaries they will span and which collaborators they will work with.Kidwell's case studies indicate that principal investigators in nascent technologies, such as nanotechnology and biotechnology, are actively spanning boundaries to accomplish their goals through their dealings with industry and universities(Kidwell, 2013).Successful collaborators welcome strangers as they seek to acquire competencies, knowledge and resources to support the research vision.

Kidwell observes that principal investigators purposefully navigate their roles, aligning themselves with organizations that support their vision and participating in boundary spanning activities to achieve their goals.As they proceed they manage the tensions between organizations but influence over their research space is essential.

These principal investigators are loyal to their vision, not their organization or the organizations that they work with.Indeed, they may even be classified as ***traitors*** in their organizations as they challenge the managerial processes and systems imposed by their institution in order to retain a dominant influence over their research environment.When their

institution is not aligned with their research vision they will willingly move to an institution where the alignment is more supportive, regardless of where that institution is located.

These observations raise important implications for universities and public research centers that must be mindful of the commitmentof principal investigators with their scientific vision.Institutions that obsessively apply rigid managerial systems and research conditions that do not provide principal investigators with the flexibility to shape the environment that according to their specifications maylose their leading scientists and potentially the future returns on investment that they have already made in these leading scientists.They may also lose industry partners who decide to follow the principal investigator.Kidwell warns that universities may be losing valuable talent because their principal investigatorsareunable to enact the research environment which they consider necessary for their work to develop.A German R&D manager quoted by Boehm and Hogan (Boehm *et al.*, 2013)states that "it is not about universities, it is about professors", highlighting the importance of the personal relationship between the original researcher and the industry partner.

ARE PRINCIPAL INVESTIGATORS BORN OR MADE?

"Are principal investigators born or made" questions how principal investigators acquire entrepreneurial and managerial capabilities.Three contributions explore competencies of principal investigators.

Is management know-how important for principal investigators?Boardman and Ponomariov(Boardman *et al.*, 2013)suggest that management know-how or management knowledge is a potentially important factor of production for university research centers.They find support for their proposition that the existence of management knowledge in a center corresponds to more structure and authority in that center.However they did note that management knowledge was not prevalent in the centers in their study.They also found that all principal investigators are not created equally – some have management knowledge, others don't.Importantly, their paper leaves as an open question as to whether management knowledge amongst principal investigators has an impact on research productivity.Management therefore matters in how things are done but we need to learn more on what impact it has on how well things get done.

The benefits of achieving principal investigator status are confirmed in Feeney and Welch's paper (2013).Theydemonstrates= that achieving principal investigator status represents more

than a career milestone for the researcher and has potential to impact significantly on their productivity as ascientist. It reports that faculty that get grants, either as principal investigator or co-principal investigator, produce significantly more journal publications and train more researchers than those who do not have grants.Moreover their research shows that the roles of principal investigators and co-principal investigators are significantly distinct from each other.Principal investigators publish more and supervise more researchers than co-principal investigators as their research activities leverage off greater teaching release. The necessity for universities and public research centers to identify high performance scientists with the potential to become star principal investigators at an early stage in their career is apparent. Feeney and Welch's paper also sheds new light on the early career decisions on which combination of research management and research leadership junior scholars will formulate in for their personal envisioning of how they will shape their principal investigator career.

While the principal investigator will do all in their power to shape their research space and deliver their intended vision, they are hindered in their endeavor in various.Cunningham, O'Reilly, O'Kane and Mangematin(2013) identify these inhibiting factors in their study of thirty publicly funded principal investigators.They identify three categories of inhibiting factors. The first, ***political and environmental inhibitors***, are derived from institutional and stakeholder requirements.These include the tensions between funding agency expectations for early technology transfer and principal investigator requirements to complete the scientific production process.Competitive funding research systems areidentified as unreliable for assuring momentum of research agendas with delays resulting from failure to win funding at different junctures of the research pathway. ***Institutional inhibitors*** include incongruent institutional arrangements for technology transfer and human capital recruitment.Compliance-based organizational arrangements are also cited as unhelpful.Finally,***project inhibitors*** relate to administration arrangements for project reporting thatre-enforcethe tension between research management and research leadership.The principal investigators in this study also identified limited professional development support as an inhibiting factor for enabling them to carry out their role more effectively.Balancing competing project stakeholder expectations (e.g. industry partner expectations) are identified as a difficult and time-consumingchallenge.

On a positive note, these challenges are not insurmountable.A number of them can be overcome at institutional level through re-aligning research management arrangements to support the diverse research agendas offered up by principal investigators.Funding agencies can target high potential principal investigators and design funding programs around their

needs.The temptation to continue imposing homogenous managerial arrangements on what are essentially heterogeneous groups of scientists must be overcome.

Principal investigator managerial capabilities not deal only with internal concerns but also with inter-organizational relationships. Hogan and Bohem(2013)suggest that commercial awareness is important and that the potential to include industry internships in the development of prospective principal investigators or the recruitment of principal investigators with industrial experience might be explored.

IMPLICATIONS OF SPECIAL ISSUE CONTRIBUTIONS

The special issue emphasizes the role of principal investigator as a linchpin of program based organization of science and technology policies. Beyond the project management, administrative, and accountability functions, contributions in this special issue underline the role of principal investigators as entrepreneurs in academia. They have a vision of what should be done, and they have their own goals and expectations about how to leave a footprint in academia. They strategize their action, they resource their strategy, they shape organization to reach their goals. Resourcing means convincing colleagues to work with them, building alliances with other teams or researchers and to invest in academic and / or industrial communities. Being a principal investigator is part of their resourcing strategy, to secure resources and collaborations, as well as to identify hot topics to be explored. Principal investigators are not only instruments of the public policy strategy. They are strategizing themselves and using the program based organization of science and technology to resource and to nurture their own strategy. This is especially the case for serial principal investigators studied by Kidwell (2013).

The second newness is that principal investigators are accumulating practices and roles. It seems that they never abandon one practice but rather pile different practices. All scholars are trained to focus on one discipline to contribute to knowledge production within a specific scientific community. Very few remain only in that role. Scholars are adding additional competencies built through practices: teaching and higher education management (programs, department or university); bridging science and industry; organizing the scientific community or invisible colleges (Vogel, 2012); or brokering science through the articulation of heterogeneousresources to reach their own scientific goals. Scientific training is mostly on the job training and companionship with mentors and senior scientists. This special issue reveals

the other practices and makes them visible. By better identifying other practices and by connecting them to personal scientific strategy, it contributes to the recognition of principal investigators as scientific entrepreneurs, within academia.

Finally, the managerial role of principal investigators needs to be recognized and supported. The rationales to transform scientists into administrators are not obvious and this evolution requires support and accompaniment to be efficient.

IMPLICATIONS

Direct implications can be drawn for policy makers, funding agencies and universities.

Implications for Policy Makers

The diversity of principal investigators and of their role in the implement of science and technology policy objectives calls for ex ante differentiation of supporting schemes. It is important to design programs where targeted research projects are expected. Such programs may explore scientific bottlenecks, technological conditions to innovate, or methodological advances which benefit to the whole community. It is also key to leave space for scientific entrepreneurs to take risks, to propose and discuss ambitious research programs and to bet on unconventional ideas (like the Ideas programs at the European Research Council).

To allow scientists to develop their projects in the different dimensions (scientific, technology transfer, training, etc.), it is important to support principal investigator led research teams with additional personnel to manage and administer projects.

Implications for universities and Research Institutions

The papers in this issue are not the first to outline challenges researchers have working in their institutions, be they universities or public research centers.Not least among these challenges is how the institution provides sufficient flexibility to the principal investigator to conduct their research projects and implement their research programs, while at the same time trying to implement its own scientific policy or to cope with accountability concerns (e.g. administration of the funded projects as required by public funding transparency and governance requirements).While we talk about the craft of research management and leadership for the principal investigator, there may also be a craft to research management and administration for university research support professionals.This craft is required to manage

the tension between conformance to administration commitments, while maintaining a flexible university research environment.Further exploration of thecharacteristics contribute to this craft is required.

Institutions must accept that the principal investigator may willinglybecome traitors to the institution when the alignment between the principal investigator objectives and the institution research environment fails.The challenge for these institutions is examine how they can manage this treachery in a way that will allow them to retain their most productive principal investigators.They also have to establish mechanisms to ensure that their principal investigators are not lost to the educational mission of the university, with principal investigators more likely to carry reduced teaching loads as an outcome of their research funding.

RESEARCH AVENUES

Science is getting more important for innovation, more expensive for tax payers and firms, more central for policy makers, and its organization is more challenging for funding agencies, university or public sector research organizations. The Journal of Technology Transfer has opened a new level of analysis to understand the implementation of programme based S&T policy and the contribution of research projects to the organization, agency or national goals in terms of S&T policies. Such a new trajectory opens different research avenues.The first research avenue requires examination of the linkages between principal investigators and his/her organisation. What is the psychological contract between principal investigator and his/her organisation? Which are the prevalentmechanisms to learn to be a project manager, a manager or a scientific entrepreneur? Does the organisation manage specifically those who are scientific entrepreneurs or those who may become scientific entrepreneurs? How does the organisation support high potential researchers? Such analysis is even more important if we consider that principal investigators may be seen as traitors by their own organization when scientific entrepreneurs' vision is not fully compatible with that outlined by the heads of their organisation.

The second axis of exploration is to better elaborate the concept of scientific entrepreneurs, especially by comparing it with entrepreneurs, intrapreneurs and academic entrepreneurs. Public sector organisations and academia need scholars who are willing to take risk, who have visions and expectations, and who are able to shape organisations to enact the environment.

Such entrepreneurial behaviours may express across the different dimensions, organizationally and institutionally within publicsectorresearch, within the scientific communities (invisible colleges), within networks to bridge public and private organisations.

The notion of principal investigators and their role as the engine of the shaping of new research avenues, new connections with heterogeneous actors, new organisations to implement visions and policies need to better understand to design not only policies but also implementation mechanisms. Research of institutions at work and of institutional changes or institution competition are central. It also impacts public management research requiring contributions on how reforms are impacting local and individual practices. Principal investigators are the ones who articulate public policies and the promotion of practices.

Finally, studying principal investigators is a way to question the evolution of the knowledge economy. Principal investigators are generally visible in their sub-field. They are publishing and their publications have impact in academia. How does visibility transform into recognition by scientists outside the subfield or by policy makers or firms?

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