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Researchers engaging with society: who does what?

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Distinguishing between research collaboration, consultancy, dissemination, and commercialization of research results, this paper analyses the determinants of researchers' societal engagement. The analytical framework integrates societal engagement as part of the credibility cycle. Several variables extend previous findings on determinants and mechanisms—herein scientific recognition and funding sources. A novel method to investigate the relationship between scientific recognition and societal engagement is explored. Drawing on a large-scale survey of European-based researchers in physics, cardiology, and economics, we find that several factors are associated with different modes of societal engagement in complex and intersecting ways. Scientific recognition is positively associated with research collaboration and dissemination, while organizational seniority is associated with all modes except for research collaboration with non-scientific actors. Female gender is positively associated with dissemination and external funding sources are positively associated will all. The findings intersect with differences in the three research fields.

Keywords: societal engagement; scientific recognition; organizational seniority; funding source; gender.

1. Introduction

Researchers' engagement with society is attracting continued interest in policy and academic circles (Perkmann et al. 2013, 2021; Thune et al. 2016). The cornerstone idea is that societal engagement contributes to dissemination of scientific knowledge and generates beneficial societal impacts in the long term, while researchers gain inspiration, contacts, and additional resources that can enrich their scientific work. Consequently, there is a consensus that societal engagement of researchers should be nurtured. However, one issue preventing the development of more nuanced support is that researchers can engage with society in numerous ways for several reasons. Not all individuals working in science have equal access to such opportunities, and not all researchers benefit equally from engaging with the society. Therefore, researchers have differential incentives for societal engagement. Without understanding who gets to engage with society and how, appropriate support measures cannot be effectively designed.

This paper advances the understanding of researchers' societal engagement in several ways. First, it develops an approach that analyses societal engagement as an intrinsic part of researchers' scientific work rather than as an additional component. To achieve this, it advances the understanding of societal engagement as part of the research credibility cycle (Latour and Woolgar 1986; Hessels, van Lente, and Smits 2009), which understands research career development as accumulating credibility and exchanging it for resources. In our analysis, the credibility circle serves as a heuristic framework.

Second, the paper introduces and analyses less commonly studied determinants of societal engagement: scientific recognition, fixed-term position, different funding sources, and scientific age, along with gender, career stage, and scientific field.

By conducting a comprehensive investigation of the relationship between these factors and different modes of societal engagement, we are able to provide a nuanced, robust analysis of the characteristics of researchers who actively engage with society. To separate modes of societal engagement, we build on the concept of academic engagement (Perkmann et al. 2021) and distinguish between four modes of societal engagement that encompass the breadth of interactions between science and society (Schneijderberg and Götze 2021): research collaboration, consultancy, dissemination, and commercialization.

The analysis is based on data from a large-scale survey conducted with researchers in cardiology, economics, and physics across five European countries. To assess the respondents' scientific recognition, citation analysis is employed, using data from Web of Science (WoS). The paper also makes a methodological contribution by introducing an innovative approach to operationalizing scientific visibility. Previous studies examining the relationship between scientific performance and societal engagement have relied on indicators such as number of publications, the h-index, and journal impact factors (e.g. Abramo, D'Angelo, and Di Costa 2011; Houweling and Wolff 2020). Our study measures the citation rate at the article level and employs well-established methods to normalize data according to field and publication age. Additionally, we use three indicators of citation impact that capture different aspects of scientific recognition to provide complementary insights.

The findings enhance our comprehension of researchers' societal engagement as a multifaceted and multidimensional phenomenon. Highly recognized 'star' scientists seem to have the opportunity to capitalize on their reputation and build public intellectual profiles. Consultancy and commercialization opportunities appear to be more exclusive and are more likely to be available to researchers occupying senior full professorship positions. In contrast, research collaboration with non-scientific actors does not correlate with specific community or organizational accolades and is an inclusive mode of societal engagement available to all types of researchers. Our findings also highlight the powerful role of research steering through funding instruments and the persistence of gendered roles in academia, even in relation to societal engagement.

The paper is structured as follows. After introducing our analytical frameworks, we provide definitions of societal engagement and a review of previous literature on the topic. We then present our dependent and independent variables with a description of the scientific recognition variable, followed by methods, results, and discussion sections.

2. Analytical approach

Previous research has analysed various types of science–society interactions but has offered limited insights into the relation of societal engagement to research activity. On one hand, societal relevance and impact are increasingly recognized as dimensions that characterize research quality (Langfeldt, Nedeva, and Sörlin et al. 2020). On the other, prior studies have largely focused on the determinants of science–society interactions rather than the mechanisms that shape them (Kyvik 1994; Gulbrandsen and Smeby 2005; Bekkers and Bodas Freitas 2008; Jensen et al. 2008; van Rijnsoever, Hessels, and Vandeberg 2008; Abramo, D'Angelo, and Di Costa 2011; Bentley and Kyvik 2011; Haeussler and Colyvas 2011; Abreu and Grinevich 2013; Tartari, Perkmann, and Salter 2014; Banal-Estañol, Jofre-Bonet, and Lawson 2015; Tartari and Salter 2015; D'Este et al. 2019; Houweling and Wolff 2020; Pekşen et al. 2021; Perkmann et al. 2021; Fini, Perkmann, and Ross 2022). Furthermore, researchers in different scientific fields engage with society differently, create impact in various ways, and address different audiences (Spaapen and van Drooge 2011; Sivertsen and Meijer 2019).

In order to frame the relationship between researchers and society and explicate potential intervening factors for societal engagement, we mobilize the credibility cycle framework, a quasi-economic model of knowledge production that shows how researchers accumulate credibility over time in a cyclical process (Latour and Woolgar 1986; Hessels, van Lente, and Smits 2009). Credibility is a reputational resource in the academic community that can be converted into tangible assets for future research, such as research grants, academic positions, and opportunities to nurture high-level contacts. Thus, the construction of knowledge is inherently connected to the

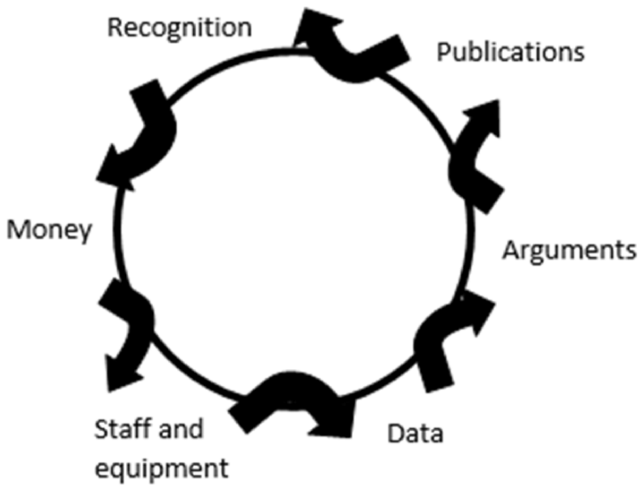

Figure 1. The credibility cycle (Latour and Woolgar 1986).

accumulation of credibility. Thus, conceived the research process can be depicted as a cycle in which conversions take place between money, staff, data, arguments, articles, recognition, and so on (Fig. 1). In this sense, credibility can be regarded as capital that takes different forms. The essential feature of the cycle is that credibility, once acquired, can be reinvested to gain more credibility.

Over the past few decades, the credibility cycle has been used to elucidate the choices and behaviours of academic researchers and explore variations over time and across epistemic cultures (Kwiek 2021; Hessels and van Lente 2011; Hessels et al. 2019). While the model is conventionally associated with scientific merit, empirical studies have demonstrated that non-academic accomplishments can also serve as sources of credibility, creating incentives for researchers to engage in society. In particular, patents (Packer and Webster 1996) and the practical implementation of research findings (Hessels and van Lente 2011) have been identified as non-research activities contributing to credibility accumulation. The opposite situation is also possible: if certain forms of societal engagement do not contribute to the accumulation of credibility, career-oriented researchers would be less likely to take part.

The challenge with integrating societal engagement in the credibility cycle is in the wide range of societal engagement types linked to a variety of scientific disciplines, which limits the possibilities of generalization. The relationship between the accumulation of credibility and societal engagement is non-linear, bidirectional, and influenced by intersecting factors and by broader institutional contexts. As there is limited research on integrating societal engagement into the credibility cycle, the initial step is to distinguish, as in Section 3, between various modes of engagement and their positions in the cyclical process of accumulating credibility. Next, we develop expectations in Sections 4 and 5 of the relationships between intersecting factors and the different societal engagement modes. The credibility cycle is used as a heuristic framework to help link societal engagement mechanisms and structure the determinants of engagement. Testing the credibility framework in relation to social engagement is a task for future research.

Table 1. Modes of societal engagement.

Mode of societal engagement	Conceptual explanation
Research collaboration	Scientific research projects that involve organizations outside the scientific community
Interactions and consultancy	Engagement that does not involve joint research, but other interactions with societal actors: consultancy, policy advice, NGOs, industry, etc.
Dissemination of research	Informing the public about research results, including outreach
Commercialization of research	Technology and knowledge transfer that create economic value from research: e.g. patents, licensing, start-ups

3. Modes of societal engagement in the credibility cycle

Scientists' societal engagement has been investigated in various national contexts, organizations, and scientific fields (e.g. Bekkers and Bodas Freitas 2008; Abreu, Grinevich, and Kitson 2009; Perkmann et al. 2013, 2021; Olmos-Peñuela, Molas-Gallart, and Castro-Martinez 2014; Thune et al. 2016). Key findings in that literature are that researchers engage with society in diverse ways (Sivertsen and Meijer 2019), and certain modes of engagement are more prevalent in some fields than others (Thune et al. 2016). Our review of empirically tested determinants of researchers' societal engagement (Appendix Table A1.1) highlights that most studies differentiate between engagement modes, with only a minority examining academic engagement as a unified concept (Perkmann et al. 2013). Based on this, four key modes of societal engagement are distinguished: collaborative research with non-academic partners, contract research and consulting, dissemination of research results in the wider society, and various forms of commercialization (patenting, firm formation, and others). [Education, especially vocational education, has been cited as a form of societal engagement, but only in specific contexts (Thune et al. 2016).] Definitions are presented in Table 1.

Previous research has examined in detail the determinants of these four modes of societal engagement. The vast majority are associated with researchers' individual characteristics: their disciplinary background and research orientation, organizational position and seniority, funding situation, and demographic characteristics. Despite this extensive list of determinants influencing societal engagement, research has not yet explained the mechanisms which link individual characteristics with engagement activities.

A key observation on the role of societal engagement in the credibility cycle is that it is bidirectional and is differentiated across modes of engagement. Researchers may wish to engage with society to gain credibility and/or as the result of already having a certain amount of credibility. On the other side, societal actors may seek credible experts who can provide input in addressing complex problems. In such a heterogenous and multifaceted realm of science–society interfaces, two factors may be of particular importance: the amount of credibility that enables researchers to engage with society and the credibility yield of different types of engagement.

First, different modes of engagement may require different baseline credibility endowments to enable meaningful interactions. For example, disseminating results among high-level policymakers usually require a certain level of recognized expertise (Fini, Jourdan and Perkmann 2018). Yet, being a part of a collaborative project with industry is a typical opportunity for early-career researchers to engage with society. The second factor concerns the credibility yield from societal engagement. Research collaboration with non-research partners can directly generate research results and in some cases does not differ from standard scientific practice. Non-academic partners also provide data that researchers could not have otherwise obtained, thus enhancing research outcomes. Importantly, they also provide access to resources and funding, generating a significant credibility yield (Packer and Webster 1996; Lee 2000). Some forms of commercialization have also led directly to increased scientific recognition, especially in certain natural sciences (Pitsakis, Souitaris and Nicolaou 2015).

Credibility yield from societal engagement differs across modes. For instance, consultancy is similar to commercialization in that it opens access to new data and resources like institutional contacts and funding. However, consultancy projects do not directly lead to research publications and thus enhance the researcher's credibility mainly in applied and practical contexts (Perkmann and Walsh 2008). Similarly, dissemination of research in the wider society can enhance researchers' reputations as accessible and trustworthy public experts and boost their institutions' altmetric performance (Bornmann 2015). However, such activities may not be recognized as valuable in the academic community, which tends to strongly favour scientific achievements (de Rijcke et al. 2016; Thelwall et al. 2023).

The nature of credibility accumulation by engaging with society may best be accessed through an in-depth qualitative examination. However, insights into the incentives linking credibility accumulation to research profiles and career outcomes can be connected to previous research on societal engagement determinants. Below, we review findings in the literature on engagement determinants and match them against the incentives of credibility accumulation to identify the gaps and other determinants worth examining.

4. Research profile, scientific productivity, and recognition

A number of determinants relating to scientists' research profiles are associated with societal engagement. Previous research has studied the association between different modes of engagement and scientific disciplines in depth and reports consistent differences (Abramo, D'Angelo, and Di Costa 2011; Jensen 2008; Abreu and Grinevich 2013; Pekşen et al. 2021; Perkmann et al. 2021). For example, physical sciences and engineering have been found to be strongly and positively associated with consultancy and research commercialization. When researchers report an overall applied or user-inspired orientation, these associations are stronger (Houweling and Wolff 2020). Social sciences, meanwhile, have an overall positive association with research collaboration, consultancy, and dissemination, but a mixed association with commercialization (Thune et al. 2016).

The association between scientific productivity and societal engagement has been investigated extensively, and studies have consistently reported positive association with all modes of societal engagement (Kyvik 1994, 2005; Lowe and Gonzalez-Brambila 2007; Bekkers and Bodas Freitas 2008; Abramo et al. 2009; Tartari, Perkmann, and Salter 2014; D'Este et al. 2019; Perkmann et al. 2021). Thus, highly productive researchers tend to engage with society, creating positive feedback loops between credibility accumulation and societal interactions.

The aspect that has not received similar scholarly attention is scientific recognition. Typically, operationalized as researchers' citation performance, scientific recognition is directly linked to credibility accumulation, because scientific articles are a key currency in the credibility cycle. A common assumption is that since societal engagement does not directly contribute to new scientific discoveries, engaging with society could conflict with the strategy of maximizing the citation impact of research outputs. Therefore, even if societal engagement generates some credibility, the opportunity cost of engaging with society rather than conducting research may be perceived as high.

However, the picture is more nuanced. Studies have identified a marginal positive relationship between citation impact and research collaboration with non-research actors and commercialization (Lebeau et al. 2008; Azoulay, Ding, and Stuart 2009; Perkmann and Walsh 2009; Fini, Perkmann, and Ross 2022). D'Este et al. (2019) established a strong link between scientific impact and new firm creation, and others have reported an inverted U-shaped relationship between societal engagement and scientific productivity and citations, suggesting that at some point the marginal growth in scientific credibility from investing in engagement starts to decline (Rentocchini et al. 2014; Muscio, Ramaciotti, and Rizzo 2017).

Findings on the relationships between scientific recognition and consultancy and dissemination are limited, and have not been robustly analysed alongside other societal engagement determinants. Some authors note that the frequency of media contacts by academics increases with the number of their peer-reviewed scientific publications (Peters et al. 2008), suggesting that greater accumulated scientific recognition may be associated with increased visibility among non-academic audiences. One reason for the mixed findings is variations in approaches to studying this relationship (Abramo, D'Angelo, and Di Costa 2011; Houweling and Wolff 2020).

Even though scientific productivity and scientific recognition are closely connected (Michalska-Smith, Allesina, and Jadhao 2017), they might be linked to credibility accumulation in different ways, because high-scientific recognition researchers gain credibility in at least two ways: by publishing articles and by receiving citations, both of which can be converted into credibility. The association between scientific recognition and societal engagement thus represents an important and under-investigated variable (Perkmann et al. 2021). Based on the marginally positive associations previously noted, we can anticipate a positive relationship between scientific recognition and research collaboration and commercialization.

5. Organizational seniority, funding, and demographic factors

Factors related to organizational seniority and resource endowments represent a second group of well-studied determinants of societal engagement. One key factor is who has the opportunity to engage with society, which we operationalize to include researcher career stage, funding situation, and gender.

Organizational seniority often reflects scientific recognition, as researchers can leverage their scientific reputation to obtain higher positions in their organizations, granting them access to more resources and more opportunities to accumulate credibility (Whitley 2000). Ascending to senior positions may also unlock additional opportunities for societal engagement. Generally, senior academic staff members have more personal contacts, experience, and networks with external actors than mid- and early-career researchers (Pekşen et al. 2021).

While most studies have found positive relationships between organizational seniority and all four modes of societal engagement (van Rijnsoever, Hessels, and Vandeberg 2008; Haeussler and Colyvas 2011; Pekşen et al. 2021), some have observed interesting differences between senior and early-career researchers. Senior researchers tend to be more engaged in research collaboration and dissemination, whereas early-career researchers are more involved in start-up development (Pekşen et al. 2021). The early-career group also appears to place a higher value on societal engagement than their senior colleagues, particularly in the humanities and social sciences (Schneijderberg et al. 2021). However, their incentives to actually engage with society are lower, because societal engagement is generally valued less in academic recruitment and promotion processes than heavily cited publications and the ability to obtain external research grants (Reymert 2021). As a result, early-career researchers need to focus on the latter aspects in order to transition from fixed-term to permanent positions.

The role of precarious employment as a societal engagement determinant has not been deeply investigated. However, it could be a significant intersecting factor that affects both junior and senior researchers in temporary positions and their incentive structures. As discussed earlier, researchers in such positions have greater incentives to focus on scientific work and types of societal engagement that yield more credibility at the expense of alternatives.

In summary, we anticipate a positive relationship between seniority and all modes of societal engagement; however, the extent of societal engagement especially in mid- and early-career stages may be moderated by whether researchers are employed on a fixed-term contract. We expect that such differences will be especially significant for modes of engagement that do not directly generate scientific credibility: consultancy and dissemination.

Funding has been previously found to be a powerful factor in steering researcher behaviour (Bloch and Schneider 2016; Deutz et al. 2021). Money plays a central role in the credibility cycle and funding bodies increasingly have expectations regarding societal engagement. In recent decades, competitive external public grants have gained in importance (Hicks 2012; Stephan 2012), and it is common for such grants to include selection criteria related to anticipated economic, environmental and societal impacts, particularly in Europe (de Jong and Muhonen 2020). However, only a few studies have examined the relationship between different funding sources and societal engagement. Research into the role of industry funding found a positive relationship between such funding and research collaboration and commercialization (Gulbrandsen and Smeby 2005). Others have found that public funding to universities complements private sources of funding provided through research contracts and consultancies (Muscio, Quaglione, and Vallanti 2013). Rich data about the role of funding as a determinant of dissemination and consultancy are lacking.

While research examining the influence of different funding streams on researchers' societal engagement is still evolving (Aagaard, Kladakis, and Nielsen 2020), it is reasonable to expect positive relationships between both public and private competitive external funding and all four modes of societal engagement.

The final category in the list of societal engagement determinants consists of demographic traits—gender and age—that are not only highly correlated with other significant variables associated with societal engagement but also have their own influences.

Findings on the association between age and societal engagement are mixed: some have reported a positive association between older age and the likelihood of societal engagement (Haeussler and Colyvas 2011; Abreu and Grinevich 2013), others have reported positive associations with the younger age (Houweling and Wolff 2020; Jensen et al. 2011; Pekşen et al. 2021). D'Este et al. (2019) and Gulbrandsen and Smeby (2005) did not find a significant association between age and technology transfer activities. The lack of consistency in age-related findings might be explained by the fact that studies typically use researchers' biological age in their analyses. While that is an important characteristic of diversity, it does not overlap perfectly with credibility accumulation. Indeed, the role of scientific age has not yet been sufficiently investigated (Fini, Perkmann, and Ross 2022). Scientific age has the important aspect of highlighting 'outlier' researchers whose scientific age does not correspond with their organizational seniority. This could be taken as the indication of credibility trade-offs that have taken place over the course of researchers' careers. Thus, scientific age is a promising alternative to biological age in models investigating determinants of societal engagement (see Tartari, Perkmann, and Salter 2014).

Previous research reports consistent and significant associations between gender and all four modes of societal engagement: women are less likely to engage than men (Haeussler and Colyvas 2011; Jensen et al. 2011; Abreu and Grinevich 2013; Tartari and Salter 2015). The only exception is dissemination, for which findings are more mixed. Notably, in fields with higher proportions of women, gender disparities are reduced (Tartari and Salter 2015). The main explanation for the general differences observed are the gendered roles in academia, which are themselves influenced by numerous intersecting factors, creating differences in the inclination of men and women to engage with society. For instance, women may have less time for societal engagement because they often take on more administrative responsibilities and devote more time to teaching and mentoring than their male colleagues, who tend to have more career-oriented mindsets (Mitchell and Hesli 2013). Another issue is the uneven distribution of resources between male and female researchers (Steffy 2021), which impacts women's ability to generate scientific recognition and to be recognized as trustworthy experts in the wider society.

Recently, some studies have found that female academics are more likely than males to use specific engagement modes such as public engagement, meetings and informal advice (Lawson, Geuna, and Finardi 2021), and they value and engage in research aimed at contributing to societal ends more frequently than their male colleagues (Zhang et al. 2021). However, we anticipate that male academics will be more active overall in our four defined modes of societal engagement.

6. Methods and data

Three fields representing different academic cultures are analysed in this study: physics, cardiology, and economics. They differ in the dimensions of hard versus soft and pure versus applied, as outlined by Biglan (1973), indicating distinctions between objects of inquiry, the nature of knowledge growth, working methods, and the internal organization of research, external relations, and output (Whitley 2000). Physics may be characterized as hard and pure, while both economics and cardiology are found at intersections between the two binaries (Simpson 2017). Since there are variations at the subfield level (Becher 1994), the present study was attentive to internal differentiation. Particularly in physics, some subfields are characterized by cost-intensive experimental infrastructure and are largely international in their organization and collaboration patterns, while others are more individually oriented (Karaulova, Nedeva, and Thomas 2020).

The three fields are linked to society in demonstrably different ways (Sivertsen and Meijer 2019) and can be viewed as representing three research areas—the natural sciences, life sciences, and social sciences—although they may not perfectly represent those academic paradigms. Physics is often associated with industry and work experience outside academia is more common than in the social sciences (Reymert and Thune 2022). Cardiology is translational, meaning it applies basic research in clinical settings and thus moves from pure to applied research. As a social science, economics often relies on data provided by national authorities, and outreach activities frequently involve consulting or general dissemination (Hylmö 2018).

6.1 Survey and other data sources

The present study analyses data from a large web survey regarding research conditions that linked respondents' answers with their scientific publications. The data cover researchers in physics and economics in five countries (Denmark, the Netherlands, Norway, Sweden, and the UK), and cardiology researchers in Norway, the Netherlands, and Sweden. (Cardiology was not covered in the UK and Denmark because of challenges in identifying respondents.)

National differences are not examined in this study. Previous research highlights that factors influencing researchers' societal engagement are more likely to arise from disciplinary, institutional, and local factors rather than national factors, and this perspective is emphasized in our research design (Haeussler and Colyvas 2011; Thune et al. 2016). However, we acknowledge that national research and evaluation systems do impact societal engagement, particularly in countries with a higher proportion of competitive funding for universities (Gläser, Lange, and Schimank 2010; Pekşen et al. 2021). Since four of the countries in our study share relatively similar conditions—the exception is the UK—investigating country differences is beyond the study scope. [The study is part of a larger research project (name anonymized), and all countries are represented by affiliated researchers in the project to ensure in-depth knowledge about their research systems. Our preliminary analyses also revealed a lack of significance in national-level variables, supporting our focus on within-discipline factors.]In each country, major research organizations were invited to participate in the survey. The selection of these organizations followed a two-step sampling strategy. For each country, we referred to the WoS journal categories to identify key research organizations and included those that had a minimum number of articles in the relevant journal category: 'Physics', 'Economics', and 'Cardiac and Cardiovascular Systems'. Next, we searched these organizations' websites to identify relevant organizational units to include in the survey. Approximately 66 per cent of the sample was identified using WoS data, while the remaining 33 per cent was added by accessing staff lists on the organizations' websites. Consequently, the sample included researchers with and without scientific publications listed on WoS, thereby encompassing different publication patterns.After the organizations were selected, all active researchers in the three fields were invited to participate in the survey. Respondents who indicated that they were not active researchers were excluded from the study. A total of 2,587 researchers completed the survey, resulting in an overall response rate of 22.3 per cent.

We then matched respondents with their WoS-listed publications between 2011 and 2017, allowing for a citation window until the end of 2018. We successfully matched 2,021 respondents to a total of 59,530 publications that received a cumulative total of 1,215,385 citations. The remaining 566 respondents could not be matched using this procedure. (We attribute this to both errors and the fact that a portion of active researchers in our sample did not have WoS publications. Such research profiles could be explained, for example, by being early in the career or focusing on applied contract research that does not necessarily result in journal publications in English.) Since respondents had the option to choose not to answer certain questions, the number of valid responses differed with the variables included in the analysis. Ultimately, approximately 1,610 respondents were included in each regression analysis.

Response rates were relatively consistent across the fields: 19.8 per cent for economics, 23.0 per cent for physics, and 24.2 per cent for cardiology. However, there were significant variations in response rates between countries, with the highest response rate observed in Norway (46.9 per cent) and the lowest in the UK (9.1 per cent; see Table 2).

6.2 Dependent variables

Table 3 details the survey's operationalization of societal engagement modes.

Respondents were asked to assess their involvement in various activities over the previous 5 years using a three-point Likert scale (*not at all, to some extent, to a large extent*). The activities included research, teaching and supervision, research management, clinical work, and four modes of societal engagement: research collaboration, consultancy, dissemination, and commercialization.

Table 2. Respondents by country and field.

Country	Cardiology	Economics	Physics	Total	Response rate (%)
Denmark	N/A	50	101	151	19.3
The Netherlands	93	139	162	394	14.9
Norway	181	135	229	545	46.9
Sweden	140	86	523	749	30.4
UK	N/A	47	135	182	9.1
Total	414	457	1,150	2,021	22.3
Response rate (%)	24.2	19.8	23.0		

$N = 2{,}021$.

Based on the responses, four binary dependent variables were created. If respondents indicated involvement to some extent or to a large extent, they were coded as engaged with society in that mode. If they indicated no involvement, they were categorized as not engaged. This approach was taken due to the incommensurability of assessments across response options. It was necessary to differentiate between engagements in different modes, as respondents were asked about their engagement in both research and teaching within the same set of questions.In absolute terms, a larger number of respondents were engaged in the dissemination of their research than in any other mode of societal engagement (Table 4). In fact, only 36 per cent of respondents did not engage in disseminating their research results. Research collaboration (58 per cent engaged) and consultancy (46 per cent engaged) were also popular modes. By contrast, only 24 per cent of respondents were involved in research commercialization activities.

6.3 Independent variables

Reflecting the expectations based on the review of previous studies on intersecting factors, four independent variables characterizing individuals and their modes of engagement with society were calculated: scientific recognition, career position, gender, and funding.

6.3.1 Scientific recognition groups. Applying journal impact factors as predictors of article impact, as suggested by Houweling and Wolff (2020), is a poor measure due to the skewed distribution of citations within journals (Zhang, Rousseau, and Sivertsen 2017). The distribution of scientific citations typically follows a long-tail pattern in which a small minority of researchers receive the majority of citations (Seglen 1992). This poses challenges in using citation indicators directly as a continuous independent variable in regression analysis. Therefore, in this study, we use direct citations of each article and combine three established indicators of citation impact that complement one another by representing different aspects of scientific recognition. We have constructed recognition categories with varying numbers of researchers in each category. The respondents were divided into three scientific recognition groups—high, medium, and low—based on the citation metrics of their articles on WoS. To assign individuals to a group, we used three complementary

Table 3. Dependent variable: modes of societal engagement.

Mode of engagement	Research collaboration	Interactions/consultancy	Dissemination of research	Commercialization of research
	To what extent did your work in the past 5 years involve the following activities?			
Specification in the survey	Research collaboration with actors outside science (e.g. industry and private sector, government organization, municipality, NGO)	Consultancy outside science (e.g. industry and private sector, government organization, municipality, NGO)	Informing the public and public debate	Commercialization of research (patents, licences, spin-offs)

Table 4. Modes of societal engagement.

Modes of societal engagement	Percentage		
	No	Yes	N
Collaboration	42	58	1,960
Consultancy	54	46	1,952
Dissemination	36	64	1,945
Commercialization	76	24	1,945

citation indicators by capturing different aspects of scientific recognition:

- Total number of citations, which can be high among very active and prolific researchers who influence the field with many publications;
- Number of citations per article compared with the average in the same field and year of publication, which permits researchers with fewer publications to earn high scores and is thus especially relevant for early-career academics;
- The share of publications in the top 10 per cent of most cited publications in the same field and year of publication, which permits researchers with extraordinarily influential publications to earn high scores.

We used these criteria to categorize respondents into three groups. The high-scientific recognition group comprised respondents ranked in the top 33 per cent in all three criteria in their field. The medium-scientific recognition group consisted of respondents who ranked in the top 66 per cent in all three criteria in their field. The low-scientific recognition group comprised respondents who scored under the top 66 per cent in at least one criterion within their field.

As per our design, the high-recognition group is the smallest and the low-recognition group the largest, encompassing nearly 50 per cent of respondents. Researchers in the high-recognition group account for only 18 per cent of respondents but received 70 per cent of the citations. The medium-recognition group comprises 33 per cent of respondents.

Before incorporating this operationalization of scientific recognition into the analysis, we estimated regression models with each citation indicator separately in the models for each dependent variable. To address potential issues such as inflated standard errors, the indicators were log-transformed prior to inclusion in the regression models (Field, Miles, and Field 2012). The regression results demonstrated that each indicator had significant effects on one or more of the dependent variables (Appendix Tables A2.1–2.4). Hence, it is crucial to consider all three citation indicators in relation to researchers' societal engagement.

However, due to multicollinearity issues, we were unable to include all indicators in the same model while obtaining controlled effects for each indicator. Multicollinearity can heighten uncertainty and pose challenges in significance testing (Stoltzfus 2011). This highlights the importance of using a grouped operationalization of scientific recognition, which enables the simultaneous consideration of all three citation indicators.

6.3.2 Career stage. We incorporated independent variables that captured two aspects of respondents' careers: the seniority of their position and whether it was temporary or permanent. The majority of respondents (75 per cent) held permanent posts. Position was categorized into three options: assistant professor (including postdocs, representing the early-career stage), associate professor (representing the mid-career stage), and full professor (representing the senior career stage). (The survey also reached those holding clinical positions, PhD students, and others; all such respondents were removed.) Nearly half the sample consisted of full professors (49 per cent), while 27 per cent were associate professors and 24 per cent assistant professors.

To assess the representativeness of the respondents, we conducted a comparison between the respondents and the total population of higher education academics in Norway in 2018, using data from the Database for Higher Education. Two researchers translated the career categories into the Norwegian system, which had the highest response rate among the countries in the study. The results of the comparison revealed that the ratio between permanent and temporary positions was approximately the same as the total population, in which 73 per cent held permanent and 27 per cent temporary positions. However, it is important to acknowledge that this ratio may vary in other countries due to differences in career systems. Regarding the career stage, our sample exhibited a higher proportion of full professors than the Norwegian population; we address this issue in Section 6.5.

6.3.3 Gender. All three fields traditionally exhibit a gender imbalance, with men dominating the representation. This gender disparity is reflected in the distribution of respondents: 79 per cent men and 21 per cent women. This gender distribution remained relatively stable across all three fields. Descriptive statistics for all independent variables can be found in Table 5, and correlation tables for dependent and independent variables can be found in Appendix Table A3.1.

Table 5. Descriptive statistics for independent variables.

Variable	(%)	*N*
Scientific recognition group		
High	18	2,021
Medium	49	
Low	33	
Position		
Assistant professor	24	1,889
Associate professor	27	
Full professor	49	
Permanent	75	
Temporary	25	1,966
Gender		
Female	21	1,809
Male	79	
Funding type		
Funded by institution	64	2,021
Funded by external public sources	68	
Funded by external non-public sources	20	

6.3.4 Funding source. The survey included questions regarding six potential sources of funding for the respondents' research over the past 5 years. The options distinguished between internal and external funding and competitive and non-competitive funding. Respondents were asked to assess the significance—major, moderate, or minor—of each funding source or indicate if it was not a source of funding.

We grouped the six survey items into three variables: funded by the institution, funded by external public sources, and funded by external non-public sources. Further details can be found in Appendix Table A4.1. In our analysis, respondents who indicated a funding source was major or moderate were assigned a code of 1, while any other answer was coded as 0.

Based on these new variables, we observed that the majority of respondents in our sample were funded by their institutions (64 per cent) and/or external public sources (68 per cent), while only a minority received funding from external non-public sources (20 per cent).

6.4 Control variables

In addition to our independent variables, we included three control variables in our analyses because they could affect the relationships we are investigating.

6.4.1 Field. Scientific fields (economics, cardiology, and physics) are included as controls because their differences may have significant moderating influences on societal engagement. These fields may have varied levels of relevance for society and contribute in different ways to societal engagement.

6.4.2 Temporary employment. We also controlled for temporary employment, assuming that individuals in such positions may be less inclined to engage in societal activities, as their primary focus is likely to be on scientific publishing and meeting the criteria for securing a permanent position (Reymert 2021).

6.4.3 Scientific age. Additionally, we controlled for scientific age, which refers to the number of years since a researcher obtained a PhD. Researchers with longer scientific age may be more likely to have a higher number of scientific publications, hold senior positions, and participate in various forms of societal engagement. Therefore, scientific age is included as a control variable. In our sample, the minimum scientific age was one year and the maximum was 40 years. On average, the researchers had a scientific age of 16 years. Due to the skewed distribution of the variable, the scientific age variable included in the regression analysis has been log-transformed.

6.5 Empirical method

We conducted binomial logistic regression analyses because our dependent variables are binary, indicating whether researchers are engaged in different modes of societal engagement. To determine if the independent variables significantly explained the differences in our dependent variables, we performed analysis of variance (ANOVA) tests. Additionally, we evaluated goodness of fit (using AIC, BIC, and pseudo-R^2) by introducing independent variables stepwise into the model and comparing the results (Field, Miles, and Field 2012); see Appendix Tables A5.1–A5.4. Lastly, we used the variance inflation factors test to check for potential multicollinearity in our models (Lin 2008).

Cardiology was only included in three countries' samples due to challenges in defining the field and finding suitable respondents in Denmark and the UK. To examine whether the exclusion of cardiologists from those countries had any impact on our results, we constructed a binary quasi-weight variable and included it in our analyses. The findings from these additional analyses were consistent with our primary results, which are thus robust to alternative specifications of the models. The results of these supplementary analyses can be found in Appendix Tables A6.1 and A6.2.

We also considered organizational differences. Our sample consisted of respondents from comprehensive universities ($n = 1518$), technical universities ($n = 414$), and research institutes ($n = 89$). Although we observed some significant differences in engagement levels among different types of organizations—with respondents from technical universities reporting higher levels of engagement than others—the organizational variable did not have a significant impact on our primary results. Due to substantial variations in the distribution of respondents across organization types, we decided to omit organization type from our analyses (see Appendix Table A6.3).

Furthermore, we accounted for differences in the field of physics, which is highly diverse in terms of both cognitive and social research organization. We divided respondents based on a question about whether they primarily conducted research alone. This division resulted in significant differences only in terms of research collaboration outside the field of science (see Appendix Table A6.4).

Regarding the career stage-independent variable, it should be noted that our sample has a higher proportion of full professors than the general population of Norwegian universities. Although this introduces a bias in our sample, it is still sufficient for exploration purposes and to establish a relationship between the variables of interest (Czaja, Blair, and Blair 2014). To further investigate the potential consequences of this bias, we included position as a control for other independent variables in the model and applied weights to address potential variations in the estimates of the position variables caused by the sample bias (Skinner and Mason 2012). The resulting estimates had only minor differences

Table 6. Full models for all dependent variables.

	Dependent variable:			
Variable	Collaboration (1)	Consultancy (2)	Dissemination (3)	Commercialization (4)
Low scientific recognition	−0.382* (0.156)	−0.070 (0.157)	−0.654*** (0.172)	0.187 (0.187)
Medium scientific recognition	0.138 (0.156)	−0.010 (0.152)	−0.386* (0.169)	0.148 (0.176)
Assistant professor	−0.234 (0.174)	−0.512** (0.177)	−0.923*** (0.179)	−0.612** (0.224)
Associate professor	−0.188 (0.129)	−0.506*** (0.129)	−0.433** (0.135)	−0.263 (0.152)
Female	0.071 (0.135)	−0.282* (0.137)	0.470** (0.146)	−0.417* (0.173)
Funded by institution	−0.156 (0.119)	−0.129 (0.119)	0.247* (0.121)	−0.206 (0.136)
Funded by external public sources	0.514*** (0.121)	0.447*** (0.125)	0.485*** (0.126)	0.873*** (0.170)
Funded by external non-public sources	0.661*** (0.141)	0.548*** (0.134)	0.147 (0.141)	0.764*** (0.143)
Temporary position	−0.392* (0.155)	−0.236 (0.158)	−0.185 (0.157)	−0.075 (0.191)
Scientific age (log)	0.143** (0.054)	0.112* (0.056)	−0.137* (0.057)	0.142* (0.067)
Cardiology	0.135 (0.156)	0.605*** (0.151)	0.333* (0.160)	−0.331* (0.167)
Economics	0.269* (0.133)	1.279*** (0.136)	0.864*** (0.148)	−2.385*** (0.295)
Constant	−0.145 (0.270)	−0.768** (0.274)	0.944*** (0.285)	−1.671*** (0.333)
McFadden Pseudo R^2	0.066	0.083	0.068	0.148
Bayesian Inf. Crit.	2,151.675	2,137.592	2,020.152	1,621.384
Observations	1,616	1,614	1,605	1,606
Log likelihood	−1,027.817	−1,020.784	−962.100	−762.712
Akaike Inf. Crit.	2,081.634	2,067.568	1,950.201	1,551.425

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are high scientific recognition, full professor, permanent position, male, and physics.

from those in Table 6, leading us to conclude that our results remain robust despite the potential bias. (For results of regressions with the weighted position variable, see Appendix Table A6.5.)

To ensure clear communication and facilitate interpretation, we report the results of our analyses as average marginal effects in the text. Marginal effects provide insights into the percentage point change in the predicted probability of engagement when there is a one-unit change in the independent variables, such as male to female (Norton, Dowd, and Maciejewski 2019). Table 6 presents the results using logit coefficients, which are also used in the Appendix tables.

7. Results

Table 6 shows the full model of the regression analysis on the four dependent variables.

As expected, scientists in different research fields engage with society differently. Cardiologists and economists are more likely to participate in consultancy than physicists. Economists are more inclined to engage in dissemination activities and are much less likely to be involved in the commercialization of research results.

The headline finding of our study reveals a notable disparity between the scientific recognition of researchers and their modes of societal engagement. Compared to researchers in the high-scientific recognition group, those in the low- and medium-scientific recognition groups exhibit 13 and 7 per cent lower likelihoods of engagement in dissemination, respectively. There are also differences regarding collaboration with non-scientific actors: researchers in the low-scientific recognition group are 9 per cent less likely to report this mode of societal engagement. No significant differences in engagement were found between the low- and medium-recognition groups. Furthermore, the results indicate overlapping confidence bands between these groups, indicating that the probability of engaging in dissemination is not significantly different. Nevertheless, it is important to emphasize that the low-scientific recognition group comprises a rather heterogeneous population, with 65 per cent of assistant professors, 52 per cent of associate professors, and 38 per cent of full professors falling into this category. No significant differences were found for consultancy or commercialization.

In terms of organizational seniority, a strong association is reported between career stage and the likelihood of participating in consultancy, dissemination, and commercialization activities (but not in research collaboration with non-scientific actors). Specifically, associate professors exhibit an 11 per cent lower probability and assistant professors a 12 per cent lower probability of engaging in consultancy than full professors. The differences are even more pronounced in dissemination: associate and assistant professors have 9 and 20 per cent lower probabilities than full professors, respectively. Regarding commercialization, assistant professors show a lower likelihood of engagement than full professors. Furthermore, our findings indicate that researchers in temporary positions are 9 per cent less likely to participate in research collaboration with societal actors than their counterparts in permanent positions. The temporary position variable did not yield significant results for the other modes of engagement.

When examining gender differences, we observed distinct patterns in the three modes of societal engagement. In the case of consultancy and commercialization, women exhibited a 6 per cent lower probability of engaging than men, but women had a 10 per cent higher probability of engagement than men in dissemination.

To delve more deeply into these disparities, we conducted tests to investigate potential interactions between gender and other independent variables. The scientific recognition group and position variables did not yield any significant results in relation to gender. However, when comparing the representation of women and men across categories, we found that women were slightly overrepresented in terms of receiving funding from external public sources. We also observed a higher proportion of women in economics compared to the other two fields, and dissemination appeared to be a more common mode of engagement in economics than in those fields.

Finally, our findings indicate a significant and positive relationship between external public funding and all modes of societal engagement. Researchers who receive funding from external public sources have a 10 per cent higher probability of engaging in both consultancy and dissemination than those who did not report moderate or major external funding. Additionally, externally funded researchers exhibit 11 and 14 per cent higher likelihoods of engaging in research collaboration and in commercialization, respectively. Researchers who list external non-public sources as a moderate or major funding source also demonstrate a greater likelihood of participating in all modes of societal engagement except for dissemination. They have a 15 per cent higher probability of engaging in research collaboration and 12 per cent higher probabilities of engaging in both consultancy and commercialization. Researchers who described institutional funding as a moderate or major source have a 5 per cent higher probability of engaging in dissemination than researchers who did not.

8. Discussion

The objective of this paper was to examine the factors that play a significant role in researchers' involvement in various modes of societal engagement. In formulating the study's design, we established a link between the literature on determinants of researchers' societal engagement and the credibility cycle framework. This facilitated the propositions regarding the mechanisms that associate societal engagement with credibility accumulation, consequently prompting the inclusion of novel variables within the model. We used data from a comprehensive survey conducted across three scientific fields in five countries. Through empirical analysis, we investigated the relationships between researchers' scientific recognition, career stage, gender, and funding sources with four modes of societal engagement while controlling for research field, type of position, and scientific age.

In answering our research question—who gets to engage with society—no uniform clear pattern emerges. Rather, we find complex associations between seniority, career stage, scientific recognition, and gender emerge when we distinguish between modes of societal engagement. This broadly corresponds with the findings of previous studies, which generally reported complex results with a number of intersecting influences. The determinants of researchers' societal engagement identified in this study reflect two aspects of researchers' profiles: their previous achievements and their demographic characteristics. Drawing on the credibility cycle framework, we proposed that researchers' different career profiles and career outcomes associated with their different social engagement strategies in our data could be related to differences in credibility accumulation.

We observe a strong indication of these linkages for dissemination, which appears to be the form of societal engagement in which 'star' scientists can capitalize on their reputations, since both highly recognized and senior researchers are much more likely to engage in dissemination than other groups. It is reasonable to suggest that dissemination opportunities become available to researchers once they advance far enough in academic communities or in their careers (Laudel and Gläser 2008). There may be positive feedback loops for credibility accumulation of scientists engaged in dissemination; for example, their public profiles may attract a wider pool of motivated doctoral candidates, but such bidirectional influences are not investigated in this paper.

We find less clear evidence on associations between credibility accumulation and other types of societal engagement. Engagement in research collaboration with non-scientific actors does not differ markedly across researcher groups. This might mean that this type of engagement could yield credibility for both senior and junior and highly and less highly recognized researchers. The absence of significance might also mean that researchers do not require a substantial amount of credibility to engage with society in this way. Considering that research projects often involve a group of researchers at different career stages, research collaboration with non-academic actors may be the most common and inclusive mode of societal engagement.

The findings are also less clear regarding consultancy and commercialization. Seniority is a significant determinant, but scientific recognition is not. If a highly recognized researcher at the early- or mid-career stage has opportunities to engage in dissemination (which is also supported by a marginally negative association between dissemination and scientific age), then consultancy and commercialization opportunities are only available to researchers once they are in their senior career stages. Yet, as with dissemination, we cannot make a firm statement about the directionality of the influence: whether consultancy and commercialization help researchers move up the career ladder, or whether researchers have more chances to engage with society once they are full professors. If such feedback loops do exist, the benefits associated with commercialization will be higher for researchers in physics, while consultancy is significantly more prevalent in economics and cardiology.

In developing new variables that test an additional set of factors that influence societal engagement, our study primarily makes an empirical contribution to the literature. In the earlier sections, we developed three propositions about the likely positive associations of high scientific reputation, organizational seniority (moderated by temporary position), receipt of funding, and male gender with the four modes of societal engagement. In the following subsections, we revisit these expectations and propose plausible explanations.

9. Scientific recognition

Scientific recognition reflects the credibility accrued in prior achievements. Our findings indicate that unlike highly productive researchers, highly cited researchers are not significantly more likely to participate in societal engagement other than dissemination. Collaboration with non-research actors, consultancy, and commercialization do not appear to yield additional credibility in the scientific community, meaning that 'star' scientists do not have any greater interest or incentive to engage with society than ordinary researchers. Our initial proposition regarding a positive association is not supported.

These findings align to some extent with previous studies that report at a best marginal association between scientific recognition and societal engagement. For example, Fini, Perkmann, and Ross (2022) and D'Este et al. (2019) found that participation in commercialization leads to research with higher citation impact. Earlier contributions also discussed mutually reinforcing effects between commercialization and highly cited research (Packer and Webster 1996). However, it should be noted that both of those papers focus on academic entrepreneurship and do not compare it to other modes of engagement.

On the other hand, the absence of a negative association likely means that high scientific recognition does not come as a trade-off for societal engagement and vice versa. It is likely that societal engagement—especially commercialization and consultancy—offers advantages and trade-offs in terms of high-scientific impact strategies. In particular, by engaging in consultancy, researchers gain access to data and contacts, but such projects do not directly lead to research outcomes, reducing the total amount of time a researcher can spend developing publications (Rentocchini et al. 2014). This may even be positively associated with the number of publications due to additional resources but may have a less obvious trade-off with the quality of those publications.

An alternative explanation could be that societal engagement generates a different kind of credibility that is distinct from scientific credibility but still contributes to overall career development. For example, researchers could be motivated by what Perkmann and Walsh (2008) call opportunity-seeking, which can lead to additional income. Future research could consider whether such different types of credibility and expertise are mutually reinforcing with or inhibiting of scientific credibility and whether there are trade-offs.

Finally, it should be noted that our method to calculate scientific recognition relied on an advanced approach by grouping three indicators of citation impact in order to gain a more informed and nuanced understanding of scientific recognition. However, this may be another reason why our findings differ from what would be expected based on the insights of previous studies (e.g. Abramo et al. 2009).

9.1 Intersecting scientific recognition, career stage, and position type

In line with our expectations and with previous research, our findings indicate that organizational seniority is a strong predictor of societal engagement. When combined with the findings on scientific recognition, we observe a specialization in how researchers accumulate credibility in the more advanced stages of their careers (Laudel and Gläser 2008). While some researchers maximize their research outputs, others benefit from engagement modes with society, such as consulting work or commercialization.

Some previous studies have suggested certain differences in societal engagement of researchers at different career stages, such that senior academics are more engaged in research collaboration and dissemination, while early-career researchers show more involvement in spin-offs (Pekşen et al. 2021). Our findings align more with the literature on determinants of societal engagement, which has consistently reported a positive association between organizational seniority and engagement (Gulbrandsen and Smeby 2005; Bentley and Kyvik 2011; Haeussler and Colyvas 2011; Abreu and Grinevich 2013; D'Este et al. 2019). To build on these findings, we incorporated the variable about whether a researcher's position was temporary or permanent; it showed only a marginal negative association with research collaboration. When considered together with the negative marginal association of the low-scientific recognition group and collaboration, we can suggest that researchers who publish less, hold fixed-term positions, and are of lower scientific age tend to collaborate less with non-research actors. These could be junior academics with an applied or teaching orientation (and thus less apt to be highly cited) who are less likely to take part in such projects.

9.2 Funding sources

Funding source acknowledgement demonstrates the most consistent and positive association with all four modes of societal engagement with the exception of non-public funding and dissemination. This aligns with our expectations and supports the view that both public and private external funding are determinants of engagement, a previously underexplored question in the literature. These results demonstrate the influence of steering instruments on researchers' behaviour. Our results show a stark difference between the engagement of researchers who are funded by their institutions and those who are funded externally.

Based on our findings, we suggest that if researchers act according to the incentives created by the credibility cycle, they will not have significant extrinsic motivation to engage with society, whereas external funding does create such a motivation. While we cannot establish a causal effect of external funding on societal engagement, there is evidently a difference in terms of various sources of external funding and formal versus informal engagement modes, with dissemination falling into the latter category. Considering that societal engagement is increasingly becoming part of universities' mandates, our findings indicate that research organizations still need to enhance their efforts to develop an institutional culture that encourages societal engagement, even for researchers who are not externally funded.

9.3 Gender

Based on prior knowledge, we anticipated that male researchers would be more involved in all four modes. In support of that expectation, the results revealed gender-dependent differences. Our first finding—the marginally negative likelihood of women to engage in consultancy and commercialization—aligns with previous research (Haeussler and Colyvas 2011; Abreu and Grinevich 2013; Thune et al. 2016). Explanations of this association are well known and relate to a large extent to the gender bias in science. On the supply side, female researchers may be less inclined to promote their research and market themselves as 'experts' (Stephan and El-Ganainy 2007). On the demand side, third parties may perceive women as less competent than men, even if they hold similar positions and have comparable scientific achievements (Murray and Graham 2007). Furthermore, male scientists tend to place more emphasis on the scientific reward and recognition system (Van der Weijden et al. 2014). In policy contexts, the value of research is often linked to commercialization, entrepreneurship, job creation, and other economic impacts. These factors have progressively become incorporated into recognition and reward systems at universities and research institutes (Ouellette and Tutt 2020). Male researchers who prioritize their careers are more inclined to engage in such activities. Unlike previous research, our study did not find an association between gender and research collaboration with non-scientific actors. The reasons for this could be numerous, and we note that this relationship should be investigated further.

On the other side of this gendered divide is dissemination, which is more likely to be conducted by women in the three male-dominated fields examined in the present study. Given that men have higher rates of scientific publishing than women and are more likely to occupy senior positions—two conditions that seem to be relevant for dissemination—this finding is somewhat surprising. It is also inconsistent with some previous studies (e.g. Bentley and Kyvik 2011). However, there is also insufficient clarity in prior research, which has reported mixed results regarding gender and dissemination (Tartari and Salter 2015; Thune et al. 2016). Considering the credibility cycle, a plausible explanation could be that dissemination actually has the least association with accumulating scientific credibility among all four modes of engagement. If that is the case, we might observe a similar effect of gendered division of labour here, with men more likely to engage in societal engagement activities that yield higher credibility rewards and less advantageous forms of engagement left to women.

There are other possible explanations. Recent research has found that female researchers are more inclined to engage in research that addresses societal needs. Zhang et al. (2021) reported that women place more emphasis on the social contribution of their research than their male colleagues and that their publications are more widely read but less cited than those by male researchers. It may therefore be the case that female researchers are more involved in less formal modes of societal activities (cf. Lawson, Geuna, and Finardi 2021). While our results support these explanations, further investigation is needed to explore gender differences in modes of societal engagement.

10. Conclusions

Given the increasing demand and necessity for research addressing societal challenges, it is crucial to comprehend how research systems are integrated into other spheres of society. This paper contributes to the literature on societal engagement in three ways. First, we link societal engagement with the credibility cycle (Latour and Woolgar 1986; Hessels, van Lente, and Smits 2009). Second, we develop a method for studying scientific recognition that allows for the classification of researchers based on their scientific recognition, providing a more nuanced understanding of the relationships between scientific recognition, researchers' characteristics, and societal engagement. Unlike previous studies' focus on productivity and number of publications, this approach uses direct citation analysis to examine researchers' scientific recognition. Third, we investigate a number of new determinants of engagement and possible intersecting factors, including position type, funding type, and scientific age.

Our findings reveal the complex and multi-faceted environment of researchers' societal engagement, which indicates that the four modes of engagement—collaboration, consultancy, dissemination, and commercialization—are associated with different determinants, fit differently within the credibility cycle, and should be considered distinct phenomena. One key takeaway is that external public and private funding are both positively associated with all modes of engagement, underlining the importance of such instruments for supporting societal engagement.

We conclude by discussing the study's limitations and avenues for future research. Since our analysis is based on cross-sectional data, we do not claim a causal relationship between our independent and dependent variables. This also applies to the conceptual interpretation: since we do not test causality, we cannot make any claims about the nature of the associations drawn between societal engagements on the one hand and researchers' characteristics and prior achievements on the other. Rather, we use the credibility cycle framework as a heuristic device that aids interpretation rather than a concept to be extended in the empirical analysis. The role of the broader context, especially factors like organizational conditions and steering, has been examined to only a limited degree in the literature, and our article also suffers from this limitation. Given the high significance of funding we have identified, the role of other forms of steering should be investigated in future studies.

The paper also has certain methodological limitations. Like other work in the field, the research relies on data from a sample of researchers in a select number of fields and countries. In our study, as in others (Abreu and Grinevich 2013; Thune et al. 2016), only a small number of respondents reported engagement in commercialization, which may have influenced the results. Additionally, we only surveyed cardiologists in three of five countries. Nevertheless, we included that field in the analysis at the cost of the diminished relevance of the country dimension. While we did not find significant differences between countries in the preliminary analysis, this could be attributed to the low number of observations in some of them, particularly the UK. Consequently, the issue of how different national performance-based evaluation and funding systems influence researchers' societal engagement remains a topic for future research.

Future studies could purposefully sample countries and respondents to investigate the role of different types of public research organizations in national research systems in terms of specialization and societal engagement. Traditionally, studies in this field have focused primarily on multidisciplinary universities while disregarding the important roles of research organizations like technical universities and research institutes. Finally, we suggest that future studies explore gender differences among the various modes of societal engagement, particularly dissemination; the findings by Zhang et al. (2021) suggest that these differences also exist in other fields.

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Appendix

Table A1.1. Review of empirically tested determinants of researchers' societal engagement.

Variable	Academic engagement	Research collaboration	Consultancy	Dissemination	Commercialization
Individual determinants: characteristics of research					
Scientific productivity	+	++	+++	++ (high) - (low)	+
Scientific recognition		+			++
Applied or user inspired orientation	+	++	++		++++ -+ (basic)
Field: biology		+	+	++	+
Field: physical sci and engineering		+ -+	+++	-+	++++
Field: Social sciences		+	++	+	-+-
Field: Humanities		–	–		–
Individual determinants: organizational position and social capital					
Position: Professor	+	+++	++	+++	++++
Position: mid-career		+	+	++	++
Position: early career			+	+	
Collaborated with industry			+		++
Entrepreneurship experience	+	+	++	+	++
Previous employment in industry	++	+	++	–	+
Previous employment in public/ third sector		+	+	+	–
Demographic characteristics					
Age	++ (older)	+ (older) + (younger)	+ (older)	+-+ (older) + (younger)	+- (older) + (younger)
Gender	– (female)	– (female) + (male)	– (female) + (male)	± (female)	– (female) + (male)
Funding					
Received industry funding			+		+
Organizational determinants					
Supportive climate of KT services		+	+		+
Peers value patents, engage with industry	++		+		++

Source: Abramo, D'Angelo, and Di Costa (2011); Abreu and Grinevich (2013); Banal-Estañol, Jofre-Bonet, and Lawson (2015); Bekkers and Bodas Freitas (2008); Bentley and Kyvik (2011); D'Este et al. (2019); Fini, Perkmann, and Ross (2022); Gulbrandsen and Smeby (2005); Haeussler and Colyvas (2011); Houweling and Wolff (2020); Jensen et al. (2008); Kyvik (1994); Pekşen et al. (2021); van Rijnsoever, Hessels and Vandeberg (2008); Tartari, Perkmann and Salter (2014); Tartari and Salter (2015); Perkmann et al. (2021).
Only significant variables are represented in the table. The plus sign means a study identified a positive association; the minus sign means a study identified a negative association. The number of each type of sign equals the number of studies that found the variable significant.

Table A2.1. Research collaboration outside science—publication indicators.

	Dependent variable:			
	Research collaboration outside science			
Variable	(1)	(2)	(3)	(4)
Assistant professor	−0.214 (0.174)	−0.199 (0.173)	−0.214 (0.174)	−0.217 (0.174)
Associate professor	−0.191 (0.129)	−0.190 (0.129)	−0.191 (0.129)	−0.204 (0.129)
Female	0.063 (0.135)	0.068 (0.134)	0.070 (0.134)	0.069 (0.135)
Funded by institution	−0.170 (0.119)	−0.134 (0.118)	−0.142 (0.118)	−0.147 (0.118)
Funded by external public sources	0.475*** (0.123)	0.567*** (0.120)	0.546*** (0.120)	0.535*** (0.121)
Funded by external non-public sources	0.662*** (0.141)	0.668*** (0.140)	0.664*** (0.141)	0.670*** (0.141)
Temporary position	−0.400** (0.154)	−0.422** (0.154)	−0.409** (0.154)	−0.405** (0.154)
Scientific age (log)	0.093 (0.063)	0.229*** (0.049)	0.202*** (0.051)	0.177** (0.055)

(continued)

Table A2.1. (Continued)

Variable	(1)	(2)	(3)	(4)
	Dependent variable: Research collaboration outside science			
Cardiology	0.036 (0.157)	0.109 (0.154)	0.096 (0.155)	0.094 (0.155)
Economics	0.415** (0.141)	0.250 (0.132)	0.268* (0.133)	0.290* (0.134)
Total number of received citations (log)	0.133*** (0.039)			
Mean normalized citation impact score (log)		0.062 (0.119)		
Percentage publications in top 10% (log)			0.073 (0.038)	
Have publication in top 10%				0.294* (0.130)
Constant	−0.761*** (0.228)	−0.575* (0.229)	−0.582** (0.219)	−0.576** (0.219)
Observations	1,616	1,616	1,616	1,616
Log likelihood	−1,030.158	−1,035.849	−1,034.124	−1,033.461
Akaike Inf. Crit.	2,084.316	2,095.697	2,092.249	2,090.922

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are full professor, permanent position, male, and physics.

Table A2.2. Interaction/consultancy outside science—publication indicators.

Variable	(1)	(2)	(3)	(4)
	Dependent variable: Interaction/consultancy outside science			
Assistant professor	−0.514** (0.177)	−0.509** (0.177)	−0.509** (0.177)	−0.510** (0.177)
Associate professor	−0.504*** (0.129)	−0.509*** (0.129)	−0.509*** (0.129)	−0.510*** (0.129)
Female	−0.287* (0.137)	−0.282* (0.137)	−0.282* (0.137)	−0.282* (0.137)
Funded by institution	−0.147 (0.119)	−0.126 (0.119)	−0.126 (0.119)	−0.128 (0.119)
Funded by external public sources	0.397** (0.127)	0.457*** (0.124)	0.457*** (0.125)	0.452*** (0.125)
Funded by external non-public sources	0.544*** (0.134)	0.550*** (0.134)	0.550*** (0.134)	0.550*** (0.134)
Temporary position	−0.227 (0.157)	−0.242 (0.157)	−0.242 (0.158)	−0.240 (0.158)
Scientific age (log)	0.045 (0.065)	0.124* (0.051)	0.125* (0.053)	0.119* (0.056)
Cardiology	0.559*** (0.152)	0.601*** (0.151)	0.602*** (0.151)	0.599*** (0.151)
Economics	1.377*** (0.146)	1.278*** (0.136)	1.277*** (0.137)	1.282*** (0.138)
Total number of received citations (log)	0.077* (0.039)			
Mean normalized citation impact score (log)		−0.001 (0.123)		
Percentage publications in top 10% (log)			−0.002 (0.039)	
Have publication in top 10%				0.030 (0.135)
Constant	−0.977*** (0.235)	−0.838*** (0.236)	−0.837*** (0.225)	−0.843*** (0.225)
Observations	1,614	1,614	1,614	1,614
Log likelihood	−1,018.955	−1,020.923	−1,020.922	−1,020.899
Akaike Inf. Crit.	2,061.910	2,065.846	2,065.844	2,065.798

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are full professor, permanent position, male, and physics.

Table A2.3. Dissemination—publication indicators.

Variable	(1)	(2)	(3)	(4)
	Dependent variable: Dissemination			
Assistant professor	−0.937*** (0.179)	−0.943*** (0.180)	−0.951*** (0.180)	−0.949*** (0.180)
Associate professor	−0.456*** (0.135)	−0.444** (0.135)	−0.455*** (0.135)	−0.479*** (0.136)
Female	0.459** (0.147)	0.455** (0.146)	0.468** (0.146)	0.467** (0.146)
Funded by institution	0.218 (0.121)	0.240* (0.121)	0.243* (0.121)	0.235 (0.121)
Funded by external public sources	0.420** (0.128)	0.498*** (0.126)	0.489*** (0.126)	0.471*** (0.126)
Funded by external non-public sources	0.155 (0.141)	0.160 (0.141)	0.159 (0.141)	0.172 (0.141)
Temporary position	−0.175 (0.157)	−0.198 (0.157)	−0.180 (0.157)	−0.178 (0.157)
Scientific age (log)	−0.240*** (0.068)	−0.080 (0.052)	−0.128* (0.055)	−0.167** (0.058)

(continued)

Table A2.3. (Continued)

Variable	Dependent variable: Dissemination (1)	(2)	(3)	(4)
Cardiology	0.194 (0.161)	0.269 (0.160)	0.254 (0.160)	0.252 (0.160)
Economics	1.072*** (0.159)	0.875*** (0.148)	0.904*** (0.149)	0.937*** (0.151)
Total number of received citations (log)	0.171*** (0.041)			
Mean normalized citation impact score (log)		0.531*** (0.133)		
Percentage publications in top 10% (log)			0.163*** (0.041)	
Have publication in top 10%				0.569*** (0.139)
Constant	0.002 (0.235)	−0.026 (0.238)	0.189 (0.226)	0.215 (0.226)
Observations	1,605	1,605	1,605	1,605
Log likelihood	−960.992	−961.173	−961.591	−961.177
Akaike Inf. Crit.	1,945.984	1,946.347	1,947.181	1,946.353

*$P < .05$; **$P < 0.01$; ***$P < .001$.
The reference categories are full professor, permanent position, male, and physics.

Table A2.4. Commercialization—publication indicators.

Variable	Dependent variable: Commercialization (1)	(2)	(3)	(4)
Assistant professor	−0.620** (0.223)	−0.591** (0.223)	−0.609** (0.224)	−0.610** (0.224)
Associate professor	−0.248 (0.152)	−0.265 (0.152)	−0.254 (0.152)	−0.252 (0.152)
Female	−0.418* (0.173)	−0.411* (0.174)	−0.416* (0.173)	−0.416* (0.173)
Funded by institution	−0.220 (0.136)	−0.194 (0.136)	−0.206 (0.136)	−0.205 (0.136)
Funded by external public sources	0.811*** (0.172)	0.893*** (0.170)	0.861*** (0.170)	0.862*** (0.171)
Funded by external non-public sources	0.746*** (0.142)	0.770*** (0.143)	0.756*** (0.142)	0.754*** (0.142)
Temporary position	−0.065 (0.191)	−0.083 (0.191)	−0.075 (0.191)	−0.075 (0.191)
Scientific age (log)	0.063 (0.080)	0.139* (0.061)	0.129* (0.064)	0.132 (0.069)
Cardiology	−0.351* (0.169)	−0.303 (0.167)	−0.317 (0.167)	−0.317 (0.167)
Economics	−2.318*** (0.301)	−2.390*** (0.295)	−2.389*** (0.295)	−2.392*** (0.296)
Total number of received citations (log)	0.054 (0.046)			
Mean normalized citation impact score (log)		−0.349* (0.157)		
Percentage publications in top 10% (log)			−0.014 (0.049)	
Have publication in top 10%				−0.046 (0.172)
Constant	−1.557*** (0.277)	−1.287*** (0.280)	−1.469*** (0.269)	−1.472*** (0.268)
Observations	1,606	1,606	1,606	1,606
Log likelihood	−762.579	−760.653	−763.214	−763.221
Akaike Inf. Crit.	1,549.157	1,545.306	1,550.429	1,550.441

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are full professor, permanent position, male, and physics.

Table A3.1. Pearson correlations between relevant variables used in the different regression models.

	Modes of societal engagement			
	Collaboration	Consultancy	Dissemination	Commercialization
Collaboration	1	0.45	0.20	0.34
Consultancy		1	0.24	0.20
Dissemination			1	0.02
Commercialization				1

	Scientific recognition				
	Scientific recognition group	Total number of received citations (log)	Mean normalized citation impact score (log)	Percentage publications in top 10% (log)	Have publication in top 10%
Scientific recognition group	1	0.74	0.65	0.74	0.65

(continued)

Table A3.1. (Continued)

	Modes of societal engagement				
	Collaboration	**Consultancy**	**Dissemination**	**Commercialization**	
Total number of received citations (log)[a]		1	0.55	0.69	0.73
Mean normalized citation impact score (log)[a]			1	0.75	0.55
Percentage publications in top 10% (log)[a]				1	0.89
Have publication in top 10%[a]					1

	Individual characteristics			
	Position	**Gender**	**Scientific age (log)**	**Temporary position**
Position	1	−0.19	0.49	−0.53
Gender		1	−0.12	0.09
Scientific age (log)[b]			1	−0.34
Temporary position[b]				1

	Funding		
	Funded by institution	Funded by external public sources	Funded by external non-public sources
Funded by institution	1	−0.12	−0.06
Funded by external public sources		1	0.11
Funded by external non-public sources			1

[a]Citation indicators used in regression models for analyses of alternative operationalizations of scientific recognition (see Appendix Tables A2.1–A2.4).
[b]Included as control variables in addition to field in the final regression models used in the paper (see Table 6 in the paper and Appendix Tables A5.1–A5.4).

Table A4.1. Recoding of funding variables.

Original variable	**New variable**
My position/research time funded by my institution	Funded by institution
Grants from my institution	
Competitive grants from external public sources	Funded by external public sources
Other public sources	
Business firms/industry	Funded by external non-public sources
Private not-for-profit foundations/organizations	

Table A5.1. Research collaboration outside science—stepwise inclusion of independent variables.

	Dependent variable:						
	Research collaboration outside science						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Low scientific recognition	−0.733*** (0.130)	−0.596*** (0.135)	−0.641*** (0.143)	−0.547*** (0.146)	−0.513*** (0.147)	−0.378* (0.156)	−0.382* (0.156)
Medium scientific recognition	0.022 (0.140)	0.110 (0.144)	0.054 (0.151)	0.094 (0.154)	0.128 (0.156)	0.129 (0.156)	0.138 (0.156)
Assistant professor		−0.632*** (0.123)	−0.641*** (0.132)	−0.681*** (0.136)	−0.419** (0.163)	−0.254 (0.174)	−0.234 (0.174)
Associate professor		−0.232* (0.117)	−0.248* (0.123)	−0.263* (0.125)	−0.255* (0.127)	−0.194 (0.129)	−0.188 (0.129)
Female			0.129 (0.127)	0.121 (0.129)	0.091 (0.131)	0.104 (0.131)	0.071 (0.135)
Funded by institution				−0.095 (0.114)	−0.158 (0.118)	−0.138 (0.118)	−0.156 (0.119)
Funded by external public sources				0.437*** (0.116)	0.455*** (0.118)	0.468*** (0.118)	0.514*** (0.121)
Funded by external non-public sources				0.633*** (0.137)	0.633*** (0.138)	0.639*** (0.139)	0.661*** (0.141)
Temporary position					−0.439** (0.153)	−0.407** (0.154)	−0.392* (0.155)
Scientific age (log)						0.143** (0.053)	0.143** (0.054)
Cardiology							0.135 (0.156)
Economics							0.269* (0.133)
Constant	0.685*** (0.112)	0.814*** (0.120)	0.812*** (0.128)	0.406* (0.186)	0.452* (0.192)	−0.028 (0.262)	−0.145 (0.270)
McFadden Pseudo R^2	0.025	0.036	0.037	0.056	0.061	0.065	0.066
Bayesian Inf. Crit.	2,623.839	2,430.976	2,205.474	2,184.555	2,141.172	2,141.19	2,151.675
Observations	1,960	1,829	1,649	1,649	1,616	1,616	1,616
Log likelihood	−1,300.548	−1,196.709	−1,080.513	−1,058.942	−1,033.647	−1,029.963	−1,027.817
Akaike Inf. Crit.	2,607.096	2,403.418	2,173.027	2,135.884	2,087.294	2,081.925	2,081.634

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are high scientific recognition, full professor, permanent position, male, and physics.

Table A5.2. Interaction/consultancy outside science—stepwise inclusion of independent variables.

	Dependent variable:						
	Interaction/consultancy outside science						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Low scientific recognition	−0.407** (0.125)	−0.184 (0.133)	−0.245 (0.140)	−0.193 (0.141)	−0.145 (0.144)	−0.053 (0.151)	−0.070 (0.157)
Medium scientific recognition	−0.116 (0.133)	−0.030 (0.138)	−0.065 (0.145)	−0.050 (0.145)	−0.038 (0.148)	−0.039 (0.148)	−0.010 (0.152)
Assistant professor		−0.962*** (0.126)	−0.886*** (0.134)	−0.895*** (0.137)	−0.701*** (0.162)	−0.585*** (0.172)	−0.512** (0.177)
Associate professor		−0.546*** (0.114)	−0.545*** (0.121)	−0.549*** (0.122)	−0.551*** (0.123)	−0.511*** (0.125)	−0.506*** (0.129)
Female			−0.089 (0.126)	−0.093 (0.127)	−0.125 (0.129)	−0.116 (0.129)	−0.282* (0.137)
Funded by institution				−0.015 (0.111)	−0.057 (0.114)	−0.042 (0.115)	−0.129 (0.119)
Funded by external public sources				0.200 (0.115)	0.206 (0.117)	0.214 (0.117)	0.447*** (0.125)
Funded by external non-public sources				0.396** (0.126)	0.423*** (0.128)	0.425*** (0.128)	0.548*** (0.134)
Temporary position					−0.321* (0.153)	−0.299 (0.153)	−0.236 (0.158)
Scientific age (log)						0.100 (0.053)	0.112* (0.056)
Cardiology							0.605*** (0.151)
Economics							1.279*** (0.136)
Constant	0.091 (0.107)	0.323** (0.115)	0.359** (0.122)	0.120 (0.181)	0.145 (0.186)	−0.187 (0.256)	−0.768** (0.274)
McFadden Pseudo R^2	0.005	0.031	0.030	0.037	0.038	0.040	0.083
Bayesian Inf. Crit.	2,704.362	2,477.446	2,248.196	2,2256.103	2,215.257	2,219.038	2,137.592
Observations	1,952	1,824	1,646	1,646	1,614	1,614	1,614
Log likelihood	−1,340.816	−1,219.951	−1,101.880	−1,094.724	−1,070.696	−1,068.893	−1,020.784
Akaike Inf. Crit.	2,687.632	2,449.902	2,215.760	2,207.449	2,161.392	2,159.787	2,067.568

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are high scientific recognition, full professor, permanent position, male, and physics.

Table A5.3. Dissemination—stepwise inclusion of independent variables.

	Dependent variable:						
	Dissemination						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Low scientific recognition	−0.668*** (0.139)	−0.437** (0.147)	−0.538*** (0.157)	−0.482** (0.158)	−0.481** (0.160)	−0.610*** (0.168)	−0.654*** (0.172)
Medium scientific recognition	−0.487*** (0.147)	−0.364* (0.154)	−0.396* (0.164)	−0.385* (0.165)	−0.389* (0.166)	−0.392* (0.167)	−0.386* (0.169)
Assistant professor		−0.983*** (0.126)	−0.988*** (0.137)	−0.942*** (0.139)	−0.813*** (0.165)	−0.973*** (0.178)	−0.923*** (0.179)
Associate professor		−0.442*** (0.121)	−0.422** (0.130)	−0.404** (0.130)	−0.393** (0.132)	−0.450*** (0.134)	−0.433** (0.135)
Female			0.571*** (0.139)	0.562*** (0.140)	0.559*** (0.141)	0.550*** (0.141)	0.470** (0.146)
Funded by institution				0.321** (0.116)	0.315** (0.119)	0.297* (0.119)	0.247* (0.121)
Funded by external public sources				0.336** (0.120)	0.358** (0.122)	0.352** (0.122)	0.485*** (0.126)
Funded by external non-public sources				0.093 (0.137)	0.082 (0.138)	0.079 (0.138)	0.147 (0.141)
Temporary position					−0.190 (0.154)	−0.227 (0.155)	−0.185 (0.157)
Scientific age (log)						−0.136* (0.056)	−0.137* (0.057)
Cardiology							0.333* (0.160)
Economics							0.864*** (0.148)
Constant	1.072*** (0.122)	1.337*** (0.133)	1.312*** (0.143)	0.802*** (0.198)	0.794*** (0.203)	1.251*** (0.276)	0.944*** (0.285)
McFadden Pseudo R^2	0.009	0.036	0.041	0.047	0.048	0.051	0.068
Bayesian Inf. Crit.	2,539.854	2,304.023	2,058.541	2,067.35	2,040.887	2,042.232	2,020.152
Observations	1,945	1,817	1,637	1,637	1,605	1,605	1,605
Log likelihood	−1,258.567	−1,133.249	−1,007.068	−1,000.372	−983.539	−980.521	−962.100
Akaike Inf. Crit.	2,523.135	2,276.498	2,026.137	2,018.744	1,987.078	1,983.042	1,950.201

$^{*}P < .05$; $^{**}P < .01$; $^{***}P < .001$.
The reference categories are high scientific recognition, full professor, permanent position, male, and physics.

Table A5.4. Commercialization—stepwise inclusion of independent variables.

	Dependent variable: Commercialization						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Low scientific recognition	−0.357* (0.145)	−0.186 (0.153)	−0.192 (0.159)	0.007 (0.166)	0.014 (0.169)	0.177 (0.178)	0.187 (0.187)
Medium scientific recognition	0.066 (0.150)	0.166 (0.154)	0.090 (0.161)	0.152 (0.166)	0.181 (0.169)	0.180 (0.169)	0.148 (0.176)
Assistant professor		−0.623*** (0.153)	−0.541*** (0.162)	−0.650*** (0.171)	−0.654** (0.206)	−0.444* (0.219)	−0.612** (0.224)
Associate professor		−0.223 (0.130)	−0.203 (0.137)	−0.243 (0.143)	−0.251 (0.145)	−0.180 (0.148)	−0.263 (0.152)
Female			−0.485** (0.159)	−0.538*** (0.163)	−0.515** (0.165)	−0.505** (0.165)	−0.417* (0.173)
Funded by institution				−0.270* (0.128)	−0.273* (0.132)	−0.258 (0.132)	−0.206 (0.136)
Funded by external public sources				1.019*** (0.160)	1.053*** (0.164)	1.072*** (0.165)	0.873*** (0.170)
Funded by external non-public sources				0.848*** (0.135)	0.873*** (0.136)	0.878*** (0.137)	0.764*** (0.143)
Temporary position					−0.022 (0.187)	0.003 (0.185)	−0.075 (0.191)
Scientific age (log)						0.176** (0.065)	0.142* (0.067)
Cardiology							−0.331* (0.167)
Economics							−2.385*** (0.295)
Constant	−1.013*** (0.121)	−0.915*** (0.129)	−0.802*** (0.135)	−1.686*** (0.225)	−1.735*** (0.233)	−2.326*** (0.321)	−1.671*** (0.333)
McFadden Pseudo R^2	0.006	0.016	0.020	0.076	0.079	0.083	0.148
Bayesian Inf. Crit.	2,150.414	2,021.115	1,839.305	1,758.052	1,721.955	1,721.888	1,621.384
Observations	1,945	1,815	1,639	1,639	1,606	1,606	1,606
Log likelihood	−1,063.848	−991.798	−897.447	−845.718	−824.070	−820.345	−762.712
Akaike Inf. Crit.	2,133.695	1,993.595	1,806.894	1,709.435	1,668.140	1,662.691	1,551.425

$^{*}P < .05$; $^{**}P < .01$; $^{***}P < .001$.
The reference categories are high scientific recognition, full professor, permanent position, male and physics.

Table A6.1. Full models with country included as a control variable.

	Dependent variable			
	Collaboration (1)	Consultancy (2)	Dissemination (3)	Commercialization (4)
Low scientific recognition	−0.374* (0.157)	−0.080 (0.158)	−0.746*** (0.175)	0.219 (0.189)
Medium scientific recognition	0.131 (0.157)	−0.003 (0.153)	−0.395* (0.170)	0.143 (0.176)
Assistant professor	−0.281 (0.178)	−0.478** (0.180)	−0.836*** (0.182)	−0.645** (0.226)
Associate professor	−0.204 (0.131)	−0.483*** (0.130)	−0.384** (0.137)	−0.300 (0.155)
Female	0.076 (0.135)	−0.303* (0.138)	0.462** (0.147)	−0.426* (0.174)
Funded by institution	−0.190 (0.120)	−0.132 (0.120)	0.262* (0.123)	−0.243 (0.137)
Funded by external public sources	0.530*** (0.122)	0.450*** (0.126)	0.452*** (0.127)	0.884*** (0.171)
Funded by external non-public sources	0.692*** (0.143)	0.561*** (0.135)	0.175 (0.142)	0.778*** (0.144)
Temporary position	−0.381* (0.156)	−0.264 (0.159)	−0.227 (0.159)	−0.085 (0.193)
Scientific age (log)	0.130* (0.055)	0.100 (0.057)	−0.120* (0.058)	0.123 (0.068)
Cardiology	0.072 (0.161)	0.616*** (0.156)	0.250 (0.166)	−0.350* (0.175)
Economics	0.188 (0.137)	1.278*** (0.141)	0.932*** (0.155)	−2.476*** (0.298)
Denmark	−0.129 (0.215)	−0.279 (0.218)	−0.465* (0.232)	0.094 (0.262)
Sweden	−0.276* (0.139)	−0.245 (0.139)	−0.276 (0.149)	−0.279 (0.164)
The Netherlands	0.091 (0.165)	−0.276 (0.163)	−0.666*** (0.174)	0.165 (0.201)
UK	−0.188 (0.212)	0.140 (0.214)	−0.738*** (0.224)	−0.013 (0.252)
Constant	0.045 (0.293)	−0.589* (0.294)	1.283*** (0.313)	−1.515*** (0.357)
Observations	1,616	1,614	1,605	1,606
Log likelihood	−1,024.359	−1,017.120	−952.169	−759.066
Akaike Inf. Crit.	2,082.718	2,068.239	1,938.337	1,552.133

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are high scientific recognition, full professor, permanent position, male, physics, and Norway.

Table A6.2. Full models with a binary quasi-weight that controls for non-sampling of cardiologists in Denmark and the UK.

	Dependent variable:			
	Collaboration (1)	Consultancy (2)	Dissemination (3)	Commercialization (4)
Low scientific recognition	−0.386* (0.157)	−0.060 (0.157)	−0.684*** (0.173)	0.200 (0.188)
Medium scientific recognition	0.137 (0.156)	−0.006 (0.152)	−0.401* (0.169)	0.156 (0.176)
Assistant professor	−0.237 (0.174)	−0.508** (0.177)	−0.939*** (0.180)	−0.605** (0.224)
Associate professor	−0.186 (0.129)	−0.511*** (0.129)	−0.417** (0.136)	−0.274 (0.153)
Female	0.073 (0.135)	−0.286* (0.137)	0.480** (0.147)	−0.423* (0.174)
Funded by institution	−0.154 (0.119)	−0.132 (0.119)	0.254* (0.121)	−0.210 (0.136)
Funded by external public sources	0.514*** (0.121)	0.449*** (0.125)	0.483*** (0.126)	0.878*** (0.170)
Funded by external non-public sources	0.666*** (0.142)	0.539*** (0.134)	0.170 (0.141)	0.753*** (0.143)
Temporary position	−0.389* (0.155)	−0.242 (0.158)	−0.166 (0.158)	−0.085 (0.191)
Scientific age (log)	0.144** (0.054)	0.110* (0.056)	−0.131* (0.057)	0.139* (0.067)
Cardiology	0.122 (0.159)	0.633*** (0.155)	0.261 (0.164)	−0.292 (0.173)
Economics	0.270* (0.133)	1.278*** (0.136)	0.869*** (0.148)	−2.388*** (0.295)
Cardiology sampling adjustment	−0.053 (0.145)	0.117 (0.146)	−0.306* (0.151)	0.152 (0.173)
Constant	−0.136 (0.271)	−0.788** (0.275)	0.998*** (0.287)	−1.698*** (0.334)
Observations	1,616	1,614	1,605	1,606
Log likelihood	−1,027.751	−1,020.465	−960.068	−762.330
Akaike Inf. Crit.	2,083.502	2,068.931	1,948.135	1,552.659

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are high scientific recognition, full professor, permanent position, male and physics. Cardiology sampling adjustment: 1 = being in countries where we don't have cardiologists.

Table A6.3. Full models with organization included as a control variable.

	Dependent variable:			
	Collaboration (1)	Consultancy (2)	Dissemination (3)	Commercialization (4)
Low scientific recognition	−0.446** (0.159)	−0.087 (0.158)	−0.679*** (0.173)	0.141 (0.189)
Medium scientific recognition	0.112 (0.158)	−0.008 (0.153)	−0.373* (0.170)	0.106 (0.177)
Assistant professor	−0.296 (0.178)	−0.538** (0.179)	−0.974*** (0.182)	−0.650** (0.227)
Associate professor	−0.222 (0.132)	−0.523*** (0.130)	−0.468*** (0.137)	−0.288 (0.153)
Female	0.097 (0.136)	−0.285* (0.137)	0.457** (0.147)	−0.389* (0.175)
Funded by institution	−0.158 (0.120)	−0.129 (0.119)	0.247* (0.122)	−0.199 (0.137)
Funded by external public sources	0.457*** (0.122)	0.434*** (0.126)	0.485*** (0.127)	0.846*** (0.171)
Funded by external non-public sources	0.646*** (0.142)	0.550*** (0.134)	0.167 (0.142)	0.747*** (0.143)
Temporary position	−0.346* (0.158)	−0.214 (0.159)	−0.152 (0.159)	−0.051 (0.193)
Scientific age (log)	0.127* (0.055)	0.107 (0.056)	−0.142* (0.058)	0.129 (0.068)
Cardiology	0.292 (0.159)	0.594*** (0.154)	0.227 (0.164)	−0.180 (0.172)
Economics	0.350* (0.138)	1.242*** (0.141)	0.725*** (0.152)	−2.300*** (0.300)
Institutes	0.764** (0.295)	0.324 (0.277)	0.632 (0.334)	0.452 (0.375)
Technical university	0.688*** (0.141)	−0.057 (0.136)	−0.462*** (0.136)	0.562*** (0.147)
Constant	−0.233 (0.276)	−0.724** (0.277)	1.105*** (0.289)	−1.776*** (0.338)
Observations	1,616	1,614	1,605	1,606
Log likelihood	−1,012.850	−1,019.958	−953.744	−755.155
Akaike Inf. Crit.	2,055.700	2,069.915	1,937.487	1,540.310

*$P<.05$; **$P<.01$; ***$P<.001$.
The reference categories are high scientific recognition, full professor, permanent position, male, physics, and university.

Table A6.4. Full models with field of science variable included that differentiates between whether physicists do most of their work alone or not.

	Dependent variable:			
	Collaboration (1)	Consultancy (2)	Dissemination (3)	Commercialization (4)
Low scientific recognition	−0.389* (0.158)	−0.093 (0.159)	−0.632*** (0.173)	0.177 (0.190)
Medium scientific recognition	0.097 (0.158)	−0.016 (0.154)	−0.355* (0.170)	0.104 (0.177)
Assistant professor	−0.216 (0.177)	−0.459* (0.180)	−0.947*** (0.182)	−0.545* (0.227)
Associate professor	−0.210 (0.131)	−0.520*** (0.131)	−0.457*** (0.137)	−0.255 (0.154)
Female	0.081 (0.137)	−0.277* (0.139)	0.448** (0.148)	−0.434* (0.177)
Funded by institution	−0.184 (0.122)	−0.115 (0.121)	0.231 (0.123)	−0.208 (0.139)
Funded by external public sources	0.491*** (0.123)	0.441*** (0.127)	0.464*** (0.128)	0.900*** (0.175)
Funded by external non-public sources	0.686*** (0.143)	0.572*** (0.135)	0.144 (0.142)	0.790*** (0.144)
Temporary position	−0.393* (0.157)	−0.251 (0.160)	−0.170 (0.159)	−0.137 (0.195)
Scientific age (log)	0.146** (0.055)	0.111 (0.057)	−0.141* (0.058)	0.139* (0.069)
Cardiology	0.089 (0.158)	0.611*** (0.153)	0.342* (0.163)	−0.347* (0.170)
Economics	0.227 (0.135)	1.286*** (0.139)	0.867*** (0.151)	−2.405*** (0.296)
Physics alone	−0.557* (0.276)	−0.126 (0.290)	0.168 (0.264)	−0.352 (0.334)
Constant	−0.062 (0.275)	−0.772** (0.279)	0.964*** (0.290)	−1.647*** (0.340)
Observations	1,587	1,583	1,575	1,575
Log likelihood	−1,005.201	−999.528	−944.463	−742.038
Akaike Inf. Crit.	2,038.403	2,027.056	1,916.926	1,512.077

*$P<.05$; **$P<.01$; ***$P<.001$.
The reference categories are high scientific recognition, full professor, permanent position, male, and physics not alone.

Table A6.5. Full models with weighted position variable.

	Dependent variable:			
	Collaboration (1)	Consultancy (2)	Dissemination (3)	Commercialization (4)
Low scientific recognition	−0.382* (0.156)	−0.070 (0.157)	−0.654*** (0.172)	0.187 (0.187)
Medium scientific recognition	0.138 (0.156)	−0.010 (0.152)	−0.386* (0.169)	0.148 (0.176)
Assistant professor	−0.234 (0.174)	−0.512** (0.177)	−0.923*** (0.179)	−0.612** (0.224)
Associate professor	−0.188 (0.129)	−0.506*** (0.129)	−0.433** (0.135)	−0.263 (0.152)
Female	0.071 (0.135)	−0.282* (0.137)	0.470** (0.146)	−0.417* (0.173)
Funded by institution	−0.156 (0.119)	−0.129 (0.119)	0.247* (0.121)	−0.206 (0.136)
Funded by external public sources	0.514*** (0.121)	0.447*** (0.125)	0.485*** (0.126)	0.873*** (0.170)
Funded by external non-public sources	0.661*** (0.141)	0.548*** (0.134)	0.147 (0.141)	0.764*** (0.143)
Temporary position	−0.392* (0.155)	−0.236 (0.158)	−0.185 (0.157)	−0.075 (0.191)
Scientific age (log)	0.143** (0.054)	0.112* (0.056)	−0.137* (0.057)	0.142* (0.067)
Cardiology	0.135 (0.156)	0.605*** (0.151)	0.333* (0.160)	−0.331* (0.167)
Economics	0.269* (0.133)	1.279*** (0.136)	0.864*** (0.148)	−2.385*** (0.295)
Constant	−0.145 (0.270)	−0.768** (0.274)	0.944*** (0.285)	−1.671*** (0.333)
Observations	1,616	1,614	1,605	1,606
Log Likelihood	−1,027.817	−1,020.784	−962.100	−762.712
Akaike Inf. Crit.	2,081.634	2,067.568	1,950.201	1,551.425

*$P < .05$; **$P < .01$; ***$P < .001$.
The reference categories are high scientific recognition, full professor, permanent position, male and physics.