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Patterns of Third Mission Engagement among Scientists and Engineers

Niels Mejlgaard & Thomas Kjeldager Ryan

Abstract

In the context of growing societal demand and interdependency, universities need to prioritize their ‘third mission’ activities and balance them against core functions. Individual researchers too are faced with multiple external constituencies and various mechanisms for interaction. The degree, target, and mode of their involvement with societal actors must be considered in light also of high performance expectations concerning traditional teaching and research activities. In this study, we explore patterns of third mission involvement among 652 researchers at the Science and Technology Faculty, Aarhus University from 2009-2012 using register-based data. First, we collect 13 indicators of third mission involvement from the university register system PURE, and find that these can be organised in distinct sets. External interaction and knowledge sharing can take many shapes, but they appear to group together empirically in ways that reflect the external partners and mode of involvement. Second, we determine five clusters of researchers based on their third mission activities. The majority of researchers has limited engagement in any kind of third mission activities, while an almost negligible minority entertain activities across the board. The remaining researchers focus their engagement on one type of third mission activity: public sector service, industrial collaboration, or executive involvement. Finally, we explore the interrelatedness of third mission involvement and research performance. Researchers who work closely with industry perform extremely well in terms of both publication productivity and impact, while those primarily engaged with public authorities perform considerably below average. We contextualise the results and highlight the limitations of the study.

1. Introduction

The notion of universities’ ‘third mission’ usefully captures the overall demand for universities to engage more actively with tasks and obligations beyond those related to traditional education and research activities. The idea of universities’ third mission has become increasingly salient in policy debate and organisational development in recent years (Pinheiro *et al* 2015a; Gulbrandsen and Slipersæter 2007).

The third mission may broadly be defined as “all activities concerned with the generation, use, application and exploitation of knowledge and other university capabilities outside academic environments” (Molas-Gallart *et al* 2002: 2; cf. Mollas-Gallart and Castro-Martínez 2007: 321). Third mission activities are, then, distinct from activities which do not involve interaction with external environments. In this paper, we adopt this broad definition of external interaction, which may encompass a rich diversity of content, interfaces, and formats, and may include a variety of societal actors with which knowledge and other capabilities are exchanged.

A number of studies have embarked on the challenging task of classifying third mission activities. Inzelt *et al* (2006) distinguish between economic and societal dimensions and identify four economic sub-dimensions (human resources, intellectual property, spin offs, and contracts with industry) and four societal sub-dimensions (contracts with public bodies, participation in policymaking, involvement in social and cultural life, and public understanding of science). Molas-Gallart *et al* (2002) provide a conceptual framework which differentiates between capabilities (what universities have) and activities

(what universities do, including, notably, teaching and research), outline 12 associated categories of third mission - or 'third stream' - activities, and consider 65 potential indicators out of which 34 indicators are discussed in terms of procedures for data collection. Their conceptual framework is instrumental in portraying the interlinkage, rather than separation, of third mission activities and core functions. This point is also effectively conveyed by Vorley and Nelles (2008): What makes third mission activities distinct is not isolation from research and education, it is rather the explicit societal orientation and interactional character of these activities.

While these contributions have provided conceptual classifications for an umbrella notion of the third mission, others have focused on categorising subsets of activities, such as different types of knowledge interaction between firms and universities specifically (Schartinger *et al* 2002; Inzelt 2004) or activities that universities employ to share knowledge and enhance interaction with citizens (Vargiu 2014; Entradas and Bauer 2016; Neresini and Bucchi 2011). In combination, the conceptual and empirical attempts to delineate the third mission demonstrate the breadth of types of activities, objectives, and targeted actors. The political desire for universities to contribute to material reproduction, nationally and regionally, has intensely stimulated university-industry interaction (Clark 1998; Rosli & Rossi 2016), but broader commitments and responsibilities towards cultural, social, and political reproduction of civil society and political communities nourish different kinds of interaction between universities, policymakers, and citizens or organisations in civil society (Goddard and Vallance 2013; Lebeau and Cochrane 2015; Pinheiro *et al* 2015b; Leydesdorff and Etzkowitz 2003). Particularly salient societal problems (e.g. ecological depletion and climate change) may fuel alternative mission statements (e.g. sustainable development), thus continuously widening and re-defining the notion of the third mission as well as associated means for transforming and co-creating society based on broad inclusion of actors (Trencher *et al* 2014).

In their organisational response to handling the third mission, universities experience what Kitagawa *et al* (2016) refer to as a 'tension'. On the one hand, there are external, homogenising forces such as international and national higher education policy frameworks as well as the tendency for copy-cattng other organisations (DiMaggio and Powell 1983) which may lead to converging third mission activities. On the other hand, universities also try to shape their third mission activities and strategies based on internal organisational characteristics and priorities. Universities must decide how to prioritize third mission efforts up against core functions, where external expectations are also high (Benneworth *et al* 2015), and choose how to distribute engagement across the diverse set of activities subsumed under the third mission heading. A number of studies suggest that organisational characteristics significantly shape the prioritisation between and implementation of third mission activities (Rolfo and Finardi 2014; Hellström *et al* 2013; Laredo 2007), while others emphasise the importance of understanding the interdependencies between universities and stakeholder networks in relation to third mission prioritisation (Jongbloed *et al* 2008; Benneworth and Jongbloed 2010).

Balancing outreach activities against each other and against core functions can be challenging enough at the level of organisations, but it might be even more difficult to navigate through claims, expectations, and opportunities as an individual academic. In a context of accelerated competition and faced with reward schemes that rarely recognize outreach (Jain *et al* 2009), how do academics decide on the extent and character of their potential third mission involvement? Is it possible to maintain interaction with several constituencies simultaneously, and what kind of benefits emerge from different third mission activities?

In this paper, we explore patterns of third mission engagement among 652 research active members of staff at the Science and Technology Faculty of Aarhus University, Denmark over a four-year stretch from 2009 to 2012 using register-based data. We build on the work sketched above by recognizing that the notion of the third mission captures relational, interactional aspects of the role of universities towards a variety of external actors in the surrounding society, and that manifestations of the third

mission are diverse and plentiful. A number of studies have approached the issue of academics' perceptions and behaviour using survey-based data collection, some within confined third mission areas such as technology transfer or entrepreneurship (Louis *et al* 1989; cf. Hellström *et al* 2013) and others with more dimensions covered (Martinelli *et al* 2008). Our intention is to cover a broad set of activities, and we take inspiration from Perkmann *et al* (2015), who base their analyses of academics' involvement in consulting, patenting, and entrepreneurship on multiple data sources and demonstrate that archives held centrally by university administration units, such as technology transfer offices, may underestimate actual activity levels. We apply two sources in our analyses: a comprehensive register based on self-registration and a quality-enhanced version of the Web of Science bibliometric database held by the Center for Science and Technology Studies (CWTS) at Leiden University.

The objective of our study is to examine patterns of third mission involvement among scientists and engineers at Aarhus University. There are three parts of the study. First, we employ a range of indicators of third mission activities, i.e. various practices related to the researchers' external interaction, and determine how these activities group together using principal component analysis. Second, we explore patterns of involvement in third mission activities using cluster analysis, resulting in an empirical typology of third mission profiles among the researchers. Third, we further characterize the clusters by examining their relation to variables not used for the clustering procedure. Finally, we explore the interrelatedness of third mission profiles and bibliometric performance, in order to tap into the relationship between third mission and 'second mission' activities. The study is intended to contribute to our knowledge about the third mission practices of individual researchers and the interrelatedness of such practices and research performance. We draw conclusions and discuss limitations of our approach in the discussion section of the paper.

2. Context of the study

A number of policy developments during the 2000s form the specific context of the study. In 2003, a new University Act significantly increased external control over Danish universities by introducing boards with external majority as the authoritative body of the university, and also involved professionalization and strengthening of management by adopting appointed rather than elected leaders at all levels of the university (Degn and Sørensen 2012). While the 2003 University Act is often portrayed primarily as a management reform, it is noteworthy that it also – for the first time and fairly late compared to other countries – stipulated the universities' third mission (Mejlgaard 2012). Consequentially, every university became legally obligated to “exchange knowledge and competencies with society and encourage its employees to take part in the public debate” (Lov nr 403 af 28/05/2003 [authors' translation]).

In 2007, a comprehensive structural reform merged a number of universities and governmental research agencies thus changing the overall organisational landscape of the Danish research and education sector (Hansen 2012). Importantly for this study, a number of large research organisations were transferred from ministries to universities. The implication was that responsibilities for providing research-based evidence for policy making on matters related to health, environment, agriculture, transportation, fisheries etc. became manifest and integral to universities, particularly to those that came to host the former governmental research agencies.

Aarhus University, up until that point a 'traditional' university covering disciplines across five faculties (Science and Technology, Medical Science, Humanities, Social Science, and Theology), was merged with, *inter alia*, the Danish Agricultural Institute and the National Environmental Research Institute¹, two major public sector research organisations working closely with their sector ministries. These were initially organised as separate faculties but later became departments at the Science and Technology Faculty. Overall, the 2007 national merger process invoked an extensive local re-organisation at Aarhus

University resulting in increased strategic management and alignment of the organisational composition and the universities' external commitments (Pinheiro and Stensaker 2014).

It is within this context of growing external demands and internal awareness of societal responsibilities and interaction that we explore patterns of researchers' third mission activities at Aarhus University.

3. Data and methods

Two sources of data are used for this study. The bulk of data is extracted from the university registration system 'PURE'. PURE is owned by Elsevier and used in over 200 universities worldwide including a large share of Danish universities and university hospitalsⁱⁱ. PURE is used by researchers at Aarhus University to register research outputs as well as a range of activities including various kinds of interaction with external environments. Registrations of output and activities are made towards a set of predefined categories, and content is visible on the researcher's public PURE-profile that also works as an online CV. We were granted administrator rights for research purposes and harvested individual-level data related to third mission activities from the database.

The analysis includes members of staff from the Science and Technology Faculty, Aarhus University, who were active researchers in the period 2009-2012. To ensure that our population were active researchers in the examined period and actually used PURE to register their individual outputs and activities, we included only those researchers who had at least one registration of any type of output or activity in each of the four years and had registered at least two peer reviewed publications in the four year period. Consequently, part-time and short-term employees, guest researchers, and a great deal of technical and administrative staff who were not research active were excluded from the analysis. Furthermore, employees who left during the period, had more than a year's leave, or began working at Aarhus University during the period were not included. A total of 652 members of staff were ultimately included in the analysis. Table 1 provides an overview of the study population arranged by department affiliation and career level.

[TABLE 1 INSERTED HERE]

We scrutinized registration categories in PURE with particular focus on indicators of third mission involvement. After identifying registration categories which could possibly capture third mission activities, we examined the actual registered content in order to assess whether there was sufficient consistency and homogeneity in the type of activities and outputs registered within each category. We wanted to ensure, in other words, that registrants had a fairly even understanding of what should be registered within each predefined category. In a few cases, we decided not to include a category from PURE, because the contents of registrations did not consistently relate to the third mission, even if the caption of the category would indicate so. One example is 'Public speaking', which presumably would capture speaking in arenas open to the public, but where the empirical contents often consisted of activities such as 'guest lecture' for university students or staff. Eventually we arrived at 12 categories, or variables, which we confidently considered indicative of third mission involvement.

In addition to the PURE registrations, we used data from CWTS' in-house version of Thompson Reuter's Web of Science citation database. Publications registered in PURE were matched with the CWTS database, which allowed us to include an indicator of researchers' relationship to industry as measured by number of co-authored publications with at least one industrial co-author. In addition, we added to the dataset the researchers' number of peer-reviewed publications during the period and an

impact indicator (normalized citations score), in order to be able to assess the interrelatedness of third mission involvement and bibliometric performance.

The 13 variables indicating third mission involvement are summarized in Table 2. All variables count the number of occurrences of the particular activity or output in the four year period. The range of activities and outputs include:

- **Councils and committees;** counts memberships in councils and committees. These are typically formed by the government, a ministry, the EU or another public authority. Examples include memberships of the European Food Safety Authority, the Trilateral Seal Expert Group, and the Working Group on Monitoring Trends and Effects of Substances in the Marine Environment.
- **Boards;** counts the number of memberships in boards of companies or organisations which the researcher had during the four year period, typically in the private sector. Examples include memberships of the Board of Advisors in companies such as Acinta ApS, Mindpass A/S, and Visanti A/S.
- **Newspaper articles;** counts article contributions to newspapers with the purpose of communicating a research topic to a wide public audience. Most articles are in national or regional traditional newspapers such as Jyllands-Posten or Weekendavisen while some are published in more specific or targeted newspapers such as Økologi & Erhverv. The common denominator communication of research-based knowledge to the broader public.
- **Other media articles;** counts written article contributions to a broad range of mainstream and specialised media beyond newspapers.
- **Reports;** counts number of published reports commissioned by public or private organisations. Typically reports are commissioned by a ministry and convey research-based knowledge as a background for policy making. A large part of the reports is commissioned by the Ministry of Environment and Food or its agencies, but this category also includes reports commissioned by the OECD, the EC, and the Arctic Council, along with a few private companies such as Vattenfall Vindkraft A/S, Femern A/S, and Niras A/S.
- **Memorandums;** counts professional analyses or investigations that do not appear in the shape of a traditional report. Typically, these are delivered to the Parliament, ministries, municipalities, or regions in relation to preparations of trial or pre-legislative work. Memorandums are accompanied by a mandatory journal filing number.
- **Questions and hearing answers;** counts short written responses to explicit questions raised within the Folketing, ministries, municipalities or regions during the process of trial or pre-legislative work.
- **Participation in radio programme, print media interview, interview for web-based media, and participation in TV programme;** all of these four variables count the number of times a researcher has participated as an interviewee in one of the respective media in the period. The scope of participation differs from brief expert comments related to news stories to longer interviews as part of documentaries or thematic programmes.
- **Publications with industrial co-authors;** counts the number of journal articles co-authored with at least one co-author from industry.
- **Patents;** counts the number of published patents or patent applications a researcher has made as a co-inventor or applicant. An example of such was the *Portable monitoring device with hearing aid and EEG monitor*, applied for by a researcher at the Department of Engineering in collaboration with Widex A/S.

[TABLE 2 INSERTED HERE]

In order to determine groups of third mission activities and empirical clusters of researchers based on their third mission engagements, we apply a three-stage exploratory analytical approach following Arundel *et al* (2015) and Leiponen and Drejer (2007). First, a principal component analysis (PCA) is performed in order to reduce the 13 variables to a small number of uncorrelated components. Second, we apply cluster analysis in order to group researchers into a set of clusters on the basis of the derived components. Third, we attempt to assess whether the clusters also are different based on variables that were not included in the cluster analysis. The purpose of this method is to explore and extract the patterns in the data. This allows us to arrive at an empirical typology of third mission behaviour that can be tested and scrutinized in further research.

We use the 652 observations and 13 variables to perform the PCA. Kaiser's criteria is applied to extract the optimal number of components. Using Kaiser's criteriaⁱⁱⁱ we find a five-component solution which explains 65% of the variation in the 13 variables. We apply the orthogonal rotation algorithm, *varimax*, which attempts to simplify the columns in the component matrix so that loadings are as close to zero or one as possible while keeping the components unrelated (Hair *et al* 2010). The Varimax rotation leads to five components in which each variable loads moderately (0.45) to highly (0.75) and variables only load highly on a single component.

The five components, calculated as indices, enter into the cluster analysis^{iv}. We apply Wards linkage algorithm^v and Euclidian distance as a dissimilarity measure often referred to as the straight line distance between two points (Hair *et al* 2010). We arrive at a five-cluster solution by using the Calinski-Harabasz pseudo-F and Duda-Hart stopping rules (Duda *et al* 2001; Calinski and Harabasz 1974).

Subsequent to the PCA and cluster analysis, we compare publication and citation performance across the five researcher clusters, in order to probe the relationship of third and 'second' mission activities among researchers at the Science and Technology Faculty at Aarhus University.

4. Results

4.1 Principal components of third mission engagement

Table 3 contains the component loadings of each of the 13 variables. The principal component analysis identifies five principal components. The five components are intuitively interpretable, and seem to reflect differences with regard to the constituencies with whom the university researchers interact as well as differences in the format of interaction. We tentatively label the components based on these aspects.

[TABLE 3 INSERTED HERE]

Participation as an interviewee in radio programmes, print media, web-based media, and TV programmes all load highly on component 1, which we label '*Reactive science communication*'. This kind of involvement in third mission activities is oriented to broad audiences, media consumers, from across society, and it is a means for disseminating scientific knowledge without extensive two-way interaction. Because these media appearances tend to happen on the initiative of journalists rather than the researchers themselves, we consider them re-active modes of communicating science.

Writing reports, memorandums, and responding to questions and hearings load highly on component 2. The vast majority of these kinds of written contributions are aimed at authorities in the public sector, and we can label component 2 '*Public sector service*'. While media participation is aimed at broad

audiences, involvement in public sector service activities involves interaction with targeted users of research-based knowledge with the purpose of informing decision making.

Writing newspaper articles and other media articles load highly on component 3, which we can refer to as '*Proactive science communication*'. This kind of engagement in science communication mostly happens on the researchers' own initiative.

Membership of councils and committees and participation in boards load highly on the component 4, which we label '*Executive involvement*'. This component captures third mission involvement in high-level decision making bodies outside academia. It includes interaction with university constituencies in both the public and private sector.

Finally, co-authoring papers with industrial partners and obtaining patents load highly on component 5. These third mission activities are clearly targeting actors in industry, and we label this component '*Industrial collaboration and commercialisation*'.

4.2 Typology of researchers based on third mission engagement

Based on the identified components, we perform a cluster analysis to identify clusters of researchers. The analysis results in five clusters. Figure 1 illustrates the different clusters' score on each of the five components, and we also present the average cluster score on each of the 13 individual variable in Table 4. High values are marked in darker colour. We label the five clusters of researchers '*Academics*', '*Executive advisors*', '*Public sector advisors*', '*Innovators*', and '*Mediators*'.

[FIGURE 1 INSERTED HERE]

[TABLE 4 INSERTED HERE]

The cluster of researchers that we call *Academics* is by far the largest with 511 researchers. The size is an expected consequence of the fact that 166 researchers have no reported third mission activities and an even larger number of researchers have low levels of reported third mission activities. As a group, these researchers have limited activities and interaction beyond the academy, and they may be focusing more on research and teaching components of their job. However, externally oriented activity is not entirely absent. On average, e.g., the *Academics* publish 0.8 articles with an industrial co-author and give just above one interview during the four year period covered.

The second cluster solution could be called *Executive advisors*. This is the second largest group counting 66 researchers, and it is characterised by having a high level of executive involvement while scoring relatively low on all of the remaining components. Thus, researchers in this cluster are active in high-level decision making bodies in organisations and companies.

The third cluster, which we label *Public sector advisors*, consists of 46 researchers. The cluster has a very high degree of activity in terms of public sector services and below average on the remaining components. These researchers are very active in producing written reports and official documents such as memorandums. As an example, the average number of policy-oriented reports published by researchers within this cluster is 16 over the four-year period. The primary third mission activity of the *Public sector advisors* is thus providing services for ministries and other public agencies within their respective area of expertise.

The *Innovators*, which is the fourth and fairly small cluster encompassing only 18 researchers, score highly on the component related to industrial collaboration and commercialization. These researchers produce patents and patent applications at a relatively high rate and co-publish articles with industrial authors more often than other researchers. *Innovators* have limited involvement in any other third mission activities.

The fifth cluster, the *Mediators*, consists of 11 highly active researchers. They are well above average active on all components related to the university third mission. However, when it comes to both proactive and reactive communication, this group of researchers is extremely actively engaged, considerably more than any of the other clusters described above.

In sum, the cluster analysis identifies one large group of researchers who are not very active in terms of third mission involvement, one small group of researchers very active across all kinds of third mission but especially concerning media appearances, and three groups who tend to specialise in one corner of the third mission; executive advise, public sector advise, and industrial collaboration respectively.

4.3 Post-hoc characterization of clusters

Table 5 contains the distribution of cluster members across departments and career categories as well as their mean age.

We find *Academics* across all departments and employment levels. Compared to the overall averages, *Academics* do not differ much, which is to be expected as this group represents 78% of the full study population. *Executive advisors* is the oldest group and 89% of them are at senior career levels. One third of the cluster members are from the Department of Animal Science, which is four times higher than the sample average. *Public sector advisors* are also above average in terms of age, and they are particularly concentrated at the Department of Bioscience and the Department of Environmental Science. We find an above average representation of (research active) technical staff, but most of the *Public sector advisors* are senior researchers. The *Innovators* are about the average age of the total population, but they are more likely to be full professors and to be working at the Department of Molecular Biology and Genetics, the Department of Chemistry, or at the Interdisciplinary Nanoscience Center. Finally, the *Mediators* are the youngest of the groups and are overrepresented in a couple of departments, but since the group is very small, we should be careful when interpreting the distribution characteristics. The same caution applies to *Innovators*, which is also a fairly small group.

[TABLE 5 INSERTED HERE]

We observe that the five clusters differ not only in terms of the components applied for the clustering procedure but also in terms of their relation to variables not used for clustering. Table 5 makes sense from a substantial perspective. It is no surprise, e.g., that we find high intensity of public sector advising in the Department of Bioscience and the Department of Environmental Science. These departments provide services to public authorities within areas of nature, environment, climate, and energy through the Danish Centre for Environment and Energy, and host many of the researchers who worked in the governmental research agencies up until the merger with Aarhus University. Likewise, the Department of Molecular Biology and Genetics, the Department of Chemistry, and the Interdisciplinary Nanoscience Center have explicitly nurtured industrial collaboration and it is plausible that *Innovators* would be particularly prevalent in these research environments.

4.4 Relatedness of third and second mission activities: research productivity and impact

Table 6 presents the publication output and impact of the analysed researchers. Publications include all of those peer-reviewed publications registered by the researcher in PURE that are also covered in the Science Citation Index of Web of Science. The mean normalized citation score (MNCS) is a measure of citation impact that is normalized on the basis of expected citations within a given year and area of research^{vi}. Since publication output and impact tend not to be normally distributed (De Bellis 2009), we provide mean as well as median scores for both production and impact. The aim of this section is to compare the patterns of third and second mission activity across clusters. In the discussion section of the paper, we consider possible reasons for differences across clusters. We believe that the observed patterns may be examined further in future research.

[TABLE 6 INSERTED HERE]

We find that the *Academics* produce on average 13.2 publications in the period 2009-2012, and the average impact measured as MNCS is 1.55, just above the sample average. The median impact score is somewhat lower, indicating that a small number of *Academics* have a very high impact. *Executive advisors* have a lower mean impact but a somewhat higher productivity in the period. *Public sector advisors* are not very productive compared to the average and also have a very low average impact compared to the other clusters. *Innovators* have both the highest median and mean impact, and they produce a staggering average of 47.1 publications on average in the four year period. *Mediators* have a higher than average production but below average impact. Overall, if we consider the median scores, *Academics*, *Executive advisors*, and *Mediators* perform fairly equally, while *Innovators* stand out with very high productivity and impact, and *Public sector advisors* perform significantly below average in terms of both productivity and impact.

5. Discussion

Two main results emerge from this study. First, we find that third mission activities carried out at the Faculty of Science and Technology at Aarhus University can be organised in distinct sets. External interaction and knowledge sharing clearly come in many shapes, but they tend to group together in ways that reflect the external partners with whom university researchers interact and share knowledge as well as the mode and intensity of involvement on the side of researchers. We find sets of activities which are aimed at cultivating broad public debate through mass media dissemination of knowledge, but we can distinguish between reactive and a proactive researcher engagement in these activities. We also find sets of activities aimed at feeding research-based advice into decision-making processes through interaction with public authorities, activities targeting executive bodies in private and public organisations, and activities broadly contributing to commercialisation and industrial use of research through collaboration between university researchers and industry. We used a broad concept of the third mission as a point of departure for identifying a range indicators, and employed PCA to explore the structure of the empirical relatedness among these. Because third mission practices are likely to be contingent upon the organisational and broader societal and political context in which they emerge and materialise, we do not propose that the five components identified in this study are universal nor exhaustive. We do argue, though, that it is sensible for universities to consider carefully their portfolio of third mission activities, realising that constituencies matter and that deliberate prioritisation of limited time and resources may be necessary. Understanding the patterns and interrelatedness of various third mission activities could be a useful starting point for strategic prioritisation.

Second, we find that researchers at the Faculty of Science and Technology at Aarhus University appear to have fairly distinct profiles concerning their involvement in third mission activities. A core observation is that the vast majority of researchers has limited engagement in any kind of third mission activities, while an almost negligible minority entertain activities across the board. The remaining researchers focus their energy and engagement on one type of third mission activity, public sector service, industrial collaboration, and executive involvement respectively. Again, we do not claim that the typology of researchers emerging from the cluster analysis would reappear in another setting. The choices that individual researchers make concerning the scale and nature of their external involvement will be conditioned by local, institutional strategies and priorities. Knowing the context of Aarhus University and the specific departments at the Faculty of Science and Technology, we realise that there are certain opportunities and incentives which will be different elsewhere. The typology does, nonetheless, suggest that also at the level of individual researchers, prioritisation processes take place, and we consider it plausible that the observed tendency towards focusing attention on one area of the third mission - if indeed any - might be common for researchers across different institutions, given the time and resource constraints within accelerated academies. Demands on performance are high, not least concerning teaching and research components of the job, and we would expect that researchers generally balance their involvement in third mission activities against the benefits of giving priority to core tasks.

We were not able to obtain systematic register-based information about the teaching activities of the sampled researchers, which keeps us from exploring the potential trade-offs or synergies between first, second, and third mission performance. Using measures of publication performance in combination with measures of third mission, however, provides a partial picture. In addition to the main results concerning clustering of activities and researchers, we find considerable variation in publication performance across the five clusters of researchers. Notably, the *Innovators*, who work closely with industry, perform extremely well in terms of both publication productivity and impact, while the *Public sector advisors*, who deliver research-based knowledge to public authorities, perform significantly below the average of all other clusters.

Now, what we disentangle concerning the relationship between research performance and third mission activities are inter-cluster differences, not causal linkages, and we hesitate to make confident conclusions based on these. Given the context of Aarhus University, we can make an informed guess that those researchers who engage very actively with public sector advising struggle with liberating time for academic publishing, and that their background in the ministerial research agencies also means that they have worked within an entirely different publishing culture in which peer reviewed articles have been a peripheral (Bloch *et al* 2012; Aagaard *et al* 2016). In a similar vein, technical staff, who make up 15.2 % of the *public sector advisors*, do not necessarily have scientific research as a primary objective. In general, the differences in productivity and impact among clusters do not necessarily relate to the third mission behaviour of cluster members. It may instead relate to the composition of career level and specialisations of researchers within each cluster. Clusters with a large share of professors may, e.g., have a higher average productivity relative to clusters with a high share of technical staff, PhDs, and Post Docs.

With regard to understanding the high publication productivity and impact of the *Innovators*, we can draw on a richer body of earlier work examining different indicators of researcher's academic enterprise and industrial engagement and the relationship with productivity and impact. These include level of industrial funding (e.g. Blumenthal *et al* 1996; Gulbrandsen and Smeby 2005), industrial co-publications (e.g. Hicks and Hamilton 1999), research collaboration with industry (e.g. Landry *et al* 1996), and patenting (e.g. Agrawal and Henderson 2002; Meyer 2006; Azoulay *et al* 2007). These studies consistently find a positive relationship between academic enterprise and industrial engagement and productivity, while the few studies that actually examine the effect on impact find divergent effects (Larsen 2000). This positive correlation has led authors to propose that the relationship between

publication output on the one hand and industrial involvement and commercialisation activities on the other is characterised by complementarity rather than trade-off (for systematic reviews, see Larsen 2011; Perkmann *et al* 2013).

Our result are in line with these previous findings. However, the referenced studies, as well as the present, involve the challenge of demonstrating a causal link between academic enterprise or industrial engagement and productivity. Beyond the problem of directionality, there may also be unrevealed external conditions, which affect both academic engagement and productivity simultaneously (cf. Larsen 2011). In our study, a few technical issues may partially explain the high publication volume for the *Innovators* compared to other groups. First, the measure of industrial involvement is partly constituted by co-publications, which is also a part of total publications. We use number of co-publications with industry in the clustering algorithm and since this is a function of publications, *Innovators* may seem to be very active with industry just because they have a higher level of production but the same average co-publications. However, not only do *Innovators* have a higher absolute number of industry co-publications, they also have double the rate of industry co-publications compared to the other groups. Second, patenting, which is also part of the clustering algorithm, may be followed by publication of the same piece of knowledge (Azoulay *et al* 2007). Finally, it is important to note when comparing productivity in terms of number of publications, that there can be large differences in the norms across different fields of science. As we find differences in the distribution of departmental affiliation within the clusters, part of the observed variation may also be attributed to field specific publication norms. Furthermore, comparisons between relatively small groups of researchers must be interpreted with care as a single observation can affect averages considerably. Hence, while our results are consistent with previous research, we note that there may very well be technical as well as unobservable reasons for the productivity to be higher for researchers who patent and co-publish more intensely than others.

The method employed in order to identify the cluster solutions also deserves a short discussion. Cluster analysis can be susceptible to the choices made regarding, algorithm, measure of distance and stopping rules. Furthermore, cluster analysis will always results in a cluster solution which means that the results in this paper should be evaluated in relation to the existing literature and should be tested in further papers to examine whether similar patterns emerge in other contexts. Finally, cluster solutions are not generalizable “because it is dependent upon the variables used as the basis for the dissimilarity measure.” (p 595 Hair *et al.*). When this is said, we have taken precautions in order to mitigate the issues of the chosen measure. We have subsequently changed clustering procedures to examine whether cluster solutions change with any practical significance and have attempted to include variables that are guided theoretically. Furthermore, the interpretation of the clusters has been examined in relation to the existing theoretical and case-specific expectations.

While we find it interesting and useful to explore a register-based approach to mapping the third mission activities of researchers, there is a need to stress a number of both internal and external validity issues in relation to using the PURE database. First, there is uncertainty about the consistency of self-registrations across individuals and groups. Individual researchers may underreport all or some activities, and there may be differences in the degree to which departments maintain an active registration culture. One can easily imagine that certain types of activities are considered more important and meriting by some individual researcher or by their departments than others, and that such activities would be more carefully registered. As PURE works as an online CV one might also expect young researchers or researchers close to advancement to update their profile in a more meticulous manner than settled or tenured members of staff. Second, the sheer number and complexity of registration fields may confuse both researchers and librarians who validate the contents so that activities may be registered in unintended categories, which would jeopardize the consistency of the variables used in this study. We did, however, assess the actual registered contents within each category to mitigate this threat to internal validity. Third, it should be noted that all activities are given equal

weight in our analysis, irrespective of differences in the actual effort that they embody. A policy-oriented 'report', e.g., counts as one activity no matter if it is 10 or 1000 pages long. We also were not able to fractionalise third mission activities, which means that a 'report', e.g., counts as an activity for all of those co-authors who have registered it in PURE. Fourth, a total of 58 names had multiple IDs. This can either be because of an error in the registration system or because of different persons having identical names. These were ultimately discarded from the analysis because it was too difficult to determine the cause. This type of inconsistency in the system is problematic, but we did, however, also perform the analysis with those 58 observations included and found no significant change in the overall results. Finally, as described earlier, we chose to include only researchers who had at least one registered activity in each of the years covered. Blank PURE profiles were omitted, since we could not confidently determine whether these represented 'no activity' or 'no registration', and we wanted to include only those staff members, whom we could fairly confidently count as continuous PURE users. Comparing our sample to official university statistics suggests that junior researchers (PhDs and postdocs/ assistant professors) are somewhat underrepresented in our study. This could be due to these researchers not sustaining their employment throughout the period covered, but could also be because of a more fragmented production of 'activities'.

In sum, there are several caveats related to PURE as a data source for the study. We consider it likely that the proportional size of clusters may somewhat misrepresent the actual distribution and that the overall volume of third mission activities may in reality be different from what we observe based on PURE registrations. Even with these reservations in mind, we do believe that our findings concerning sets of activity types and profiles of researchers contribute to developing a more fine-grained picture of how the third mission is being practised at the level of organisations and how researchers can enact their individual responsibilities beyond those related to teaching and research.

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Table 1: Number of researchers by department and career level

	Technical staff (e.g. lab ass.)	PhD fellow	Postdocs / assistant prof	Associate prof / senior researcher	Professor	Total
Department of Agroecology	7	2	6	45	7	67
Department of Animal Science	0	1	11	36	4	52
Department of Bioscience	18	12	22	80	20	152
Department of Chemistry	6	10	8	15	11	50
Department of Computer Science	0	0	1	4	3	8
Department of Engineering	3	1	9	9	2	24
Department of Environmental Science	4	2	2	25	3	36
Department of Food Science	1	0	6	21	1	29
Department of Geoscience	0	4	2	21	4	31
Department of Mathematics	0	0	4	8	6	18
Department of Molecular Biology and Genetics	10	6	14	36	10	76
Department of Physics and Astronomy	9	11	7	23	13	63
Interdisciplinary Nanoscience Centre	1	7	9	9	2	28
Other	1	2	7	5	3	18
Total	60	58	108	337	89	652

Table 2: Third mission indicators; Occurrences per researcher in the period 2009-2012

Variable	Mean	STD	No. of zero-observations	Max
Councils and committees	.65	2.54	499	54
Boards	.20	.78	585	10
Newspaper articles	.13	.67	611	9
Other media articles	.02	.35	644	8
Reports	1.89	5.28	480	42
Memorandums	1.06	3.78	513	42
Questions and hearing answers	.54	3.36	559	63
Participation in radio programme	.28	1.05	578	10
Participation in print media interview	1.24	5.90	524	109
Participation in web-based interview	.36	1.92	603	23
Participation in TV programme	.22	.85	580	11
Publications with industrial co-authors	.95	1.75	382	16
Patents	.14	.66	608	8

Table 3: Rotated components loadings; Loadings below 0.3 not reported, N=652

Variable	Comp. 1 <i>Reactive science communication</i>	Comp.2 <i>Public sector service</i>	Comp.3 <i>Proactive science communication</i>	Comp. 4 <i>Executive involvement</i>	Comp. 5 <i>Industrial collaboration and commercialisati on</i>
Councils and committees				0.69	
Boards				0.70	
Newspaper articles			0.53		
Other media articles			0.76		
Reports		0.58			
Memorandums		0.59			
Questions and Hearings answers		0.55			
Participation in radio programme	0.45				
Participation in print media interview	0.48				
Participation in web-based interview	0.56				
Participation in TV	0.50				
Publications with industrial co-authors					0.68
Patents					0.71

Note: Loading below 0.3 are not visible.

Table 4: Cluster solution and scores on each variable; Average number of occurrences per researcher in the period 2009-2012

Component	Variable	Academics <i>N=511</i>	Executive advisors <i>N=66</i>	Public sector advisors <i>N=46</i>	Innovators <i>N=18</i>	Mediators <i>N=11</i>	Total <i>N=652</i>
Executive involvement	Councils and committees	.29	3.26	.74	.67	1.64	.65
	Boards	.02	1.75	0	.06	.45	.20
Proactive science communication	Newspaper articles	.10	.15	.09	.11	1.5	.13
	Other media articles	.02	0	0	0	.91	.02
Public Sector Service	Reports	.80	.60	16.0	.17	4.5	1.89
	Memorandums	.37	.52	8.90	.11	5.37	1.06
	Questions and Hearings answers	.20	.42	4.34	.06	1.9	.54
Reactive science communication	Participation in radio programme	.17	.18	.24	0	6.36	.28
	Participation in print media interview	.71	.88	.87	.22	3.13	1.24
	Participation in web-based interview	.18	.11	.15	.11	1.12	.36
	Participation in TV	.13	.27	.11	0	4.73	.22
	Publications with industrial co-authors	.80	.73	.59	6.7	1.3	.95
Industrial collaboration and commercialisation	Patents	.08	.03	0	2.6	.18	.14

Note: Grey and dark-grey shadings indicate values that are considerably above average and the highest average respectively.

Table 5: Cluster distributions across age, career level, and departments

	<i>Academics</i>	<i>Executive advisors</i>	<i>Public sector advisors</i>	<i>Innovators</i>	<i>Mediators</i>	All observations
Mean Age	49.4	54.5	54.2	50.8	48.8	50.3
Number of researchers	511	66	46	18	11	652
Departments (number of cluster participants from department)						
Department of Agroecology	51	9	5	0	2	67
Department of Animal Science	26	22	2	0	2	52
Department of Bioscience	109	10	30	0	3	152
Department of Chemistry	47	0	0	3	0	50
Department of Computer Science	4	4	0	0	0	8
Department of Engineering	21	1	0	1	1	24
Department of Environmental Science	26	1	9	0	0	36
Department of Food Science	24	2	0	1	2	29
Department of Geoscience	30	1	0	0	0	31
Department of Mathematics	15	3	0	0	0	18
Department of Molecular Biology and Genetics	67	4	0	5	0	76
Department of Physics and Astronomy	55	5	0	2	1	63
Interdisciplinary Nanoscience Centre	21	1	0	6	0	28
Other	15	3	0	0	0	18
Level of employment* (Number of cluster participants in type of employment)						
Technical staff (e.g. lab ass.)	48	3	7	2	0	60
PhD fellow	55	0	0	1	2	58
Postdocs / assistant prof	98	4	4	1	1	108
Associate prof / senior researcher	248	46	33	4	6	337
Professor	62	13	2	10	2	89

* Employment level is constructed from employment titles in the beginning of the observed period.

Table 6: Publication volume and impact for each cluster; Average per researcher in the period 2009-2012

	<i>Academics</i>	<i>Executive advisors</i>	<i>Public sector advisors</i>	<i>Innovators</i>	<i>Mediators</i>	All observations
Mean publications*	13.2	15.6	8.8	47.1	20.6	14.2
Median Publications	10	11	7	38	11	10
Mean MNCS**	1.55	1.35	1.13	1.60	1.30	1.50
Median MNCS	1.24	1.22	.93	1.55	1.18	1.24

* Publications are the number of peer-reviewed publications published in the period 2009-2012 that are covered by the Web of Science.

** MNCS is the mean normalized citation score developed by CWTS (cf. Waltman & Eck 2013).

Figure 1: Illustration of average component score for each cluster

ⁱ As part of the structural reform in 2007, Aarhus University also merged with the Danish School of Education and Aarhus School of Business, and later, in 2012, Aarhus Engineering School was also merged into Aarhus University.

ⁱⁱ Further information about PURE is provided at <https://www.elsevier.com/solutions/pure>.

ⁱⁱⁱ Kaiser's Criteria: An eigenvalue above 1 indicates that an additional component has more explanatory power than the variables alone and is therefore included (Hair *et al* 2010).

^{iv} Calculation of indices: Each variable that loaded above 0.4 on a component was included in the component index and entered with equal weight. Each value of the variable was divided by its maximum so that each variable had a maximum of one and a minimum of zero. The variables then were summed and divided by the number of variables. The reason for this standardisation is to ensure that different types of variables entered into the index with similar weight – summing two different scales would give weight to the scale with the highest values. The interpretation of the indices is that a value of one is the same as having the highest value in each of the variables that enter into the index while zero is the opposite. The correlation between the indexes and the initial components (calculated in Stata using all 13 variables) was over 0.98 in all cases. These indices were then used in the cluster analysis described below. Other studies have used the components derived from all variables, however this solution ensures an interpretability in the calculated measures. The cluster analysis arrives at the same conclusion using component scores instead of indices.

^v Wards linkage is a common hierarchical agglomerative algorithm that combines clusters sequentially starting with n clusters. Clusters are combined so that the combination of clusters minimizes the within cluster sum of squares for the total set of clusters (Hair *et al* 2010)

^{vi} MNCS is the average number of citations of a set of publications (from a university or other organisational unit, in our case the researcher clusters), normalized for field differences, publication year, and document type. An MNCS value of two for instance means that the set of publications has been cited twice above world average (Waltman *et al* 2012).