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Navigating multiple logics: Legitimacy and the quest for societal impact in science

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ABSTRACT

Academic scientists are encouraged to pursue research that delivers both scientific and societal impact. This may involve a search for alternative mechanisms of social approval which lead to endorsement of scientists' research goals. We explore how scientists mobilise and accumulate different forms of legitimacy, which might favour their participation in practices related to innovation and societal impact. We propose three specific sources of scientific legitimacy: i) scientists' social networks (research-related legitimacy ties), ii) prominence in the relevant academic community (reputation-based legitimacy); and direct contact with the primary beneficiaries of the research (beneficiary-based legitimacy). To explain scientists' participation in activities oriented towards innovation and societal impact, we test the significance of each of these sources of legitimacy and their potential interplay empirically, using a large sample of Spanish biomedical scientists.

1. Introduction

Science policy increasingly seeks to incentivise academic scientists' participation in research that contributes more directly to societal and economic goals (Renault, 2006; Von Schomberg, 2013). Over the last few decades, institutional-level initiatives to facilitate scientists' adoption of practices related to a 'commercial logic', such as academic patenting, academic entrepreneurship and other technology-transfer activities, have been implemented worldwide (Grimaldi et al., 2011; Hvide and Jones, 2018; Thompson et al., 2018). More recently, science policy has introduced initiatives to encourage academic engagement in scientific research with societal impact and calling for greater adherence to socially responsible research principles (Mazzucato, 2018; Owen et al., 2012; Perkmann et al., 2013). These actions have revealed the multiple missions that exist within academia, allowing for a range of research perspectives and goals and leading to the emergence of multiple institutional logics: training, science, commercial, pro-social. However, these institutional logics might challenge the capacity of scientists to balance conflicting priorities and incentives. The potential tensions related to these concurrent logics in academia have been studied in some depth, particularly in terms of simultaneous scientific and market-related goals (Bjerregaard, 2010; Fini et al., 2010; Perkmann et al., 2018), arguing that a commercial logic could compromise the scientists' commitment to open dissemination of research outputs or autonomy to establish a research agenda (Gulbrandsen and Smeby, 2005; Tartari and Breschi, 2012).

In this paper, we focus on scientists' capacities to accumulate and mobilise legitimacy. This intangible resource could contribute to involvement in practices that challenge some aspects of the traditional normative system in science, for example, involvement in downstream activities related to innovation, knowledge commercialisation and societal impact. Legitimacy has been defined from various perspectives, but can be considered as a societal perception that an agent's actions are in line with an accepted set of norms, values and beliefs (Suchman, 1995). The role of legitimacy in the successful negotiation among different logics has been discussed in various fields. For instance, in work on innovation management, employee legitimacy is critical to facilitate progress from conception to implementation of an idea (Baer, 2012; Harvey, 2014). Advancing an initial idea through the different phases of development is, in part, a social-political process, involving the idea proposer's active search for social support, through feedback from peers (Harrison and Rouse, 2015) or partnering with an

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'innovation champion' (Perry-Smith and Mannucci, 2015). The importance of social endorsement also operates in settings such as biomedicine, where approval from key actors is particularly crucial for translating the results of basic research into clinical applications and medical innovations. For instance, the participation of patients as active players in planning, designing and evaluating the research, increases confidence in the research findings and legitimates decision-making, in areas such as Alzheimer's biomarker research (Nielsen and Boenink, 2020), bipolar disorder management (Nestsiarovich et al., 2017) and research into rare diseases (Aymé et al., 2008; Mavris and Le Cam, 2012).

However, despite the relevance of legitimacy, we know little about how academics gather and mobilise it to obtain social endorsement for research ideas, practices and priorities, and whether this endorsement is conducive to scientists' involvement in downstream activities that deviate from the traditional norms of science. We draw on the conceptual framework proposed by Suddaby et al. (2017), which distinguishes different configurations of legitimacy - that is, legitimacy as process, property and perception - and examine three potential sources of legitimacy. The first source, *research-related legitimacy ties*, adopts a relational approach to personal networks and focuses on network tie content (Levin et al., 2015; Walter et al., 2015). This allows explicit examination of the extent to which the focal scientist obtains legitimacy from her/his personal research network (Levin and Cross, 2004). It is consistent with Suddaby et al.'s (2017) conceptualization of legitimacy as a *process*, which considers legitimacy as the result of interactions in which focal actors exercise agency to persuade and influence third parties and pursue a meaning-making strategy. The second source, *reputation-based legitimacy,* depends on the scientist's academic status within his/her peer community. This is in line with Suddaby et al.'s (2017) legitimacy as a *property*, which conceptualises legitimacy as a capacity, property or trait possessed by an actor in some measurable quantity, and which might be intangible (not directly observable, but measured by proxy), and can be acquired, accumulated, lost and restored. Finally, *beneficiary-based legitimacy* derives from direct contact between the focal scientist and the main potential beneficiaries of the research (e.g., patients and medical practitioners, in the case of biomedical scientists). We posit that compared to scientists with few interactions with potential beneficiaries, those who maintain their connections with research beneficiaries are likely to receive particularly relevant assessments of the appropriateness of their research results and research activities, compared to scientists with few or no beneficiary contacts. This is in line with Suddaby et al.'s (2017) legitimacy as *perception*, which highlights the importance of judgements from specific third parties, with unique capacity to assess the relevance of an entity's product, practice or characteristics.

Drawing on these conceptualisations of legitimacy, we develop and empirically test a set of hypotheses related to the Spanish biomedical research system context. We focus on the population of biomedical scientists involved in a policy initiative - the CIBER programme (Spanish Biomedical Research Networking Centres) - aimed at fostering research excellence and reduce the gap between scientific research and practices with beneficial health impact. We analysed the responses to a large-scale survey administered to all biomedical scientists participating in the CIBER programme. The results show that research-related legitimacy ties are critical for scientists' involvement in innovation and that their influence is moderated by reputation-based and beneficiary-based sources of legitimacy.

2. Theory and hypotheses

2.1. Multiple logics in conflict: why legitimacy matters?

Historically, the dominant institutional order in academia has been governed by a set of norms and rules that prioritise the search for fundamental knowledge, peer recognition, open disclosure of results and research freedom (Benner and Sandström, 2000). From an institutional theory and sociology of science perspective, this is described as a 'science logic' (Merton, 1973; Stephan, 2010; Stuart and Ding, 2006), which does not prioritise societal impact of research or commercialisation of research results (Stephan, 2010). For instance, Subramanian et al. (2013, p. 597) state that 'the goal of publishing is largely for the establishment of academic reputation. Journal editors and the peer review process seldom require the degree of practicality expected of a patent application'.

Since the 1980s there has been a noticeable shift towards the co-existence of multiple logics in academic institutions (universities, public research centres) (Grimaldi et al., 2011; Gulbrandsen et al., 2011). The intensified commercial logic is evident in the establishment of university technology transfer offices to facilitate the commercialisation of academic knowledge (Rasmussen, 2008), increased patenting activity by university scientists (Azoulay et al., 2007; Carayol and Carpentier, 2020) and the creation of university-industry centres (McKelvey et al., 2015). It implies increased acceptance that one of the primary missions of scientists is to provide concrete solutions to problems that are valued in the marketplace (Aghion et al., 2008; Sauermann and Stephan, 2013).

At the same time, there is a greater awareness of the multiple forms of scientists' public engagement, which extends beyond a narrow focus on commercialisation and embraces more relational forms of interaction with non-academic actors (Abreu and Grinevich, 2013; D'Este and Patel, 2007; Perkmann et al., 2013). These multiple forms of academic engagement with society[1] and the prominence given to co-creation and responsible research and innovation in science policy discourse (Owen et al., 2012; Von Schomberg, 2013), suggest 'an increasing emphasis on more deliberative and upstream forms of reflexive public engagement with science and technology' (Owen et al., 2021, p. 8). This logic encourages participatory multi-actor dialogue and exchanges to foster the co-creation of research and innovation outcomes and provide inputs to policy agendas. In the biomedical field, adoption of patient-centred research practices (Carman et al., 2013; Nielsen and Boenink, 2020) is also shifting how scientists are setting their research priorities and organising their research activities.

However, academic scientists can find it difficult to balance these multiple logics, since the norms and the incentive structures governing the reward system in science, do not always favour the co-existence of the range of behaviours and practices these logics endorse (Sauermann and Stephan, 2013). Some scholars maintain that commercial and science logics are conflicting, and that the adoption of market-related practices by academic scientists could undermine the guiding principles of science (Hessels and Van Lente, 2008; Krimsky, 2004; Ziman, 1996). From an individual perspective, scientists who participate in commercialisation often need to build a hybrid academic-entrepreneur identity (Jain et al., 2009) and are required to have a range of managerial skills (Fini et al., 2010). These individuals are considered fairly unique and have been described as 'bridging' scientists (Gittelman and Kogut, 2003; Subramanian et al., 2013). Despite the potential benefits of a patient-centred perspective, its implementation in the biomedical field can be difficult and involve interpretation problems and sometimes conflicting priorities among biomedical scientists and healthcare professionals (Carman et al., 2013).

These diverging views about what constitutes legitimate behaviour can create tension among academics about how to deal with conflicting demands and prescriptions (Lander, 2016; Perkmann et al., 2018; Tartari et al., 2014). We suggest that this requires the construction and mobilisation of different forms of legitimacy. Legitimacy can be defined as 'a generalized perception or assumption that the actions of an entity

[1] According to the European Commission, public engagement '[….] is about bringing together researchers, policy makers, industry and civil society organisations and NGOs, and citizens, to deliberate on matters of science and technology' (https://ec.europa.eu/programmes/horizon2020/en/h2020-section/public-engagement-responsible-research-and-innovation).

are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions' (Suchman, 1995, p. 574). Legitimacy is particularly important when individuals become involved in practices, such as academic entrepreneurship or innovation, which go beyond the primary normative conventions in academia (Karlsson and Wigren, 2012) or research activities aimed at responding directly to societal needs. For instance, Tartari et al. (2014) and Stuart et al. (2006) show that, when deciding about collaboration with industry, scientists tend to look to their academic peers and check social norms for clues to what is considered legitimate behaviour. We suggest that scientists able to mobilise social endorsement will be more likely to participate in downstream, innovation-related activities or activities oriented towards social impact.

2.2. Research-related legitimacy-ties

Individuals rely on their social networks for legitimacy and credibility. Social capital is often valued more as a source of credibility, status, reputation and/or integrity for networked actors (Bowey and Easton, 2007; Coleman, 1994) than for the access it provides to knowledge or tangible resources. For instance, at firm level, partnering with a company with a central position in the network provides greater credibility to the focal firm (Zhang and Tang, 2020). Entrepreneurs also rely on their personal connections to cope with uncertainty and compensate for lack of formal institutional support (Chen and Tan, 2009). In particular, in knowledge-intensive industries, entrepreneurs devote significant time and effort to cultivating personal networks that provide support for their business activities (Johannissson, 1998).

Within organisations, the legitimacy provided by social connections is crucial for translating breakthrough ideas into concrete innovations. The capacity of employees to propose new ideas depends critically on their social relationship structures (Phelps et al., 2012; Tortoriello et al., 2012). In the initial stages of developing an idea, the validation and credibility received from network partners is important to overcome resistance from sceptical peers and unconvinced stakeholders confronted with ideas that seem too radical (Perry-Smith and Mannucci, 2017). Bunduchi (2017) identifies lobbying, relationship building and encouraging feedback to gain legitimacy for new product ideas, involving advertising the new idea through demonstrations and regular communication with relevant stakeholders, building relations with both close and distant peers, and obtaining feedback on the feasibility of the idea. These activities can be seen as part of a purposeful plan designed to build ties with peers and stakeholders in order to gain their support for a new idea and allow triangulation to check its robustness (Ter Wal et al., 2020).

The scientific credibility and endorsement offered by a well-crafted personal network are also important in the science system. Since academics who challenge the conventional wisdom and suggest new ideas or practices may face significant resistance from the scientific community (Chai and Menon, 2019; Wang et al., 2017), persuading and gaining the support of peers is crucial. These social ties can work to mitigate potential conflicts of interest between academic and commercialisation or entrepreneurial practices (Axler et al., 2018) which might facilitate scientists' engagement in innovation-related processes (Greenwood et al, 2002, 2011). Mobilisation of personal networks to obtain endorsement for research activities could be particularly important for scientists who become involved in practices, such as academic entrepreneurship, that go beyond the primary normative conventions in academia (Karlsson and Wigren, 2012).

This sort of legitimacy is rooted in the idea of legitimation as a process (Suddaby et al., 2017), since the scientist engages purposefully in diverse sets of activities and events to gather endorsement from his or her social network. To study the role of social networks in scientists' mobilisation of legitimacy to support their research agendas, we adopt a relational approach (Chua et al., 2008; Levin et al., 2015; Rodan and Galunic, 2004) and examine their personal ties. This allows us to distinguish between the tangible and intangible resources available from their sets of relations and to focus on those resources related to research validation and credibility (Levin et al., 2011). Within the science system, there is competition for attention for new ideas (Chai and Menon, 2019) and social ties can be exploited to highlight particular research agendas and advance research goals. The intangible value of research-related legitimacy ties is rooted in the endorsement, such as validation and credibility, they provide for the focal scientist's research agenda.

Thus, we suggest that scientists with more social ties that provide validity and credibility to their research will be better able to balance different logics in science and participate in innovation and activities with societal impact. Therefore, we hypothesise that:

Hypothesis 1. Scientists with personal networks rich in ties that provide legitimacy for the advance of research (research-related legitimacy ties), will exhibit greater involvement in innovation.

2.3. Reputation-based legitimacy

We define reputation-based legitimacy as the credibility obtained from accumulated authority and recognition from academic peers. This resonates with the idea of legitimacy as an actor *property*; the individual is seen as owning legitimacy, considered as an outcome of the normative expectations of the environment (Suddaby et al., 2017). Within the science system, normative expectations of legitimacy are based mainly on the quality of academic publications and citation records.

The reputational benefits derived from publications and citations extend beyond academia. Academic reputation is vital for capitalising on scientific knowledge in the market for university-originated technology (Azoulay et al., 2009). For instance, prominent academic scientists, recognized by peers as 'star scientists', are more likely to be involved in inventions with potentially high commercial value (Lowe and Gonzalez-Brambila, 2007; Zucker et al., 1998), are better able to identify technological opportunities (D'Este et al., 2012) and are more likely to obtain backing from venture capital firms to fund working prototypes of their inventions (Zhang, 2009). Karlsson and Wigren (2012) show also that acknowledgement from academic peers increases the likelihood that the entrepreneurial scientist will be perceived as trustworthy by potential customers and suppliers, and more likely to start a firm. Relatedly, academic reputation facilitates the commercialisation of scientific findings (Bourelos et al., 2012; Urban and Chantson, 2019), since highly renowned scientists are better able to convince funders about the commercial value of their ideas (Ioannidis, 2011). In the biomedical setting, the importance of scientific rigour to confirm credibility is especially salient. For instance, scientific articles demonstrating the safety and efficacy of a drug serve as certification of legitimacy (Polidoro and Theeke, 2012). This suggests that, in this setting, academic publications are effective for conferring authority and recognition not only from peers, but also from a broader audience.

Based on the above insights, we contend that scientific reputation should reinforce the positive relationship between research-related legitimacy ties and innovation involvement. In other words, scientists with high levels of scientific endorsement for their research activities, based on social interactions (research-related legitimacy ties), and high

levels of authority and recognition from peers, are particularly well placed to participate in innovation activities. Therefore, we hypothesise that:

Hypothesis 2. The positive relation between personal networks rich in research-related legitimacy ties and scientists' involvement in innovation will be amplified by higher levels of reputation-based legitimacy.

2.4. Beneficiary-based legitimacy

To examine the third source of legitimacy proposed in this study, we focus on scientists' direct interactions with their research beneficiaries. The literature suggests that direct interaction with beneficiaries can promote innovation activity with potential societal impact. Organisational behaviour research defines beneficiary contact as direct links between the firm's employees and the beneficiaries of their work, and considers it an important relational aspect of workplace motivation (Grant, 2012, 2008). In an academic context, beneficiary contact refers to scientists' direct interactions with the potential beneficiaries of their research activities. In the case of biomedical scientists, this generally includes direct interactions with medical practitioners and other healthcare professionals, patients, and patient representatives (Pratt et al., 2016). Since these actors might play a critical role in assessing and setting health research priorities, their judgements can contribute decisively to collective legitimacy. This is in line with the idea of legitimacy as *perception,* which prioritises the importance of judgement from third parties with a unique capacity to assess the relevance of potential outputs (Suddaby et al., 2017).

There are complementary ways in which direct interaction with beneficiaries promotes innovation activity. On the one hand, drawing on organisational research, direct links with users and beneficiaries help to overcome barriers to entry caused by lack of credibility or legitimacy among newcomers (Venkataraman et al., 1990). We propose that direct ties with research beneficiaries could have a similar effect in an academic context and provide scientists with greater credibility, allowing engagement in innovation-related projects and a commercial logic or engagement in activities aimed at having an impact on society. Beneficiary contact provides the scientist with a better understanding of the application context and a greater awareness of the potential societal impact to be derived from adhering to a commercial or a public engagement logic. Interaction with industry practitioners in the context of scientific research activity, has been identified as a strong predictor of effective technology transfer (D'Este et al., 2012; Grandi and Grimaldi, 2005; Landry et al., 2007). Also, direct contact or co-development with beneficiaries is considered a critical source of knowledge to identify potential pathways to commercial exploitation of the findings from scientific research (Owen and Goldberg, 2010). For instance, in the field of rare diseases and orphan drugs, there is growing awareness of the role of patients in the research process. Rather than being only the subjects of clinical trials, patients and their associations are participating increasingly in setting research priorities, designing research projects and lobbying (Aymé et al., 2008; Mavris and Le Cam, 2012).

On the other hand, those scientists with more frequent direct interactions with the potential beneficiaries of their research will be more likely to consider active participation in innovation, knowledge commercialisation and other activities with societal impact. Ties to beneficiaries are more likely encourage curiosity-driven research combined with activities that prioritise improving the wellbeing of end-users (Iorio et al., 2017; Lam, 2011; Llopis and D'Este, 2016). This pro-social motivation, deriving from close interaction with beneficiaries, is likely to foster greater engagement in activities and practices that go beyond scientific achievement (Cohen et al., 2020; Llopis and D'Este, 2016).

In light of the above, we propose that the specific form of legitimacy conferred by close links to beneficiaries (beneficiary-based legitimacy) is likely to complement and reinforce the relational legitimacy derived from the scientist's social network. More specifically, if the research-related legitimacy derived from the personal network is complemented by support resulting from close connections with beneficiaries, the scientist will be more likely to engage in innovation activities. Thus, we hypothesise that:

Hypothesis 3. The positive relation between personal networks rich in research-related legitimacy ties and scientists' involvement in innovation will be amplified by higher levels of beneficiary-based legitimacy.

3. Context and data

3.1. The biomedical context

We test our hypotheses in the context of the biomedical field where public funding is aimed at supporting research into the root causes of diseases (i.e., scientific discovery) and the development of new treatments, diagnostic methods and medical devices to improve healthcare (i.e., technological advances). The rationale for this support is the apparent gap between biomedical scientific discovery and translation into applicable results: the translation from bench to bedside (Morgan et al., 2011). Public support for biomedical research has increased in many OECD countries aimed at 'taking the findings from basic or clinical research and using them to produce innovation in health care settings' (Cooksey, 2006, in Morgan et al., 2011, p. 946). Consistent with the definition of translational research in biomedicine - that is, 'the process of the bi-directional transfer of knowledge between basic work in the laboratory and elsewhere with that of the person, in health or disease' (MRC, 2007; quoted in Morgan et al., 2011, p. 946), these policy initiatives are frequently aimed at encouraging the formation of diverse, heterogeneous research networks.

Thus, biomedical research provides an ideal setting for our study. The relevance of a network legitimacy strategy seems relevant to commercial logic activities in a biomedical context, where the cognitive and institutional barriers to translational research are widely recognised (Adler and Kwon, 2013; Currie and White, 2012; Llopis et al., 2021). In a biomedical scientific research context, legitimacy based on social exchanges can be expected to play a critical role in scientists' successful exploitation of commercial logic practices.

3.2. Data

Our context is the biomedical research field in Spain. The Spanish Government has launched several public policy initiatives and programmes aimed at promoting cooperation among different biomedical fields. One of these involved creation of the CIBERs. In 2006, the Spanish Ministry of Health undertook a reorganisation of biomedical research in Spain, aimed at fostering excellence in biomedical research and improving the quality, value and effectiveness of the healthcare services delivered to the general population. A crucial aim of the CIBER programme was the promotion of research cooperation among professional communities working on similar biomedical research areas. Our research population comprises all scientists affiliated to the nine CIBERs.[2]

We collected data on scientists' participation in practices related to medical innovation and on the structure and content of their personal networks. Our primary data come from the responses to a large-scale survey. Administrative data and other public databases were exploited to compile the lists of names, affiliations, and e-mail addresses of the

[2] The 9 CIBERs are Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN), Diabetes and Metabolic Associated Diseases (CIBER-DEM), Epidemiology and Public Health (CIBER-ESP), Hepatic and Digestive Diseases (CIBER-EHD), Obesity and Nutrition (CIBER-OBN), Mental Health (CIBER-SAM), Neurodegenerative Diseases (CIBER-NED), Rare Diseases (CIBER-ER) and Respiratory Diseases (CIBER-ES).

biomedical scientists in the CIBER programme. Our target population accounted for a total of 4758 individuals (which represents 85 % of all scientists affiliated to the CIBERs). In April 2013, we contacted each of the scientists, via an online platform, to invite them to respond to our survey. We received a total of 1309 responses, a response rate of 27.5 %.[3] After excluding incomplete responses, we obtained a working sample of 993 observations (a response rate of 21 %) for the empirical analysis in this study. Appendix Table A1 presents detailed information on response rates and useable responses. The first part of the survey included a set of questions about respondents' personal networks. It was based on the standard egocentric network survey procedure for the collection of such data (e.g., Levin and Cross, 2004). We obtained bibliometric data from the Web of Science, which provides information on the publication and citation profiles of all biomedical scientists from 2000 onwards.

3.3. Measures

Dependent variable. Our survey asked respondents to report the extent of their involvement in a list of activities and outputs, associated to innovation, knowledge commercialisation and the pursuit of societal impact in the biomedical setting. After conducting fieldwork interviews and reviewing the literature on translational research, we obtained a list of 11 items reflecting a variety of activities and outputs that might be associated to innovation involvement. A drop-down menu allowed respondents to indicate frequency of participation in each practice, ranging from 0 (never) to more than 10 times a year (based on year 2012 -the year before the survey was administered). We conducted Principal Component Analysis (PCA) with varimax rotation to explore whether the proposed items reflected the dimensions of interest. The results highlighted four factors (see Table 1), which is evidence of heterogeneous practices. We labelled the factors identified based on the nature of the practices.

Factor 1 (*Invention and commercialisation*) is the first dimension and is related to drug discovery and commercial exploitation. Factor 2 (*Drug development*) is related to participation in the design of clinical trials to check drug safety and efficacy. Factor 3 (*Clinical guidelines)* captures advances related to the development of clinical practice protocols for medical practitioners. Factor 4 (*Diagnostics and prevention*) relates to the development of medical diagnostics and prevention devices, and health-related disease prevention guidelines for the public.

Our results point to these four broad categories of practices related to innovation. We combined these activities to obtain a unique indicator, *innovation involvement,* and constructed a categorical variable ranging from 0 (no involvement in any of these practices) to 3 (involvement in 3 or more practices). For instance, involvement in a patent application for a new drug and the design of clinical guidelines for patients scores 2, based on involvement in activities related to two distinct factors of innovation-related practices (according to factors shown in Table 1). The advantage of this indicator is that it explicitly recognises and captures the variety of a scientist's innovation practices in the biomedical context.

Independent variables. Our *research-related legitimacy ties* indicator is adapted from the scale developed by Levin et al. (2011) to capture the range of resources an actor obtains from his or her personal network. The first question was a name-recall type that asked respondents to 'write down the names of those persons (up to ten) from outside your research group that are particularly important for the advancement of your research activities'. To assess the value of each tie, respondents were asked to answer a set of name-interpreter questions. Specifically, they were asked to indicate which, among a set of resources, were obtained from the network members listed: i) specific solutions to problems arising in your research; ii) help to identify new sources of information relevant to your research; iii) suggestion for a new focus which facilitated development of your research; iv) help to increase your capacity to convince others of the scientific value of your research (validity); v) help to gain research credibility with third parties (credibility)[4] (Levin et al., 2011; Walter et al., 2015). These five resources were captured by dummy codes (1 if the specific resource was obtained from an alter and 0 otherwise). It should be noted that these resource types are not mutually exclusive (e.g., the same alter might provide both solutions and access to new sources of information): thus, each alter potentially could provide 0 to 5 distinct resources to the focal individual.

Based on these data, we followed a three-step process to construct our measures of resource-related ties. First, we normalised each resource by the total number of distinct resources from each alter. For instance, if the alter provided four distinct benefits to the focal individual, each benefit type was scored 0.25; if the alter provided only one benefit to the focal individual, that benefit scored 1. Second, to aggregate the individual network member scores into a unique score, we summed the scores by resource type. We conducted PCA (varimax rotation, eigen based); the results suggest that respondents obtain two broad types of network resources. First, *validity* and *credibility,* and second, *specific solutions*, *access to new sources of information*, and *new focus on existing problems*. We averaged the respondent scores for validity and credibility to build our *research-related legitimacy ties* indicator. We considered *specific solutions*, *access to new sources of information*, and *new focus on existing problems as problem-solving ties* and constructed an indicator based on the average score for these three items; we used this variable as one of our control variables.

We collected bibliometric data for our survey respondents to construct a proxy for *reputation-based legitimacy*. This variable is based on all publications by our survey respondents during 2000–2011. Specifically, we calculated Normalized Citation Scores (NCSs) for each publication. NCS is known as the 'crown indicator' among citation-based indicators (Waltman et al., 2011; Waltman and Eck, 2012) because it normalises citations by field and by citation window length. Thus, a paper with a NCS above (below) 1 means that, on average, the publication has been cited more (less) frequently than might be expected based on field and publication year. To obtain a scientist-level score, we averaged the NCS for each scientist's publication during the period 2000–2011 to obtain a Mean NCS (MNCS) for each scientist.

Our indicator *beneficiary-based legitimacy* uses data obtained from the ego-network survey. Respondents were asked to indicate contact type for each network contact: i) basic scientist; ii) clinical scientist; iii) medical practitioner; iv) patient or patient representative; v) private sector; vi) public administration; vii) other. Our indicator is based on the count of medical practitioner and patient/patient representative contacts, and ranges from 0 (none of these categories) to 10 (all contacts are classified as medical practitioners and patients or patient representatives).

Control variables. We include several control variables. First, we control for other social network variables that might influence the

[3] We conducted several tests for non-response bias. We compared response rates in terms of institutional affiliation, academic position and group size (based on archival data). Results show that response rates were similar across categories. We also performed a wave analysis to check whether responses differed depending on the date the completed questionnaire was returned since the response patterns of late respondents can be used to proxy for the response patterns of non-respondents (Rogelberg and Stanton, 2007). We classified the sample into early and late respondents and analysed differences in the means of the two groups, for a range of variables, such as participation in medical innovation activities and network size. The hypotheses related to differences in means are all rejected.

[4] Some of the items in Levin et al.'s (2011) scale were adapted to our setting. Levin et al.'s (2011) original 5 items are: i) specific answers or input; ii) identifying relevant information sources iii) help with problem-solving; iv) validating the idea; v) legitimacy.

Table 1
PCA of 'innovation-related practices'.

Items	Invention and commercialisation	Drug development	Clinical guidelines	Diagnostics and prevention
Patent applications for new drugs or therapeutic substances	**0.763**	0.055	−0.035	0.059
Licenses granted from patents	**0.729**	0.090	0.003	−0.053
Participation in spin-off companies	**0.733**	−0.001	−0.012	0.088
Clinical trials phases I, II, III, new drugs or therapeutic substances	0.188	**0.620**	0.363	−0.079
Clinical trials phase IV, new drugs or therapeutic substances	0.155	**0.818**	0.204	−0.046
Clinical trials phase IV, new diagnostic techniques	−0.120	**0.730**	−0.222	0.219
Development of guidelines for healthcare professionals	−0.048	0.204	**0.772**	0.237
Development of guidelines for patients	−0.025	0.018	**0.811**	0.067
Patent applications for new diagnostic techniques	0.216	−0.051	0.128	**0.764**
Clinical trials phases I, II, III, new diagnostic techniques	−0.062	0.276	−0.026	**0.693**
Development of guidelines for the general population	−0.041	−0.166	0.395	**0.632**

Table 2
Descriptive statistics. N = 993.

Variables	Mean	SD	Min	Max
Innovation involvement	0.80	0.95	0.00	3.00
Research-related legitimacy ties	0.50	0.51	0.00	2.63
Reputation-based legitimacy	0.99	1.41	0.00	28.63
Beneficiary-based legitimacy	1.56	1.87	0.00	10.00
Problem-solving ties	1.07	0.67	0.00	3.33
Network density	0.32	0.33	0.00	1.00
Network range	1.68	0.73	1.00	4.00
Av. tie strength	1.82	0.70	1.00	4.00
Extrinsic motivation	3.70	1.18	1.00	7.00
Intrinsic motivation	6.18	0.81	1.00	7.00
Published papers	19.76	29.26	0.00	301.00
Group size	17.79	10.36	2.00	79.00
PI tech. perf	1.00	2.29	0.00	21.00
University	0.32	0.47	0.00	1.00
Hospital	0.33	0.47	0.00	1.00
PRO	0.25	0.44	0.00	1.00
Other organisation type	0.10	0.30	0.00	1.00
Principal investigator	0.12	0.32	0.00	1.00
Postdoc w/projects as PI	0.32	0.47	0.00	1.00
Postdoc w/o projects as PI	0.28	0.45	0.00	1.00
Predoc	0.16	0.37	0.00	1.00
Technician	0.07	0.26	0.00	1.00
Other positions	0.05	0.21	0.00	1.00

scientist's propensity to be involved in innovation-related practices. The first is *problem-solving ties*, that is, ties providing specific solutions, allowing access to new information or offering a different perspective on a problem. The second is personal network density. Since the degree of closeness among network members can affect flows of knowledge and other resources (Obstfeld, 2005), we control for personal network density. Respondents were asked about alter-alter relationships (Burt et al., 1998; Podolny and Baron, 1997). Drawing on previous work, we measure personal network density based on the sum of the alter-alter ties within each ego-network contact, divided by the total number of possible alter-alter ties - n (n – 1)/2 (Everett and Borgatti, 2005). Maximum density occurs when all focal actors' alters are directly connected to each other. The ratio ranges from 0 to 1, with low values indicating a sparse network and high values indicating a high level of network cohesion (network density). In the regression models we add the linear and squared terms to control for quadratic effects. The third network feature is *network range*, which reflects the diversity of the focal actor's network connections. To build this variable, we considered the categories: basic scientist; clinical scientist; medical practitioner or patient representative; public administration, industry or other groups. *Network range* captures personal network heterogeneity, measured by the number of different professional categories to which the respondent reports at least one link (Smith et al., 2005; Wong and Boh, 2010). Finally, we control for average tie strength, that is, frequency of the respondent's interaction with his or her network contacts. The variable ranges from 1 (once or a few times per year), to 4 (once or several times per day).

Our model controls, also, for several individual-level aspects. First, respondent's academic position (research team leader; postdoc with a project as principal investigator; postdoc with no projects as principal investigator; pre-doctoral scientist) and number of academic papers published in the period 2000–2011. Based on self-determination theory (Ryan and Deci, 2000), we asked respondents about their intrinsic and extrinsic motivations for conducting research.

At the group level, we included a series of dummies for whether the research group is in a university, a hospital, a public research organisation or some other type of organisation. We control, also, for research group size and group's previous performance based on number of patent applications filed by the group's principal investigator. Finally, we account for research area using a set of dummies to control for the specific CIBER.

4. Results

Table 2 presents the descriptive statistics for all our variables; Table 3 reports the correlations. Table 4 (last two rows) presents the Variance Inflation Factor (VIF) values, which show that there are no major multicollinearity problems affecting our independent variables (Hair et al., 2006). Note that, although our relational network indicators (*research-related legitimacy-ties* and *problem-solving ties*) are correlated at 0.320 ($p < 0.05$) (Table 3), this is not a particularly high value, which suggests that each of the indicators is capturing a fundamentally

Table 3
Correlation matrix.

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Innovation involvement	1.000												
2	Research-related legitimacy ties	0.216*	1.000											
3	Reputation-based legitimacy	0.059	−0.001	1.000										
4	Beneficiary-based legitimacy	0.381*	0.419*	0.011	1.000									
5	Problem-solving ties	0.081*	0.320*	0.014	0.430*	1.000								
6	Network density	0.024	0.027	−0.026	0.081*	−0.016	1.000							
7	Network range	0.151*	0.391*	−0.002	0.406*	0.504*	−0.043	1.000						
8	Avg. tie strength	0.097*	0.051	0.009	−0.019	−0.090*	0.155*	−0.000	1.000					
9	Extrinsic motivation	0.156*	0.092*	0.078*	0.058	−0.076*	0.036	0.017	0.052	1.000				
10	Intrinsic motivation	0.012	0.095*	0.017	−0.001	0.030	−0.010	0.054	0.044	0.233*	1.000			
11	Published papers	0.224*	0.135*	0.133*	0.142*	0.154*	−0.038	0.163*	0.004	0.121*	−0.007	1.000		
12	Group size	0.008	0.003	−0.047	−0.013	−0.036	0.035	−0.026	0.003	−0.014	−0.068*	−0.090*	1.000	
13	PI tech. perf	−0.030	0.040	−0.001	−0.100*	0.045	0.017	0.001	0.012	0.004	0.019	0.036	0.129*	1.000

N = 993; *p < 0.05.

Table 4
Ordered probit regressions. Dependent variable: Innovation involvement.

	M1: Control variables		M2: Legitimacy ties		M3: Independent variables		M4: Interaction 1 Legitimacy ties*Reputation		M5: Interaction 2 Legitimacy ties*Beneficiary		M6: Full model	
	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors
Research-related legitimacy-ties			0.156***	(0.04)	0.093**	(0.05)	0.088*	(0.05)	0.142***	(0.05)	0.138***	(0.05)
Reputation-based legitimacy					0.021	(0.03)	0.067*	(0.04)	0.021	(0.03)	0.068**	(0.03)
Beneficiary-based legitimacy					0.291***	(0.05)	0.295***	(0.05)	0.351***	(0.05)	0.356***	(0.05)
Legitimacy-ties * Reputation							0.116**	(0.05)			0.119**	(0.05)
Legitimacy-ties * Beneficiary									−0.083***	(0.03)	−0.085***	(0.03)
Problem-solving ties	−0.003	(0.05)	−0.016	(0.05)	−0.105**	(0.05)	−0.107**	(0.05)	−0.120**	(0.05)	−0.122**	(0.05)
Network density	0.121*	(0.07)	0.065	(0.07)	0.014	(0.07)	0.017	(0.07)	−0.021	(0.07)	−0.018	(0.07)
Network density_sqr	−0.107**	(0.04)	−0.065	(0.05)	−0.042	(0.05)	−0.045	(0.05)	−0.025	(0.05)	−0.028	(0.05)
Network range	0.103*	(0.06)	0.056	(0.06)	0.018	(0.06)	0.021	(0.06)	0.002	(0.06)	0.004	(0.06)
Avg. tie strength	0.099**	(0.04)	0.091**	(0.04)	0.105***	(0.04)	0.111***	(0.04)	0.102***	(0.04)	0.108***	(0.04)
Extrinsic motivation	0.133***	(0.04)	0.126***	(0.04)	0.114***	(0.04)	0.116***	(0.04)	0.114***	(0.04)	0.116***	(0.04)
Intrinsic motivation	0.017	(0.04)	0.006	(0.04)	0.014	(0.04)	0.012	(0.04)	0.016	(0.04)	0.015	(0.04)
# published papers	0.124***	(0.05)	0.126***	(0.05)	0.126***	(0.05)	0.121***	(0.05)	0.121***	(0.05)	0.115**	(0.05)
Group size	0.078	(0.06)	0.071	(0.06)	0.059	(0.06)	0.055	(0.06)	0.059	(0.06)	0.054	(0.06)
PI tech. perf	0.053	(0.04)	0.045	(0.04)	0.061	(0.05)	0.062	(0.05)	0.069	(0.05)	0.069	(0.05)
University (Dum = 1)	−0.060	(0.16)	−0.045	(0.16)	−0.039	(0.16)	−0.032	(0.16)	−0.043	(0.16)	−0.036	(0.16)
Hospital (Dum = 1)	0.809***	(0.15)	0.816***	(0.15)	0.662***	(0.16)	0.669***	(0.16)	0.650***	(0.16)	0.656***	(0.16)
PRO (Dum = 1)	0.002	(0.16)	0.035	(0.16)	0.043	(0.16)	0.048	(0.16)	0.057	(0.16)	0.063	(0.16)
_cons/cut1	−0.190	(0.24)	−0.170	(0.24)	−0.242	(0.25)	−0.244	(0.25)	−0.249	(0.25)	−0.252	(0.25)
_cons/cut2	0.679***	(0.24)	0.704***	(0.24)	0.656***	(0.25)	0.656***	(0.25)	0.655***	(0.25)	0.654***	(0.25)
_cons/cut3	1.538***	(0.24)	1.573***	(0.24)	1.561***	(0.25)	1.567***	(0.25)	1.562***	(0.25)	1.568***	(0.25)
CIBER dummies	Yes		Yes		Yes		Yes		Yes		Yes	
Academic position	Yes		Yes		Yes		Yes		Yes		Yes	
N	993		993		993		993		993		993	
Log pseudolikelihood	-1038.3		-1031.8		-1013.1		-1011.0		-1009.7		-1007.4	
R^2 McKelvey & Zavoina	0.280		0.292		0.322		0.325		0.330		0.333	
Mean VIF	2.35		2.33		2.29		2.28		2.29		2.29	
Largest VIF	5.52		5.52		5.56		5.56		5.56		5.56	

Note: *p < 0.1, **p < 0.05, ***p < 0.01. Robust standard errors are clustered by CIBER. Coefficients for all continuous variables have been standardised.

different network resource.

Table 4 presents the regression results of the ordered probit model. Ordered probit analysis is appropriate for qualitative dependent variables with more than two ordinal categories, which applies to our dependent variable.[5] Model 1 includes only the control variables and shows that the two structural network indicators (*density* and *range*) are positively associated to our dependent variable. In the case of *density*, the effect is positive, but decreasing, as shown by the positive and

[5] A likelihood ratio test confirmed that the parallel regression assumption was not violated.

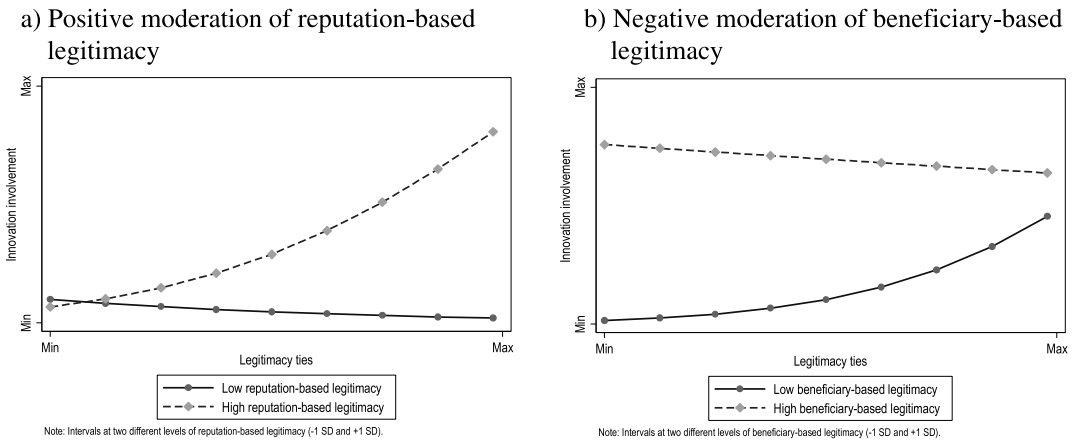

Fig. 1. Average marginal effects on the interactions.

significant sign of the main effect and the significant and negative sign of the quadratic term. Note that the significant effect of these variables is observed only in Model 1. This suggests that our *research-related legitimacy ties* indicator is partly capturing the effects of the structural properties of the network. Model 2 includes *research-related legitimacy ties* and shows that this variable is associated positively to innovation involvement ($\beta = 0.156$, p. <0.01), which supports Hypothesis 1.

Hypothesis 2 predicts that *reputation-based legitimacy* reinforces the positive relation between *research-related legitimacy ties* and *innovation involvement*. Our results support this hypothesis (Model 4); the interaction between legitimacy ties and reputation-based legitimacy is positive and significant ($\beta = 0.116$, $p < 0.05$). Fig. 1(a) depicts the average marginal effects of this interaction and shows that the positive influence of *research-related legitimacy ties* on *innovation involvement* increases for scientists with higher levels of academic reputation legitimacy. Hypothesis 3 predicts a positive moderation between *research-related legitimacy ties* and *beneficiary-based legitimacy* on scientists' involvement in innovation activities. Model 5 rejects this hypothesis; we found a negative and significant effect ($\beta = -0.083$, $p < 0.01$). This suggests the presence of a negative moderation effect as depicted in Fig. 1(b). Finally, Model 6 reports the results of the model including all the interaction terms; all the relevant coefficients are significant, which confirms the robustness of our findings.

4.1. Robustness checks

We conducted a set of robustness checks to confirm our results. First, we employed a different indicator for innovation involvement. Instead of clustering these activities in 4 different categories, we consider frequency of participation in each of the 11 activities. Appendix Table A2 presents the results of the negative binomial regressions. Second, we replicated the models considering an alternative computation of *research-related legitimacy ties*. Specifically, we built an alternative indicator based on the number of different benefits reported by each respondent and created a new *legitimacy ties* indicator as the sum of the relational benefits associated to validity and credibility. Because the survey considers a maximum of 10 network contacts, the theoretical value of this variable ranges between 0 (none of the contacts provided either validity or credibility) and 20 (all network contacts provided validity and credibility). The results of the ordered probit regression are presented in Appendix Table A3. The results in Appendix Tables A2 and A3 provide substantial support for the positive role of research-related legitimacy ties on scientists' involvement in innovation but provide weaker support for a positive interaction between research-related legitimacy ties and reputation-based legitimacy. In all cases, we find a strong negative interaction between research-related legitimacy ties and beneficiary-based legitimacy.

5. Conclusions

This study adds to research on the factors influencing scientists' involvement in downstream activities, such as involvement in innovation or other activities related to the pursuit of societal impact. Specifically, we showed that scientists' capacities to mobilise and accumulate credibility and social endorsement can facilitate the adoption of practices that go beyond the science logic of the normative structure in academic institutions (Benner and Sandström, 2000; Stuart and Ding, 2006). We adopted a multifaceted approach to legitimacy (Suchman, 1995; Suddaby et al., 2017) and suggested that scientists' legitimacy can be obtained through three fundamental channels: formation of personal ties aimed at obtaining support to advance the scientist's research goals (research-related legitimacy ties); academic reputation (reputation-based legitimacy); and direct interaction with the primary beneficiaries of their work (beneficiary-based legitimacy). We found a positive association between personal mobilisation of legitimacy ties and scientists' participation in innovation-related practices. This relationship is moderated by reputation-based and beneficiary-based legitimacy, but in different directions: the former reinforces the positive influence of research-related legitimacy ties, the latter exerts a substitution effect.

5.1. Theoretical implications

The first contribution of this paper is that it explicitly situates the importance of legitimacy in science to explain how scientists deal with the tensions associated with the increased diversity of institutional logics prevailing in the normative structure of science. Debate on the relevance of legitimacy in the science system has been limited and focuses, mostly, on the importance of reputation and credibility related to tackling novel research questions (Chai and Menon, 2019; Wang et al., 2017) or engaging in academic entrepreneurship and other forms of commercialisation (Axler et al., 2018; Greenwood et al., 2011; Klingbeil et al., 2018).

We contend that understanding how scientists accumulate and mobilise different forms of legitimacy could provide useful insights for

understanding scientists' adaptation to the requirements of hybrid logics in science. Policymakers are calling increasingly for academic scientists to demonstrate both the societal impact of and the commercial returns from their research results. Because academic science is governed by reward systems and values that tend to differ from those derived from a more downstream focus on societal impact or commercialisation, academic researchers can find it difficult to deal with the tensions and contradictions between these logics (Perkmann et al., 2018; Sauermann and Stephan, 2013). Previous work has examined potential solutions to managing these tensions such as 'hybrid spaces' in university-industry centres, where commercial practices are accepted (Perkmann et al., 2018). We believe our paper contributes by proposing that, at the individual level, mobilising different types of legitimacy allows engagement in activities related to innovation and societal impact. Our results suggest that building legitimacy would seem to be an effective strategy for scientists keen to engage in practices that might conflict with prevailing academic norms or assessment priorities.

The second contribution of our paper is its multifaceted conceptualisation of scientists' legitimacy. So far, most prior research on reputation and legitimacy in science focuses exclusively on scientists' publication records or peer recognition in the form of academic citations, which are used to proxy for accumulated legitimacy (e.g., Azoulay et al., 2007; Lowe and Gonzalez-Brambila, 2007). While this type of credibility and endorsement is important, it is only one among several other types. We drew on the creativity and innovation management literatures (Bunduchi, 2017; Perry-Smith and Mannucci, 2017) to propose three sources of legitimacy in science, which are broadly in line with Suddaby et al. (2017) configurations of legitimacy: as process, property and perception. Our results suggest that all three sources of legitimacy are important for promoting biomedical scientists' participation in innovation.

The third contribution is our operationalisation of research-related legitimacy ties, that is, the type of legitimacy derived from the scientists' personal research networks. Prior research in different fields, suggests that features of the focal individual's social network are predictors of his or her reputation and legitimacy. For instance, Mehra et al. (2006) found that the centrality of firm leaders in external and internal friendship networks was associated to greater reputation among subordinates. In science, many studies employ bibliometric data and centrality in co-authorship networks to proxy for academic reputation (Badar et al., 2013; Li et al., 2013). However, much of this work takes a structural approach and examines aspects such as network density, brokerage, or composition. Although our study acknowledges the importance of structural centrality as a source of legitimacy, we adopt a relational perspective to more directly examine the properties of the dyadic linkages among network partners (Chua et al., 2008; Levin et al., 2011; Levin and Cross, 2004; Moran, 2005). Drawing on Levin and Cross (2004), we tried to disentangle the social exchanges that provide the focal scientist with research-related legitimacy - specifically, validity and credibility to support scientists' research activities. Our findings are robust to the influence of other personal network attributes (network density and tie strength), which confirms the supplementary explanatory power of a relational approach to capture the importance of personal networks for achieving legitimacy and endorsement for research agenda.

The final contribution is related to the strong association between direct interactions with beneficiaries and scientists' involvement in innovation. Our results are consistent with claims about the importance of productive interactions for explaining how academic knowledge achieves societal impact (Molas-Gallart and Tang, 2011; Spaapen and Drooge, 2011). Our findings are in line with research that highlights the importance of patient organisations in biomedical research, arguing that interactions with beneficiaries provide new knowledge on particular applications, in terms of identification of new research targets and improved quality and effectiveness of the information collected and protocols followed. For instance, in the specific case of rare-diseases, patient organisations can provide crucial experience-based knowledge and help to prioritise research goals (Aymé et al., 2008; Mavris and Le Cam, 2012). In addition to providing evidence for the strong association between direct interaction with beneficiaries and involvement in innovation, our analysis shows that beneficiary-based legitimacy is more important for scientists with fewer research-related legitimacy ties. In other words, establishing close connections with patients, patients' associations and medical practitioners is especially important for scientists who do not count on social endorsement to support their research agendas. This is characteristic of scientists working on novel, breakthrough topics that diverge from their academic discipline. While these scientists might find it difficult to garner support from their community (Chai and Menon, 2019), this might be mitigated by support from research beneficiaries. In this regard, many patient organisations are involved in strategic decisions and suggest specific problems for inclusion in research agendas, providing social legitimation for prioritising specific research topics (Rabeharisoa, 2003).

5.2. Implications for managers and practitioners

Pressure from society to demonstrate the practical results of scientific research is especially strong in biomedicine where the expectation in society is that scientific research should deliver both fundamental scientific discoveries and innovative new treatments and improved healthcare. However, this dual expectation faces significant challenges. Our findings shed new light on some mechanisms that might facilitate scientists' participation in commercial activities and applications of scientific research. The results of our study contribute to research using social network analysis to assess translational research in biomedicine (e.g., Leischow et al., 2008; Lurie et al., 2009).

We show that, although the focus of translational initiatives is on creating close connections among distinct biomedical actors, the flows of intangible resources these links allow are equally important. For example, a scientist who occupies a prominent position within a research network but fails to cultivate a network of contacts able to endorse and provide credibility for her research agenda will be less likely to participate in innovation activity. Since most of the scientists in our sample are affiliated to a university or a hospital, our findings show that this relationship works in both basic and clinical-oriented research settings.

Also, our relational network approach should help policymakers to formulate more tailored translational policy initiatives. Further research could investigate alternative combinations of of structural and relational network approaches to understand how certain network configurations contribute to the translation of scientific findings into applications. For instance, exploring whether participation in a network of heterogeneous actors convers greater legitimacy, or how basic scientists acquire legitimacy via their clinical counterparts would seem potentially relevant directions for future research. In addition, the finding that contact with beneficiaries is more relevant for scientists with lower levels of legitimacy ties in their personal research networks has significant implications. A stronger focus on the relational architecture of scientists' jobs (Grant, 2007), which affects the opportunities to connect to and interact with potential research beneficiaries, could enhance scientists' downstream knowledge and enable greater participation in innovation activities.

We argue that proximity to users could have a positive effect on the perceived social impact of research among relevant stakeholders and could provide the scientist with social credibility and support for implementing the findings from scientific discovery. In this sense, beneficiary-based legitimacy would increase the chances of successful translation of basic scientific research into practical applications in biomedicine. Therefore, a research network that allows direct interaction with beneficiaries would provide another way to achieve legitimacy and, potentially, might compensate for lack of other relational forms of legitimacy mobilisation through research network partners.

5.3. Limitations

Our study has some limitations which could be addressed in future studies. Similar to most research based on survey and cross-sectional data, it is difficult to establish direct causal relations. We have avoided causal inferences and provide systematic and robust statistical associations among the key variables in our study. Moreover, we conducted a number of robustness checks with different specifications, which showed that our findings are robust to alternative measures and regression analyses. Further research could employ a longitudinal approach to complement the analysis in this paper and check the validity of our results. Relatedly, it should be noted that the different items that constitute the basis for our dependent variable do not provide direct indicators of the impact on patients' health. Instead, our survey captured a set of activities and practices that, subsequently, might lead to a positive impact on beneficiaries. Also, the set of activities we considered to address the multifaceted nature of medical innovation do not capture aspects such as the availability and coverage of medical devices and drugs after regulatory approval, which, we acknowledge, is a significant milestone in the assessment of healthcare systems. Future work could extend our study by including more direct proxies for larger healthcare impact (e.g., patients impacted, total revenue from a developed diagnostic, etc.), and explore whether our results still hold.

Moreover, our survey data refer to the context of biomedical research in Spain. While our focal scientists belong to a variety of biomedical research fields and environments, it would be interesting to explore the extent to which our findings are generalisable to other countries and/or research settings. Finally, our variable for research-based legitimacy ties was based on the social ties considered by our respondents to be particularly important or relevant for their research-related activities. While this allowed us to disentangle validity and credibility from other tangible and intangible resources that might flow through the network, future work could explore alternative ways to capture research-related legitimacy. It might investigate whether there is an imprinting legitimacy effect derived from pre-existing ties (Guercini and Milanesi, 2019) or being a part of highly reputed scientific teams (Thomas et al., 2020).

Table A1
Response rate and usable responses by CIBER.

	Population surveyed	Nº of returned questionnaires	Response rate (%)	Nº of useable responses	% of useable responses (relative to population surveyed)
CIBER – BBN	872	238	27.3	175	20.1
CIBER – DEM	331	96	29.0	78	23.6
CIBER – EHD	459	154	33.6*	119	25.9*
CIBER – ER	517	177	34.2*	144	27.8*
CIBER – ES	439	159	36.2*	133	30.3*
CIBER – ESP	610	107	17.5*	75	12.3*
CIBER – NED	750	186	24.8	143	19.1
CIBER – OBN	303	71	23.4	50	16.5
CIBER – SAM	477	121	25.4	76	15.9*
Total	4758	1309	27.5	993	20.9

Note: *indicates significant statistical difference in response rates ($p < 0.05$). Statistical significance was calculated by comparing the relative frequency with which the surveyed scientists are classified into the categories of respondents and non-respondents. A Chi-squared test was performed to compute statistical differences.

Table A2
Negative binomial regressions. Dependent variable: frequency of participation in distinct medical innovation activities.

	M1		M2		M3		M4		M5		M6	
	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors
Research-related legitimacy-ties			0.188***	(0.06)	0.131**	(0.06)	0.118*	(0.06)	0.228***	(0.07)	0.215***	(0.07)
Reputation-based legitimacy					0.021	(0.07)	0.050	(0.06)	0.024	(0.07)	0.056	(0.05)
Beneficiary-based legitimacy					0.293***	(0.06)	0.304***	(0.06)	0.402***	(0.07)	0.418***	(0.07)
Legitimacy-ties * Reputation							0.129	(0.08)			0.141*	(0.07)
Legitimacy-ties * Beneficiary									−0.144***	(0.03)	−0.149***	(0.03)
Problem-solving ties	0.004	(0.07)	−0.003	(0.07)	−0.099	(0.07)	−0.117*	(0.07)	−0.143**	(0.07)	−0.163**	(0.06)
Network density	0.034	(0.09)	−0.060	(0.09)	−0.130	(0.09)	−0.112	(0.09)	−0.201**	(0.10)	−0.184*	(0.10)
Network density_sqr	−0.009	(0.06)	0.059	(0.06)	0.094	(0.06)	0.079	(0.06)	0.129**	(0.07)	0.114*	(0.07)
Network range	0.198**	(0.08)	0.142*	(0.08)	0.098	(0.08)	0.093	(0.08)	0.079	(0.08)	0.074	(0.08)
Avg. tie strength	0.146**	(0.06)	0.125**	(0.06)	0.139**	(0.06)	0.150**	(0.06)	0.129**	(0.06)	0.140**	(0.06)
Extrinsic motivation	0.208***	(0.07)	0.187***	(0.06)	0.187***	(0.06)	0.190***	(0.06)	0.176***	(0.06)	0.177***	(0.06)
Intrinsic motivation	0.071	(0.05)	0.063	(0.05)	0.080	(0.05)	0.074	(0.05)	0.082	(0.05)	0.076	(0.05)
# published papers	0.117**	(0.05)	0.117**	(0.05)	0.132**	(0.05)	0.129**	(0.05)	0.120**	(0.05)	0.115**	(0.05)
Group size	0.168**	(0.08)	0.155*	(0.08)	0.130	(0.09)	0.116	(0.09)	0.136	(0.09)	0.123	(0.09)
PI tech. perf	0.096	(0.06)	0.088	(0.06)	0.113*	(0.07)	0.121*	(0.07)	0.120*	(0.06)	0.130**	(0.07)
University (Dum = 1)	−0.091	(0.24)	−0.105	(0.24)	−0.086	(0.24)	−0.074	(0.24)	−0.086	(0.24)	−0.073	(0.24)
Hospital (Dum = 1)	1.122***	(0.23)	1.103***	(0.23)	0.967***	(0.23)	0.977***	(0.23)	0.916***	(0.22)	0.924***	(0.22)
PRO (Dum = 1)	0.232	(0.25)	0.227	(0.25)	0.238	(0.24)	0.233	(0.24)	0.261	(0.24)	0.256	(0.24)
Cons	0.271	(0.33)	0.195	(0.32)	0.281	(0.32)	0.315	(0.33)	0.231	(0.32)	0.260	(0.32)
Lnalpha	0.478***	(0.10)	0.455***	(0.10)	0.409***	(0.10)	0.400***	(0.10)	0.377***	(0.10)	0.365***	(0.10)
CIBER dummies	Yes		Yes		Yes		Yes		Yes		Yes	
Academic position	Yes		Yes		Yes		Yes		Yes		Yes	
N	993		993		993		993		993		993	
Log pseudolikelihood	−1591.3		−1586.0		−1574.9		−1572.7		−1568.7		−1566.1	

Note: *p < 0.1, **p < 0.05, ***p < 0.01. Robust standard errors are clustered by CIBER.
Coefficients for continuous variables have been standardised.

Table A3
Ordered probit regressions. Dependent variable: Innovation involvement.

	M1		M2		M3		M4		M5		M6	
	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors	coef.	std. errors
Research-related legitimacy-ties			0.147***	(0.05)	0.135**	(0.06)	0.137**	(0.06)	0.215***	(0.06)	0.216***	(0.06)
Reputation-based legitimacy					0.021	(0.03)	0.051	(0.03)	0.020	(0.03)	0.051	(0.03)
Beneficiary-based legitimacy					0.294***	(0.05)	0.298***	(0.05)	0.373***	(0.05)	0.377***	(0.05)
Legitimacy-ties*Reputation							0.093	(0.06)			0.098*	(0.06)
Legitimacy-ties*Beneficiary									−0.106***	(0.03)	−0.108***	(0.03)
Problem-solving ties	0.002	(0.08)	−0.094	(0.09)	−0.082	(0.10)	−0.083	(0.10)	−0.066	(0.10)	−0.064	(0.10)
Network density	0.077	(0.07)	0.075	(0.07)	0.023	(0.07)	0.027	(0.07)	−0.023	(0.07)	−0.022	(0.07)
Network density_sqr	−0.073	(0.05)	−0.071	(0.05)	−0.047	(0.05)	−0.051	(0.05)	−0.026	(0.05)	−0.028	(0.05)
Network range	0.054	(0.06)	0.049	(0.06)	0.013	(0.06)	0.013	(0.06)	−0.012	(0.06)	−0.013	(0.06)
Avg. tie strength	0.104***	(0.04)	0.093**	(0.04)	0.106***	(0.04)	0.108***	(0.04)	0.096**	(0.04)	0.100**	(0.04)
Extrinsic motivation	0.136***	(0.04)	0.125***	(0.04)	0.112***	(0.04)	0.114***	(0.04)	0.113***	(0.04)	0.115***	(0.04)
Intrinsic motivation	0.015	(0.04)	0.009	(0.04)	0.015	(0.04)	0.015	(0.04)	0.019	(0.04)	0.020	(0.04)
# published papers	0.122***	(0.05)	0.127***	(0.05)	0.126***	(0.05)	0.123***	(0.05)	0.119**	(0.05)	0.116**	(0.05)
Group size	0.078	(0.06)	0.072	(0.06)	0.059	(0.06)	0.054	(0.06)	0.055	(0.06)	0.051	(0.06)
PI tech. perf	0.049	(0.04)	0.046	(0.04)	0.062	(0.05)	0.062	(0.05)	0.074	(0.05)	0.073	(0.05)
University (Dum = 1)	−0.063	(0.16)	−0.049	(0.16)	−0.041	(0.16)	−0.031	(0.17)	−0.036	(0.17)	−0.026	(0.17)
Hospital (Dum = 1)	0.816***	(0.15)	0.822***	(0.15)	0.666***	(0.16)	0.675***	(0.16)	0.653***	(0.16)	0.663***	(0.16)
PRO (Dum = 1)	0.011	(0.16)	0.033	(0.16)	0.042	(0.16)	0.048	(0.16)	0.061	(0.16)	0.064	(0.16)
External network size	0.093	(0.09)	0.085	(0.10)	−0.055	(0.10)	−0.062	(0.10)	−0.100	(0.10)	−0.107	(0.10)
_cons/cut1	−0.148	(0.24)	−0.157	(0.24)	−0.262	(0.25)	−0.266	(0.25)	−0.274	(0.25)	−0.281	(0.25)
_cons/cut2	0.724***	(0.24)	0.717***	(0.24)	0.637**	(0.25)	0.633**	(0.25)	0.635**	(0.25)	0.629**	(0.26)
_cons/cut3	1.584***	(0.24)	1.582***	(0.24)	1.539***	(0.25)	1.539***	(0.25)	1.542***	(0.25)	1.540***	(0.25)
CIBER dummies	Yes		Yes		Yes		Yes		Yes		Yes	
Academic position	Yes		Yes		Yes		Yes		Yes		Yes	
N	993		993		993		993		993		993	
Log pseudolikelihood	−1038.8		−1035.3		−1016.2		−1015.0		−1010.1		−1009.2	
R^2 McKelvey & Zavoina	0.283		0.288		0.319		0.321		0.332		0.334	

Note: *p < 0.1, **p < 0.05, ***p < 0.01. Robust standard errors are clustered by CIBER. Coefficients for continuous variables have been standardised.

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