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THE ROLE OF PARTICIPATING IN USER-DRIVEN RESEARCH PROJECTS ON SCHOLAR'S ACADEMIC PERFORMANCES: A MODEL THROUGH C-K DESIGN THEORY

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THE ROLE OF PARTICIPATING IN USER-DRIVEN RESEARCH PROJECTS ON SCHOLAR’S ACADEMIC PERFORMANCES: A MODEL THROUGH C-K DESIGN THEORY

ABSTRACT:

Many scholars and policy makers have advocated, at least since the 1980s, to foster the consideration of use and needs of the innovation ecosystem’s partners in science and research projects. Hence, based on literature analysis, we review the role of being involved in user-driven research projects to explain academic performance variance. We highlight that very few scholars record user-driven outputs such as: patents applications, spin-off creations, university-industry co-publications or co-patents. Those who do record significant higher academic performances in terms of publications, citations and average journal rankings. Conversely, a large share of academics are considered as “engaged scholarship” (Perkmann & al., 2013) but without producing above user-driven outputs. We propose a model based on Design Theory to help in the understanding of the situation. In particular C-K framework is useful to represent knowledge dynamic. Based on Hatchuel & al. (2013) works we considered scientific knowledge production as a design process of modelling: proposing new theories based on observations and anomalies. We make the assumption that scholars can be fixed in specific design paths (in particular related to their discipline areas) and that user-driven projects help scientists browse new independent knowledge that help to propose new original theories. We propose a taxonomy of knowledge that can be exchanged with ecosystem’s partners to reach this goal. Applying this model to our case, we highlight that two restrictive conditions are necessary in order to help ecosystem’s partners such as industrial to stimulate science. First, the user-driven research project has to include bi-directional knowledge exchange. Second, the exchanged knowledge has to be different from the initial knowledge base of each party.

We then discuss how those insights could help explaining the variance of academic performances and the role of being engaged in user-driven projects. Indeed, it seems that those conditions are very restrictive and that only a few academics are able to participate in that projects. A large share is instead involved in more transactions projects that are not maximising the exposure to new distinct knowledge for the scientist. Finally we discuss our model through two case studies. In particular, we took two famous cases of scientific discoveries identified as fundamental research ones and discuss the role of user-driven projects. The first is based on Pasteur discovery of the microbiology and the second on CRISPR-Cas9.

Keywords: Academic performances, Design Theory, Science Policy

The question of the consideration of use in science on innovation system performances has long been interpreted as the division between basic versus applied science. By definition, basic science would be carried out without any usage considerations and only following a curiosity-driven paradigm: knowledge production is assumed not to be directly tailored for industrial utilisation (Godin 2006; Bush 1945; Calvert 2006). On the opposite, applied science would conduct researchers to tailor their works to be quickly and easily absorbed by firms to foster innovation (Cohen and Levinthal 2004). Hence, it raises the question of the optimal relative weight of basic versus applied research to maximise National Innovation Systems efficiency. This debate involved numerous researcher generations. For example in the 1930s, Henri Le Chatelier was opposed in a famous controversial debate regarding science organisation in France to Jean Perrin. He called for a science serving human progress therefore necessarily close to the industry. Inspired by Taylor's works, he even proposed that science agenda would have to be shaped by an industrial college (Le Masson and Weil 2016). Nevertheless, after the Second World War the linear model became hegemonic (Godin 2006) and this debate has been on hold for a few decades. However, the step-by-step thinking of the linear model was proved to "*oversimply and misrepresent real life innovation*" (Ooms et al. 2015, 79). Indeed, innovation processes are iterative, characterised by trial-and-error and incremental progress (Kline and Rosenberg 1986). Those theoretical insights coupled to a policy-maker emphasis on university impact since the Bayh-Dole Act in 1980 (Miller, McAdam, and McAdam 2016; Taylor Aldridge and Audretsch 2011) open new thoughts regarding science organisation and how relationship between university and industry has to be shaped.

Seminal theoretical contributions includes Gibbons & al. (1994) who predicted that epistemological and institutional barriers between various forms of knowledge production were dissolving. Curiosity-driven basic research with little or no view for practice ("Mode 1") would be increasingly replaced by research activity carried out in the context of application and favouring both transdisciplinary networks and direct contacts between academics and practitioners (“Mode 2”) (Gibbons et al. 1994). In the *Pasteur’s Quadrant* model (Stokes 1997), Strokes advocated that many of the most famous scientists of all time such as Pasteur, Keynes or Manhattan project’s research teams did (Stokes 1997, 76) were motivated by both practical contributions and theoretical understanding simultaneously. The *Pasteur’s quadrant* introduced a dual approach: scientists can be classified according to both their orientation towards fundamental understanding and the consideration of use of their research. The contribution of Etzkowitz & Leydesdorff (2000) regarding the “Triple-Helix” system also called for an emphasis on collaborations between ecosystems of universities, firms and States and the creation of hybrid collaborative systems between those actors (Etzkowitz and Leydesdorff 2000). Those collaborations are considered as key to enhance regional and economic social development by fostering exchange and co-production of knowledge that can be leveraged by firms (Guerrero, Cunningham, and Urbano 2015). Finally, those models also echoes contributions in the open-innovation field following Chesbrough’s initial works (Chesbrough and Rosenbloom 2002). It has nevertheless been noted that the “Triple-Helix” system led to costly and complex issues regarding knowledge ownership and spin-off ventures with mainly limited ambitions and high attrition rates (Carayannis and Campbell 2012). It conducted to a shift from rapid monetization of knowledge with firms to more open innovation system. This approach involve value creation through coordinated innovation network and closer collaboration between universities and industries (Miller, McAdam, and McAdam 2018), including an emphasis on broader social and environmental stakes (Carayannis and Campbell 2017).

Our brief review of major theoretical contributions regarding science organisation in National Innovation System clearly advocate for a “rapprochement” of science with ecosystem’s end-users needs and uses. We focus here on “user-oriented” research projects which we define as research projects that conduct scholars either to filling patents, establishing spin-off ventures or publishing university-industry (U-I) co-publications or filling U-I co-patents. The key questions are then: **(1) from an empirical perspective, what are the academic performances of those researchers that fulfil user-oriented research projects' criteria versus their peers that are not involved in that kind of projects? (2) How we can explain potential performances variance between them?**

Our objective is first to review major empirical contributions regarding academic performances of researchers involved in user-oriented research projects. Academic performance is here considered in a traditional way: through publications and impact factors although we are aware of this measurement system limitations. We show that only few scholars are recording outputs that characterised user-oriented research projects (ie. patents, spin-off, U-I co-publications or co-patents). Nevertheless, they record higher scientific performances than their peers who do not, including number of scientific publications, number of citations, average ranking of publication's journals. We also note that a large share of scholars are considered (or self-declared) as user-oriented but without recording those outputs. In particular we show that some of them are working with research institutions that clearly separated fundamental research from the consideration of use and that institutions can also record largely acceptable academic performance. In order to give insights regarding those empirical findings, we demonstrated the importance to focus on the knowledge dynamic between scholars and their ecosystem's partners (in particular industrial partners). Based on Design Theories and C-K framework (Hatchuel & Weil, 2003; 2009), we model science reasoning to define the conditions that foster scholar's access to new and original partner's knowledge. In particular we show what sort of knowledge can be bring by an industrial partner to the scholar in order to stimulate new ideas and expansive partitions generation. We finally discuss our insights and further research areas.

1. LITERATURE REVIEW

1.1. Few scholars produce tangible user-driven research outputs but record high scientific & technological impacts:

To classify scholars involved in user-driven research activities, proxies have been used such as: patent filling, spin-off creations or micro-level University-Industry (U-I) collaborations data. Still very few academics are engaged in user-driven activities involving measurable and tangible outputs and evidence can be given for the following output types: (1) patents, (2) spin-off creations and (3) university-industry knowledge collaborations.

First, a very few share of faculty members filled patents (Martínez, Azagra-Caro, and Maraut 2013; Agrawal and Henderson 1997; Azoulay, Waverly, and Toby 2009). For example, in their 15-year longitudinal study regarding two (applied) MIT departments, Agrawal & Henderson (1997) note that on average 10% to 20% of faculty members filed a patent in a given year although 60% published at least one academic paper (Agrawal and Henderson 1997). Those professors are also in general more involved with industrial partners than their peers (Azoulay, Waverly, and Toby 2009). Second, regarding spin-off, again there is evidence that very few academics are involved in that kind of activities. For example in 2011, the number of spin offs per university per year among 157 college and research universities was only 4 in average in the United-States (OECD 2013). Third, regarding knowledge co-development, on a study on Italian inventors Crescenzi & al. (2017) showed that only 19% of patents filled by several inventors include both firm and academic inventors (Crescenzi, Filippetti, and Iammarino 2017). Tijssen (2012) estimated that only 4.2% of Thomson Reuters' Web of Science index publications are attributed to industry-science co-publications (Tijssen 2012).

Nevertheless, the empirical literature focusing on user-driven scholars measured rather by (1) academic patents, (2) spin-off creation and (3) university-industry knowledge collaborations shows that they have a significant higher scientific impact than their peers not involved in that kind of activities. Regarding the first type of output, academics that filled patents have a greater scientific impact than their peers measured by the number of published articles in peer-reviewed journals, the number of received citations and journals ranking. Indeed, filling patents is associated to being extensively cited in the academic literature (Agrawal and Henderson 1997; Breschi, Lissoni, and Montobbio 2008; Van Looy, Callaert, and Debackere 2006). In-depth analyses show that those academics publish in average more scientific articles than their peers (Azoulay, Waverly, and Toby 2009; Van Looy, Callaert, and Debackere 2006) and they publish it in better ranked journals (Azoulay, Waverly, and Toby 2009; Breschi, Lissoni, and Montobbio 2008). In their longitudinal study and controlling for similar career characteristics, Van Looy & al. (2006) showed that in average, the positive effects regarding production, citations and journal ranking are starting even before the time that the academic is filling its first patent. Nevertheless, it should be noted that being extensively involved in patenting activities do not necessarily lead to further additional research performance gains (Azoulay, Waverly, and Toby 2009; Fabrizio and Di Minin 2008): an inverse-curvilinear is probably more representative of the effect of patenting on academic performances (Banal-Estañol, Jofre-Bonet, and Lawson 2015). Second, similar results are observed for those involved in academic spin-off. For example, by studying the development of the biotechnology industry, Zucker & Darby (1996) introduced the notion of "*star scientists*": those who have recorded more than 40 genetic discoveries by 1990 in GenBank (or more than 20 articles reporting genetic discoveries). It appeared that they account for only 0.8% of all scientists listed in GenBank through 1990 but represent 17.3% of biotechnology field published articles. Those "*star scientists*" were particularly involved in entrepreneurship to ensure the diffusion of recombinant DNA or were even hired by firms willing to developed biotechnology capabilities (Zucker and Darby 1996). Third, we also found evidence that academics engaged in U-I collaborations also better perform than their peers. Tijssen (2018) by measuring scientific impact of academics with at least 10% of scientific co-publications with industrial co-authors reported that they record in average a higher number of publications and a higher level of citations both from scientific journals and patents - scientific articles cited in the "non-patent literature" of the patent application (Tijssen 2018).

There is also evidence that user-oriented researchers also record higher technological impact than their peers. Those insights are reported by a couple of study exploring firms' side. At macro level analysis, Comin & al. (2018) showed that a +1% increase of expenditures in the most user-oriented PRO in Germany, Fraunhofer-Gesellschaft, conducts to +1% increase in economic growth and +0,7% of productivity growth (Comin et al. 2018). At micro-economic level, Baba & al. (2009) showed that U-I collaborations with "*Pasteur scientists*" following Strokes' representation lead to significant increase of firm's R&D productivity (Baba, Shichijo, and Sedita 2009).

1.2. Lots of academics engaged in user-driven research without recording dedicated outputs:

We have shown that only few academics record tangible outcomes from their user-oriented research (ie. patents, co-patents, spin-off or co-publications). Nevertheless, there is evidence that numerous academics report carrying out user oriented research. It also match with the fact that policy-makers and University Technology Transfer (UTT) offices have influenced scholars to be more involved in user-driven research projects.

Tijssen (2018) classified academic research activities throughout four categories: inventor, entrepreneur, crossover researchers (ie. those who have already a professional track record with a company involvement or who are involved in joint-research with the industry) and researchers. He noted through a survey at European universities that only 30% of academics considered themselves as "researcher" (Tijssen, 2018, p. 1633). Perkmann & al. (2013) in a literature review regarding university-industry interactions reported results of a couple of studies on academic engagement[1] (Perkmann et al. 2013). It appeared that for example, consulting activities might concern between 17% (life science academics in Germany, 12-month study) and up to 68% (Ireland, entire careers) of academics. Collaborative research might concern between 17% (US researchers in universities, 12-months study) and up to 44% (UK physical and engineering academics, 24-month study) of academics.

Furthermore, academics have received incentives by policy-makers and their UTT offices to be more involved in academic research commercialisation (Miller, McAdam, and McAdam 2018). As Azoulay (2009) reported: "*Both the current level and the trend line for academic patenting leave little doubt that the contemporary research university has become a locus of commercially oriented innovation*" (Azoulay, Waverly, and Toby 2009).

Those elements tend to indicate that there is numerous scholars involved in academic engagement but that a large share do not produce a significant amount of user-driven outputs such as patents, spin-offs, co-patents or co-publications. We can nevertheless claim that the presence of those outputs might not be sufficient to classify a researcher as "user-oriented" and then review its academic performances.

1.3. Some scholars are still involved in institutions with clear separations between fundamental and user-driven research projects:

A couple of researchers are recording adequate academic performances without being involved in user-driven activities. In particular, some institutions are still evolving through the

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[1] Perkmann & al. (2013) defined academic engagement as "*knowledge-related collaboration by academic researchers with non-academic organisations. These interactions include formal activities such as collaborative research, contract research, and consulting, as well as informal activities like providing ad hoc advice and networking with practitioners*". (p. 424)

linear model paradigm. The so-called “linear model” is mainly linked to Vannevar Bush’s report *Science the Endless Frontiere* published in 1945 (Bush 1945).

A few scholars gave evidence that the linear model is still present in National science organisation systems (Goldstein and Narayanamurti 2018; Godin 2006). Calvert’s qualitative study in 2006 showed that policy-makers still consider the conceptual divide between basic and applied useful to interact with scientists. Nevertheless, the study also showed that “*scientists can tailor their work to make it appear more applied.* […] *because the boundary of basic research is so flexible and contingent, it can be used in many different ways*” (Calvert 2006, 213–214). There is some evidence of the non-relevance of the basic vs. applied divide from the academic point of view (Gulbrandsen and Smeby 2005). Nevertheless, as Balconi & al. (2010) said: “*it becomes a legitimate question to ask why is the LM [linear model] continuously criticised if it is so patently wrong*” (Krawczyk-Stuss et al. 2015, 1).

In particular there is lasting evidence of the linear model in some highly successful Public Research Organisation with a very sharp division between an “applied research department” and a “basic research department”. Some examples are reported for the Department of Energy (Goldstein and Narayanamurti 2018) or the CEA in France (Cour des Comptes, 2017). Nevertheless, even if Narayamuti & al. (2017) consider that “*this false dichotomy* [between basic vs. applied] *has become a barrier to the development of a coherent national innovation policy*.” (Narayanamurti, Odumosu, and Vinsel 2017, 31), those PRO still record good scientific performances. CEA Science, the basic science department of the CEA, has scientific publications per researcher very similar to the MIT in the United States or Max Planck in Germany and filled in 66 patent per year in average during the period 2007 – 2015 (Cour des Comptes, 2017). It could indicate that as it is difficult to produce in a long-term high performance “user-oriented research” without suffering from some negative effects, protecting fundamental research migt conduct to adequate academic performance results.

Finally, it appears that we found divergent results in the literature. First, a couple of scholars developed theories advocating for more “user-oriented” research throughout the ecosystem in order to foster academic and technological advances. We found that those researchers with tangible outcomes regarding “user-oriented” research such as patent, spin-off, U-I co-patents or co-publications better perform than their peers in terms of scientific and technological impacts. Nevertheless, on one hand there is a large share of scholar involved in university-industry interactions that do not record those tangible user-oriented outputs. On the other hand, the “*linear model*” is still performing in few organisations with a clear divide between basic and applied research and they record high scientific performance levels. As the result, we need to propose a new model to better understand academic performances regarding user-oriented research and University-Industry interactions. We then define the following research questions: **How to define a model that takes in account (1) why do scholars involved in user-oriented projects with tangible outputs better perform than their peers in terms of academic impact? (2) Why does it seems that difficult for scholars to produce those tangible outputs even if they are participated in projects with innovation ecosystem’s partners?**

2. CAPITALIZING ON DESIGN THEORIES TO MODEL KNOWLEDGE DYNAMIC IN USER-DRIVEN RESEARCH PROJECTS:

2.1. Literature insights and the focus on knowledge dynamic to explain variance in scholar’s academic impact:

In order to explain the academic impact variance between scholars involved in user-oriented research projects and those who do not, colleagues firstly dug into individual characteristics. As Zucker & Derby (1996) explained: “*It is misleading to think of scientific breakthroughs as* *disembodied information which, once discovered, is transmitted by a contagion-like process in which the identities of the people involved are largely irrelevant*" (Zucker and Darby 1996, 12709). We identified three types of personal factors in the literature. The first is related to human capital and the Matthew's effect (eg. Azoulay et al., 2009; Banal-Estañol et al., 2015; Van Looy et al., 2006): those academics who produce user-driven outputs could be, by nature, the "naturally" top-performer. The second factor is focusing on social capital and reputation: ties and networks could be particularly relevant to perform U-I collaborations or to establish spin-off (eg. Breschi et al., 2008). Third factor, personal values and culture that could help academics to avoid science-industry barriers (Kanama and Nishikawa 2017; Antonioli, Marzucchi, and Savona 2017; Galán-Muros and Plewa 2016). We acknowledge that individual characteristics constitute a very strong baseline to explain the level of involvement of academics in user-oriented research projects. Nevertheless, they might partly being influenced by broader factors such as the sector or discipline - life science for example is merely oriented toward "user-orientation" (Blumenthal et al. 1996; Cohen, Nelson, and Walsh 2002) – or university policies regarding commercialization (Agrawal and Henderson 1997). Furthermore, we found evidence in the literature that focusing on the knowledge dynamic between scholars and their innovation ecosystem's partners might help to give additional insights regarding variance in academic performances and the role of participating in user-oriented research projects.

The first insight is based on the discovery - invention cycle (Narayanamurti, Odumosu, and Vinsel 2017; Goldstein and Narayanamurti 2018). Hence, user-oriented research projects might sometimes conduct actors to firstly produce a new invention. Following the invention, scholars are producing the necessary scientific discovery going along with the invention. Examples include: James Watt' invention of the steam engine and the science of thermodynamics, Bell laboratories' invention of the transistor and associated scientific advances in physics; the atomic bomb and further scientific advances regarding chemistry and physics. Indeed, scientists involved in a new invention could be able to produce more original academic knowledge due their privileged access to this invention.

Second insight, some academics involved in user-driven research projects recognize that it helped them regarding their scientific knowledge production. Van Looy & al. (2016) highlighted that by filling patents, scholars have raised the quality of their research. Indeed they access original knowledge through the review of the patent literature in addition to the traditional literature in scientific journals. Siegel & al. (2003) in a study on 98 academics involved in U-I interactions in five different universities showed that 65% of the scientists stated that those interactions have positively influenced their scientific empirical works. As stated by one interviewee: "*there is no doubt that working with industry scientists has made me a better researcher. They help me refine my experiments and sometimes have a different perspective on a problem that sparks my own ideas*" (Siegel, Waldman, and Link 2003, 23). Indeed U-I interactions can lead to new and interesting research topics and research agenda (Gulbrandsen and Smeby 2005). In its study on academic engagement and academic performances, Banal-Estanol & al. (2015) also highlighted that: "*the generation and/or refinement of ideas through puzzle-solving may in turn improve research outcomes because the resulting ideas can be transformed into more and/or better academic papers*" (Banal-Estañol, Jofre-Bonet, and Lawson 2015, 1161).

Defining a model encompassing knowledge dynamic regarding user-oriented research projects to better explain technological and scientific impact of those scholars appears critical. Furthermore, integrating the role of industrial partners in user-oriented research projects could also help regarding the literature gap identified by de Wit-de-Vries & al. (2018) on the knowledge contribution of industrial partner in U-I collaborations. Indeed, authors showed that it is mainly reduced to formulating interesting research question and providing data in the application context (de Wit-de Vries et al. 2018).

2.2. C-K Design Theory fundamentals and main principles:

C-K design theory aims to provide a unified and rigorous framework for Design and has been initially developed by Hatchuel & Weil (2003, 2009). C-K theory is largely used in the industrial context to develop tools and methods to coordinate innovation efforts and to deeply understand innovation process (Hatchuel and Weil 2003, 2009). In particular, its ability to describe the generation of new objects and new knowledge has been highlighted both in academic literature and following industrial use. The theory is based on the interplay between two distinct but interdependent spaces. First, the knowledge space (K) that contains all propositions with a logical status (ie. true or false) regarding available knowledge that a designer is able to draw on to perform its design activity. Second, the concept space (C) that contains all propositions regarding outputs or objects that are set up by the designer but neither true nor false according to the state of the designer's knowledge. Indeed, when designers are faced with concepts, they cannot affirm whether such a thing may be possible or that this would never be the case. Those concepts are partially unknown outputs or objects so those propositions are qualified as "undecidable" relative to the content of the knowledge space (K) if it is not possible to prove that these are true of false in the knowledge space. The C space has a tree structured and each node represent a partition in sub-concepts.

Furthermore, during the design process, both concept and knowledge spaces are expandable following four possible transformation: C➔K (ie. conjunction) ; K➔ C (ie. disjunction) ; C➔C (ie. partitions) and K➔K. In particular, the design process attempts to define conjunction: to transform an "undecidable" proposition in the concept space into a logical proposition in the knowledge space.

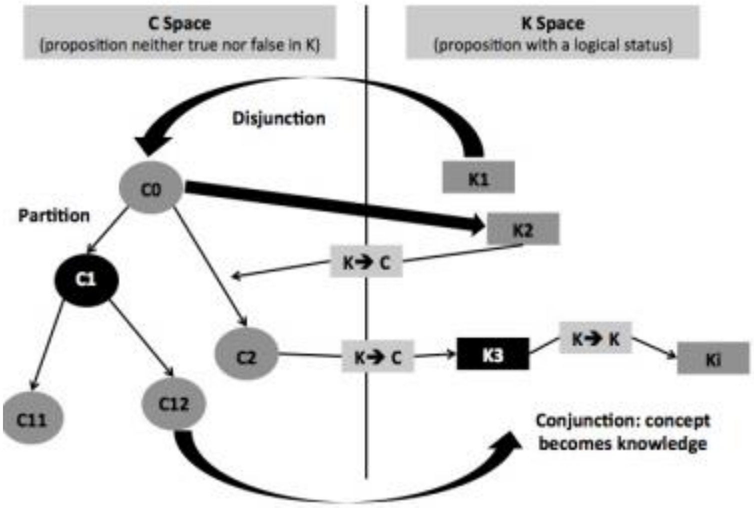

Figure 1: C-K design formalism (from Hatchuel & Weil, 2003)

2.3. C-K theory as an adequate tool to model user-oriented research projects and associated knowledge dynamic:

C-K theory have been previously used by Gillier & al. (2010) to help to better understand knowledge stakes when two distinct entities are interacting - ie. the "*matching – building model*" regarding R&D partnerships (Gillier et al. 2010). Drawing on the former, Klasing-Chen & al. (2017) were the first to used C-K theory as a framework to give insights regarding University - Industry (U-I) collaborations. In particular, they used C-K theory to illustrate how foster U-I collaborative PhD performances through the mapping of knowledge dynamic. They build an innovative methods called "C-K co-generation" in order to jointly design mutually beneficial research programs between an industrial, a PhD student and an academic supervisor (Klasing Chen et al. 2017). They highlighted that "*knowledge transfer existed and led to new applications and small value creations, but allowed little evolutions in the partner's generativity. The most important value creation came from new concepts, proposed thanks to several interactions between partners and to the specific mechanisms used when building a C-K map*" (Klasing Chen et al. 2017, 312)

C-K theory also conducted to further theoretical development regarding “fixation” effects that are very useful to understand knowledge dynamics. Indeed, it highlights how a designer could be lock-in in a specific design path and then not able to explore more innovative paths (Agogué 2012; Hatchuel, Le Masson, and Weil 2011). In particular, the literature in management identified that some innovation pathways do not seem achievable for a specific firm due to lack of adequate knowledge, lack of absorptive capacity or due to specific historical pathways depending on starting point and hazardous events (Sydow, Schreyögg, and Koch 2009). Kaplan & Tripsas (2008) introduced the notion of “*cognitive path dependence*” by showing how actors select ideas within a collective cognitive framework around a dominant technological trajectory (Kaplan and Tripsas 2008). Thrane & al. (2010) highlighted how collective cognitive framework can lead to constrain the exploration of alternatives (Thrane, Blaabjerg, and Møller 2010). C-K theory is a useful tool to recognize the presence of fixation effects and even could help actors to explore non-fixed paths.

3. A MODEL OF USER-ORIENTED RESEARCH PROJECTS EFFECTS ON SCHOLAR’s ACEDEMIC PERFORMANCES:

3.1. Scientific reasoning through C-K theory framework:

We supposed a situation in which a scientist would like to produce new original scientific knowledge. Hatchuel & al. (2013) demonstrated how scientific reasoning could be analysed with Design theories. Indeed, the scientific method is based on the logic of modelling: an operation that conducts scholars to produce scientific knowledge by using both observations and models. In particular authors established that science is driven by anomalies that has to be explained: “*facing anomalies, the scientist makes the hypothesis that there may exist an unknown object Xx, observable but not yet observed, that would reduce the anomalies if it verifies some properties*” (Hatchuel et al. 2013, 3–4). In particular, the design process leads to knowledge development regarding this unknown object and/or the increase of observations (that can be provoked by new experimental plans). Scientific knowledge production could be envisioned as a design process of theories that match a specific set of criteria (such as observability, consistency, completeness, etc.).

We set two assumptions:

- **Assumption 1:** scholars could suffer from fixations effects related to their discipline area and could then not be able to provoke expansive partitions (ie. propose concepts that are radically new). We provide below main rationales of those fixation effects.
- **Assumption 2:** scholars need to acquire missing knowledge related to non-fixed design paths in order to provoke conjunctions of new and original concepts. This is usual assumption in C-K theory framework.

In figure 2, we formulate the situation through usual C-K theory's frame.

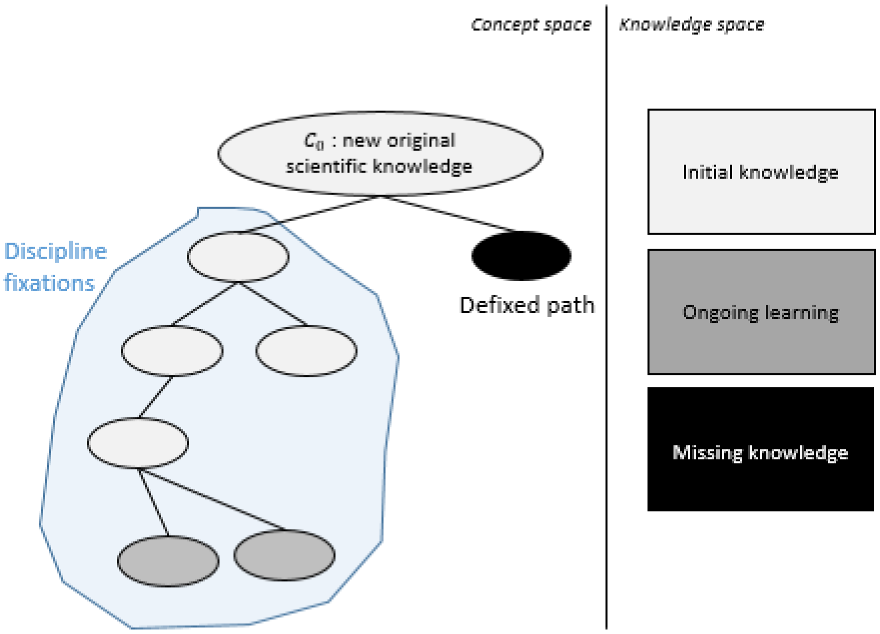

Figure 2: New original scientific knowledge production through C-K frame

In Table 1, we briefly assess rationales regarding fixations effects discussed in the first assumption.

Fixation factor	Details
Economic factors	Economic incentives that researchers received to stay in non-creative design path to maximise their probability to publish high-ranked scientific journal articles (eg. rewards based on scientific journal ranking).
Social factors	Social incentives to stay in fixed design path regarding peer recognition and acceptance in laboratories, particular scientific discipline or groups.
Organisational factors	Orientation given by science programmes, funding, grants and strategic priorities regarding fixed design paths.
Cognitive factors	Use of cognitive routines calling for existing solution with stable paradigms in designer process.

Table 1: Academics fixation effects

3.2. User-oriented research projects favour acquisition of new knowledge that helps to provoke expansive partitions outside the fixation path:

When participating in user-oriented research projects, scholars can have access to new knowledge that would not necessarily have been browse. This access is fostered through interactions between scholars and their innovation ecosystem's partners. In this section, we focus only on industrial partners. We propose a typology of new knowledge that scholars could access through interactions with industrial partners. We illustrate our insights with historical examples.

Knowledge	Details	Example
Object of scientific modelling	New object created by the industrial partner or new stakes for the firm. It may conducts researcher to study other dimensions of existing object or completely new objects.	After the Second World War, bipolar-contact transistor was firstly invented in Bell labs by Shockley, Bardeen and Brattain. It is only after the invention of this transistor that those researchers were able to provoke radically new scientific discoveries regarding how this transistor was working.
Methodologies, equipment & tools	New tools created by the industry to detect new observations that can become new resources for scientific modelling.	The invention of CRISPR Cas-9 is considered as the “Swiss knife” of biotechnology. This technique allow advanced and targeted DNA modification processes. It is now made available by industrials in the biotechnology industry and can be used to very diverse applications and in particular new unexpected research such as palaeontology.
Anomaly detection and interpretation	Industrial issues that require scientific advances to be solved.	At the end of the 19th century, Pasteur was solicited by brewers in the North of France regarding the fact that they were not able to produce high quality beetroot alcohol. Setting up a new laboratory in a brewer’s plant, Pasteur was able to discover modern microbiology.
Results and findings	New results due to large scale testing centres of the industry or real condition testing.	The utilisation of Large Hadron Collider through the ecosystem helps scientists to validated Higgs' Boson and then to propose new scientific knowledge due to the testing of its theory.

Table 2: New knowledge that can be access through user-oriented research and historical examples

Those situations, related to particular conditions and contexts, showed that through interactions within industrial partners, academics performing user-oriented research projects can browse unexpected knowledge regarding their discipline. It could help them to produce new original scientific knowledge that will be then have impact on academic impact. We need to dig into those conditions to help in the understanding of academics performances regarding their participation in user-oriented research projects.

3.3. Success conditions of user-driven research projects to provoke new original scientific knowledge production:

We have demonstrated through the literature review that scholars who recorded user-oriented inputs mainly get impressive scientific impact performances. We assume that those scholars are mostly involved in intensive relationships with innovation ecosystem's partners and particularly industrial ones. For example, a scholar that fills patents has to be mostly aware of ecosystem needs and stakes related to its potential invention. Those piece of information are mainly acquired through being engaged in intensive relationships with partners. Similar situations may occur for entrepreneurship or co-publications. As showed in the upper section, interactions through user-driven research projects increase the probability for scholars to access very new knowledge. We demonstrated through the C-K framework that this knowledge acquisition foster expansive partitions (ie. new theoretical proposals) and then conjunctions. We suppose that those are being recognized by peers from the academic community explaining then high scientific impacts.

Nevertheless we also demonstrated through the literature review that lots of academics were engaged in user-oriented research projects but without recording associated outputs. We assume that it could be explain through the mode of interaction between scholars and their ecosystem partners. Indeed, our core assumptions regarding our C-K model is that the condition to propose a radically new concept is that scholars have access to new and missing knowledge regarding the non-fixed path. It implies that in order to stimulate science, scholars' interactions with their innovation ecosystem partners **(1) have to be based on bi-directional knowledge flows** and **(2) exchanged knowledge has to be distinct from each actor initial knowledge base**.

Those two conditions are restrictive and user-driven research projects fulfilling those conditions seem rare. Indeed, by studying 27 large university – industry research projects, McCabe & al. (2017) built a typology of three types of collaborations. In "**low collaborations**" academics performed the majority of the research activities. The industry partner only contributed to practical aspects of the research design by providing access to data or the research site. In "**high collaborations**", Industry partner contributed to practical aspects, problem formulation and problem solving. Academic presented research results and get feedbacks from the industry partner but industry knowledge was not utilised in the analytical aspect of the research activities. Finally in "**deep collaborations**", Industry partner contributed to practical and analytical aspects of several research activities including problem formulation and theory building. Regarding our model, scholars involved in "deep collaborations" would be the ones that record the highest academic impact due to their exposure to various industry partner's knowledge. But the issue is the following: it seems that "***there is a ceiling to the coproduction of knowledge*** *arising from the preconceived beliefs of both academics and industry partners regarding the superior value of academic knowledge*" (McCabe, Parker, and Cox 2016, 23). Authors highlighted that in particular academics mainly assume control over much of the research activities and then industry partner fails to confront or challenge academic decision-making due to their preconceived view on each role. On first hand, collaborations that foster bi-directional knowledge flow are very rare cases. On the other hand, low collaborations might conduct to non-performant results because there is no such exchange of knowledge for the researcher and it conduct to opportunity costs. Furthermore, establishing U-I collaboration with knowledge coproduction mainly occurred for experimented-academics (Azoulay, Waverly, and Toby 2009), following less engaging previous interactions such as knowledge transfer or research services (Gulbrandsen and Smeby 2005) and mainly with firms that have high level of absorptive capacity (Cohen and Levinthal 2004).

As a result, only a few share of scholars are able to produce user-driven outputs that lead to higher scientific impact because the necessary user-driven research projects conditions are rarely occurring and/or mainly required experienced scholars. It also implies that research projects only focusing on science transfer – which are not maximising bi-directional knowledge flows – are less probable to conduct to radically new theories. In those transfer cases, innovation ecosystem's partners are not stimulating science through new concept generations: the scientific knowledge production is prescribed by partner's needs. It helps to understand why some scholars are declared as implicated in engaged scholarship activities or user-driven research projects but without recording user-driven outputs.

Finally, it might give some insights regarding institutions that clearly separate fundamental research from potential applications. In those cases, scholars from fundamental research departments have to find other ways than partnering with the industry to browse radically new knowledge (eg. transdisciplinary fundamental research). Nevertheless, they are protected from opportunity costs of projects that not fulfil the set of conditions fostering academic impact. It is then possible that clearly separate fundamental research from applications could have conduct scholars to find other organisational ways to favour new knowledge acquisitions.

4. EMPIRICAL CASE STUDIES:

In this section, we briefly address historical examples that are mainly interpreted as successful fundamental research projects and for which scholars recorded high academic impact. We attempt here to highlight the role of user-driven projects and the conditions set in the above sections. As a first example, we took a very well-documented case from the 19th century: Louis Pasteur and the invention of the microbiology. As a second example, we selected a very recent case regarding CRISPR-Cas9.

4.1. Louis Pasteur and the microbiology invention: the role of the North of France Brewers

The works of this sub-section are mainly based on the detailed bibliography *Louis Pasteur* (Debré 1993). In 1856, the French scientist Louis Pasteur was solicited for help by M. Bigo, a beer brewer from the North of France. Indeed, the industrial process of beetroot's alcohol was suffering from critical issues that industrials were not able to solve with their traditional techniques. They were sometime producing bad quality alcohol, very sour and with a foul odour and the production's success was non predictable. Interpreting the situation through Design Theory: Louis Pasteur was attempted to design a new theory to explain the fermentation process. At that time, fermentation process was mainly explained by two scientific paradigms. First, Lavoisier who considered that the fermentation process was the splitting between sugar and acid that create alcohol. Second, von Liebig and Berzelius who broadly considered that the putrefaction status of decomposing corpses is contagiously affecting other elements creating then: alcohol. Those two insights constitute the fixed design paths. Following the collaboration with M. Bigo, Louis Pasteur made a seminal scientific discovery. Indeed, he proposed a radically new concept: he demonstrated that there were existing living micro-organisms, comprising of the yeast in the brewer fermentation process. We then now show how this situation fulfil our conditions to explain the role of user-oriented research projects regarding this highly impacting scientific discovery.

We showed in upper sections that scholars participated in user-oriented research projects can record high academic performances if they are proposing new concepts outside the fixed path. Their capacity to propose radically new concepts are notably dependent of project configurations that need to include bi-directional knowledge flows and knowledge exchange distinct from the initial knowledge base of actors. The situation here fulfil those criteria. First, this project was clearly a user-oriented one: Pasteur was both motivated by helping M. Bigo and proposing new theoretical insights regarding the fermentation process. Indeed, as well as designing its scientific discovery, he also provided new fermentation techniques based on eliminating or feeding yeasts to help the brewers to improve their production process. Second, Louis Pasteur and M. Bigo were engaged in a knowledge exchange process. Indeed, they set up a completely new laboratory in the basement of M. Bigo's company. M. Bigo gave lots of insights to Pasteur regarding the industrial process and access to samples of fermented or filtered juice that the scientist analysed with its microscope. Third, their knowledge base were very different and they were not engaged in a transactional process in which science development would have been prescribed by the industrial. Indeed, at that time Pasteur was known for its works on crystals and has never worked on fermentation. M. Bigo stimulated the design of a new theory by giving to Pasteur: (1) a particular anomaly (ie. the bad quality alcohol was not explained by pre-existing scientific models), (2) a capacity to increase the number of observations to help him in the testing process.

In this historical example, we illustrated with a particular case how our restrictive set of criteria are fulfilled. In particular, we highlighted how the industry partner was able to stimulate science to allow Louis Pasteur to make a big scientific discovery.

4.2. CRISPR-Cas9 discovery: the role of the Danisco company

The discovery of CRISPR-Cas9 is mainly attributed to J. Doudna and E. Charpentier following an article in *Science* in 2012 that explain this technique of genome editing (Jinek et al. 2012). It is view as one of the major scientific discovery of recent times and main involved scholars are regularly quoted as potential Nobel Prizes owners (Abbott 2016). The CRISPR system, Clustered Regularly Interspaced Short Palindromic Repeats, is "*an adaptive immune system used by microbes to defend themselves against invading viruses by recording and targeting their DNA sequences*" (Lander 2015, 18). Coupled to Cas9 protein, it constitutes a crucial advance in genome editing. "*CRISPR-Cas has emerged as a highly flexible research tool for genome editing and is already transforming biological and biomedical research*"

(Egelie et al. 2016, 1027). The origin of the identification of CRISPR started in 1989 with F. Mojica, a Spanish doctoral student, who identified a repeated sequence of 30 DNA bases. Digging into this anomaly for a long period of time, he finally published a paper establishing CRISPR existence for the whole scientific community in 2005. CRISPR-Cas9 is today "*the quickest, cheapest and most reliably targeted method, and is being constantly improved on all three dimensions*" (Tylecote 2018, 2). This scientific discovery is very generative as demonstrated by the large number of classes for patent applications related to CRISPR-Cas9 (Egelie et al. 2016) or regarding the diverse applications in other scientific discipline such as palaeontology.

CRISPR-Cas9 is mainly presented as a fundamental research success (Abbott 2016; Le Deaut and Procaccia 2017). Academic performances of the main scholars that have contributed to this scientific discoveries are clearly established as the highest in their discipline area. But how the CRISPR-Cas9 case could illustrated our insights regarding the role of ecosystems partners of stimulating science? Mainly based on Lander (2015) works regarding scholars who have made this scientific discovery possible, we are focusing on a particular contribution: the role of the company Danisco (Lander 2015). Danisco was a Danish firm that bought Rhodia Food in 2004, a French company with a business unit in Dangé-Saint-Roamin that was focusing on bacterial starter cultures for cheeses and yogurts production. In 2005, the company launched a research project focusing on a lactic-acid bacteria (*Streptococcus thermophilus*). The issue of the company was that this lactic-acid bacteria, which was intensively used for cheeses and yogurts production, were sometime attacked by viruses. The project aimed at first to understand why some lactic-acid bacteria were able to protect themselves from the viruses while other did not. In the second time, the project aimed at implementing new industrial processes (Le Deaut and Procaccia 2017). Broadly, Danisco scientists were able to identify that CRISPR was an adaptive immune system by showing that the insertion of multiple CRISPR was correlated with an increase of lactic-acid bacteria resistance. Their works was patented in 2005 and published in *Science* in 2007.

In this case, we can also interpret the situation by using Design Theory framework. Scientists from Danisco were aiming at designing new scientific knowledge to support their production process. P. Horvath, the team leader of this scientific discovery received several scientific prizes[2] that show its high academic impact. The research project was encompassing fundamental research and a user-oriented aspects through the willingness to foster cheeses and yogurts production process. We described in upper sections two major restrictive conditions that can conduct scholars involved in user-oriented research projects to provoke expansive partition through being stimulated by their ecosystem's partners: (1) be engaged in bi-directional exchange of knowledge with their ecosystem's partners and (2) sharing knowledge that are distinct from their initial knowledge base. The particularity of this case study is that the Danisco research team is mixing the role regarding the partners. Indeed, P. Horvath is considered as the scholar but he is also includes in Danisco. He had experienced regarding lactic-acid bacteria topic (he get a Ph.D. from the University of Strasbourg by focusing on genetics of lactic-acid bacteria in the production of sauerkraut, a central ingredient in Alsatian *Choucroute garnie)* and carried the research works. But the entity previously considered as the industrial partner is in that case study also Danisco. Nevertheless, as in the Pasteur case, conditions are fulfilled as the research team (1) get access to a particular anomaly that has to be modelled (ie. the fact that some acid-lactic bacteria were suffering from viruses attacks while other did not) and (2) to get access to large-scale testing facilities. The P. Horvath's research team exchanged knowledge inside its own team and both with other Danisco's business units and scholars from other institutions. By analysing this case, we can note that the situation fulfil

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[2] He received the Gairdner prize in 2017 (in particular with E. Charpentier and J. Doudna), the Massry Prize in 2015 and the Warren Albert prize for its contributions regarding CRISPR-Cas9 (Le Deaut and Procaccia 2017)

our criteria but that the situation encompass a larger number of actors with more complex identity. It highlights the necessity to focus on more complex innovation ecosystem for future research.

5. CONCLUSION:

Our main objective was to review academic performances of scholars involved in user-oriented research projects and to contribute to the explanation of the potential variance with scholars who do not.

Based on our literature review, we showed that first, there is a few number of scholars that record user-oriented research project outputs such as patent applications, spin-off creations, University-Industry co-publications or co-patents. Those scholars nevertheless record higher scientific and technological impacts than their peers, measured for example in terms of number of publications, average journals rankings or citations. Furthermore, lots of scholars are considered as “engaged” toward collaborations with non-academic organisations, in particular with industrial partners. It implies that lots of scholars are not recording user-oriented research project outputs. We also noted that some scholars are part of institutions that have clearly separated a fundamental research department from an applications one that give us insights regarding the share of scholars not involved in user-driven research projects.

In order to give insights in the understanding of this situation, we drew on the knowledge dynamic to explore the role of being engaged in user-driven research project on scholar’s academic performances. We demonstrated that C-K Design Theory is a useful resource to model the knowledge dynamic. In particular, based on Hatchuel & al. (2013) works, we represented the scientific reasoning through a C-K framework. Indeed, science is based on modelling: the design of new scientific knowledge implies the design of new theories that better explain observations and/or anomalies. We then highlighted how browsing new knowledge (distinct from scholar knowledge base) can help scholars to propose radically new concepts (ie. theories). In particular we defined a taxonomy of knowledge types that can be bring by ecosystems partners (ie. in particular industrials) to favour new expansions.

Based on this model, we gave insights regarding the role of being involved in user-driven research projects to explain the variance in scholar's academic performances. We highlighted two restrictive conditions for those projects to foster academic performances through a stimulation of science by innovation ecosystem's partners. First, user-oriented research projects have to involved bi-directional knowledge exchange with ecosystem's partners. Second, exchanged knowledge between scholars and ecosystem's partners has to be distinct from initial knowledge bases of the parties. We noted that because those conditions are restrictive, only a few scholars are able to fulfil those criteria and then both produce user-driven outputs and record high academic performances. We also highlighted that due to adverse effects of user-driven research projects that do not fulfil those criteria (eg. opportunity costs of being involved in that kind of projects without necessarily positive effects on academic performances), some institutions seem to preferred to clearly separate fundamental research from its applications and to find other internal ways to foster academic impact (eg. transdisciplinary research).

Finally, in order to test our model through empirical case studies, we attempted to show what would be the potential contribution of user-driven research projects in scientific discoveries that are mainly presented as "basic research" and for which scientists recorded a large scientific impact. Through the Pasteur and the CRISPR-Cas9 cases, we showed that user-driven projects were involved in the scientific discovery and that those matched our criteria regarding bi-directional knowledge exchange and independence of shared knowledge regarding the initial situation. In particular, we highlight how industrial partners could help in the provision of new anomalies that could be modelled by science. In the CRISPR-Cas9 case, we also highlight the complexity of the ecosystem in particular where scientists are part of an R&D team connected with scholars.

Our model need to be further tested through in-depth qualitative studies to better understand the condition of success of those user-driven projects on academic performances. In particular, a focus on how managing those project would be useful for scholars and practitioners. Furthermore, we particularly focus on industry partner in the ecosystem. The role of State, Non-Governmental Organisations and university offices also need to be further assess.

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