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Complementarity and trade-off between academic work tasks

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Abstract

Professors have multiple responsibilities, and contribute to research, education and third mission activities. These tasks are expected to be complementary, in such a way that synergies between tasks can lead to positive outcomes. But are academic tasks really complementary or are they characterised by trade-offs? This study of Norwegian university professors, predictably observe a trade-off between student supervision—a key part of professors' educational responsibilities—and research performance, but also detect important synergies between supervision and third mission activities.

1. Introduction

Universities have multiple missions and are expected to contribute to generating new knowledge through research and to educate new generations of scholars and professionals. Universities are also expected to contribute to the so-called ‘third mission’ – which concerns the diffusion and use of knowledge in society and the economy broadly defined (Laredo 2007, Sanchez-Barrioluengo 2014). Due to the multiple missions of universities, debates on academic work and how universities balance education, research and third mission activities are ongoing discussions in many countries (Sanchez-Barrioluengo 2014). Policies and university mission statements are often based on the premise that these activities are complementary, as seen in the pervasive concepts ‘research-based education’ and ‘academic entrepreneurship’. Prior research on the topic of task complementarity and academic work has addressed mainly pairs of activities, and for the main part, these two ‘classic’ forms of task integration. However, compared to the optimism inherent in these concepts, empirical research on this issue has more often emphasised trade-offs between different tasks (Fox, 1992; Kossi et al., 2016; Artes et al., 2017). Prior research on academics’ participation in third mission activities has found that there is some degree of complementarity between research and third mission activities such as industry collaboration and commercialisation of research (e.g. Gulbrandsen & Smeby, 2005; Van Looy et al., 2004), but results are not consistent. Research on the relationship between teaching and research do in general not demonstrate a high degree of complementarity between the two activities (Hattie & March 1996; Verburg, et al. 2007; Landry et al. 2010, Kossi et al., 2016). There is presently limited research into the complementarities between educational and third mission activities (Wang, et al. 2016; Bianchini et al. 2015; Fudickar et al, 2018). Few studies attempt to look at academics’ performance across all three tasks (Landry 2010; Bianchini et al. 2015), due to lack of common understanding of key variables (Verburg et al, 2007), data availability and differences in perspectives — making a synthesis across research findings difficult. With this in mind, it is still necessary to build more systematic knowledge on academic task complementarity. This paper will make a contribution to the research literature by addressing this shortcoming, and asks the following research question: Is it possible to achieve complementarity between tasks at the individual level, or is a trade-off inevitable? Further knowledge on this issue is relevant for policy makers, managers and academics trying to grapple with the balance between multiple tasks and its impact on academic workload and performance. For instance, in recruitment, career development and promotion of academics a wide set of qualification criteria is emphasised, and according to Van den Brink and Benschop (2011), professors are often asked to be “sheep with five legs”. For academics and managers alike it is pertinent to gain a better understanding of the feasibility of mastering and succeeding with multiple tasks, or whether is it better to specialise.

To shed light on the potential complementarities and trade-offs between key tasks that academics perform, we make use of an individual level dataset that contains information on the academic work of 1481 Norwegian university professors (tenured faculty; associate and full professors) across all fields of science. The Norwegian university setting is a suitable context to study the question of task complementarity and trade-offs, since Norwegian university professors are expected by their employment contracts to contribute to research, education and third mission activities, in addition to administrative responsibilities (Bentley & Kyvik 2012; Kyvik, 2013). This leaves us with a large sample of professors with similar task expectations, where synergies and and tension between tasks could be investigated. We perform an analysis of the relationship between different academic tasks by looking at how professors behave across multiple task domains. We make use of regression analysis, but do not develop a causal model to account for performance or to predict academics' behaviour. The reason for this is that there is still limited knowledge on which to assume causality, and existing knowledge points to several different conclusions. To deal with this uncertainty, we develop hypotheses that address the correlation between tasks. As such, the results of the study should not be interpreted in causal terms.

Before presenting the methodological approach in detail, we review existing research on the issue of task complementarity in academe and outline a set of hypotheses. We then describe the main results obtained through the regression analyses and discuss the results in light of existing literature. The concluding section discusses the limitations of the study and the implications for further research, management and policy.

2. Literature and hypotheses on task complementarity among academics

A prior research has predominantly looked at task complementarity in pairs of activities, such as relationship between teaching and research, prior research on each pair of tasks is reviewed below.

2.1 Relationship between education and research activities

In most higher education systems, there is a shared view that there should be a relationship between education and research activities. The basic idea, stemming from the notions of Humbolt about the unity of research, teaching and learning (Nybom, 2003), is that research and educational activities should be complementary. The knowledge generated by academics through research activities should spill over to their teaching and supervision, in the form of deeper knowledge, broader understanding of the literature, advanced analytical and methodological skills etc. Derived from this perspective, a basic assumption would be that academics who are active researchers are also good teachers and educators, due to their more substantial or deeper knowledge of the scientific field. Scientific expertise is expected to contribute

positively to the quality of teaching and supervision. The relationship is usually investigated in this direction (i.e influence of research on teaching), and seldom on the other way around, even though it is assumed that teaching, and particularly of graduate students, can have positive effects on research for instance by offering relevant research problems, potential for collaboration, and more (Duff and Marriott, 2017).

As the potential synergy between teaching and research activities in higher education institution is a fundamental question within the field of higher education research, a large number of studies have been performed on this issue. Researchers who have addressed the issue empirically, have often formulated the relationship between research and education tasks more in terms of a trade-off (Fox, 1992; March & Hattie 2002; Landry et al. 2010; Artes et al. 2017). According to their argument, investing time and resources in research activities means forgoing time that could be invested in education and teaching activities, or vice versa.

Hattie & March (1996) and Braxton (1996) published early meta-analyses of the evidence about the link between teaching and research and reach similar conclusions. Their meta-analyses indicated that there was no significant relationship found between research and teaching performance, neither positive nor negative. A more recent literature review on the same issue discusses this conclusion and finds that it is difficult to systematically assess this question, as the concepts teaching, and research performance are not operationalised in similar fashion and that the variables used in most studies are limited (Verburg et al. 2007). In particular, the operationalisation of teaching varies a lot. Verburg et al. (2007) show the variety of different aspects and measures of teaching used, including: Teaching quality, the time used on teaching, the number of courses taught, the amount of interaction with students, the researchers' teaching approaches, the researchers' attitudes to teaching, teaching skills, commitment to teaching, investments in teaching, and amount of supervision of students. Student evaluation scores or ranking scores of the institutions have also been used as indicators of academic's teaching activities (e.g. Bianchini et. al 2015), but they are also criticised (e.g. Mengel et al. 2017; Wiers-Jenssen 2015).

As usually is the case when the evidence is inconclusive, more detailed studies of how the teaching-research nexus plays out in different scientific fields and kinds/levels of education is necessary. It is also necessary to disentangle relationships between variables at different levels of analysis, as there might be a positive relationship at the university level, but a negative relationship at the individual level (Landry et al. 2010; Artes et al. 2017). Likewise, studies have tended to look at the relationship as a linear one, but later studies have indicated that there might be a threshold effect at play, and that the relationship between research and teaching follows an inverse U-shaped curve. The latter indicates that research activities up to a certain level is positive for teaching, but when a threshold is met, the positive effects diminishes (Garcia-Gallego et al. 2015). It is also important to highlight that most studies

reviewed look at the effect of research on teaching. This again could have impact on the expected relationship between the two variables. Research activities might be positive for teaching, but we have limited understanding of whether teaching is positive for research (Landry et al. 2010).

Artes et al. (2017) has summarised the evidence on this issue and claim that it supports the assumption that research and teaching are positively related, but that the association follows a non-linear or an inverse U-shaped curve. Their empirical study indicates that there is a positive relationship between research performance and teaching performance, when comparing academics with high and low teaching assessment scores as the dependent variable. They also find evidence that supports the assumption of a threshold effect, with no significant differences between academics with high or medium research performance, but significant differences between these two groups, compared to low research performers. Bianchini et al. (2015) also come to this conclusion; that the relationship between teaching and research performance likely follows an inverted U-shaped pattern.

Based on the substantial, but still inconclusive, evidence of the education-research-relationship, we formulate the following hypothesis about the potential complementary between educational and research tasks, in line with the threshold effect, as discussed above. *Moreover*, as teaching cannot be captured as one activity, indicator or output, teaching activities should instead be studied as a set of different activities. Supervising students reflect an important part of professors' teaching obligations and are also the teaching activity that may be most integrated with research. Due to this, we choose to study supervision activities as an indicator of teaching obligations. *We expect a positive relationship between moderate levels of educational responsibilities, in the form of supervision of students, and research activity (Hypothesis 1).*

2.2 Relationship between third mission and research activities

Considerable research has also been performed on the relationship between research and third mission activities. Following Sanchez-Barrioluengo (2014) the concept 'third mission' activities is here used for activities performed by academics to utilise their knowledge and expertise outside the academic context. As has been described by others (Molas-Gallart, 2002; Perkmann et al. 2013; Sanchez-Barrioluengo 2014) this concept is made up of heterogeneous sets of activities, where some are more prevalent across all fields of science and some are rather exclusive to certain fields of science. Early research on this issue focused on activities that was targeting a commercial use of academic knowledge, such as patenting, licencing, and industry partnerships (Geuna & Nesta, 2006; Gulbrandsen & Smeby 2005; Lee & Bozeman, 2005). Later research that widened the initial empirical focus outside engineering and sciences, and found that academics in most fields of science utilised their knowledge in external communities, through interacting and communicating in many different ways (e.g. Abreu & Grinevich,

2013; Perkmann et al., 2013). Although we recognize that it is rather common for academics to communicate research and attempting to finding use for their knowledge in external communities, and that such activities are embedded in educational and research practices, for our purpose it is important to target ‘third mission’ activities that are clearly distinguishable from teaching and research activities; i.e. they can be related, but not overlapping.

Following Perkmann et al. (2013), we distinguish between two ‘typical’ modes of utilising scientific knowledge and expertise outside academia – commercialisation and collaboration. Both kinds of activities entail that academics actively pursue activities to diffuse and make use of scientific knowledge in external communities. The first in the form of ensuring ownership and transferring the rights to exploit scientific knowledge commercially in the form of patents, licenses or other activities based on ownership of technology. The latter – research collaboration - entails diffusing knowledge to firms and public sector organisations in the form of research agreements, partnerships, consulting and advisory activities, etc. The relationship between participating in commercialisation versus external collaboration and research performance is likely different (Perkmann et al. 2013).

Prior literature that has looked at the impact of participation in commercialisation on research performance, usually measured by publication data, indicates a positive relationship (Geuna & Nesta, 2006; Larsen 2011). There seems to be some degree of complementarity between these tasks, where academics that are active in commercialisation activities also score highly on research productivity. This effect seems to be more prominent in some disciplines, and particularly in the life sciences, and it also seems to be mediated by the status and age of academic employees, as well as their research orientation (Perkmann et al. 2013; Abreu & Grinevich 2013; Bianchini et al. 2015).

Research has also looked at the relationship between external collaboration and research performance. Early contributions to this literature found a positive relationship between industry partnerships (for instance measured by industry research funding) and research performance, but this positive relationship was mainly found in technology and natural sciences (Van Looy et al. 2004; Gulbrandsen & Smeby 2005; Abramo et al. 2009). Recent analyses have attempted to look deeper into this issue, by measuring different levels and kinds of external collaboration, and their association with scientific performance. The empirical evidence indicates that the association between the variables is not linear but takes an inverted U-shape (Muscio et al. 2017; Banal-Estanol et al. 2015). This indicates that up to a certain level, being involved in external collaboration is likely positive for research performance.

Based on the literature, we formulate two hypotheses about the complementarities between academics’ participating in third mission activities (distinguished by two different modes as described above) and research performance: We expect that there *is a positive association between research*

commercialisation and research activities (hypothesis 2). As high levels of academic commercialisation is rather uncommon, we do not expect to be able to distinguish between levels of participation on this specific variable. *We also expect a positive relationship between moderate level of external research collaboration and research performance (hypothesis 3)*. For the latter hypothesis, prior research indicates that a threshold effect may be involved.

2.3 Relationship between teaching responsibilities and third mission activities

This relationship is less well documented at presently, partly because there is a lack of available studies and adequate data, but also because there is limited understanding of how educational activities are connected to research work, as seen above. This limitation has been acknowledged in existing studies (Perkmann et al. 2013; Bianchini et al. 2015). Education and teaching are also highly heterogeneous phenomena, and while some forms of teaching activity is closely related to research practices (such as supervising postgraduate students), others (such as teaching undergraduates) might be more disconnected from operative research.

As there is limited knowledge available, it is difficult to propose hypotheses about the connections between education and third mission activities. Some authors claim that resources, knowledge and networks available through academic entrepreneurship and external collaboration can influence the quality of education and instruction positively (Etzkowitz 1998). For instance, Lin & Bozeman (2006) found that academics who collaborate with industry, support and supervise more graduate students compared to peers who do not collaborate with industry. Other authors claim that the effect could be negative, and that third mission tasks might reduce the time and effort academics spend on teaching and other educational tasks (Gulbrandsen & Smeby 2005). It is also important to keep in mind that there is substantial differences between fields of science, as particularly third mission activities vary considerable between scientific fields (Perkmann et al., 2013; Thune et al., 2016).

A Chinese study has attempted to systematically investigate the relationship between third mission activities and teaching performance (Wang et al. 2016). They operationalised third mission tasks, in two separate models, following Perkmann et al. (2013), and propose that the two models have different kinds of impact on teaching. They operationalise ‘teaching performance’ by relying on institutional ranking scores, that computes a score for teaching quality based on numbers of ‘excellent alumni’, ‘excellent academics’ and the number of ‘first tier’ educational programs. This measurement of teaching performance does not reveal much about the actual teaching activities, and also measures the status and resources that each institution possesses. Wang et al. (2016) hypothesises that commercialisation is not positive for teaching performance, but that research collaboration would be. They find support for their hypotheses and also that the combined model (high on commercialisation and high on external

collaboration) is positive for teaching performance. Contrary to this finding, Bianchini et al. (2015) find that faculty who perform extra-academic tasks (measured by consulting activities) have ‘lower commitment to teaching’. Similar results were also obtained in studies made by Lee & Rhoads (2004) and Sanchez-Barriolungo (2014). Bianchini et al. (2015) highlight that there are substantial disciplinary differences. Landry et al. (2010), on the other hand, find no significant relationship between commercialisation and other knowledge transfer activities, and teaching.

With the available evidence still being limited and pointing to different conclusions, any hypothesis must be regarded as tentative. We nonetheless formulate the two following expectations, and in accordance with established knowledge, we discern third mission activities directed at research commercialisation and activities related to external collaborating (e.g. Perkmann et al. 2013). *We expect that there is a negative relationship between educational activities and research commercialisation (hypothesis 4).* Finally, based on Wang et al. (2016) and the general pattern of threshold effects found in related research, *we expect a positive relationship between educational tasks up to a certain threshold and external research collaboration (hypothesis 5).*

3. Data, measurements and methods

3.1 Target population and sources of data

To test the hypotheses, we used data from a survey administered to approximately 80 percent of academic staff in Norway. To draw the sample, we utilised a database of all scientific staff employed in Norwegian research organisations (the national research personnel registry). The database includes names, gender, age, institutional affiliation, position and home address to all research staff in the public sector research organisations and is updated on an annual basis. The sample for the survey was drawn from the registry (university employees only), and the survey was sent to 8585 individuals. The survey was administered to all individuals who were permanent employees (excluding PhD students, post docs and short-term, temporary staff). It generated a 52,5 percent response rate and was carried out in 2014. The survey collected demographic information about the academic employees and their participation in education and third mission activities. Based on the responses, we matched each individual respondent in the survey with their publication output drawn from a bibliometric database that contains the bibliometric records of all scientific employees in Norway, which was used to measure the research variables.

For this analysis, we needed to select a sample from the population that have relatively similar working conditions and expectations to contribute to all three tasks. As the Norwegian higher education system is a binary system with two main types of institutions – research-intensive universities and teaching-

intensive university colleges or polytechnics, the institutional missions and the working conditions of the academic staff, particularly when it comes to time available for research, are different in different types of higher education institution. Moreover, different academic positions entail different working condition and time available to do research (Christiansen 2016). Prior analysis of the data set showed that academic staff in the rank of professor (associate and full professor) have relatively similar working conditions and receive approximately the same amount of time for research activities. To control for the institutional and positional differences that influence the respondents' academic work, and to ensure a relatively high level of research activity among the respondents, only professors employed at four comprehensive universities were selected. Our final analysis included 1481 responses, which represent 42 % of the whole population of professors (full and associate professors) in Norway.

3.2 Operationalisation of main variables

3.2.1 Research activities

As customary in studies of academic work and performance, bibliometric data was used to measure individuals' research activities and performance. The number of scientific publications produced by the academics in the years 2011-2013 (the three years prior to the administration of the survey) was collected from a Norwegian bibliographic database and matched with the respondents in the survey. The bibliographic database (called 'Cristin') contains all publications produced by Norwegian academics with a complete coverage of all peer-reviewed scientific and scholarly publications, including journal articles, monographs, book chapters and conference proceedings in all fields of research (Sivertsen 2016). The database also contains information about whether the publications were published in 'ordinary' scientific journals with peer review (called *Level 1*), or in highly prestigious journals and publishers (called *Level 2*). A maximum 20 percent of publication outlets in each field of science can be at *Level 2*. From this data source, we are able to measure research performance of academics in two ways: The number of publication points (i.e. the number of publications produced in the three years period) and the quality of the output (i.e. the number of publications that are in level 2 outlets in the same time-period).

3.2.2 Education-related activities – supervision of students

Prior studies have used many different operationalisations of education and teaching activities in universities, including teaching hours, number of programs taught, number of students supervised, teaching evaluations and subjective assessments of time spent on teaching-related activities. The exact amount of time spent different education and teaching activities would be the ideal way to measure it, but time estimates is well-known to be complicated (Eurostat, 2019) and administrative data (time sheets etc.) are difficult to obtain access to. The number of students supervised has also been used as an indicator of teaching activity (Lin & Bozeman 2006; Kyvik & Smeby, 1994), but is probably better at

capturing graduate level than undergraduate teaching. Moreover, as supervision represents a teaching practice where professors use their research skills actively, it represents a good example of a setting where task integration can be expected. Hence, we have chosen this measurement in this analysis, after trying out several measures that were meant to capture the amount of time academics spent interacting with students regardless of levelⁱ. When choosing to operationalise academics' participation in educational activities in terms of supervision of students, we are aware of the fact that our variable does not cover most teaching activities but argue that supervision is both an important part of academic teaching and also a relatively reliable indicator.

In the survey, the respondents were asked to report the number of bachelor and master students they supervised at the time of the survey. This means that this is a quantitative indicator, and it does not say anything about the quality of the supervision. Since we are interested in the synergies and trade-offs between tasks, the amount of an activity is relevant for us, as it reflects the time invested in this activity. 99 percent of the respondent reported that they supervised between zero and 42 students, while one percent answered between 43 and 172 students. We defined this latter percent of respondents as outliers and removed them from the final sample.

3.2.3 Third mission activities – research commercialisation and collaboration

As discussed above, third mission activities involve many and rather different activities, but it is customary to discern activities directed at research commercialisation and collaboration (e.g. Perkmann et al. 2013). We operationalise third mission activities in correspondence with this distinction. The respondents were asked to report their activity in *research collaboration activities* with external partners (including contract research, collaborative R&D with public sector, and collaborative R&D with industry) and their participation in *research commercialisation* (contribution to the development of new products, applied for patent, started new firm, licensed out proprietary knowledge (IPR) based on research activity) during a period of three years. The latter activities are mainly carried out by researchers in the STEM fields, whereas research collaboration (with private and public partners) is much more distributed across different fields of science.

Finally, in the analyses we control for gender, age, academic field and institution, as these variables impact on academic work and time available for different activities, and therefore need to be considered. Table 1 provides an overview of the variables included in the analysis.

Table 1: The variables used in the analysis

Variable	Values	Frequency	Percent
Gender	Female = 0	445	30

	Male = 1	1036	70
Age	Less than 40 years	130	9
	40 - 49 years	368	24
	50 - 59 years	500	34
	60 years or more	483	33
	Academic field	Humanities	339
	Social sciences	392	26
	Natural sciences	247	17
	Technology	219	15
	Medicine and health (reference category)	284	19
<u>Research activity</u>			
Publication points	Min. value = 0, max value = 23,4, mean 2,987, SD = 3,108 10,5 percent (155) has zero publication points		
Publication at level 2 (High ranked journals)	Min. value = 0, max value = 1 mean 0,271, SD= 0,274 42,5 percent (630) has zero publication at level two		
<u>Teaching activity</u>			
Supervision	Min. value = 0, max value = 42, mean 4,570, SD= 5,831		
<u>Third mission activity</u>			
		Supervised (N = 1135)	Not supervised (N= 346)
Commercialization			
Developed new products	11,4 percent, n=169	11,2 %	12,1 %
Applied for patent	6,5 percent, n=97	6,7 %	6,1 %
Started new firm	3,4 percent, n=51	3,8 %	2,3 %
Licensed	1,8 percent, n=27	1,8 %	2,0 %
Research collaboration			
Contract research	14,7 percent, n=218	16,7 %	8,1 %
Collaboration R&D with public sector	18,7 percent, n=277	20,0 %	14,5 %
Collaboration R&D with private sector	19,9 percent, n=294	21, 6 %	14,2 %

3.3 Regression analyses

While the education and third mission variables are self-reported activities in this study, the research variables are measured by the scientific output per person collected from a bibliometric database. The education variable (amount of supervision) and third mission variables (commercialisation and external collaboration) are *activities* while the research variables measure the output or the products of research activities. Thus, in our model research output is treated as the dependent variable. However, in the analysis we first investigate the relationship between the two independent variables (Hypothesis 4 and 5) and analyse the level of activity in third mission activities between academics who supervise students and those who do not. Significant differences were tested by using a two-dimensional test for random selection at five percent. To control for potential effects of gender, age and academic field, logistic regression models were used. In these analyses, third mission activities were set as the dependent variables since supervision is assumed to be a required activity regulated by contracts, while

participating in third mission activities is more voluntary and therefore likely to be more unevenly distributed.

In the second step, we investigate how participating in educational and third mission activities relate to research performance (Hypotheses 1, 2 and 3) using logistic regressions with research performance as the dependent variable. As seen above, research performance has been operationalised into two dummy variables – having publication points and having publications in highly ranked journals. Individual variables included in the same regression model have all a correlation smaller than 0.360 Pearsons P (See Appendix table A1.1 for more details).

In a third step, and mainly to control the results, we run a separate model with only parts of the sample. Since it is more common for researchers within the STEM-field to participate in third mission activities, and particularly research commercialisation, we also ran a separate the analysis on this group. However, this analysis did not produce significantly different results from the analyses of the whole sample, and instead confirmed our overall conclusions.

4. Results

4.1 The relationship between supervision and third mission activities

The relationship between third mission activities and educational activities is the least well understood relationship. Since these activities are assumed to be the main independent variables in our model, the relationship was investigated first (Hypothesis 4 and 5). As expected, our analysis indicates a positive relationship between supervising students and participating in research collaboration (hypothesis 5). However, we did not find a similar positive relationship between supervision and participating in commercialisation (hypothesis 4). This was also in line with the expectation.

In table 1, the percentage of professors who have participated in the two categories of third mission activities is displayed, comparing the ones who supervise students to those who do not. Professors who supervise students are more actively engaged in research collaboration compared to their peers who do not supervise students, and this difference is significant. The small observable difference between the two groups of professors in terms of participating in commercialisation activities is however not significant.

To control for academic and demographic differences, the participation rates in different third mission activities were also investigated with logistic regression analysis. In this analysis, different categories of third mission activities were used as dependent variables (Appendix Table A1.2 and A1.3 for details). Whether or not professors were supervising students and, and if so, the number of students supervised, were the independent variables The logistic regression analysis confirmed the positive relationship

between supervising students and research collaboration. The relationship between supervising students and research commercialisation activities were not significant, in line with the results of the bivariate analysis. Also, a positive relationship between *the number of students* supervised and the professors' participation in research collaboration was observed for the variable "R&D collaboration with the public sector" and "Contract research". This finding largely supports the expectation of hypothesis 5, but indicates a small increasing effect rather than the cap-off that was expected.

The relationship between the number of students supervised and the commercialisation activities was not significant and confirmed the bivariate findings. Thus, Hypothesis 4 that estimated a negative relationship between educational responsibilities and commercialisation, was therefore rejected due to lack of supporting evidence.

4.2 The relationship between supervision, third mission activities and research performance

Our main model included all three variables with supervision and third mission activities as independent variables, and research output as the dependent variable. Research performance was operationalised into two dummy variables - having publication points (Table 2) and having publication points in highly ranked journal (Table 3).

In line with the expected threshold effect proposed in Hypothesis 1, the analysis showed a positive relationship between educational tasks and research performance, and that this relationship was moderated by the volume of educational tasks as measured by the number of students supervised. Supervising some students was positive for research productivity, increasing the possibility of having publication points, but supervising many students seem to halt productivity. Furthermore, increasing number of students to supervise decreased the chances of having published in highly ranked journals.

As described, we operationalised third mission activities in two separate categories – commercialisation and external collaboration. Both were expected to be positively associated with research productivity (Hypothesis 2 and 3). The findings indicate that only external collaboration activities were positively related to research performance measured as having publication points. However, none of the research commercialisation variables had significant effects. Moreover, only participation in R&D collaboration with industry was positively related to having published in highly ranked journals. Neither research collaboration nor commercialisation had a significant effect on having published in highly ranked publications. Consequently, only partial support for Hypothesis 2 was found and hypotheses 3 was rejected.

Table 2 Logistic regression. Publication points as the dependent variable.

Model	1	2	3	4	5	6	7
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Supervising students	0.957*** (0.188)					0.870*** (0.190)	
Number of students supervised		-0.0321* (0.0148)					-0.0349* (0.0149)
Contract research			0.946** (0.330)			0.591 (0.342)	0.522 (0.368)
R&D collaboration with public sector				0.792** (0.295)		0.536 (0.303)	0.351 (0.352)
R&D collaboration with industry					0.956** (0.318)	0.677* (0.326)	0.467 (0.384)
<u>Control variables</u>							
Male	-0.0693 (0.200)	-0.582* (0.272)	-0.118 (0.198)	-0.0722 (0.198)	-0.0894 (0.198)	-0.117 (0.201)	-0.619* (0.273)
Age (Over 60 years old is ref.cat)							
Under 40 years old	0.963* (0.396)	1.023 (0.547)	1.063** (0.393)	1.017** (0.393)	0.998* (0.393)	0.984* (0.398)	1.057 (0.549)
Between 40 and 50	0.691** (0.243)	0.502 (0.290)	0.831*** (0.240)	0.837*** (0.239)	0.761** (0.240)	0.645** (0.245)	0.478 (0.292)
Between 50 and 60	0.424* (0.207)	0.360 (0.262)	0.542** (0.204)	0.525* (0.204)	0.507* (0.204)	0.377 (0.209)	0.340 (0.264)
Academic discipline (Humanities is ref. cat)							
Social Science	0.625** (0.225)	0.644* (0.268)	0.596** (0.223)	0.547* (0.224)	0.621** (0.222)	0.517* (0.227)	0.548* (0.272)
Natural Science	1.436*** (0.329)	1.765*** (0.493)	1.283*** (0.325)	1.252*** (0.325)	1.120*** (0.328)	1.269*** (0.334)	1.580** (0.501)
Technology	0.367 (0.261)	0.641* (0.322)	0.232 (0.261)	0.248 (0.261)	-0.000 (0.279)	-0.0476 (0.285)	0.254 (0.363)
Medicine	1.520*** (0.303)	2.047*** (0.541)	1.327*** (0.298)	1.226*** (0.299)	1.228*** (0.298)	1.342*** (0.307)	1.884*** (0.547)
Constant	0.532* (0.254)	2.055*** (0.327)	1.136*** (0.223)	1.135*** (0.223)	1.180*** (0.224)	0.560* (0.256)	2.037*** (0.329)
Observations	1481	1135	1481	1481	1481	1481	1135
Pseudo R ²	0.076	0.084	0.062	0.060	0.062	0.093	0.094

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3 Logistic regression. Publication points in highly ranked journals as the dependent variable.

Model	1	2	3	4	5	6	7
Supervising students	0.238 (0.131)					0.195 (0.132)	
Number of students supervised		-0.0208* (0.0106)					-0.0227* (0.0107)
Contract research			0.287 (0.158)			0.147 (0.166)	0.159 (0.180)
R&D collab. with public sector				0.253 (0.144)		0.162 (0.149)	0.0812 (0.167)
R&D collaboration with industry					0.444** (0.158)	0.372* (0.163)	0.423* (0.185)
<u>Control variables</u>							
Male	0.304* (0.121)	0.251 (0.138)	0.290* (0.122)	0.301* (0.121)	0.290* (0.122)	0.282* (0.122)	0.230 (0.139)
Age (Over 60 years old is ref.cat)							
Under 40 years old	0.388 (0.211)	0.458 (0.248)	0.423* (0.211)	0.406 (0.211)	0.398 (0.211)	0.392 (0.212)	0.465 (0.248)
Between 40 and 50	0.237 (0.147)	0.192 (0.167)	0.268 (0.145)	0.272 (0.145)	0.233 (0.146)	0.206 (0.148)	0.159 (0.168)
Between 50 and 60	0.227 (0.134)	0.138 (0.156)	0.255 (0.133)	0.246 (0.133)	0.236 (0.133)	0.206 (0.135)	0.124 (0.156)
Academic discipline (Humanities is ref. cat)							
Social Science	0.256 (0.150)	0.232 (0.168)	0.240 (0.150)	0.227 (0.151)	0.250 (0.150)	0.210 (0.152)	0.188 (0.170)

<i>Natural Science</i>	1.143*** (0.183)	1.098*** (0.217)	1.111*** (0.183)	1.102*** (0.183)	1.012*** (0.187)	1.027*** (0.188)	0.942*** (0.225)
<i>Technology</i>	0.359* (0.178)	0.407* (0.200)	0.310 (0.180)	0.318 (0.179)	0.151 (0.193)	0.124 (0.195)	0.135 (0.223)
<i>Medicine</i>	1.116*** (0.172)	1.069*** (0.210)	1.076*** (0.171)	1.039*** (0.172)	1.020*** (0.172)	1.028*** (0.175)	0.979*** (0.215)
Constant	-0.769*** (0.186)	-0.317 (0.199)	-0.614*** (0.161)	-0.612*** (0.160)	-0.592*** (0.160)	-0.744*** (0.186)	-0.313 (0.200)
Observations	1481	1135	1481	1481	1481	1481	1135
Pseudo R^2	0.043	0.044	0.043	0.043	0.046	0.048	0.050

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The overall results showed mixed support for our expectations. We found support for a positive relationship between supervision and research performance, and a positive relationship between third mission activities, in the form of research collaboration, and research performance. As expected, a threshold effect was at play between supervision and research performance. Only moderate volumes of supervision work were positive for research output but did not increase the chances of having published in highly ranked journals. Likewise, only external research collaboration, and not commercialisation of research, was positively related to research performance, when measured by publication points. Moreover, only R&D collaboration with industry was positively related to having published in highly ranked journals. We also found a positive relationship between supervision and external research collaboration, and this was particularly strong for ‘R&D collaboration with public sector’ and ‘contract research’. However, we found no significant relationship between supervision and commercialisation activities.

5. Discussion

The results obtained by the regression analyses indicate that there is no straightforward pattern in the relationships between education, research and third mission activities. The hypotheses set forth in the literature section illustrated this complexity. As discussed above, the literature on the relationship between academic teaching and research and between research and third mission activities is substantial, but evidence has not pointed to consistent results. The relationship between education and third mission activities has been less explored in the literature to date (Bianchini et al. 2015). Parts of the explanation for the complex picture that emerges on the issue of task complementarity among academics, is that variables have been operationalised in different ways (Verburg et al. 2007), and the questions asked and the direction of hypotheses reflect subject-field specific interest (higher education vs research policy studies). After reviewing literature, it seemed clear that it is necessary to build more systematic knowledge on academic task complementarity, and a contribution to this goal was a main ambition of this paper. With inconclusive evidence available, our ambition was to address complementarity between

tasks as a set of correlations, and we did not aim to develop a causal model that can explain high performance or predict behaviour.

The analyses performed provide us with mixed evidence on the potential complementarities and trade-offs between academic tasks. Hypothesis 1 set forth an expectation that there would be a positive relationship between participating in educational tasks and research performance. Recent research indicates complementarity between teaching and research up to a certain level whereby the positive effect of teaching activities on research decrease (Bianchini et al. 2015, Garcia-Gallego et al. 2015; Artes et al. 2017). In our analysis, we find support for this assumption, as the analyses find that supervising students is positively associated with research performance, at least up to a certain level of supervisory activity. In line with prior research, we also find that this form of task complementarity is particular for graduate level teaching and supervision (Lin & Bozeman, 2006), as this educational activity is expected to draw on research experience to a large extent. This finding is largely in line with prior research on this topic (Artes et al. 2017), but our results contribute to nuance the existing knowledge about this relationship, and underlines that the level of education influence the trade-off vs. complementarity question. We also find that participating in educational activities is positively associated with research productivity, but it is not positively associated with having published in highly ranked journals. This entails that productivity is related to supervising students, as students assumingly contribute with some labour as well, whereas exceptional performance might be favoured by a concentration on research tasks only.

We also tested two hypotheses about a relationship between third mission activities and research performance. In line with prior research (Perkmann et al., 2013), third mission activities were divided into two broad categories – research commercialisation and collaboration. We expected a positive relationship between commercialisation and research productivity (hypothesis 2), in line with prior research (Perkmann et al. 2013; Author et al. 2017), but did not find clear support for this. In line with our expectation and prior research (Smeby & Gulbrandsen, 2005) there was a positive relationship between participating in research collaborations and research performance (hypothesis 3), but we only find this for research productivity and not for research quality indicators. This finding also supports other research on this issue (Muscio et al., 2017; Banal-Estanol et al., 2015).

These results on task complementarity illustrate the complexity involved. Third mission activities in the form of collaboration with private and public organisations can be closely related to research work that leads to scientific publications, as we find in this study. Commercialisation of research is also related to research activities, but after initial idea generation, the time spent on commercialisation is probably less connected to ongoing research and publication activities. Moreover, other studies of academics that are productive academic entrepreneurs (i.e. has many patents, license agreements etc.) often show that these are few and rather unique individuals. They tend to be senior, male academics in natural sciences and

medicine, with unusually high scientific productivity (Anonymous author et al. 2017; Perkmann et al. 2013). As an extra control measure, we carried out another analysis on STEM-researchers only. These analyses gave the same results as for our analyses on the whole population and hence confirmed our findings. Thus even though some of these activities are more common in the STEM-fields, the overall results seem to be applicable across all fields. This does not mean that for some individuals there is a positive relationship between commercialisation and research performance, which is probably related to individual talent and specificity of the research activities that we do not capture in this study.

The third relationship we looked at was between third mission activities and educational tasks. We created two exploratory hypotheses (4 and 5), as the available knowledge was limited (Landry et al. 2010; Bianchini et al. 2015; Sanchez-Barriollungo 2014; Wang et al. 2016) and pointed in relatively different directions (positive, negative and no relationship has been found). Since prior research on task complementarity often point to a cap-off effect, we formulated our hypotheses to reflect this general finding. We expected that having a high load of educational responsibilities would be negative for commercialisation, and that a moderate level of such tasks would be positive for research collaboration. Our results indicate that there is a significant, positive relationship between external collaboration and supervision of students. We do not find clear evidence that commercialisation is negatively related to supervision, as expected in hypothesis 4, as the evidence is too limited. Contrary to our expectation in hypothesis 5, we find that educational activities in the form of supervision has a positive relationship to participation in external collaboration, and we a small increased effect of numbers of students supervised. These results are only relevant for collaboration with public sector organisations.

We interpret these results as in accordance with the hypothesis set forth about the positive relationship to research collaboration (hypothesis 5), but we do not find support for the negative relationship between education and commercialisation, as expected by hypothesis 4. These results are contrary to the results obtained by other researchers that have looked at the relationship in the opposite direction; i.e. they have looked at the impact of third mission activities on teaching (or attitudes to teaching) (Landry et al. 2010; Bianchini et al. 2015). The significance of our results is therefore difficult to determine. In line with Perkmann et al., (2013) we conclude that there is necessary to perform further research on the connection between third mission and educational activities. Our results indicate that these tasks might be better connected than expected, but further research that looks more in detail into how academics integrate such tasks is necessary.

6. Limitations and conclusion

As seen in the literature section, a significant problem in the existing research on this issue is the lack of standardised variables and a clear theoretical understanding of the relationships between the variables.

Research activities and performance are commonly captured by publication data (although they also are proxies for research activities), but educational and third mission activities on the other hand are broad categories that also vary significantly between fields of science. Also, few, if any universities keep and make publicly available registry-based information on staff teaching hours or their degree of interaction with external stakeholders. For such ‘softer’ or activity-based measures, we had to rely on information provided by the individuals themselves. In this paper, we opted for using numbers of students supervised as a proxy for educational activities that has been applied by other studies (Lin & Bozeman 2006; Kyvik & Smeby, 1994), which we at the same time acknowledge represents a limited part of the educational tasks performed by staff. The number of teaching hours or numbers of courses taught would have been other relevant operationalisations, but such data was unavailable at the population level. We tested by using data that was intended to capture the amount of time academics spend interacting with students (face to face, in writing etc), and the analysis confirmed our conclusion. But since it is a less reliable indicator of work load, we excluded it from the analyses. Another shortcoming is that our dataset also had no measure for the quality of teaching or the teaching performance of academics, as this information is not systematically collected or available at an individual level. But since we were interested in complementarity and trade-off with respect to work tasks, we were mainly interested in variables that measured the amount of effort spent on different activities, hence quantitative indicators were preferred. We opted for using number of students supervised (graduate and undergraduate) as it would be easier for respondents to recall and this would hopefully give us a more objective assessment than subjective estimations of time spent on teaching. Another shortcoming is that we opted to use a relatively narrow operationalisation of the concept ‘third mission’ tasks, to delineate these type of tasks from regular research and teaching work.

These choices of operationalisations are significant limitations in this work, as it has been in most other studies (Verburg et al., 2007). Further work needs to address these shortcomings with a broader and more inclusive measurement of different educational activities in particular. Ideally, data from administrative records could support such an analysis, but these data are not available at the population level, but could be used in analysis on specific universities or departments. Our choice of variables might mean that the high degree of synergy observed between supervision, research productivity and external research collaboration, might be an overestimation of this relationship in a positive sense. If we had used a broader variable to capture educational activities than supervision, a higher degree of trade-off and a clearer impact of threshold effects might have been observed. Further research should look into this issue.

However, the measurement issue is also related to the still weakly developed understanding of the relationships between the tasks in a causal sense. As most of the research on these issues has addressed tasks in a pairwise fashion, they appear to suggest a causal model where an independent variable (e.g. teaching) influence a dependent variable (e.g. research performance). As described above, different

literatures tend to use different dependent variables, and the different analysis often tend to reach different conclusions about what causes what. As it clearly is not straightforward in the larger context what is actually influencing what, we opted to investigate the relationship between different tasks, and not to explain what influences performance on one of the variables in a causal manner.

From the literature review and the empirical work, we observe that academics have to balance a complex portfolio of activities, and how the different work activities are connected might be rather idiosyncratic. Individual abilities, talents and time available for work are other variables influencing academic work and how tasks are handled by academics and how ‘good’ they become at their job. To gain a thorough understanding of this, qualitative data or detailed individual level data on academic work is needed in further investigations.

Bearing in mind the limitations, the results of this study suggest that there are some academic tasks that go well together, whereas others exist in tension. There seem to be synergy between supervision and third mission activities, and a positive relationship between supervision, external research collaboration and research performance. These results indicate that there might be a potential for looking further at how academics with an interest in utilising their knowledge in settings of applications, also find a way of involving students in such activities. Further studies of academics’ involvement of students in third mission work would be relevant in this regard. The relationship between educational tasks and research performance seem to be the relationship with most trade-offs, at least when we look at the volume of teaching duties in relationship with research performance, and this is in line with most prior work on this issue.

In terms of managerial implications, we observe an interesting link between supervision and third mission tasks, and in particular external collaboration. The education-third mission link has to a limited extent been addressed in policy and practice, and this is an area where further policy development is needed. Higher education policies and institutional arrangements have tended to focus on supporting research-teaching connections and research-commercialisation linkages. Our analysis indicates also that this is a good priority as available knowledge and our results indicate that at the levels of individual academics, achieving complementarity between these tasks seem to be the most difficult to achieve in practice. At the same time, increasing linkage between education and third mission activities should be developed further.

Finally, recruitment and career development practices in universities ask university professors to have a wide set of skills, essentially asking professors to be proficient multitaskers or be something akin to “five-legged sheep”. We have argued that the potential for achieving the synergies should be based on a real potential that such tasks are complementary in everyday academic work. This study indicates that there are indeed both task trade-offs and task complementarities at play, and apparently rather few academics who are able to multitask and perform highly across a wide range of tasks. A career policy

that emphasises recruitment of different kinds of employees to a more diverse set of academic roles may represent the most efficient way to fulfil the multiple missions of universities in the end.

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Appendix

Table A1.1 Correlation between the independent variables in the regression analysis. Pearson R. Significant (2-tailed)

		Gender	Age				Academic Discipline					Supervision		Third mission					
		Gender	-40	40-50	50-60	60+	Hum	SS	NS	Tech	Med	Super(dummy)	Super(num)	Contract r.	Public	Private	Product	Patent	Licensed
Age																			
Under 40	PR	-0,036																	
Between 40 and 50 years old	PR	-0,066	-0,178																
Between 50 and 60 years old	PR	-0,015	-0,221	-0,411															
Over 60 years old	PR	0,098	-0,216	-0,400	-0,497														
Academic discipline																			
Humanities	PR	-0,085	-0,010	0,021	-0,022	0,008													
Social Science	PR	-0,088	-0,013	-0,009	-0,008	0,023	-0,327												
Natural Science	PR	0,143	0,098	0,003	-0,009	-0,052	-0,244	-0,268											
Technology	PR	0,144	0,025	0,060	-0,028	-0,042	-0,227	-0,250	-0,186										
Medicine	PR	-0,077	-0,090	-0,070	0,066	0,053	-0,265	-0,292	-0,218	-0,203									
Teaching																			
Supervision (dummy)	PR	-0,010	0,002	0,100	0,057	-0,150	0,031	0,082	-0,044	0,055	-0,132								
Supervision (number of students)	PR	0,022	-0,014	0,046	0,022	-0,055	0,185	0,053	-0,110	0,022	-0,173	0,425							
Third mission																			
Contract research	PR	0,094	-0,055	0,035	0,006	-0,004	-0,104	0,032	-0,012	0,160	-0,057	0,103	0,075						
Collaboration with public sector	PR	0,031	-0,014	-0,023	0,057	-0,027	-0,167	0,046	-0,019	0,073	0,079	0,060	0,055	0,245					
Collaboration with private sector	PR	0,116	0,001	0,086	0,010	-0,090	-0,215	-0,187	0,136	0,355	-0,010	0,079	0,013	0,257	0,169				
Developed product	PR	0,092	-0,044	0,025	0,022	-0,019	-0,115	-0,105	0,016	0,084	0,149	-0,013	-0,013	0,091	0,133	0,247			
Applied for patent	PR	0,060	0,005	0,044	0,025	-0,068	-0,144	-0,146	0,072	0,205	0,065	0,011	-0,050	0,106	0,006	0,286	0,240		
Started firm	PR	0,051	0,007	0,003	0,061	-0,068	-0,059	-0,046	0,035	0,109	-0,017	0,034	0,009	0,110	0,042	0,129	0,165	0,264	
Licensed	PR	0,045	-0,024	-0,032	0,009	0,034	-0,026	-0,070	-0,007	0,071	0,049	-0,008	-0,034	0,086	0,064	0,147	0,189	0,209	0,223

Table A1.2 The relation between supervising students (dummy) and third mission activities (dependent variable)

	Commercialization			Research collaboration		
	Developed new products	Started a new firm	Licensed	Contract Research	Collaboration R&D with public sector	Collaboration R&D with private sector
	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13
Supervising students (Dummy)	0.0241 (0.200)	0.374 (0.401)	0.0653 (0.459)	0.782*** (0.219)	0.436* (0.177)	0.559** (0.188)
<i>Control variables</i>						
Male	0.686** (0.219)	0.517 (0.385)	0.657 (0.564)	0.508** (0.189)	0.140 (0.157)	0.323 (0.181)
Age (Over 60 years old is ref.cat) Under 40 years old	-0.288 (0.388)	0.740 (0.592)	-1.085 (1.062)	-0.736* (0.350)	0.00753 (0.272)	0.126 (0.285)
Between 40 and 50	0.351 (0.228)	0.668 (0.465)	-0.831 (0.597)	0.0520 (0.199)	-0.0316 (0.191)	0.629** (0.200)
Between 50 and 60	0.213 (0.209)	1.109** (0.418)	-0.212 (0.443)	-0.0304 (0.187)	0.249 (0.167)	0.348 (0.189)
Academic discipline (Humanities is ref. cat)						
Social Science	0.236 (0.335)	0.313 (0.576)	-1.563 (1.121)	0.826*** (0.244)	1.325*** (0.249)	0.615 (0.335)
Natural Science	0.965** (0.324)	1.120* (0.545)	0.262 (0.721)	0.614* (0.278)	1.034*** (0.278)	2.391*** (0.309)
Technology	1.340*** (0.314)	1.667** (0.519)	1.206 (0.616)	1.429*** (0.255)	1.521*** (0.269)	3.247*** (0.308)
Medicine	1.715*** (0.298)	0.699 (0.581)	0.933 (0.612)	0.387 (0.282)	1.565*** (0.258)	1.817*** (0.315)
Constant	-3.654*** (0.367)	-5.548*** (0.704)	-4.637*** (0.787)	-3.409*** (0.325)	-3.146*** (0.298)	-4.141*** (0.363)
Observations	1481	1481	1481	1481	1481	1481
R ²						
Pseudo R ²	0.074	0.071	0.080	0.061	0.047	0.197

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

* The regression analysis with Applied patent as dependent variable did not converge

Table A1.3 The relation between the number of students supervised and third mission activities (dependent variable)

	Commercialization			Research collaboration		
	Developed new products	Started a new firm	Licensed	Contract Research	Collaboration R&D with public sector	Collaboration R&D with private sector
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
The number of students supervised	0.0158 (0.0167)	0.00194 (0.0291)	-0.0611 (0.0595)	0.0214 (0.0134)	0.0342** (0.0127)	0.0199 (0.0150)
<i>Control variables</i>						
Male	0.770** (0.260)	0.780 (0.457)	0.502 (0.656)	0.453* (0.201)	0.0103 (0.174)	0.276 (0.201)
Age (Over 60 years old is ref.cat) Under 40 years old	-0.346 (0.446)	0.665 (0.671)	0 (.)	-0.675 (0.374)	-0.0475 (0.302)	0.120 (0.320)
Between 40 and 50	0.272 (0.263)	0.394 (0.541)	-1.269 (0.677)	0.111 (0.216)	-0.127 (0.210)	0.607** (0.227)
Between 50 and 60	0.175 (0.246)	1.220** (0.468)	-0.629 (0.508)	0.0235 (0.205)	0.0824 (0.190)	0.243 (0.219)
Academic discipline (Humanities is ref. cat)						
Social Science	0.478 (0.389)	0.496 (0.717)	0 (.)	0.886*** (0.262)	1.398*** (0.278)	0.687 (0.377)
Natural Science	1.212** (0.393)	1.605* (0.676)	0.342 (0.845)	0.740* (0.306)	1.245*** (0.318)	2.708*** (0.357)
Technology	1.594*** (0.370)	2.026** (0.647)	1.360 (0.704)	1.510*** (0.276)	1.785*** (0.298)	3.465*** (0.351)
Medicine	1.917*** (0.371)	1.210 (0.714)	0.782 (0.733)	0.402 (0.322)	1.794*** (0.301)	1.935*** (0.369)
Constant	-3.953*** (0.438)	-5.742*** (0.833)	-3.850*** (0.863)	-2.815*** (0.317)	-2.884*** (0.319)	-3.793*** (0.402)
Observations	1135	1135	739	1135	1135	1135
R ²						
Pseudo R ²	0.081	0.096	0.067	0.052	0.052	0.221

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

* The regression analysis with Applied patent as dependent variable did not converge

Endnotes

ⁱ The survey included a question about how much time each academic spent providing feedback to students at undergraduate and graduate levels. We tested this as a second operationalization of “educational activity”, as we assumed that it captured better undergraduate teaching activities compared to supervision. The results showed a positive association between amount of student feedback, publishing and participation in third mission activities and thus confirmed our main conclusion in this paper. However, since recollection of the time spent on an activity in a post-hoc manner can be subjected to bias, and it is more questionable to which degree interacting with represent formal obligations, we did not include this variable in the final analysis.