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DOI

[10.1007/s11573-020-00979-x](https://doi.org/10.1007/s11573-020-00979-x)

Publication date

2020

Document Version

Final published version

Published in

Journal of Business Economics

Citation (APA)

Werker, C., & Hopp, C. (2020). Balancing act between research and application: How research orientation and networks affect scholars' academic and commercial output. *Journal of Business Economics*, 90(8), 1171-1197. <https://doi.org/10.1007/s11573-020-00979-x>

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Balancing act between research and application: how research orientation and networks affect scholars' academic and commercial output

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Abstract

Scholars' balancing act between research and application leads to trade-offs between commercial and research output. Yet what some scholars may consider as poles apart might lead to super-additive outcomes for others. Based on a survey carried out at three leading European universities of technology we investigate the influence of scholars' research orientation and networks on their output productivity. Our results point to a very specific group of ambidextrous scholars that is comparatively small. The scholars in this group are able to successfully balance research and application. In contrast, all scholars focusing on either pure basic or pure applied research face a trade-off between publications and innovations. In general, our findings suggest that the output productivity of all scholars is the higher the better their research orientation fits with their network activities. In particular, ambidextrous scholars rely on effectively accessing and utilizing their network to increase commercial and research output.

Keywords Academia · Output · Research orientation · Networks · Ambidexterity

JEL Classification O31 · O38 · J4

'Two souls, alas! are dwelling in my breast.'
Goethe (1808)¹

¹ 'Zwei Seelen schlagen ach! in meiner Brust.' Goethe v., Johann Wolfgang (1808/2000): *Faust: Der Tragödie erster Teil*, Reclam Verlag, Ditzingen (Germany).

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1 Introduction

In recent decades policy makers have increasingly asked scholars and universities to concentrate on the third mission of commerce in addition to the traditional missions of research and teaching. Scholars and universities are supposed to successfully balance research and commerce (European Commission 2012; Stilgoe et al. 2013).

Many scholars, however, consider research and commercial activities as poles apart (Ambos et al. 2008). While the balancing act between research and commerce in academia has been widely documented (Ambos et al. 2008; D'Este and Perkmann 2011; Etzkowitz and Viale 2010; Philpott et al. 2011), the question of whether the trade-off between research and commercial output in academia can be overcome (and to which extent) has not been answered conclusively yet.

Empirical evidence on the successful achievement of research and commercial goals is rather sketchy and at times, even contradictory. Evidence from Finland shows that scholars (across all disciplines) are able to continue to produce output for the academic market while increasingly producing output for other markets as well (Ylijoki et al. 2011). Similar effects have been found for fields such as life sciences and engineering, where scholars meet both research and commercial demands (Agrawal and Henderson 2002; Link et al. 2007). For US biotechnology researchers the evidence is mixed, as publications go hand-in-hand with patents but high-impact innovations are negatively correlated with high quality scientific papers (Gittelman and Kogut 2003). So, it is no surprise that not all universities and scholars have been able to successfully integrate research and application on a larger scale (Etzkowitz and Viale 2010; Philpott et al. 2011). When looking at the university level we see comprehensive universities struggling with the balance between research and application, while universities of technology ‘... such as MIT, Imperial College, Aachen and Zurich have managed to combine sustained ‘third mission’ contributions with high-quality basic research over much of their history.’ (Martin 2012, p. 18).

To understand why accomplishing research and commercial goals simultaneously is difficult and how it can be achieved nonetheless, it is important to look at the level of the individual researcher. Scholars produce for different markets that are characterized by various values and logics in terms of epistemic communities, goals, identities, required skills and abilities, users, kinds of output and selection mechanisms (Gittelman and Kogut 2003; Jain, George and Maltarich 2009; Ylijoki et al. 2011). As a consequence the trade-off between research and commerce is difficult to overcome for individual scholars. While universities can establish distinct departments to deal with both research and commercial requirements separately, individual scholars have to incorporate both and might struggle mightily (Ambos et al. 2008). So, most of the time, scholars delivering commercial output differ from those producing research output (Ambos et al. 2008).

The question therefore pertains as to whether “ambidextrous” scholars, those aiming at both scientific understanding and use of methods developed, exist and how they accomplish to navigate the trade-offs between the different spectrums. The research on ambidextrous scholars is crucial for understanding innovation and technological change (Stokes 1997; Subramanian et al. 2013), because when scholars “... engage in research that is driven by considerations of both basic understanding and use, the

‘learning-based’ logic for interaction is likely to be prevalent” (D’Este and Perkmann 2011, p. 330). In principle there are two different types of ambidextrous scholars. First of all, ambidexterity on the level of the individual scholar shows when scholars carry out research that simultaneously provide fundamental insights and practical solutions. A typical examples are biochemists solving fundamental problems in parallel with designing new drugs. Second, ambidexterity on the level of the individual scholar also emerges when scholars combine projects of different orientations, e.g. one project contributing to the fundamental understanding of their disciplines, another aiming at pure application. While both projects might serve as inspiration for each other, they could as well stand-alone.

To shed light on ambidexterity’s contribution to academic output and productivity we investigate how individual scholars’ research orientation and their networks affect the kind and extent of academic and commercial output they produce. In order to compare scholars focusing on either pure basic or pure applied research with those balancing between research and application, we focus on a sample of scholars from the natural sciences and engineering working at three leading European Universities of Sciences. These scholars are arguably particularly attractive partners for technology transfer (Berbegal-Mirabent et al. 2015) and hence, should yield enough ambidextrous scholars to juxtapose the supposed trade-offs.

By doing so, we contribute to a currently underdeveloped area of research regarding ambidexterity: While there have been analyses of commercial activities in academia on the systemic and university level, the level of the individual academic has so far been under-investigated (Grimaldi et al. 2011).

We contribute to the literature by first conceptualizing research orientation for individual scholars to specify and clarify the nature of ambidexterity. This helps us to determine the nature and extent of ambidexterity in our empirical base. Second, we theorize and empirically test how scholars’ networks can reinforce their research orientation. As collaborations vary in purpose, nature and content, our results show that scholars’ research orientation and the fit with their networks determine output and productivity. Hence, our research exemplifies whether output productivity depends more on the access to networks (network as a mediator) or more on the use (network as a moderator).

2 Literature, baseline expectation and hypotheses

2.1 Research orientation and output

2.1.1 Research orientation and ambidexterity

For a long time research orientation has been discussed by contrasting basic and applied research (Bush 1945): Academia’s task was basic research and industry’s task was applied research. While scholars have increasingly turned to more applied research, they still carry out basic research (Bentley et al. 2015; Etzkowicz and Viale 2010; Kyvik 2013). In order to capture more nuances of research orientation we use three categories provided by Stokes (1997), i.e. Bohr, Pasteur and Edison research

<u>Rigor:</u> Quest for fundamental understanding	Yes	<i>II:</i> Pure basic research	<i>III:</i> Use-inspired basic research
	No	<i>I:</i> No research	<i>IV:</i> Pure applied research
		No	Yes
		<u>Relevance:</u> Considerations of use	

Fig. 1 Basic and applied research revised (adapted from Stokes 1997, p. 73)

activities. These categories are characterized by two aspects, rigor and relevance, which are orthogonally related. Rigor is the degree to which scholars pursue fundamental understanding with their research, while relevance is the extent to which they seek to solve a specific problem. As a result, we get the four quadrants depicted in Fig. 1: in Quadrant I, no research takes place. Quadrant II covers pure basic research seeking fundamental understanding only, i.e. Bohr research. Quadrant IV covers pure applied research aiming at solutions for societal and economic problems, i.e. Edison research. Quadrant III combines the quest for fundamental understanding with considerations of use, i.e. Pasteur research.

Scholars doing *Bohr research* aim at building and extending the scientific knowledge base. They do not directly contribute to commercial demands. These scholars primarily produce for the academic market; industry is like a different world for them (Lam 2010). Scholars concentrating on *Edison research* help to solve societal and economic problems, therefore producing commercial output. Their knowledge production strongly focuses on practical use and commercial exploitation (Lam 2010, p. 327). They want to get technologies to work and care less about underlying theoretical mechanisms, even if those mechanisms are of interest to a broader academic audience. Scholars doing mainly *Pasteur research* projects aim at meeting both research and commercial demands. They transform scientific insights into solutions for practical problems and use practical problems as inspirations for scientific questions. They produce both academic and commercial output by crossing the science-application divide and exploiting the interactive relationship between rigor and relevance (Lam 2010).

As such, scholars focussing on both academic and commercial output face a daunting task, as they forego specialisation in lieu of branching out to two separate domains and communities, with likely different requirements. There is evidently a competing logics story here that scholars face: research-oriented scholars aim to publish groundbreaking results in peer-reviewed journals while practice-oriented scholars aim to develop improved products/processes. These two types have opposing goals, interests, and probably views on what research should be. First, academic and commercial output undergo different selection processes (Gittelman and Kogut 2003): Innovative output depends on technical richness and market impact, while publications undergo

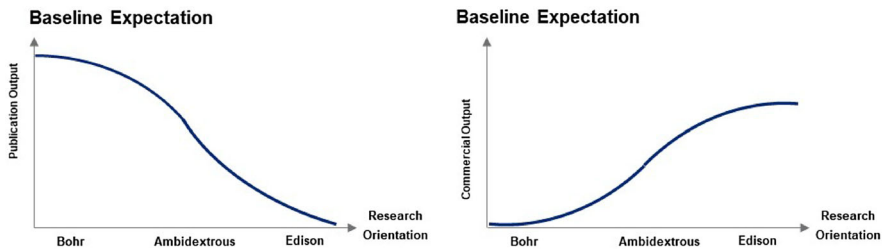


Fig. 2 Baseline expectation

review processes by the academic community. Second, scholars have limited time and resources and can either spend those on research or commercial activities.

To specify scholars' ambidexterity which has been merely discussed in general terms so far (e.g. Etzkowitz and Viale 2010) we use Stokes' (1997) categorization to consider two major forms of ambidexterity on the individual level: The first one would be straightforwardly scholars focusing on Pasteur research, because those scholars combine basic insights with application in each of their research projects. Typical examples are areas of life and health-science solving fundamental problems in parallel with designing new drugs. The second form of ambidexterity emerges when scholars combine projects of different orientations that stand-alone, e.g. one project contributing to theoretical mathematics and another one helping to design race-cars more aerodynamically. Ambidexterity in individual researchers therefore implies two different activities that have a seemingly incompatible nature while providing a super-additive outcome.

2.1.2 Research orientation and output: baseline expectation

Prior findings document that scholars' research orientation has a significant effect on the corresponding output each researcher produces (Abreu and Grinevich 2013; Philpott et al. 2011; Stokes 1997). Broadly speaking, publication counts represent the "currency" of academic productivity (Altbach 2015) and individualized incentives for publishing are pervasive (Honig et al. 2014). While generally, all academics have publishing incentives that should result in output for the academic market, only those scholars aiming at practical application of their work also produce for markets outside academia (Ylijoki et al. 2011). These commercial outputs range from patents, licences, spin-off companies, to consultancy reports for industrial or public partners (D'Este and Perkmann 2011; Grimaldi et al. 2011; Perkmann et al. 2013).

Based on these prior findings we form the following baseline expectation (see also Fig. 2): publication output of scholars mainly focusing on Bohr research is high; it is lower for ambidextrous scholars; it is lowest for scholars mainly focusing on Edison research. We expect the opposite for commercial output, i.e. that it is high for scholars mainly focusing on Edison research, lower for ambidextrous scholars and lowest for scholars mainly focusing on Bohr research.

2.2 Research orientation, networks and output performance

2.2.1 Research orientation and networks: hypotheses on direct effects

Scholars might need access to related, complementary knowledge from external sources, i.e. the partners in their networks in order to better exploit their own knowledge (Gittelman and Kogut 2003).

Scholars' collaborations might involve partners from either the academic or the industrial sector. They collaborate with other scholars, or, via contracts, with business-people and venture capitalists (Chang et al. 2009; Etzkowitz and Viale 2010; McAdam et al. 2016). Scholars collaborating outside the university sector face the challenge of managing their evolving relationship with the industrial sector while maintaining their academic role (Lam 2010). When scholars get involved with industrial partners, they usually address industrial problems or holes in academic development (Chang et al. 2009; Etzkowitz and Viale 2010). Scholars collaborating with industrial partners want to learn from them as well as raise funds from them for their own research. Interestingly, scholars seem to engage in industrial collaborations mainly for research-related motives, with commercialization being less important to them (D'Este and Perkmann 2011). Empirical findings on scholars in UK engineering suggest that their overall output—publications and patents—is highest when they are involved with private partners in some but not all of their projects (Banal-Estañol et al. 2015).

We therefore expect a relationship between scholars' research orientation and the network they build and engage with. Scholars mainly concentrating on Bohr research work primarily with academic partners in order to push the frontier of their discipline. By this, they gain new insights which might in turn trigger off fundamental research questions requiring further academic collaboration. In contrast, scholars mainly concentrating on Edison research work primarily with industrial partners, thereby particularly aiming at solutions for economic or societal problems. Solutions they find might trigger ideas of how to deal with related problems leading to longer term collaborations with industrial partners. Ambidextrous scholars, i.e. those mainly concentrating on Pasteur research or those combining research projects of different orientations, expect to benefit from collaborating with both academic and private partners.

Accordingly, we suggest the following direct effects (see also Fig. 3):

H1a. Scholars focusing on Bohr research collaborate mostly with the academic sector, ambidextrous scholars less so, and scholars focusing on Edison research the least.

H1b. Scholars focusing on Bohr research collaborate least with the private sector, ambidextrous scholars more so, and scholars focusing on Edison research the most.

2.2.2 Output performance: indirect effects of networks

The relationship between research orientation and output is governed by indirect effects of scholars' networks. Generally speaking, scholars can access or use a well-defined community, be it an epistemic community, a community of practice or a mixed community, or to a number of un-related communities. A well-defined community pro-

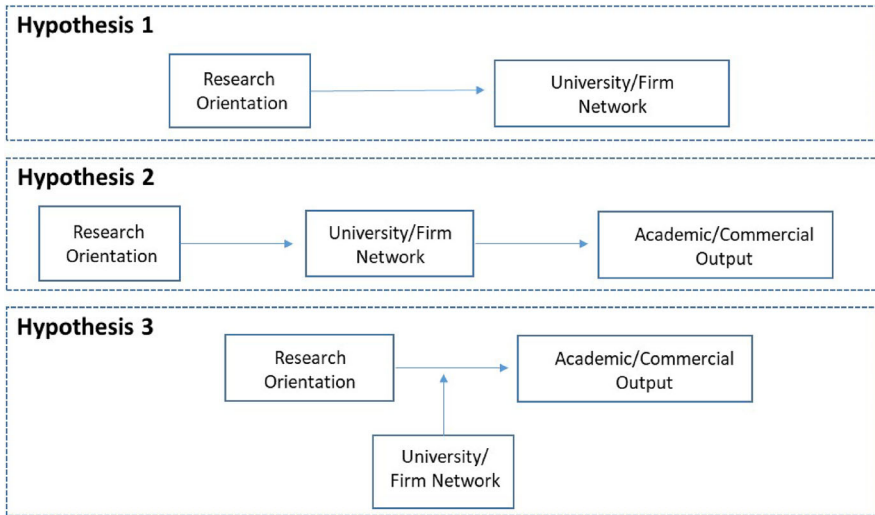


Fig. 3 Graphical depiction of hypotheses

vides scholars with a theoretical set-up as well as fitting methods for their research endeavours while at the same restricting their perspective (Cornelissen 2017). When faced with a complex environment these scholars are limited to ‘see what they are ready to see’ (Hodgkinson and Rousseau 2009, p. 534), restraining the range of novelty they can come up with. In contrast, scholars connecting to un-related communities tap into various kinds of theoretical frameworks and empirical methodologies, thereby combining ideas from different communities, overcoming disconnected perspectives and fragmented knowledge landscapes (Fleming 2001). Combining ideas from communities of practice and epistemic communities might be fruitful (Fleming 2001).

Scholars form and maintain ties with others to access knowledge and to collaboratively learn (Werker et al. 2016). When scholars collaborate with other scholars, they tap into the knowledge base of the so-called invisible college, an epistemic community of scholars investigating similar or related research questions (Azoulay et al. 2010; Crane 1972; De Solla Price and Beaver 1966; Verspagen and Werker 2004). Within these kinds of collaborations scholars aim at the academic market, i.e. at contributing to the knowledge base of their field (Ylijoki et al. 2011). Scholars collaborating with industrial partners rely on communities of practice, i.e. sharing a domain of interest, interacting to learn and sharing a repertoire of resources, e.g. tools or ways of addressing problems (Wenger 1998). Scholars use their relationships with partners in epistemic communities or communities of practice to access and use additional knowledge in order to solve practical problems (Ylijoki et al. 2011).

When analysing the dynamics of ties it becomes clear that the formation of collaborations differs considerably from its maintenance (Lazzeretti and Capone 2016). Collaborative ties often emerge from a network of stable relationships enabling dynamics of interactive learning. When scholars ‘... engage in research that is driven by considerations of both basic understanding and use, the ‘learning-based’ logic for interaction is likely to be prevalent’ (D’Este and Perkmann 2011, p. 330). Therefore,

we expect ambidextrous scholars to benefit most from combining different communities.

We distinguish two indirect effects, i.e. a mediation (access) and a moderation (use) effect. Accordingly, we postulate an access (mediation) relationship in which scholars' research orientation contributes to explaining the formation of their network relationships. The *mediation effect* captures scholars' access to epistemic communities or communities of practice is what ultimately affects their academic and commercial output. In particular, we suggest that better access to fitting network partners, i.e. academic partners for scholars focusing on Bohr research, industrial partners for scholars focusing on Edison research and both kinds of partners for scholars focusing on Pasteur research, increases the kind of output they specialize in, i.e. research output for scholars focusing on Bohr research, commercial output for scholars focusing on Edison research and both kinds of output for scholars focusing on Pasteur research.

Through the access to network partners, research orientation has an indirect (mediating) effect on academic/commercial output of scholars as follows (see also Fig. 3):

H2a. Through better access to collaborations with other scholars, those focusing on Bohr research produce more academic output and less commercial output.

H2b. Through better access to collaborations with industrial partners, scholars focusing on Edison research produce more commercial output and less academic output.

H2c. Through better access to collaborations with both academic and industrial partners, scholars focusing on Pasteur research produce more academic and commercial output.

The moderation effect captures that, depending on their research orientation, scholars may make better use of their potential via their network. Accordingly, we suggest that the combination between research orientation and networks affects the kind and extent of their output. We expect scholars specializing in Bohr, Edison or Pasteur research to particularly benefit from using knowledge of their well-defined sub-community, be it epistemic communities or communities of practice or a combination of both. Scholars focusing on Bohr, Edison or Pasteur research should have a comparative advantage when working with their specialized network, be it academic, industrial or a mixed one. Accordingly, we suggest the following moderating hypotheses:

The use of network partners positively moderates the effect of research orientation on academic/commercial output of scholars as follows (see also Fig. 3):

H3a. A stronger focus on Bohr research leads to higher academic output if those scholars engage in academic collaborations but not if they engage in industrial collaborations.

H3b. A stronger focus on Edison research leads to higher commercial output if those scholars engage in industrial collaborations but not if they engage in academic collaborations.

H3c. A stronger focus on Pasteur research leads to higher academic output and commercial output if those scholars engage in relationships with both academic and commercial partners.

3 Data, variables and models

3.1 Survey data

We look into academics working at three leading European universities of technology: the German RWTH Aachen University, the Dutch Delft University of Technology, and the Swiss Federal Institute of Technology Zurich (ETH). So, our dataset should comprise a sufficiently large number of basic, applied, and ambidextrous academics.

In order to assess the influence of research orientation on output, we concentrate on early career scholars, i.e. postdocs and assistant professors. By trimming our sample to solely include scholars within 5 years after their dissertation, we avoid issues of reverse causality. For late career researchers, a reverse causality would be possible as they might consider their research orientation based on their previous output and not vice versa. This does not hold for early career scholars within 5 years after their dissertation, because they start forming networks and producing their first academic and commercial output in the 5 years after receiving their PhD degree. Their (perceived) research orientation can therefore be treated as the impetus to their networking and research endeavours.

248 scholars holding a PhD, each located either in the Delft University of Technology, RWTH Aachen University, or the Swiss Federal Institute of Technology Zurich filled in our web-based survey between November 2012 and June 2013.² Of our 248-person sample, 56 worked at Aachen, 75 at Delft, and 117 at Zurich (for details on the rather miniscule differences in career paths at the three universities of technology please refer to Appendix 1). The respondents are distributed over status groups and disciplines as follows. In our sample, 50 post-docs and 6 assistant professors work for RWTH Aachen University, 44 post-docs and 31 assistant professors for Delft University of Technology, and 107 postdocs and 10 assistant professors for Swiss Federal Institute of Technology Zurich. To make our results comparable, we asked scholars only from disciplines present at all three universities to fill in the questionnaire. The largest categories are information science (about 13%), materials sciences (about 13%), and environmental sciences (about 16%). RWTH Aachen has a more pronounced focus on environmental science and Delft on design and urban planning.

3.2 Dependent, independent and control variables

In order to check the baseline expectation as well as to test the hypotheses **H1–H3**, we construct indicators for output, network, research orientation and seven control vari-

² Due to the privacy and administrative requirements in three different country, it took seven months to carry out the surveys at all three universities. We sent the survey to scholars at Delft University of Technology in November 2012, at the RWTH Aachen University in December 2012, and at the Swiss Institute of Technology in May 2013. The response rates at the three universities were relatively modest and differ, i.e. roughly 11% at RWTH Aachen University, roughly 16% at Delft University of Technology and roughly 9% at the Swiss Institute of Technology. The reason is that for practical reasons the universities approached different statistical population that were larger than the intended population. We therefore applied exclusion restrictions to the sample (completion of a PhD; being an academic staff member).

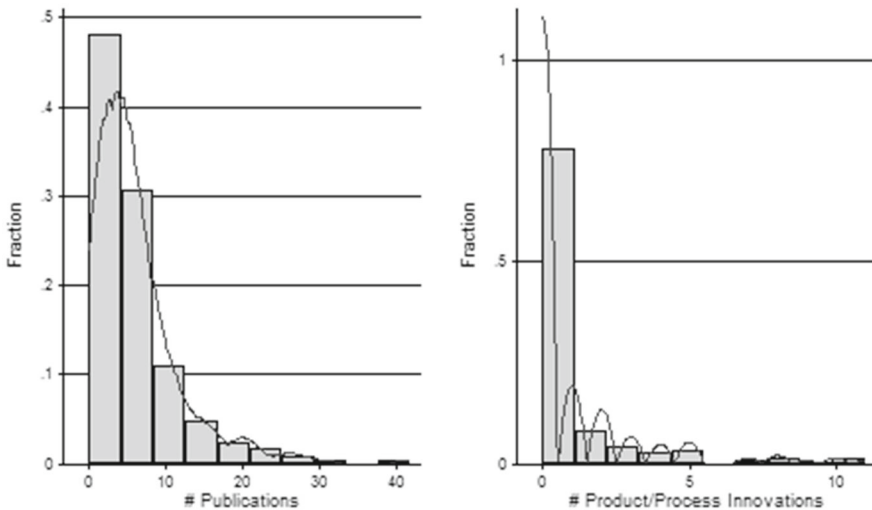


Fig. 4 Distribution of dependent variable—output

ables from our sample.³ In the following, we depict the variables used in our empirical estimation briefly, provide more in-depth explanations about their operationalization, and denote the exact questions employed in Appendix 2.

For the *network of scholars*, we capture both collaborations with other scholars and collaborations with industrial partners. For *academic output* we employ the number of peer-reviewed publications reported by respondents for the time period 2007–2011. For *commercial output* we use a count measure of process and product innovations reported for the same time period (for a graphical depiction of both measures see Fig. 4). The respondents were also asked for their patent activities. However, while patents have traditionally been a very popular measure, they have only been a very specific and rare mechanism of technology transfer (Gittelman and Kogut 2003; Grimaldi et al. 2011). The findings in our survey support these previous findings, as 230 respondents report zero patents, with only 12 having more than two patents in the 5 year period. Consequently, we took the variable capturing process/product innovations as a proxy for commercial output, because it was reported much more frequently: twenty-nine respondents report one product/process innovation, forty-five two to five product/process innovations, and nine individuals report more than five product/process innovations.

For *research orientation*, we provided the respondents with Fig. 1 depicting the different quadrants and a definition of each quadrant, and asked how they would categorize their research in terms of it. We asked the respondents to what extent they would situate their research in each of these quadrants and accordingly depict the aforementioned two types of ambidexterity as follows: Researchers that indicate a relatively high Pasteur orientation and who combine basic insights with application in each of their research projects; and ambidextrous researchers with intermediate level of

³ All questions in the survey were used in about ninety interviews as well as in a pre-test of the survey. In particular, regarding research orientation the interviewees were aware of the distinction between basic versus applied research and combinations of it; some of them even knew the book by Stokes (1997) book.

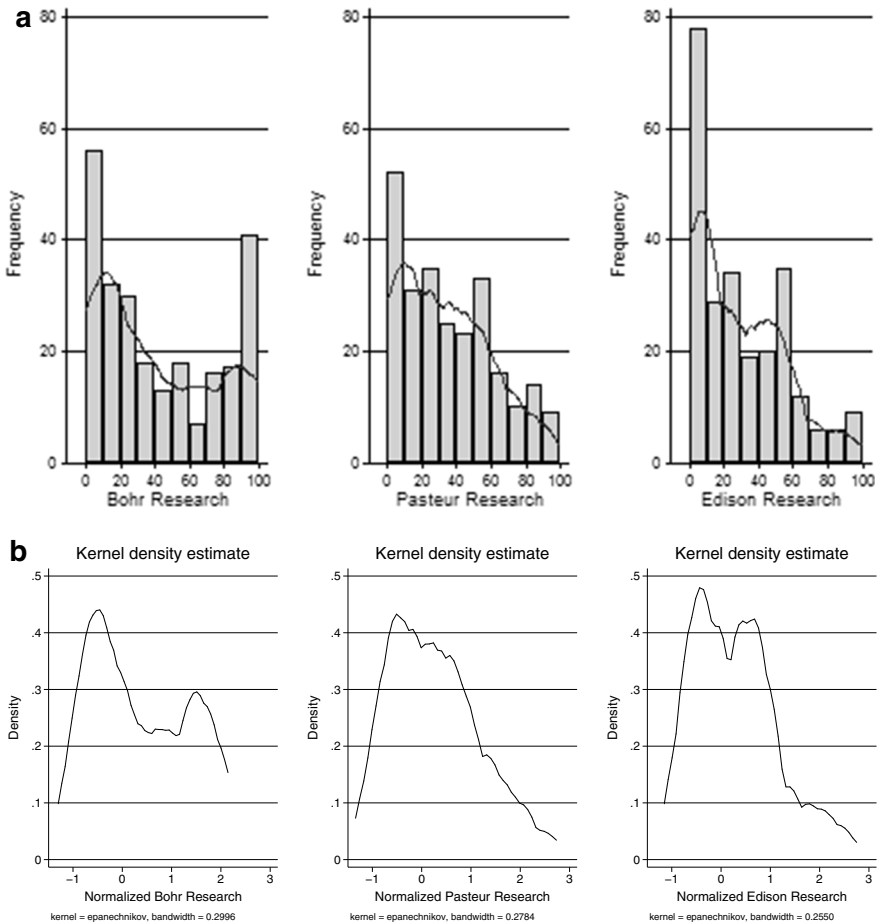


Fig. 5 Distribution of dependent variable: **a** research orientation. **b** Normalized research orientation

research orientation (thus combining projects of different research orientations; one project contributing to the fundamental understanding of their disciplines, another aiming at pure application).

Scholars categorize their research differently across the research orientation spectrum (Bohr: 40 percent, Pasteur, 33, Edison: 27), and standard deviations vary (Bohr: 36 percent, Pasteur: 27 percent, Edison: 26 percent). Consequently, Fig. 5a shows that research orientation is over-dispersed at the very low and high end of each distribution, resulting in high and unevenly distributed variances. To account for the differences in dispersion of each category, we operationalize each research orientation by standardizing the percentage answers with the standard deviation. This results in a mean research orientation of zero and standard deviation of one. The distribution appears in Fig. 5b, in which we move from minus to plus one standard deviation in the graph. Consequently, interpretations capture how a one-unit increase in each research orientation (relative to how others perceive themselves on this dimension) affects the dependent variable for each regression. We consider this approach to be more prudent

than a simple dichotomized distinction, as it allows for testing the marginal transitions between the quadrants in an orthogonal way which also allows differentiating between the two types of ambidexterity. Figure 5a, b graphically summarize the unadjusted and normalized research orientation for each category.

The following additional control variables complete our model. First, we include the *Age* at the time of the interview of the respondent.⁴ Second, we control for a respondent's prior experience in the private sector. Third, we control for whether or not the respondent's family has an entrepreneurial background. Fourth, following prior work we include *Gender*, with females being the reference group (e.g. Bentley 2011). Fifth, we include a dummy variable for Delft and RWTH Aachen University of Technology to account for differences between the universities (with the Swiss Federal Institute of Technology Zurich as the reference group). Sixth, we control for administrative and teaching responsibilities.

3.3 Models and descriptive statistics

To test the baseline expectation we estimate a negative binomial regression model using the academic and commercial output as dependent variable, and research orientation as independent variable. The negative binomial regression model employed includes an additional random component accounting for unobserved heterogeneity not incorporated in the regressions determining the mean function. In the following, we graph the results to allow for an easier interpretation when checking if the baseline expectations are met.

To test **H1**, we employ the university and firm network as dependent variable, and research orientation as independent variable. Due to the summation over different questions for the dependent variables, as described in Sect. 3.2, we employ an ordinary least squares regression with robust standard errors. For **H2**, we include output as dependent, network as mediating, and research orientation as independent variable. For **H3**, we include output as dependent, network as moderating, and research orientation as independent variable.

Table 1 presents summary statistics and simple bivariate correlations for our sample. As to the personal characteristics, respondents are mostly male (67%) and almost all are younger than 40. Twenty percent of the respondents have private sector experience and about a quarter report entrepreneurs within the family. The respondents are distributed among the different quadrants for which we account by our standardized estimates. We normalized the indicated research orientation (the percentage of Bohr, Pasteur, and/or Edison research) by the standard deviation within each category. Hence, the research orientation is normalized to a mean of zero and a standard deviation of one to account for distributional differences. With each category, higher scores indicate a stronger focus on either type relative to all other respondents.

⁴ As a caveat to this approach, we naturally have only very little variation in age as the sample has been truncated to early-stage researchers. We estimated the models also without the age variable and the results remain invariant.

Table 1 Summary statistics and correlation matrix

Variable	Mean	StDev	2	3	4	5	6	7	8	9	10	11	12	13
Publications	5.98	5.85												
Innovation	0.99	1.97	0.18											
Bohr research	40.13	35.45	0.07	-0.20										
Pasteur research	32.75	27.15	-0.02	-0.03	-0.67									
Edison research	26.90	26.44	-0.07	0.30	-0.65	-0.12								
Age	1.05	0.29	-0.05	0.12	-0.09	-0.06	0.19							
Gender	0.67	0.47	0.12	0.03	-0.11	0.06	0.09	0.10						
Private sector experience	0.19	0.39	-0.16	0.07	-0.22	0.02	0.25	0.02	-0.03					
Parents/spouse private sector experience	0.26	0.44	-0.05	0.05	-0.13	0.00	0.16	0.08	0.01	0.09				
Admin/teaching responsibility	32.75	23.86	-0.10	0.04	-0.16	0.11	0.11	0.17	-0.07	-0.01	0.08			
TU Delft	0.30	0.46	0.03	0.08	-0.21	0.16	0.13	0.16	0.08	-0.03	0.11	-0.07		
RWTH Aachen	0.23	0.42	-0.03	0.09	0.10	-0.09	-0.04	0.04	-0.15	-0.11	-0.06	0.32	-0.36	
ETH Zurich	0.47	0.50	0.00	-0.15	0.10	-0.07	-0.08	-0.17	0.05	0.12	-0.05	-0.21	-0.62	-0.51

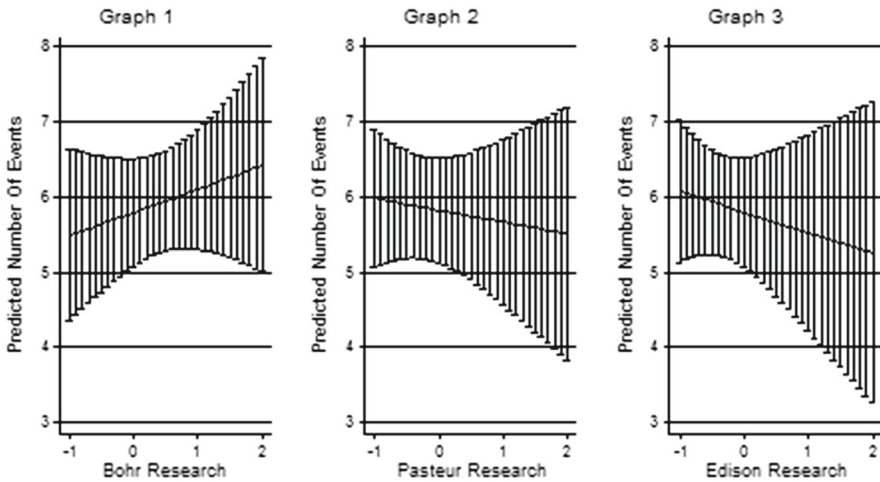


Fig. 6 Marginal effect of research orientation on publication output

4 Empirical results

4.1 Research orientation and output: is the baseline expectation met?

In the following, we present the results concerning our baseline expectation. As prior research has emphasized graphical representations of effect sizes in non-linear models (Hoetker 2007; Wiersema and Bowen 2009), we graph the emphasis on one research orientation relative to all other research orientations in Fig. 6. We use our standardized (normalized) research orientation measures and depict the marginal effect on research output. Hence, we measure in which way a unit increase in Bohr orientation (Graph 1 in Figure 6) affects the publication outcome. Similar interpretations apply for Graphs 2 and 3 in Figure 6, i.e. for Pasteur and Edison research. All interpretations are made relative to other scholars' perception. Hence, a one-unit change relative to being Bohr and Edison gives an indication as to how scholars that are ambidextrous across different projects would publish or how many more innovations they would produce if they concentrate more (or less) on the respective research orientation, with those who concentrate the most as the reference. Figure 6 shows that scholars doing more Bohr research publish more. At the same time, scholars doing more Edison research publish less. Ambidextrous researchers, those with an intermediate level of research orientation (thus combining projects of different research orientations) publish more than Edison researchers.

As depicted in Fig. 7, we find that the number of product/process innovations increases for Edison research and sharply decreases for Bohr research. No significant differences in Pasteur research are noticeable. Hence, we find that Pasteur and Edison research produce more commercial output than Bohr research; Edison research produces the most commercial output. Those ambidextrous scholars combining projects of different research orientations will produce more commercial output when turning more to Edison research. As expected, scholars only doing Edison research produce

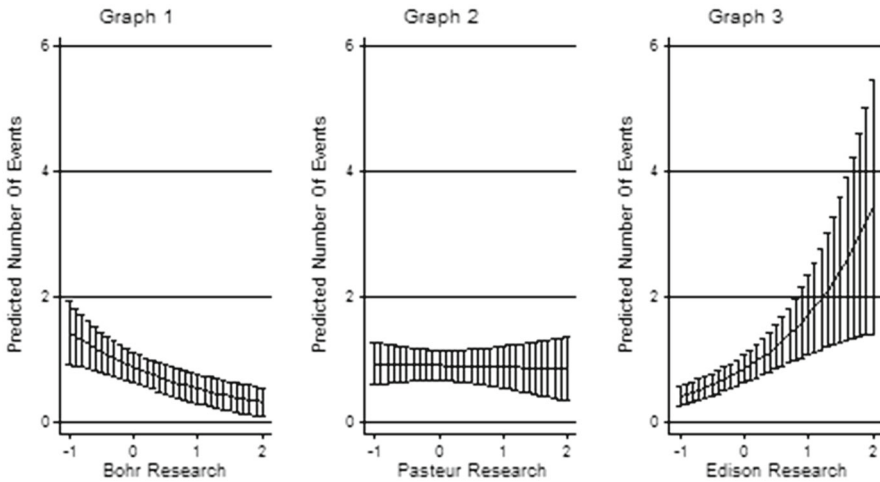


Fig. 7 Marginal effect of research orientation on innovation output

most commercial output. As such, we can confirm that the baseline expectation is fully met.

4.2 Research orientation, network and output performance: results

4.2.1 Research orientation and network: are there direct effects?

To test **H1a** and **H1b**, on the relationship between research orientations on the one hand and collaboration with the academic and commercial sector on the other hand, we proceed in two steps. First, as shown in Table 2, Bohr research is associated with collaborations with other scholars. The coefficient is positive and highly significant ($\beta = 0.882$, $p < 0.01$). The negative coefficient for Edison research illustrates the lower importance of collaborating with other scholars ($\beta = -0.942$, $p < 0.01$). At the same time, we find opposite effects for the importance of the firm network. Bohr research indicates less reliance on firms ($\beta = -0.896$, $p < 0.01$), while Pasteur research is positively associated with having industrial partners ($\beta = 0.810$, $p < 0.01$). In sum, our findings support **H1a** and **H1b**.⁵

⁵ We corroborated our analysis using a seemingly unrelated regression framework. Bohr research orientation is positive on working with universities while Edison research orientation affects the network utilization negatively. Similarly, we find negative effects of Bohr orientation on the utilization of firm networks. Again, we find that there are still effects of networks and research orientation for all but one relationship (Edison and firm network) when employing a more complex empirical framework. Our main results remain unchanged in direction and order of magnitude. We believe that these extensions attest to the fact that our results are prudent.

Table 2 Determinants of partner network

	(1) With university	(2) With university	(3) With university	(4) With firms	(5) With firms	(6) With firms
Bohr research	0.882*** (0.286)			- 0.896* (0.488)		
Pasteur research		- 0.225 (0.274)			0.810* (0.483)	
Edison research			- 0.942*** (0.305)			0.443 (0.600)
TU Delft	0.416 (0.678)	0.122 (0.683)	0.235 (0.664)	1.760 (1.266)	1.854 (1.260)	2.049 (1.251)
RWTH Aachen	- 0.147 (0.670)	- 0.073 (0.698)	- 0.026 (0.685)	2.203 (1.520)	2.225 (1.517)	2.085 (1.523)
Age	0.024 (0.625)	- 0.113 (0.625)	0.410 (0.652)	- 0.983 (1.156)	- 0.603 (1.239)	- 1.141 (1.209)
Gender	- 0.015 (0.579)	- 0.184 (0.585)	- 0.053 (0.565)	- 0.249 (1.166)	- 0.156 (1.169)	- 0.123 (1.166)
Private sector experience	0.012 (0.640)	- 0.474 (0.650)	0.065 (0.652)	0.139 (1.472)	0.597 (1.440)	0.387 (1.491)
Parents/spouse private sector experience	- 0.176 (0.615)	- 0.344 (0.644)	- 0.106 (0.619)	- 0.540 (1.218)	- 0.328 (1.210)	- 0.491 (1.215)
Admin/teaching responsibil- ity	- 0.017 (0.011)	- 0.022* (0.012)	- 0.020* (0.011)	- 0.001 (0.023)	0.000 (0.024)	0.004 (0.024)
p>Chi-Square	0.041	0.503	0.045	0.457	0.420	0.781
Observations	248	248	248	248	248	248

*p<0.1, **p<0.05, ***p<0.01

4.2.2 Research orientation and output: indirect effects on access to networks

To account for the combination of research orientation and network influencing output, as suggested in **H2**, we test whether the network mediates the effect of research orientation on academic and commercial output. We follow the procedures laid out in Preacher et al. (2007) and provide bias adjusted p-values using bootstrapped standard errors. We report the mediating effects of the academic/firm network on academic/commercial output in Table 3. The mediating effect of network types for Bohr research is positive and significant at ($\beta = 0.055$, $p < 0.1$). Scholars focusing on Bohr research have better access to academic networks which in turn affects their academic output. However, collaborations with firms reduce both academic output ($\beta = -0.028$, $p < 0.1$) and commercial output ($\beta = -0.063$, $p < 0.1$) for Bohr research. Hence, scholars concentrating on Bohr research publish more when they have better access to other scholars. However, their commercial output does not benefit from collaborating with either industrial or academic partners. Scholars focusing on Edison research have worse access to aca-

Table 3 Indirect effect of research orientation (through university/firm network) on academic and commercial output

	Mediator (network type)	Output (dep. variable)	Beta	St. error
Bohr research	University	Academic	0.055***	0.023
	Firm	Academic	- 0.028*	0.016
	University	Commercial	0.064	0.040
	Firm	Commercial	- 0.063*	0.036
Pasteur research	University	Academic	- 0.017	0.019
	Firm	Academic	0.027**	0.013
	University	Commercial	- 0.015	0.027
	Firm	Commercial	0.066*	0.040
Edison research	University	Academic	- 0.057***	0.022
	Firm	Academic	0.014	0.015
	University	Commercial	- 0.068	0.047
	Firm	Commercial	0.031	0.044

The direct effect of the explanatory variable research orientation on the mediator network is $\beta = 0.90$, $p < 0.01$ and $\beta = -0.91$, $p < 0.1$ for Bohr research on university and firm networks, respectively. For Pasteur research the effect is $\beta = -0.27$, $p = \text{n.s.}$, and 0.87 , $p < 0.1$ on university and firm networks, respectively. For Edison research the effect is $\beta = -0.96$, $p < 0.01$ and $\beta = 0.47$, $p = \text{n.s.}$ on university and firm networks, respectively

demographic networks which reduces their academic output ($\beta = -0.057$, $p < 0.01$). Yet we find no evidence for a mediation effect for firm networks affecting commercial output for scholars focusing on Edison research.

In contrast, both commercial output ($\beta = 0.066$, $p = 0.1$) and research output ($\beta = 0.027$, $p > 0.05$) of scholars concentrating on Pasteur research benefit from working with industry partners. Better access to both types of networks affects commercial and academic output simultaneously. At the same time, there is no negative effect of working with university partners on both types of output. So while scholars mainly focusing on Bohr or Edison research have a blind spot in either working with industry or university partners, scholars concentrating on Pasteur research are ambidextrous in their network access and successfully handle a network of university and industry partners, thereby increasing their academic output. In sum, we find support for **H2**.

4.2.3 Research orientation and output: indirect effects on use of networks

As it concerns the moderation perspective to network utilization, we tabulate in Table 4 the results from an interaction effect of research orientation and networks employed on the respective output. We hypothesize that the absence or presence of networks affects the relation between research orientation and output. This analysis is supplementary to the mediating effects, as it suggests a complementarity between networks and research orientations. We find a positive and significant effect for the interaction between the university network and Pasteur research on academic output ($\beta = 0.021$, $p > 0.1$). Pasteur research orientation leads to more academic

Table 4 Interaction effect of research orientation (with university/firm network) on academic and commercial output

Independent variable	Moderator (network type)	Output (dep. variable)	Beta	St. error
Bohr research	University	Academic	- 0.020	0.013
	Firm	Academic	- 0.013	0.006
	University	Commercial	- 0.018	0.035
	Firm	Commercial	0.004	0.023
Pasteur research	University	Academic	0.021*	0.013
	Firm	Academic	0.011	0.007
	University	Commercial	- 0.015	0.015
	Firm	Commercial	0.003	0.019
Edison research	University	Academic	0.012	0.018
	Firm	Academic	0.009	0.009
	University	Commercial	0.040	0.034
	Firm	Commercial	0.005	0.017

output for those scholars focusing on Pasteur research and collaborating with other scholars. Similarly, the interaction effect between firm networks and academic output reports a similar effect (p -value = 0.12) but just misses the critical cut-off value. Nonetheless, it carries economically meaningful interpretations. Overall, we find evidence that only those concentrating on Pasteur research are able to benefit from a boost of learning by better utilizing their network in terms of higher output. So, our findings partially support hypothesis **H3c**. All other types simply differ in their access but not the utilization of the corresponding networks. Neither Bohr nor Edison type researchers appear to benefit from better utilization of either network type more efficiently. So, we cannot find support for hypotheses **H3a** and **b**.

5 Discussion

5.1 Theoretical and conceptual contributions to ambidexterity in academia

Ambidexterity implies that although at first sight basic research seems to be incompatible with applied research, combining both activities may provide super-additive outcomes for some scholars. Research-oriented and practice-oriented scholars have opposing goals, interests, and probably views on what research should be. They experience a trade-off between engaging in ground-breaking academic output published in peer-reviewed journals and developing improved products/processes for mainly commercial use. Yet ambidextrous scholars might thrive on doing both basic and applied research.

Our findings indicate that two kinds of scholars fit the notion of the ambidextrous scholar. The first kind mainly focuses on Pasteur-type research, i.e. in each research project, aiming at both fundamental understanding and use. Scholars of this type are able to deal with and benefit from a mixed network of both academic and industrial partners. They produce above average research and above average commercial output. The second kind of ambidextrous academic brings together projects of different research orientations, i.e. Edison, Pasteur and Bohr research.

Regarding the access and utilization of networks, we find that ambidextrous scholars focusing on Pasteur research orientation complement academic and industrial partners, thereby achieving a higher academic output. This is in line with findings that ambidextrous scholars are able to keep a network of industrial and academic partners, thereby being able to inhabit both research and industrial communities (Gittelman and Kogut 2003; Ylijoki et al. 2011). While scholars focusing on Pasteur research might also belong to a well-defined community, be it one combining academic and industrial partners, scholars combining projects of different research orientation connect to unrelated communities. They tap into different knowledge bases and can benefit from ideas emerging from a project of one research orientation finding their way into projects of other research orientations. Using their networks in this way might explain why scholars combining projects of different research orientation publish more than all their peers (see Sect. 4.1).

5.2 Practical implications for policy, management and scholars

Our results indicate that *policy makers* might wish to reconsider the value of Bohr research for society. In recent decades they have increasingly stimulated universities and scholars to become ambidextrous. However, our findings suggest that scholars combining different research orientations can be more productive in their academic output. Therefore, it is important to keep supporting Bohr research. Bohr research at universities receive considerably less money from third parties (Bentley et al. 2015) and therefore normally rely on governmental funding. Hence, policy makers should set goals for Bohr research in the light of societal needs and make sure that the funding for Bohr research aligns with these goals. Policy makers could support scholars focusing on either Bohr or Edison research in combining projects from different research orientations. Moreover, policy makers can stimulate collaborations taking into account the different research orientations, i.e. supporting academic collaborations for Bohr research, industrial collaborations for Edison research, and both kinds of collaborations for Pasteur research.

To stimulate the research and commercial output of their staff members, *university management* might wish to consider our findings in the light of the changing role of universities in recent decades (see Sect. 1). Following findings on how to manage ambidexterity in private firms (e.g. Venugopal et al. 2017) we suggest that university management should take a mediating role to enable organizational ambidexterity of universities. Although our findings stem from universities of technology, which are traditionally able to bridge research and application (see Sect. 1), all universities would profit from responding to the various research orientations of their staff members. On

a meta-level, university management can determine a strategy and design incentives how to balance research and application for the university as a whole, and how different disciplines can contribute to this strategy (Carayol 2007). Scholars concentrating on Bohr research might benefit most from universities' support in collaborating with other scholars in their own field but located elsewhere, e.g. by generous sabbatical schemes. Scholars concentrating on Edison or Pasteur research might benefit most from advice and help with ethical issues emerging from their collaboration with private partners, particularly with the question of how to balance industry and university interests (Hillerbrand and Werker 2019).

Our results suggest that *scholars* themselves would benefit from developing a strategy regarding their research orientation and their network. Particularly those scholars concentrating on projects of solely Bohr or Edison research could benefit by broadening their horizon. Scholars doing only Bohr research could consider the specific practical use of their research. Scholars doing only Edison research could consider the wider and deeper basic insights of their findings. Both types of scholars could benefit from looking for some small collaboration outside their research orientation. In fact, according to our findings, this might lead to a considerable increase in their publication output. To increase their output, all scholars could benefit by fitting their network to their research orientation.

5.3 Limitations and avenues for further research

To understand the implications of our work, it is of importance to be cognizant of the boundary conditions and limitations to which our work is subject to. To begin with, our study used peer-reviewed publications and process- and product innovation as a simple count-measure of academic and commercial productivity. Publication indicators were used before in this area of inquiry (e.g. Gittelman and Kogut 2003; Ylijoki et al. 2011) and are a valuable indicator mirroring academic output (Nelson 2012). The indicators product- and process innovation capture commercial output (Hughes et al. 2018; Linton and Walsh 2008; MacPherson 1998). However, using the number of output units in terms of publications and innovations does not give a direct indication of the quality of the output. In the case of peer-reviewed publications we can ensure some degree of quality check due to the review process. There are a number of ways to account better for quality, e.g. including the impact factor of the journals. Yet this might become more cumbersome for respondents potentially lowering the response rate even further. In the case of product- and process innovation the users of new products or production processes judge the quality. While our results certainly highlight how scholars place emphasis on either output measure depending on their research orientation, it would be worthwhile to investigate further if ambidextrous Pasteur scientists achieve higher quality publications and/or innovations when combining the two poles. Higher quality output would further attest to the super additivity that is achieved when combining research and commerce.

Additionally, our study has focussed on academic careers as the underlying motive for engaging in research and/or commerce. Career motives might, however, be different for different disciplines. Especially in more applied areas of research, such as

engineering different academic career paths might be envisioned by young scholars, even in early career positions after obtaining their PhD. As such, further research could investigate whether scholars that show an interest in non-academic career positions, focus more on commercial output to be able to keep the door open for this particular career option. Along these lines, we treated research orientation as a precursor to the output they generate. Given the focus on early career researchers, it might well be that research orientation is a combination of personal and career interest and supervisor and mentor relations. In unreported analyses, we found that the PhD that an individual obtained already acts as a predictor to the work that some engage in after their PhD. As such, a more longitudinal focus on academic output in early careers could shed more light on individual interests, mentoring relations, and incentives that steer output and create ambidextrous Pasteur type researchers.

6 Conclusion

Our results reveal that the supposed trade-off between research and commercial output only exists for scholars focusing on either pure basic or pure applied research; it does not exist for ambidextrous scholars. Scholars are particularly productive when their research orientation, network partners, and kind of output match.

Our results clarify how ambidextrous scholars which have been considered the *deus ex machina* in solving technological and societal problems, look like and how they operate. Principally, there are two kinds of scholars fitting the notion of ambidextrous academic. The first kind mainly focuses on Pasteur-type research, i.e. combining goals of fundamental understanding and application in each project. The second kind brings together projects of different research orientations, i.e. Edison, Pasteur and Bohr research. Both kinds of ambidextrous scholars are productive; both expertly combine a research with an industrial network. Yet the second kind of ambidextrous academic is particularly interesting, as it indicates that it may be possible to turn a Bohr or Edison researcher into an ambidextrous one.

Our contributions show the diversity of scholars' research orientation, networks and output, thereby opening roads for future research. As insights into the characteristics of ambidextrous scholars and their success have been scarce (Ambos et al. 2008; Etzkowitz and Viale 2010), we suggest investigating this type of academic in more detail. How do scholars become ambidextrous? What are the drivers for this type of research, for choosing network partners and for choosing to become an ambidextrous academic? How are these scholars able to combine academic and industrial networks, and produce both research and commercial output? Is it possible and desirable for others to do this as well? As previous analyses suggest that there are specific research areas where scholars can productively combine research and commerce (Agrawal and Henderson 2002; Link et al. 2007; Thursby and Thursby 2011), would this only be possible and reasonable for particular research areas? Answers to these questions

would benefit society as a whole. As Louis Pasteur himself wrote, ‘Science and its applications are united, like the tree and the fruit that it bears.’⁶

Acknowledgements Open Access funding provided by Projekt DEAL.

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Appendix 1: Career paths at the three universities of technology

RWTH Aachen University provides two different early career options after the PhD degree: postdoc positions and assistant professorships (i.e. *Wissenschaftlicher Mitarbeiter*, *Akademischer Rat auf Zeit* or *Juniorprofessor*), the latter of which is for people intending to qualify for a full professorship. As the Swiss Federal Institute of Technology Zurich is located in the German-speaking part of Switzerland, its system corresponds to the German one. As a consequence, the Swiss Federal Institute of Technology Zurich offers early career positions similar to those offered at RWTH Aachen University, i.e. either postdoc positions or assistant professorships (i.e. *Oberassistent*). In principle, the Dutch Delft University of Technology provides two similar types of early career positions, i.e. postdoc positions (*onderzoeker*) and tenure-track assistant professorships (*universitair docent*). The only major difference is that assistant professors usually go on to become tenured assistant professors after 5 years; they might stay assistant professors for the remainder of their careers, or they might move up the academic ladder or on to another job.

Appendix 2

See Appendix Table 5

⁶ ‘Il y a la science et les applications de celle-ci, réunies comme le sont le fruit et l’arbre qui le porte’ (Pasteur 1871).

Table 5 Variable names, operationalization and question(s) employed

Variable name	Operationalization	Question(s) Employed
Publications	Number of peer-reviewed publications	How many scientific papers did you (co-) publish in the period 2007–2011?—Number—in peer-reviewed scientific journals'
Innovation	Count measure of process and product innovations	To how many new product innovations (process innovation) did you contribute in the time period 2007–2011?
Bohr research	Extent to which respondents would situate their research in each of these quadrants	What kind of research have you carried out in the last 5 years, i.e. basic research, user- inspired research or applied research (in %)? In case you were active in a mixture of two or three quadrants please indicate the % accordingly
Pasteur research		
Edison research		
University network	Importance of collaborations with other scholars (located regionally, nationally and internationally) on a scale of 1 to 4, with 1 being not important at all and 4 being very important. We summed the answers to these questions into one single construct. Cronbach's alpha: 0.89	Please indicate the importance (Score 1 indicating not important at all and score 4 indicating very important) of the following co-operations for your research for the time period 2007–2011. Academics from within university (a) within region of your current university, (b) within your country, (c) within EU, (d) outside the EU
Firm network	Importance of collaborations with industrial partners (small, medium and large firms; located regionally, nationally and internationally) on a scale of 1 to 4, with 1 being not important at all and 4 being very important. We summed the answers to these questions into one single construct. Cronbach's alpha: 0.94	Please indicate the importance (Score 1 indicating not important at all and score 4 indicating very important) of the following cooperations for your research for the time period 2007–2011. Small and medium-sized companies; Large companies (≥ 200 employees) (a) within region of your current university, (b) within your country, (c) within EU, (d) outside the EU
Age	Age at the time of the interview of the respondent	To which age range do you belong? (1 = <40; 2 = 40–49; 3 = 50–59; 4 = > 59)

Table 5 continued

Variable name	Operationalization	Question(s) Employed
Gender	Variable that takes on the value of one for a male and zero for a female respondent	What is your gender?
Private sector experience	Variable that equals one if the respondent has worked in the private sector, and zero otherwise	Have you worked in the private sector within the past 5 years?
Parents/spouse private sector experience	Variable equals one if the respondent's family has an entrepreneurial background, and zero otherwise	Have your parents and/or your partner/spouse ever (partly) owned a firm?
Admin/teaching responsibility	Percentage of working time spent on teaching and administration	How do you divide your time between research, teaching and administration? Please use the actual time that you spend on the different tasks and not the ones suggested in your job description.—Please indicate in % (the sum should be 100%)
TU Delft	Dummy variable for Delft and RWTH Aachen University of Technology, with the Swiss Federal Institute of Technology Zurich as the reference group	Not applicable
RWTH Aachen		
ETH Zurich		

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