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What Stimulates Researchers to Make Their Research Usable? Towards an 'Openness' Approach

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Abstract Ambiguity surrounding the effect of external engagement on academic research has raised questions about what motivates researchers to collaborate with third parties. We argue that what matters for society is research that can be absorbed by users. We define 'openness' as a willingness by researchers to make research more usable by external partners by responding to external influences in their own research practices. We ask what kinds of characteristics define those researchers who are more 'open' to creating usable knowledge. Our empirical study analyses a sample of 1583 researchers working at the Spanish Council for Scientific Research (CSIC). Results demonstrate that it is personal factors (academic identity and past experience) that determine which researchers have open behaviours. The paper concludes that policies to encourage external engagement should focus on experiences which legitimate and validate knowledge produced through user encounters, both at the academic formation career stage as well as through providing ongoing opportunities to engage with third parties.

Keywords Valorisation · Usable research · External influences · Researchers' societal engagement · Research micro-practices

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Introduction

There are increasing imperatives to understand how research benefits society, given the increasing dependence of socio-economic growth and wellbeing on societal capacity to create and generate new knowledge (Rutten and Boekema 2012). Academic literature has focused on understanding processes whereby academic knowledge creates societal value (Donovan 2007). But a pressing scientific question remains of why academics choose to engage societally (D'Este and Perkmann 2011): collaboration has a 'dark side' (Bozeman et al. 2013) of knowledge exchange potentially conflicting with 'academic logic' (Sauermann and Stephan 2013) raising unpalatable choices and conflicting interests for researchers (Collini 2009; Jain et al. 2009; Philpott et al. 2011; Tartari and Breschi 2012). With others reporting more positive relationships between 'star scientists' and their external engagement (Bekkers and Bodas Freitas 2008; Gulbrandsen and Smeby 2005; Haeussler and Colyvas 2011; Louis et al. 1989), this persistent ambiguity undermines understanding university-society engagement and hinders optimising the contribution of research to societal development and wellbeing.

Several studies addressing researchers' motivations for engagement characterise motivation as an extremely complex notion where insufficient conceptual development may lead to excessive reductionism (Baldini et al. 2007; D'Este and Perkmann 2011; Lam 2011; Lee 2000; Perkmann et al. 2013). Science takes place in extended communities, and academic decision-making is a complex phenomenon with many influences, where real decisions reflect the interplay of these complex tensions (see Miller and Neff 2013, for a systematic treatment). These tensions are particularly evident in academic engagement practices, where scientists can face choosing between questions inspired by knowledge generation or conditions of use, and between pursuing immediately useful or generally ubiquitous knowledge (Stokes 1997). To render this complex situation researchable, we focus on the outcomes of those decision-making processes, namely academic practices within wider scientific decision-making systems selecting and co-ordinating suitable questions for academic effort (Gläser 2012) and seeking to resolve tensions arising within these scientific communities (Miller and Neff 2013).

We specifically focus on academic micro-practices that could potentially make research more easy to use by non-academic agents, which we define as 'open' behaviour. Our starting contention is that if academics are sensitive to external user needs in these research micro-practices, then external partners will later be able to absorb that knowledge more easily. We argue that where knowledge is cognate with users' own knowledge bases, this will make that knowledge easier for potential users to use. Therefore, we define usable knowledge as a potential produced by being cognate with user knowledge. We argue that this characteristic of cognateness emerges through knowledge-building processes (what we call micro-practices of science) that involve users, raising the likelihood that those users will eventually be inspired and affected by the new knowledge (Neff 2014). And those research micro-practices incorporating external knowledge are *ceteris paribus* at least as – and

potentially more – likely to generate usable[1] knowledge for external partners. Using an existing Spanish researcher survey (IMPACTO) we operationalise the way external influences[2] may emerge in different types of research practices. We seek to identify which factors are most closely associated with academics' propensity to include external influences in their research processes. Our study suggests that two main factors (academic identity and past experience) appear to determine researchers' open behaviours.

Research Processes as Building Blocks of Scientific Decision-Making

Increasing interest in researcher engagement has paralleled a realisation that macro-frameworks for understanding how research benefits society should evolve from linear models to reflect more interactive knowledge-creation processes (Geuna and Muscio 2009). Innovation processes interact with scientific production: usable knowledge for innovation emerges from research closely linked to users, as highlighted in a range of models, including 'Mode 2' knowledge production (Gibbons et al. 1994), 'system of innovation' (Edquist 1997), the 'Triple Helix' (Etzkowitz and Leydesdorff 2000) or 'post-academic science' (Ziman 1996). These models all highlight that these macro-changes are also evident in individual academics' behaviours. This has made those academics increasingly responsive to external stakeholders in setting research agendas (Hessels and Van Lente 2008), responding to shifts in research policy priorities (Gläser 2012; Leisyte et al. 2008), changes in funding patterns (Gulbrandsen and Smeby 2005), variations in prevailing research modes (Gibbons et al. 1994), and increasing promotion of direct academic-society interactions (Martin 2003). Nevertheless, academics retain substantial autonomy over their individual choices, such as determining which projects to develop, methods to apply and collaborations to establish (Aghion et al. 2008; Gläser 2012).

Individual research practices may be influenced in different ways by external users, including agenda-setting, project planning, research execution and the translation of results of inquiry into applications (Kitcher 2001; Sarewitz and Pielke 2007). Where outsider users are involved in these research practices, this then creates connections and feedbacks which shape those projects' directions; Neff (2014) suggests that this can in turn affect the ways in which users are inspired or affected by the resulting research findings. Nowotny et al. (2001) argue that research more open to external influences is more contextualized, and therefore requires less transformation from the academic to the practical realm. Following this, we here characterise five distinctive kinds of research practice, which we refer to as

[1] We contend useful knowledge has to be usable; otherwise it can never be useful. However, usable knowledge does not necessarily have to be useful. Thus, we focus on the production of usable knowledge (sensitive to users' interest) as a precondition for its eventual usefulness.

[2] By 'external influences' we refer to mechanisms through which third parties may influence researchers' micro-practices and thus the knowledge produced (more or less usable by external parties). External influences might occur directly (users-researcher knowledge exchange) or indirectly (researchers becoming aware of external problems).

processes that may involve external research users and hence where 'open behaviour' may be demonstrated:

(1) *reframing*: deciding a future personal research agenda of potential interesting questions, partly shaped by past research; researchers whose past research has been affected by external influences starts from a knowledge base of usable knowledge;
(2) *inspiration*: identifying one potential question as one to which the individual can commit to do more research activity; researchers may be inspired by users or external issues for a concrete future research project idea;
(3) *planning*: producing a tangible method and plan to answer a specific question; a researcher may include external knowledge, interests and needs as key research resources within that proposal;
(4) *execution*: undertaking a piece of research, gathering and analysing data to make a scientific contribution; a researcher may incorporate external knowledge in its implementation;
(5) *dissemination*: presenting results in ways accessible to potential users; a researcher may arrange dissemination activities together with users in ways that allow users to provide feedback, to inspire new insights or future usable research orientations.

Researchers usually build their future research agendas blending newly encountered academic literature with their previous knowledge base: research is path-dependent (Neff 2014) and decision-impregnated (Knorr-Cetina 1981), with future decisions structured by past decisions (reframing). Literature on university-industry relationships has addressed research agenda skewness towards external influences (Lee 1996; Nelson 2001; Verspagen 2006). Researchers whose past activities (knowledge base) incorporated external influences will already overlap with potential users' knowledge, and therefore their activities are more easily taken up by potential users. Thus, we argue that past research conducted with external partners leads to future research being more usable.

Secondly, researchers may demonstrate open behaviour and include external knowledge in the formation of ideas (inspiration) where they perceive a problem, identify it as fitting with their research agenda, and conceptualise it as a problem that their research can solve. Researchers' open behaviour in inspiration processes corresponds to what others have referred to as scientific research orientation. Stokes' (1997) typology has two dimensions of researcher *ex ante* orientations giving four quadrants based on scientific excellence and societal relevance: researchers may be oriented towards fundamental understanding (Böhr quadrant), to use considerations (Edison quadrant), to useful and excellent knowledge (Pasteur quadrant), or to gather and analyse data in ways neither immediately useful nor scientifically excellent (what Alrøe and Kristensen (2002) call the Linnaeus quadrant). Researchers who are inspired by use conditions ('Edison' or 'Pasteur') may follow research questions influenced by socio-economic considerations, choosing more research questions whose answers create more usable kinds of research.

A third dimension of research processes relates to operationalising a question into a research proposal, setting out *ex ante* the putative research execution. The extent to which external knowledge is incorporated in project activities affects how cognate final knowledge will be with potential users. Reflecting on creating impact in research planning sensitises researchers to potential opportunities (Hessels and Van Lente 2008: 742). Thus, researchers demonstrating these 'pro-social' research behaviours (D'Este et al. 2013) are more likely to develop research projects which, if selected, create more usable knowledge.

The fourth distinctive kind of research process involves the execution of research: mobilising resources to prosecute activities delivering scientific results. Previous studies identified that researchers engage externally to access knowledge resources otherwise unavailable (Abreu et al. 2009; Baldini et al. 2007; D'Este and Perkmann 2011; Lam 2011; Lee 2000; Zomer et al. 2010), pointing to resource control – including over critical knowledge resources – as a common way of influencing research content (Gläser 2012: 9). Researchers' open behaviour in execution is demonstrated by involving external knowledge resources in the execution of a project, affecting the nature of the knowledge produced, and raising its usability by making it more cognate with user knowledge.

Finally, dissemination involves actively passing knowledge to either academic (e.g. via scientific journals) or societal audiences (e.g. patenting, dissemination in the media, generation of clinical guidelines). Societal dissemination activities have been widely addressed in the literature (Jensen 2011; Olmos-Peñuela et al. 2014b), and although often seen as being downstream, one-way (from researcher to user) and post-dating research activities, they can potentially involve two-way interactions/dialogues between researchers and external actors (Martín-Sempere et al. 2008). Participating in these two-way dialogues can expose researchers to new knowledge and research opportunities. Exchange-based dissemination may influence researchers' perceptions of their findings, raising future questions more cognate with users' knowledge. We thus expect that behaviours involving participation in such co-creative societal dissemination processes are associated with higher research usability.

What Makes Researchers Open to External Influences?

Many factors could be associated with researchers' open behaviour (as defined above); some studies assume a direct correspondence between engaged behaviours and academics' desires to acquire particular benefits (D'Este and Perkmann 2011; Lam 2011). However, this exclusive focus on individual benefit ignores that academics are influenced by different kinds of factors from their personal circumstances to their wider institutional scientific systems (Villanueva-Felez et al. 2013). We stylise two kinds of personal factors influencing behaviour; firstly, academic *identities* that shape their decision-making processes, formed during their education and academic formation (e.g. Ph.D.). Secondly, following Knorr-Cetina (1981), *previous research experiences* and completed research projects also affects the choice of future questions. We also distinguish three kinds of contextual factors;

immediate operational environment of the work-floor and working group, researcher's wider *personal academic contact network*, and academic discipline as an *epistemic community*. Researchers' open behaviour may be associated with a range of researcher-specific (personal/contextual) factors, providing us with our independent variables as showed in Fig. 1.

Personal Factors Associated with Academic Decisions

Our first personal factor is academic identity and how academics view the extent to which it is valid/legitimate to involve external (non-academic) interests in research question setting (Jain et al. 2009; Lam 2011). Literature defines diverse researcher archetypes, from an ideal-type pure-Mertonian scholar – where only scientific considerations are valid in research concerns (Merton 1973) – to pure post-academic science entrepreneurs – whose norms legitimate multiple kinds of knowledge and non-academic drivers (Ziman 1996). We contend that the extent to which individuals believe that they are right to involve external knowledge in research processes affects their research behaviour, and that *researchers with an identity closer to the entrepreneurial type are more likely to demonstrate 'open behaviour' in their research processes* (**H1**).

The second personal factor is researchers' experiences and achievements. Researchers who have already acquired usable knowledge and skills are likewise well-positioned to participate in future entrepreneurial activities (Ajzen 2001; Hoye and Pries 2009). Likewise, academic entrepreneurial intentions are well-predicted by academics' previous experience in entrepreneurial activities (Goethner et al. 2012). Researchers with past successful collaborations face fewer uncertainties/difficulties in assessing those collaborations' potential cost or benefits compared to

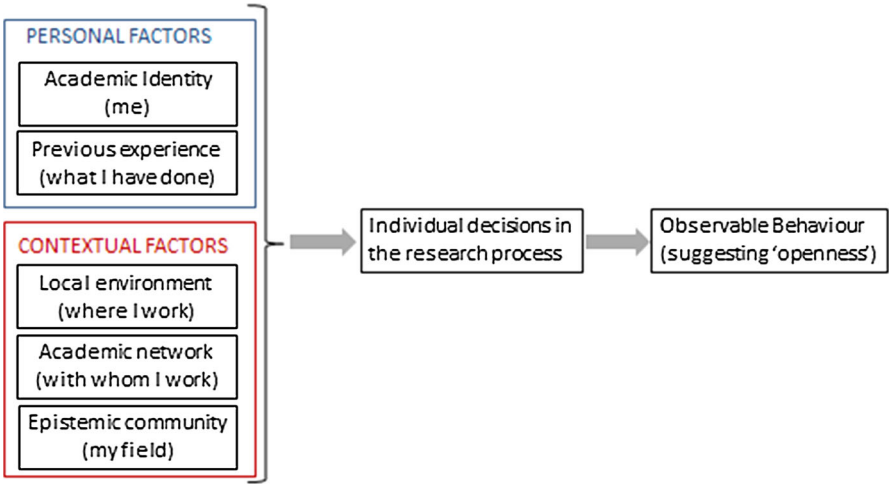

Fig. 1 How individuals' research decisions are shaped by personal and contextual factors. *Source*: authors' own design

those with no such experience (Audretsch et al. 2010). Researchers with positive experiences of engagement are *ceteris paribus* more likely to again choose for engagement than those without previous collaborations. We thus expect that *researchers who regard that past collaborative experience positively are more likely to demonstrate 'open behaviour' in their research processes than researchers that did not experience those benefits, or considered them to be scientifically irrelevant* (**H2**).

Contextual Factors Associated with Academic Decisions

Contextual factors – researchers' working environments and networks – may influence personal preferences via norms, standards and shared behaviours. For empirical reasons, we are not able to consider institutional-level factors that might influence behaviours, as all our researchers operate within the same institutional context. Nevertheless, it is clear that academic behaviour is influenced by institution-level decisions, particularly whether knowledge produced through user engagement is counted as valid in promotion and tenure decisions (Watermeyer 2015). Likewise, we do not consider here system-level contextual factors, what might be called 'the place of engagement in a particular country's socio-technical imaginary' (Jasanoff and Kim 2013). This place is formed by peak system institutions, such as funding agencies, research councils, industry and employer organisations, ministries and ministerial statements, and may create strong incentives or disincentives for researchers to seek out or eschew user contact in their micro-practices of research (Benner and Sandström 2000).

The first contextual factor for which we develop hypotheses is the immediate work environment: the laboratory, research group, department or institute that influence researchers' practices, and the way that institutional-wide guidelines regarding the value of engagement in promotion are applied in local context (Bandura 1977; DiMaggio and Powell 1983; Miller and Neff 2013; Schein 1985; Watermeyer 2015). Bercovitz and Feldman (2008) suggest that academic entrepreneurs' decisions to participate in entrepreneurial activities are mainly affected by currently local norms (reflecting their academic organisations' institutional practices and support measures), as well as norms acquired during their 'academic formation', the practice-based acquisition of research skills in the frameworks of Ph.D.s, and postdoctoral positions (see also Bleiklie and Høstaker 2004; Lee and Boud 2003). Conversely, outdated departmental structures might discourage engagement with external agents or characterise the resultant knowledge as being less valid or legitimate than disciplinary knowledge produced according to standard routines within the disciplinary paradigm (Downing 2005). We therefore suggest that *researchers who perceive their working environment as offering positive institutional support for engaging with external agents are more likely to demonstrate 'open behaviour' in their research processes* (**H3**).

The second contextual factor we highlight is academics' immediate scholarly networks: researchers' behaviour depends on their professional network's behavioural norms and practices (Fromhold-Eisebith et al. 2014; Kronenberg and Caniëls 2014). If a scholar's network is exclusively related to its own discipline,

with little use of external knowledge, then the research outputs will be themselves more bounded by the community. Conversely, where researchers have connections to wider networks with their own norms, either scholars from other institutes, sectors or countries, or scholars from other disciplines, this then increases the ability of knowledge to flow to users (Shane 2000; Venkataraman 1997). We thus suggest the following two hypotheses:

Researchers active in research networks more connected to external researchers are more likely to demonstrate 'open behaviour' in research processes (**H4a**).

Researchers active in research networks more connected to researchers in other disciplines are more likely to demonstrate 'open behaviour' in research processes (**H4b**).

Our final contextual factor is an academic's wider disciplinary community that co-ordinates scientific activities through a mix of formal and informal institutions which continually provide signals to researchers and make judgements on the quality and value of their research activities (Barnett 2009; Becher and Trowler 2001). Some of these disciplinary communities are closely intertwined with users, often referred to as vocational academic communities, covering disciplines such as accountancy, nursing, planning or law (Durning 2004). These disciplinary communities are far more likely to accept the wider legitimacy of external knowledge and therefore are willing to provide positive stimuli and judgements on those producing knowledge dependent on user knowledge (Becher 1994). More generally, the extent to which academics demonstrate 'open behaviour' will be influenced by the extent to which open behaviour is an accepted norm within that community (Deem and Lucas 2007; Jacobson et al. 2004; Miller and Neff 2013). Thus we contend that *researchers in disciplines where external knowledge is seen as being a legitimate contribution towards valid knowledge creation processes are more likely to demonstrate 'open behaviour' in their research processes* (**H5**).

Other Factors

Other factors may also shape researchers' propensity towards 'open behaviour', providing our control variables. An older generation of 'Ivory tower' trained researchers may embody Mertonian norms discouraging external interactions (Bercovitz and Feldman 2008; Tartari and Breschi 2012). We include researchers' academic *position* in the lifecycle to control for researchers' being part of an 'Ivory tower generation' less willing to behave openly in research.

Secondly, researchers may be influenced by direct benefits that external collaborations provide, including ease of access to financial or in-kind resources and prestige (Baldini et al. 2007; D'Este and Perkmann 2011; Gulbrandsen and Smeby 2005; Lam 2011). We therefore control for the extent to which individuals have derived financial and prestige benefits otherwise unrelated to our five research processes.

Thirdly, the kind of external agent may affect interactions that researchers have with them, and we control for three kinds of partners. Firstly, entrepreneurial science perspectives see *firms* as more legitimate research partners than other societal partners

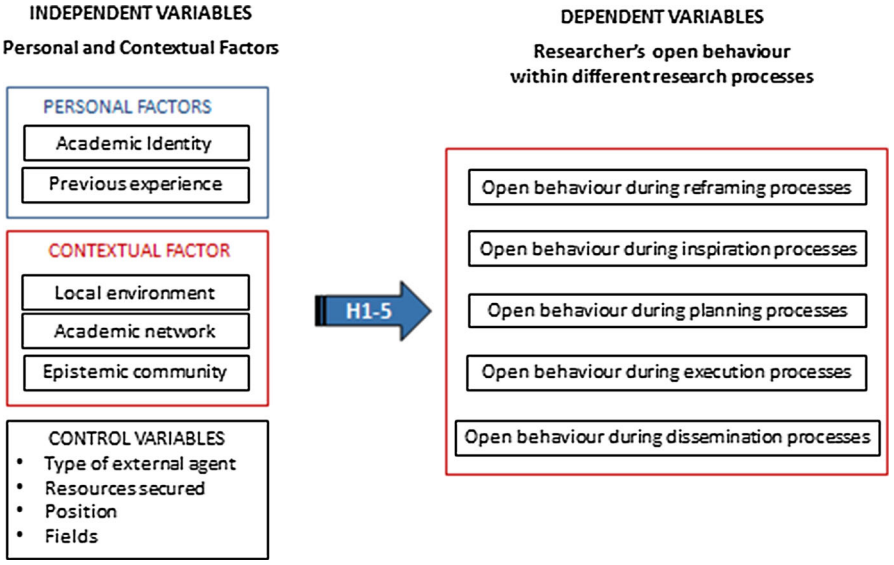

Fig. 2 Conceptual framework. *Source*: authors' own design

(Berman 2011). Conversely, academics engaged with interactive well informed *policy-makers* may exhibit more open research behaviour in undertaking policy research (Krueger and Gibbs 2010). Those working with *non-profit organisations* (NPOs) may be ethically committed to those organisations' goals and hence see interacting with them as scientifically valid (Tinker and Gray 2003).

We also control for researchers' disciplinary field; if you accept other disciplines' norms, then it is easy to accept that non-academic knowledge is legitimate within disciplinary knowledge creation processes (Hessels et al. 2011; Lowe et al. 2013). Our baseline are differences between social science & humanities (SSH) and STEM fields (science, technology, engineering & mathematics) following prior research showing engagement patterns differ between SSH and STEM (Olmos-Peñuela et al. 2014a).

Personal and contextual factors (and control variables) may be associated with researchers' open behaviour in the different research processes (termed reframing, inspiration, planning, execution and dissemination), ultimately affecting the type of knowledge generated and its usability (see Fig. 2). We now explain our dataset, variable construction and analytical plan.

Data and Methodology

Data

The empirical study focuses on Spain's largest public research organisation, the Spanish Council for Scientific Research (CSIC), using the IMPACTO project

Table 1 Population and sample distribution by scientific field of knowledge

	Population (N)	Population (%)	Sample (N)	Sample (%)	% Differences χ^2 test (*)
Biology & biomedicine	771	18.2%	244	15.4%	−2.8%
Food science & technology	285	6.7%	128	8.1%	1.4%
Materials science & technology	562	13.3%	201	12.7%	−0.6%
Physical science & technology	569	13.4%	204	12.9%	−0.5%
Chemical science & technology	480	11.3%	209	13.2%	1.9%
Agricultural sciences	412	9.7%	203	12.8%	3.1%*
Natural resources	759	17.9%	277	17.5%	−0.4%
Social sciences & humanities	402	9.5%	117	7.4%	−2.1%
TOTAL	4240	100	1583	100	

Source: Olmos-Peñuela et al. (2014a); (following Weingart (2009), we have used this table already when publishing on this database)

Note: χ^2 test was used to assess whether differences exist between population and sample distribution for each field

* indicates statistical differences at 5%. Agricultural sciences are statistically overrepresented in the sample

database containing results of a questionnaire distributed to CSIC's contracted and tenured researchers. The questionnaire[3] included questions covering researchers' profile (position, disciplinary field), their research characteristics (research orientation, operationalising research projects, researchers' task relevance), and external engagement (motivations, frequency, type of external entities, collaboration outputs). Data was collected in 2011 through a multi-method process combining online questionnaires with telephone follow-up ensuring a final sample proportionally distributed by fields and seniority.

Our study population are CSIC's 4240 contracted/tenured researchers in 2011 across 126 research institutes organised in eight scientific fields. Our final sample was 1583 researchers (37% of the population). Table 1 gives a summary of the population distribution, indicating the sample is representative of the study population. Chi Square tests (χ^2) indicate that for the eight fields there are no differences in population and sample distribution (except for the overrepresented agricultural sciences).

Dependent Variables

Table 2 shows definitions and descriptive statistics of our empirical dependent variables. Five dependent variables capture 'open behaviour' in our five research processes.

The variable measuring *open behaviour during research reframing processes* is captured using a binary variable taking the value '1' if the researcher reported

[3] See Olmos-Peñuela et al. (2014a) for more details about the questionnaire structure and data collection.

experiencing *changes* or *substantial changes* in research agenda resulting from relationships with external entities (27.8%), otherwise '0'.

The variable measuring *open behaviour during inspiration processes* is a binary variable taking the value '1' if the researcher reported that the scientific activity was *inspired* or *significantly inspired* by considerations of use (71.4%), otherwise '0'.

The variable measuring *open behaviour during planning processes* is a continuous variable constructed from three items (Cronbach $\alpha = 0.789$) capturing researchers' pro-social behaviour (following D'Este et al. (2013)), identifying the potential use of the results, users and intermediaries. This variable ranges from 1 to 4 with average researcher scoring 2.52.

The variable measuring *open behaviour during planning processes* is a continuous variable constructed from four items (Cronbach $\alpha = 0.713$) measuring researchers' use of external knowledge (i.e. to keep abreast of the areas of interest of external parties, to test research's feasibility/practical application, to obtain information or materials necessary for developing current research lines, and to explore new research lines). This variable ranges from 1 to 4, the average researcher scoring 3.11.

We test that those multiple-item scale variables (open behaviour in planning and execution processes) satisfy the unidimensional criterion. Additionally, Cronbach α indicates that the items forming each index are reliable; with Q-Q plot procedures showing both variables match a normal distribution.

The variable measuring *open behaviour during dissemination processes* is a binary variable with a value '1' if the researcher reported as *important* or *very important* at least one co-creative dissemination activity (28.5%) (i.e. obtaining patents or other intellectual property rights; developing exhibitions and/or catalogues; generating clinical guidelines, standards, codes of practices), and '0' otherwise.

Independent and Control Variables

Our explanatory variables are regrouped in six categories: (1) academic identity; (2) previous experience; (3) local environment; (4) academic network; (5) epistemic community; and (6) control variables. For succinctness these variables' operational definitions and descriptive statistics are presented in Table 3 with correlation coefficients shown in the "Appendix".

First we present descriptive results of our control variables to illustrate the sample's main characteristics. Our sample is composed of *Post-Doc* contracted researchers (18.1%) and permanent researchers categorised following CSIC's structure as *Tenured scientists* (36.4%), *Scientific researchers* (27.2%) and *Research professors* (18.3%).[4] Following the CSIC classification, the sample is divided into eight scientific fields: *natural resources* (17.5%) is the largest sample field, followed by *biology & biomedicine* (15.4%); *chemical science & technology* (13.2%);

[4] CSIC's academic ranking system has three kinds of permanent positions, research professor ('profesor de investigación') being the most senior figure, followed by scientific researcher and tenured scientist ('investigador científico' and 'científico titular', respectively).

Table 2 Operational definitions and descriptive statistics of the dependent variables: researchers' open behaviour during different research processes[a]

	Measure	Sub-items	Method and descriptive statistics
Dependent variables (continuous)			
Open behaviour during planning processes	Measured as an index on a Likert scale ranging from 1 (never) to 4 (regularly) for frequency that researcher engages in each listed activity when conducting research. Scores initially ranged from 3 to 12. To account for "does not apply" answers, each respondent's index was calculated as arithmetic mean of applicable sub-items divided by number of applicable sub-items	To identify the potential results of your research that can benefit users To identify the potential users who can apply the results of your research To identify the intermediaries in order to transfer the results of your results	Sum of three items divided by number of applicable items **Range: 1–4** **Mean: 2.52** **S.D: 0.73** **Cronbach's α:0.789**
Open behaviour during execution processes	Measured as an index on a Likert scale ranging from 1 (not important) to 4 (very important) for degree of importance researcher attaches to listed sub-item as reason for interacting with external entities (firms, public administration agencies, non-profit organisations). Scores initially ranged from 4 to 16. To account for "does not apply" answers, each respondent's index was calculated as arithmetic mean of applicable sub-items divided by number of applicable sub-items	To keep abreast of about the areas of interest of these non-academic entities To test the feasibility and practical application of your research To obtain information or materials necessary for the development of your current lines of research To explore new lines of research	Sum of four items divided by number of applicable items **Range: 1–4** **Mean: 3.11** **S.D: 0.55** **Cronbach's α:0.713**

	Description	Descriptives % of '1'
Dependent variables (categorical)		
Open behaviour during reframing processes	*Dichotomous variable* Coded '1' if researcher experienced changes or substantial changes in past research agenda as result of relationships with external entities, otherwise '0'	**27.8%**
Open behaviour during inspiration processes	Dichotomous variable: Coded '1' if researcher scientific activity was inspired or significantly inspired by practical use and/or application of knowledge outside academic environment, otherwise '0'	**71.4%**

Table 2 continued

	Description	Descriptives % of '1'
Open behaviour during dissemination processes	Dichotomous variable Coded '1' if researcher reported at least one of following three activities as important or very important external collaboration result: 1) obtaining patents or other intellectual property right; 2) developing exhibitions and/or exhibition catalogues; 3) generating clinical guidelines, standards, and codes of practices, '0' otherwise	**28.5%**

[a] This paper adopts the convention that all material reproduced from the questionnaire appears translated into English by the authors and represents a faithful rendering of the Spanish original

physical science & technology (12.9%); *agricultural sciences* (12.8%) and *materials science & technology* (12.7%). Among the smallest field of the sample we found *food science & technology* (8.1%) and *social sciences & humanities* (7.4%). Our sample of researchers collaborated at least once over the last 3 years with *firms* (76.2%), *government agencies* (78.3%) and *non-profit organisations* (48.6%). Our last control variable is a continuous variable labelled *resources secured* (proxying direct benefits excluding knowledge, *cf.* section "Other factors") measured as an index of 5 items (Cronbach $\alpha = 0.668$, indicating its reliability) covering the degree of importance the researcher attaches to non-knowledge resources in interacting with external entities. This variable ranges from 1 to 4 with average researcher scoring 2.86, satisfies the unidimensionality criterion, and matches with a normal distribution (according to the Q-Q plot procedure).

Regarding our independent variables, the academic identity category is captured through the binary variable *entrepreneurial ideal*, taking the value '1' if the researcher reported to attach *importance* or *significant importance* to contributing to the resolution of socioeconomic problems (64%), otherwise '0'.

We capture previous research experience in accessing knowledge using the binary variable *knowledge accessed,* taking the value '1' if the researcher reported obtaining *important* or *very important* information or material for research development as a direct consequence of working with external entities (58.5%), otherwise '0'.

Local environment is captured using two binary variables, institute informal support and institute formal support. *Institute informal support* takes a value '1' if the researcher reported their research institution environment *positively* affects relationships with external entities (28.7%), otherwise '0'. Likewise, *institute administrative support* takes the value '1' if the researcher reported the research centre's administrative and managerial capacity for collaboration *positively* affects external relationships (25.6%), otherwise '0'.

Personal academic network is captured using two variables, personal network and multidisciplinary network. *Personal academic network* is a continuous variable ranging from 1 to 6 capturing (following van Rijnsoever et al. 2008) the extent to

Table 3 Operational definitions and descriptive statistics of the independent (personal and contextual factors) and control variables[a]

	Measure	Sub-items	Method and descriptive statistics
Independent variables (continuous)			
Personal academic network	Personal academic network is measured as index capturing researchers' organisational distance from people with whom they usually conduct research activities. Researchers were asked to indicate two most frequent type of people with whom they usually conduct research. 'Type of people' is an ordinal variable ranked according to researchers' distance from other academics, and ranges as follows: 1. Alone or with people from firms and non-academic entities 2. With people from own research group 3. With people from own research institute 4. With people from other CSIC research institute 5. With people from universities and research centres in Spain 6. With people from universities and research centres in other countries Respondents' scores are computed as average of two most frequent options accounting for "does not apply" answers. Thus, for each respondent, the sum of the score was divided by number of applicable item(s). Final scores take non-integer values from 1 to 6, where 1 indicates that researchers' do not usually work with other academics, and 6 indicates they primarily work with researchers in other countries		Sum of two most frequent options divided by number of applicable items **Range: 1–6** **Mean: 3.42** **S.D: 0.84** **Cronbach's α: N.A**
Resources secured	Measured as an index on a Likert scale ranging from 1 (not important) to 4 (very important) for degree of importance researcher attaches to each sub-item as personal motivation for external interactions (firms, public administration agencies, non-profit organisations). Scores initially ranged from 5 to 20. To account for "does not apply" answers, each respondent's index was calculated as arithmetic mean of applicable sub-items divided by number of applicable sub-items	To obtain additional funds for your research To be part of a professional network or expand your professional network To have access to the experience of non-academic professionals To have access to equipment and infrastructure necessary for your lines of research To obtain grants and job opportunities for your students	Sum of five items divided by number of applicable items **Range: 1–4** **Mean: 3.05** **S.D: 0.53** **Cronbach's α: 0.668**

	Description	Descriptives % of '1'
Independent variables (categorical)		
Entrepreneurial ideal	*Dichotomous variable* Coded '1' if researcher attaches importance or significant importance to contributing to the resolution of socioeconomic problems, otherwise '0'	**64%**

Table 3 continued

	Description	Descriptives % of '1'
Knowledge accessed	*Dichotomous variable* Coded '1' if researcher, as a direct consequence of external collaboration, has obtained important or very important information or material for the development of the research lines, otherwise '0'	**58.5%**
Institute informal support	*Dichotomous variable* Coded '1' if researcher reports that research institute support to initiate collaborative activities positively affects current external relationships, otherwise '0'	**28.7%**
Institute formal support	*Dichotomous variable* Coded '1' if researcher reports that research institute's administrative and managerial capacity positively affects current external relationships, otherwise '0'	**25.6%**
Multidisciplinarity network	*Dichotomous variable* Coded '1' if researcher reports usually conducting research with researchers from other scientific disciplines, otherwise '0'	**28.8%**
Lack of scientific merit	*Dichotomous variable* Coded '1' if researcher reports that lack of scientific merit is an obstacle or a major obstacle in establishing external relationships, otherwise '0'	**29.7%**
Position	Academic position was measured as follows: **post-doc [POST]** researcher is a binary variable coded '1' if researcher is post-doctoral contracted scientist, otherwise '0'; **tenured scientist [TEN]** is a binary variable coded '1' if researcher is tenured scientist, otherwise '0'; **scientific researcher [SCIEN]** is a binary variable coded '1' if researcher is scientific researcher, otherwise '0'; finally, **professor researcher [PROF]** is a binary variable coded '1' if researcher is professor researcher, otherwise '0'. The first category was used as reference category in the econometric models. These mutually exclusive categories are based on CSIC's research staff categorisation	**POST: 18.1%** **TEN: 36.4%** **SCIEN: 27.2%** **PROF: 18.3%**
Firm	*Dichotomous variable* Coded '1' if researcher has collaborated at least once over last three years with firms located in Spain, otherwise '0'	**76.2%**

Table 3 continued

	Description	Descriptives % of '1'
Government agencies	*Dichotomous variable* Coded '1' if researcher has collaborated at least once over last three years with government agencies, otherwise '0'	**78.3%**
Non-profit organizations (NPOs)	*Dichotomous variable* Coded '1' if researcher has collaborated at least once over last three years with NPOs, otherwise '0'	**48.6%**
Fields	Research fields were measured with a series of dichotomous variables defined as follows: **Biology & biomedicine [BIO]** is a binary variable coded '1' if respondent is researcher in biology and medicine, otherwise '0'; **Food science & technology [FOOD]** is a binary variable coded '1' if respondent is researcher in food science and technology, otherwise '0'; **Materials science & technology [MAT]**, is a binary variable coded '1' if respondent is a researcher in materials science & technology, otherwise '0'; **Physical science & technology [PHY]** is a binary variable coded '1' if respondent is researcher in physical science & technology, otherwise '0'; **Chemical science & technology [CHE]**is a binary variable coded '1' if respondent is researcher in chemical science & technology, otherwise '0'; **Agricultural sciences [AGR]** is a binary variable coded '1' if respondent is researcher in agricultural sciences, otherwise '0'; **Natural resources [NAT]** is a binary variable coded '1' if respondent is researcher in natural resources, otherwise '0'; and finally **Social science & humanities [SSH]** is a binary variable coded '1' if respondent is researcher in social science and humanities, otherwise '0'. This last category of researchers was used as the econometric model's reference category. These mutually exclusive categories are based on CSIC's scientific areas organisation	**BIO:** **15.4%** **FOOD:** **8.1%** **MAT:** **12.7%** **PHY:** **12.9%** **CHE:** **13.2%** **AGR:** **12.8%** **NAT:** **17.5%** **SSH:** **7.4%**

[a] This paper adopts the convention that all material reproduced from the questionnaire appears translated into English by the authors and represents a faithful rendering of the Spanish original

which researchers are organisationally distant from their academic collaborators. The average researcher scores 3.46, higher scores meaning higher organisational distances. This variable's normality was verified with the Q-Q plot procedure.

Multidisciplinary network is a binary variable that takes the value '1' if the researcher reported to *usually* conduct research with researchers from other scientific disciplines (28.8%), otherwise '0'.

The epistemic community category is captured using the binary variable *lack of scientific merit*, which measures whether the lack of scientific merit attached to external collaborations hinders establishing external relationships. 29.7% of the sample reported lack of scientific merit associated with external collaborations as *a major obstacle or an obstacle* (coded as '1') for establishing relationships with external entities, otherwise '0'.

Analytical Plan

The analytical plan conducted using the structural equation package Mplus 3, (see Muthén 1998–2004) consists of using a multivariate model which allows to estimate simultaneously a number of regressions for explaining 'open behaviour'. More specifically, testing our conceptual framework requires estimating five regression equations, one for each dependent variable associated with 'open behaviour' during different research processes. Due to our dependent variables' nature, we use different kind of regressions: binary probit for our binary variables (open behaviour during reframing, inspiration and dissemination processes), and ordinary least square for our continuous variables (open behaviour during planning and execution processes). The multivariate model analysis simultaneously estimates these five equations, accounting for possible correlations between the five dependent variables. Controlling for the existence of mutual covariances between equations disturbances allows us to overcome receiving inefficient estimators that could be obtained if error terms would be correlated when separately estimating regressions (Belderbos et al. 2004). We use weighted least squares mean and variance adjusted estimators – WLSMV (Landry et al. 2010; Ouimet et al. 2007) since we combine different types of regressions.

The first analytic stage consists of estimating the saturated multivariate model, estimating the five regressions jointly, but that cannot assess for model fit because of its zero degrees of freedom.

The second stage is to estimate the previous saturated model but removing the insignificant independent variables (i.e. when p-value>10%, two-tail), which means fixing insignificant coefficients at zero. This leads to the unsaturated model with free error terms. We conduct an iterative process in which we progressively remove all insignificant independent variables identified at each iteration until obtaining a model with all significant parameters for the independent variables. The resulting unsaturated model with free error terms can be assessed for model fit, since fixing insignificant parameters at zero allows estimating a model with degrees of freedom (unlike the saturated model). The insignificance of this unsaturated model with free error terms indicates a good fit of the model.

Finally, to verify whether it would be more appropriate to estimate separately the five regression equations, we estimate the 'constrained unsaturated model with free error terms fixed at zero', the result of estimating the final unsaturated model

(without insignificant independent variables) but fixing the covariances between the equation error-terms at zero. This constrained unsaturated model's lack of significance indicates the model has a good fit – and it is appropriate to estimate the regressions separately; whereas its significance indicates a poor fit of the model – and the appropriateness of estimating the regressions simultaneously through a multivariate model.

Results

Table 4 presents the fit of the unsaturated model with free error terms, excluding insignificant parameters found in the saturated model. The results of comparing the unsaturated model and the constrained unsaturated model are reported in Table 4's lower section. The unsaturated model has 36 degrees of freedom and an insignificant χ^2 statistic of 38.25 (p-value = 0.368), indicating that the final unsaturated model has a very good fit. The R^2 estimates are presented in Table 4's lower section: 'open behaviour' is most effectively explained during execution processes. For the constrained unsaturated model, the computed value of the χ^2 is significant ($\chi^2 = 257.66$; 44 degrees of freedom; p-value = 0.000), indicating a poor model fit. This suggests that the use of separate regression models is not appropriate to estimate the factors affecting 'open behaviour' during different research processes since it avoids the interdependences between the openness dependent variables, which may lead to inefficient estimators. For our empirical analysis, this implies that the unsaturated model with error-term covariances better reflects the data than the constrained unsaturated model with error-term covariances fixed at zero.

Error-term covariances between 'open behaviour' during different research processes (indicating interdependences between the dependent variables) are listed in Table 4's lower part. Results show strong significant and positive associations between researchers' open behaviour during the five research processes (except for indicating a weak positive relation between open behaviour during execution and dissemination processes). More specifically, covariances range from 0.354 to 0.029, being the highest relationship between open behaviour during reframing and inspiration processes. Overall, this suggests that researchers demonstrating open behaviour tend to demonstrate it consistently throughout their research processes.

Given that our evidence suggests that our model make sense, we can then turn to consider which factors are associated with researchers' open behaviour as a means of identifying to what extent the evidence validates the hypotheses in the "What Makes Researchers Open to External Influences?" section related to the personal and contextual factors that might lead researchers to behave in more open ways. To this end, Table 5 summarises those results showing a significant relationship between the independent variables and researchers' open behaviour. From this we found 3 variables significantly related to open behaviour in all five research processes: *entrepreneurial ideal*, *knowledge accessed*, and collaborating with *firms*. Both of our personal factors – an identity closer to the entrepreneurial ideal (H1)

and researchers with a positive evaluation of their past collaborative experience (H2) – are significantly and positively associated with more 'open' behaviour. Of the control factors, collaborations with firms emerge as related to researchers' open behaviour across all the research processes, whereas collaborations with government agencies and NPO were only associated with open behaviour in some processes (*planning* process for government agencies and NPO and *dissemination* process for NPO).

It is important to interpret these results, because as they are written they make them look like it is strictly speaking 'entrepreneurial scientists' who collaborate with firms and who are open, but what we are referring to are academics that have a set of professional norms which accept the validity of different kinds of knowledge, rather than those with a purely Mertonian strict view of legitimate knowledge. Open behaviour is also associated with academics who have past positive experiences of working with users, and whose own research trajectory has been shaped by that external knowledge. Finally, working with firms is not necessarily about commercialisation of knowledge, but working with users who have very different requirements for their knowledge production than the academic community. That is more the case than it is with government agencies and NPO, where academics and these groups co-determine research questions and agendas and hence are already much more cognate (as argued by Villanueva-Felez et al. 2013).

The other variables are more ambivalent, and we restrict ourselves to brief comments. We only find a positive relationship between researchers' positive perception about *informal institutional support* and open behaviour in dissemination processes (H3). Likewise, we find a low significant negative relation between having *personal networks more closely connected to users* and open behaviour in *execution* processes (H4a). *Multidisciplinary networks* emerge as significant and positively associated with open behaviour in three of the five processes (*inspiration, planning* and *dissemination,* H4b). This fits with our headline results, that is, that an acceptance of other kinds of knowledge (in this case produced outside one's own disciplinary paradigm) is associated with open behaviours.

We also tested our findings against the control variables, and we find that non-research personal characteristics are not generally associated in either direction with openness. *Academic position* appears not to be significantly associated with open behaviour. Academics reporting receiving research resources through collaboration (*resources secured*) is significant and positively associated with open behaviour in *planning* and *execution*, but barely significant and negatively linked to openness during *reframing* processes. There is little evidence that researcher field is associated with openness – our results suggest a higher open behaviour amongst SSH researchers compared to those in natural resource disciplines in three processes (*reframing*, *inspiration* and *dissemination*). Conversely, SSH researchers tend to exhibit less open research behaviour than researchers in food and physical science & technology in *planning* and *execution* processes.

Table 4 Unsaturated multivariate model results explaining 'open behaviour' during different research processes

Independent variables	Dependent variables									
	Open behaviour during reframing		Open behaviour during inspiration		Open behaviour during planning		Open behaviour during execution		Open behaviour during dissemination	
	Coeff *(β)*	*t* value	Coeff. *(β)*	*t* value	Coeff. *(β)*	*t* value	Coeff. *(β)*	*t* value	Coeff. *(β)*	*t* value
Intercept					1.536***	9.757	1.129***	11.970		
Threshold 1	1.023***	3.019	0.286	0.691					1.752***	4.920
Academic identity										
Entrepreneurial ideal	0.309***	3.130	1.026***	10.246	0.360***	8.545	0.095***	3.553	0.167*	1.689
Previous Experience										
Knowledge accessed	0.356***	3.888	0.313***	3.106	0.171***	4.128	0.119***	4.780	0.640***	6.665
Local environment										
Institute informal support									0.244**	2.594
Institute administrative support										
Academic network										
Personal network							−0.027*	−1.782		
Multidisciplinary network			0.292**	2.643	0.162***	3.913			0.194**	2.176
Epistemic community										
Lack of scientific merit			0.274**	2.554						
Control variables										
Firm	0.449***	3.276	0.329**	2.695	0.248***	4.548	0.101***	3.191	0.563***	4.088
Government Agency					0.142**	2.668				
Non-profit organisation					0.171***	4.317			0.228**	2.575
Resources secured	−0.148*	−1.750			0.079**	2.052	0.589***	25.857		
Tenured scientist[a]										
Scientific researcher[a]							−0.065**	−2.506		

Table 4 continued

Independent variables	Dependent variables									
	Open behaviour during reframing		Open behaviour during inspiration		Open behaviour during planning		Open behaviour during execution		Open behaviour during dissemination	
	Coeff *(β)*	*t* value	Coeff. *(β)*	*t* value	Coeff. *(β)*	*t* value	Coeff. *(β)*	*t* value	Coeff. *(β)*	*t* value
Professor researcher[a]										
Biology & Biomedicine[b]										
Food science & technology[b]					0.240***	3.064	0.106**	2.143		
Materials science & technology[b]			0.761***	4.328						
Physical science & technology[b]					0.251***	4.069	0.144***	3.762		
Chemical science & technology[b]										
Agricultural sciences[b]	−0.342***	−2.390					0.098**	2.407	−0.342**	−2.390
Natural resources[b]	−0.298***	−2.202	−0.491***	−3.530					−0.298**	−2.202
Covariance between disturbances	ε_1		ε_2		ε_3		ε_4			
ε_2	0.354***									
ε_3	0.127***		0.209***							
ε_4	0.062***		0.072***		0.034***					
ε_5	0.287***		0.235***		0.116***		0.029*			
Number of cases	1064									
R^2	0.112		0.325		0.219		0.437		0.202	
Unsaturated model with free error terms		$\chi^2(36) = 38.25$, *p-value* $= 0.368$								
Constrained unsaturated model with free error terms fixed at zero:		χ^2 (44) $= 257.66$, *p-value* $= 0.000$								

*, ** and *** indicate that the variable is significant at the 10%, 5% and 1% level, respectively

[a] The reference category is Post-Doc

[b] The reference category is Social sciences & humanities

Table 5 Summary overview of significance and directionality of results in Table 4

Independent variables	Open behaviour during reframing	Open behaviour during inspiration	Open behaviour during planning	Open behaviour during execution	Open behaviour during dissemination
Academic identity					
Entrepreneurial ideal	+++	+++	+++	+++	+
Previous Experience					
Knowledge accessed	+++	+++	+++	+++	+++
Local environment					
Institute informal support					++
Academic network					
Personal network				−	
Multidisciplinary network		++	+++		++
Epistemic community					
Lack of scientific merit		++			
Control variables					
Firm	+++	++	+++	+++	+++
Government Agency			++		
Non-profit organisation			+++		++
Resources secured	−		++	+++	
Scientific researcher[a]				− −	
Food science & technology[b]			+++	++	
Materials science & technology[b]		+++			
Physical science & technology[b]			+++	+++	
Agricultural sciences[b]	− − −			++	− −
Natural resources[b]	− − −	− − −			− −

The number of characters corresponds to significance: 1 is 10%, 2 is 5%, 3 is 1%

Signs correspond to the direction of the relationship between dependent and independent variables: '+' is positive direction, '−' is negative direction

[a] The reference category is Post-Doc

[b] The reference category is Social sciences & humanities

Discussion and Conclusion

Our paper explores whether there is a link between an orientation towards accepting the legitimacy of external knowledge (open orientation) and academics incorporating that external knowledge in micro-practices of science (open behaviour). We are driven here to respond to D'Este and Perkmann's (2011) argument that understanding researchers' decisions to engage externally is a pressing question demanding further fundamental consideration in science policy studies, given that engagement may both aid and hinder scientific research efforts (Gulbrandsen and Smeby 2005). We propose our new concept of 'openness' as a means of addressing two salient theoretical points. Firstly, theory suggests that when researchers incorporate user knowledge into their micro-practices of research (researcher openness), that should mean that the resultant knowledge will ultimately be more easily taken forward by users (more 'usable') (Spaapen and van Drooge 2011). Secondly, researcher openness might be explicable in terms of a set of individual level characteristics of a personal and professional nature (*cf.* Bercovitz and Feldman 2008).

Our first finding is to validate recent interest in researcher influences and motivations, underscoring a need for further research to explore how personal and contextual factors influence researchers' external engagement decisions. Complementing Lam's (2011) work on extrinsic rationales for engagement, we find that personal/intrinsic factors are also important, in terms of the willingness of researchers to accord legitimacy to non-scientific knowledge in research processes as well as to past experiences with engagement. Although we have termed the first personal variable 'entrepreneurial ideal', what our variable captures is researchers who are prepared to allow external considerations (and external knowledge) to play a role in research micro-practices. The second personal variable is the extent to which an individual is able to see past user engagement activities as beneficial for their own lines of research. The final significant variable is working with firms, a type of user who can be regarded as having a significant institutional distance from university knowledge. Finally, we find (more weakly) that being active in multidisciplinary research networks is also associated with more generally open research behaviours. Interpreting these results together suggests that open behaviour is correlated to researchers having practical and conceptual understanding of the conditions under which research can be usable, transferred and communicated across community boundaries, and experiences in managing the potentially negative trade-offs that this brings.

Taking this interpretation one step further, our (if perhaps slightly tentative) message to policy-makers (including universities) is that propensity towards open behaviour appears to be something that is developed continuously during an academic career – beginning with the Ph.D. and followed with later engagement experiences. If policy-makers are serious at stimulating scholars' openness and creating knowledge more useful for society, then they should target creating positive opportunities for engagement experiences, and ensure that early-career academic formation activities involve interactive learning experiences where good research goes hand-in-hand with creating societal impact (*cf.* Watermeyer 2015). Policy-makers therefore aiming to promoting researchers' external engagement should not exclusively use short-run

incentive and benefits measures for instant engagement. They should ensure that the longer-term processes related to academic identity formation at both initial training (e.g. Ph.D.) and also post-qualification stages provide researchers with opportunities to engage constructively and beneficially with third parties (including academics in other disciplines) in ways that they regard as being academically legitimate.

Given the fact that our own research is exploratory, we accept that further research is needed to integrate between the more extrinsic motivational literatures (e.g. Lam 2011) and our own arguments. Given that our research was quantitative, we see clear value in further exploring these extensive results with more qualitative data asking researchers about the details of how they incorporate user knowledge in their micro-scale research practices. Certainly, as a study of a single institution (CSIC) within one national context, we cannot explore comparatively how researchers' decisions are influenced by either CSIC's own characteristics, or the place of engagement in Spain's socio-technical imaginary (Jasanoff and Kim 2013). Our future research will therefore compare different (kinds of) institutions analysing whether the more symbolic and systems-level factors affect individual researcher 'openness' and the homologisation of researcher norms across science systems (Nedeva 2013).

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Compliance with Ethical Standards

Conflict of interest Elena Castro Martínez was a researcher of the IMPACTO project whose data have been used for the empirical analysis presented in the paper. The paper is the result of the collaboration conducted by the authors, supported by the Eu-Spri forum grant. The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Appendix

See Table 6.

Table 6 Correlation coefficients for independent and control variables

	1	2	3	4	5	6	7	8	9	10	11
1. Entrepreneurial ideal	1										
2. Knowledge accessed	.120	1									
3. Institute informal support	.026	.091	1								
4. Institute administrative support	.052	.070	.649	1							
5. Personal network	−.070	−.072	−.026	−.025	1						
6. Multidisciplinary network	.144	.104	−.037	.015	.036	1					
7. Lack of scientific merit	−.045	−.062	−.004	−.023	−.013	−.027	1				
8. Firm	.222	.143	.010	.019	−.107	.104	−.070	1			
9. Government Agency	.117	.104	.056	.065	.007	.045	−.012	.120	1		
10. Non−profit organisation	.132	.128	−.017	−.002	.031	.140	.006	.187	.232	1	
11. Resources secured	.208	.183	.092	.081	−.021	.059	−.037	.096	.084	.066	1
12. Post−doc scientist	−.007	.014	.083	.093	.013	−.063	.068	−.205	−.042	−.082	.115
13. Tenured scientist	−.012	.021	.063	.083	−.027	.010	−.037	.053	−.025	−.051	.023
14. Scientific researcher	−.027	.011	−.079	−.123	−.010	.027	.012	.051	.053	.083	−.050
15. Professor researcher	.053	.053	−.061	−.041	.032	.019	−.033	.079	.011	.048	−.086
16. Biology & biomedicine	−.064	−.091	−.079	−.064	−.085	−.074	.007	−.059	−.055	−.056	.023
17. Food science & technology	.098	.052	.027	−.018	−.123	.069	−.062	.128	−.023	.016	.055
18. Materials science & technology	−.029	.002	−.086	−.037	.022	.019	.007	.078	−.052	.040	.047
19. Physical science & technology	−.041	−.032	.067	.050	.083	−.065	−.011	−.074	−.022	−.082	−.053
20. Chemical science & technology	.006	.028	.056	.055	−.017	.055	−.033	−.017	−.115	−.092	.026
21. Agricultural sciences	.096	.001	−.020	.003	−.066	−.060	−.018	.103	.072	−.026	−.007
22. Natural resources	−.059	.041	−.009	−.026	.093	.031	.053	−.064	.103	.057	−.038
23. Social science & humanities	.029	.009	.071	.051	.081	.052	.049	−.075	.102	.183	−.053

Table 6 continued

	12	13	14	15	16	17	18	19	20	21	22
1. Entrepreneurial ideal											
2. Knowledge accessed											
3. Institute informal support											
4. Institute administrative support											
5. Personal network											
6. Multidisciplinary network											
7. Lack of scientific merit											
8. Firm											
9. Government Agency											
10. Non−profit organisation											
11. Resources secured											
12. Post−doc scientist	1										
13. Tenured scientist	−.356	1									
14. Scientific researcher	−.287	−.462	1								
15. Professor researcher	−.222	−.358	−.289	1							
16. Biology & biomedicine	.008	−.018	−.033	.052	1						
17. Food science & technology	−.091	.045	.017	.016	−.127	1					
18. Materials science & technology	.018	.011	−.041	.016	−.163	−.113	1				
19. Physical science & technology	.029	.003	−.006	−.026	−.164	−.114	−.147	1			
20. Chemical science & technology	−.048	.003	.030	.009	−.166	−.116	−.149	−.150	1		
21. Agricultural sciences	−.127	.047	.050	.009	−.164	−.114	−.146	−.148	−.150	1	
22. Natural resources	.133	−.052	−.001	−.067	−.197	−.137	−.176	−.177	−.180	−.177	1
23. Social science & humanities	.055	−.028	−.015	−.002	−.121	−.084	−.108	−.109	−.110	−.108	−.130

Beyond .051 de correlation coefficient are significant at standard level 5%

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