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# Do larger departments lead to better research? The correlation between disciplinary community size and quality of publications in seven scientific disciplines in Finland

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## ABSTRACT

The quality of scientific research is, in our time, being measured more extensively and exactly than ever before. Gathering researchers in a certain discipline together into larger units is often presented as a means of advancing research productivity. This study asks, is there a relationship between the size and publication quality of disciplinary communities in seven disciplines in Finland? Our data consists of university statistics drawn from the Finnish national education statistics service, Vipunen. We define a disciplinary community as researchers working in a discipline within the same university. The disciplines included are physics, history and archaeology, medical and health sciences, mathematics and statistics, psychology, economics and political and administrative sciences. We use average Publication Forum scores per publication, as used in the Finnish university funding model, to measure research quality. The time period studied covers the years 2011–2012. Our study shows that there is no statistically significant correlation between the size and research quality of a disciplinary community. In the light of the data set observed, there are no economies of scale in research from the perspective of research quality.

## TIIVISTELMÄ

Tieteellisen tutkimuksen laatua mitataan 2000-luvulla aiempaa laajemmin ja tarkemmin. Saman alan tutkijoiden kokoamisen yhteen suuriin yksiköihin esitetään usein edistävän tutkimuksen tuottavuutta. Tutkimuskysymyksemme on: onko tieteenalayhteisön koon ja tutkimuksen laadun välillä yhteyttä seitsemällä tieteenalalla Suomessa? Tutkimusdatamme koostuu opetushallinnon tilastopalvelu Vipusesta otetuista yliopistotilastoista. Määrittelemme tieteenalayhteisön tietyin tieteenalan tutkijoiksi samassa yliopistossa. Tarkastellut tieteenalat ovat fysiikka, historia ja arkeologia, lääke- ja terveystieteet, matematiikka ja tilastotiede, psykologia, taloustiede sekä valtio-oppi ja hallintotieteet. Käytämme yliopistojen rahoitusmallin mukaisesti lasketuja keskimääräisiä julkaisufoorumipisteitä per julkaisu mitataksemme tutkimuksen laatua. Tutkimuksemme käsittää dataa vuosilta 2011–2012. Tutkimuksemme osoittaa, että tieteenalayhteisön koolla ja tutkimuksen laadulla ei ole merkittävää tilastollista yhteyttä. Lähdeaineiston perusteella tutkimuksessa ei ole mittakaava-etuja tutkimuksen laadun näkökulmasta.

# 1. INTRODUCTION

A prevalent trend of the last three decades in higher education systems has been performance-based steering and management. Performance steering essentially requires quantified measures and indicators to follow and build on. This steering trend, combined with the rise of information technology and networks, has led to scientific research being measured much more precisely than ever before. Measurement first focused on the simple matter of counting the number of publications being produced by researchers in different universities and research institutions. However, as this was correctly observed to be unsatisfactory as an approach, quantifying and measuring the quality of research has come to be a central area of development. As ministries and national research funding organizations, in the spirit of performance steering, want to get the most value for their dollar, euro or yuan, the question of whether research and teaching should be organized into small or large units has been a hot research policy topic in many countries around the globe. Unfortunately for the discussion, the research findings on the topic have thus far been rather inconclusive.

In this paper, we offer our contribution to the topic by examining whether there is a relationship between the size and publication quality of disciplinary communities in seven disciplines in Finland. Our data consists of university statistics drawn from the Finnish national education statistics service, Vipunen. We define a disciplinary community as researchers working in a discipline within the same university. We use average Finnish Publication Forum scores per publication, as used in the Finnish university funding model, to measure research quality. The time period studied covers the years 2011–2012.

We have selected seven disciplines to be included in this study: physics, history and archaeology, medical and health sciences, mathematics and statistics, psychology, economics, and political and administrative sciences. We have chosen a heterogeneous set of disciplines since it would seem possible that in some disciplines, a larger disciplinary community would benefit research quality and in others, it would not. Another criterion for selecting disciplines was that the disciplines to be studied should be researched in several Finnish universities and that the disciplines should be relatively large with regard to their number of research staff. Only Finnish universities and their disciplinary communities are included in the study. Of the studied disciplines, only medical and health sciences is a main discipline in the Vipunen data set; all others are components of the main disciplines. We have chosen to study the main discipline of medical and health sciences (as opposed to a selected discipline within the main discipline), because the medical disciplines are very specialized and we expected a fruitful comparison between universities to present itself in the comparison of the whole area of research.

Our work is laid out in five chapters. After the introduction (Chapter 1), in the second chapter we go through our key concepts and describe our research data and the Publication Forum. In Chapter 3, we first briefly introduce our statistical methods and then go on to describe and interpret our statistical data, discipline by discipline. In Chapter 4, we take a look at previous research on economies of scale in research, and in Chapter 5 we present our conclusions.

The results of our work are very timely. The structural development of higher education institutions for the past decade has been, and continues to be, on the national political agenda in Finland (see Opetus- ja kulttuuriministeriö [OKM] 2015a, 11). Within the last 5–10 years, there have been several mergers of Finnish universities and state research institutes, which aim at sharper profiling and positioning, better recognizability and visibility, and improving the scientific and societal impact of the institutions concerned. State research institutes, small departments and independent research institutes within universities have been merged into university faculties and larger units. The aim of the larger units is to increase productivity, enhance interaction between researchers and to improve the quality of scientific research. By elevating research quality, the aim is to support national competitiveness and enable success in a globalized world. Research and higher education (HE) policy are used to support internationality, strengthen international research projects and increase international mobility. (Marttila & Aittola 2010, 95; Löppönen et al. 2009, 56–57; Nuutinen & Lehvo 2014, 35.)

This study also contributes to evaluating whether it is rational, for the purposes of improving research quality, to build larger research departments and other production units. The quantity and quality of publications currently define 13% of the state core funding in the Finnish university funding model. As

of 2017, publication quality has had a greater impact on this funding than it has had in previous years—in fact, more than it has ever had before in Finland. It is prudent for universities, in order to maximize their core funding, to create incentives for their research staff to conduct high-quality research and publish their results via distinguished channels. (OKM 2014, 25.) A central question ever present in the minds of the management of any organization—and alas, most certainly in any HE and research organization—is the best way to organize work to fulfil the current goals and best serve the underlying mission of the organization. According to the results of this study, gathering more researchers of a discipline under the roof of one university does not directly lead to better quality research, so decision-makers must consider other policy options if research quality is to be increased.

## 2. CONCEPTS, DESCRIPTION OF THE RESEARCH DATA AND THE PUBLICATION FORUM

### 2.1 Concepts

A central concept in our study is that of a “disciplinary community”, which we define as a group of researchers working in the same discipline in the same university. This definition does not make any assumptions regarding the actual production unit (department, etc.) within the structure of the university. In practice, researchers in the same discipline may work in various departments or research institutes within the university. For example, in 2011–2012 in the University of Helsinki, researchers in the main discipline of medicine and health sciences worked in the departments and the research programs unit of the Faculty of Medicine, in the Faculty of Pharmacy and in three independent institutes: the Neuroscience Center, the Institute for Molecular Medicine Finland and the Institute of Biotechnology. On the other hand, researchers in veterinary medicine, with whom medical scientists in genetics closely collaborate, have common methodology and share infrastructures, do not in the official classification belong in same main discipline but are classified as a sub-discipline of agriculture and forestry. Researchers in different production units—and sometimes even within the same production unit—may work either in shared premises and laboratories or in different buildings, on different campuses, and even in different countries. On the other hand, as communication takes place in real time and does not depend on physical proximity, the location of the researchers is not necessarily essential in all kinds of research. Almost without exception, researchers form international networks with colleagues in their discipline. In spite of these remarks, we believe that working within the same university, through the mechanisms and structures of research groups, common infrastructure and premises, shared teaching duties and physical and social nearness, leads to the closer collaboration of researchers within a discipline than does working across university boundaries.

Another key concept in our work is the quality of publications. We define the quality of a set of publications as the amount of Publication Forum (in Finnish “julkaisufoorumi”, abbreviated to PF in English and JUFO in Finnish) points awarded, which takes into account the scientific nature of a publication (publication type), the amount of work required (article vs. monograph) and publication quality (publication channel). Publication Forum points are those used as of 2015 by the Finnish state in awarding basic state funding to universities (see Table 3 below). A key element of the points model is its consideration of publication quality using the quality classification of publication channels. The publication channel does not in itself signal how often a single publication is referred to within the research community, nor does it rank the publication’s actual scientific impact over a longer period of time or its wider impact on society. However, the Publishing Forum classification is controlled by the Finnish research community and we believe it to be the best—and in practice the only—publication quality classification in Finland that considers all scientific disciplines. For this study, the quality classification of a single publication is not relevant as long as the method used yields

a valid classification of the publication output of an entire disciplinary community within a university over the two-year observation period.

## 2.2 A description of the source material

Our data set consists of publication data and research staff data from the years 2011–2012 drawn from the service Education Statistics Finland Vipunen (data from OKM 2015b, OKM 2015c and OKM 2015d). Both publication data and research staff data is classified according to discipline and university. We have selected six disciplines and one main discipline (medical and health sciences) for observation.

*Table 1: Average Publication Forum points by university and discipline in 2011–2012*

<b>Average Publication Forum points by university (PF-points / publication) in 2011–2012</b>	<b>Physics</b>	<b>History and Archaeology</b>	<b>Medical and health sciences</b>	<b>Mathematics and statistics</b>	<b>Psychology</b>	<b>Economics</b>	<b>Political and administrative sciences</b>
Aalto University (Aalto)	2.40	-	-	2.07	-	1.26	-
University of Helsinki (UH)	2.10	1.02	1.73	2.03	1.85	1.14	1.24
University of Eastern Finland (UEF)	1.87	0.82	1.84	2.07	1.84	1.08	-
University of Jyväskylä (UJ)	2.25	1.25	1.53	1.81	1.69	0.91	1.23
University of Lapland (UL)	-	-	-	-	-	-	1.31
Lappeenranta University of Technology (LUT)	2.68	-	-	1.67	-	1.11	-
University of Oulu (UO)	2.26	0.70	1.50	2.08	-	1.30	-
Svenska handelshögskolan (Hanken)	-	-	-	-	-	1.52	-
University of Tampere (UTA)	-	1.09	1.81	1.45	1.78	0.97	0.97
Tampere University of Technology (TUT)	1.69	-	-	1.43	-	1.16	-
University of Turku (UTU)	2.41	0.77	1.85	1.77	1.88	0.95	1.02
University of Vaasa (UV)	-	-	-	-	-	1.14	1.17
Åbo Akademi (ÅA)	1.92	0.98	1.79	1.66	1.98	1.33	1.66



Table 2: Teaching and research staff (full-time equivalent person years) by university and discipline in 2011–2012

Teaching and research staff (full time equivalent person years) by university and discipline in 2011–2012	Physics	History and Archaeology	Medical and health sciences	Mathematics and statistics	Psychology	Economics	Political and administrative sciences
Aalto University	334.0	-	68.2	206.7	93.8	758.0	21.9
University of Helsinki	598.7	161.6	1546.3	282.7	161.3	55.9	102.5
University of Eastern Finland	277.1	25.1	1019.0	38.3	17.2	85.6	1.2
University of Jyväskylä	234.5	96.8	257.3	54.0	109.5	145.3	22.4
University of Lapland	0.2	-	1.0	6.7	6.0	5.4	19.4
Lappeenranta University of Technology	17.7	-	0.1	58.1	-	119.6	-
University of Oulu	149.0	64.8	488.9	115.8	0.2	144.2	-
Svenska handelshögskolan	-	-	-	-	-	247.4	-
University of Tampere	0.4	67.3	527.4	36.9	41.2	97.6	150.1
Tampere University of Technology	168.1	-	-	83.3	-	10.0	-
University of Turku	72.9	74.3	715.6	113.4	54.8	311.9	20.6
University of Vaasa	1.0	-	-	16.0	-	213.5	22.9
Åbo Akademi	33.9	23.9	40.9	32.1	27.3	73.0	53.4

The data found in the statistics service Vipunen is produced by Statistics Finland, the Ministry of Education and Culture, the Finnish National Agency for Education and CIMO (the Centre for International Mobility and Cooperation). The information covers secondary- and upper secondary-level education, polytechnics and universities. The data used in this article was produced by the Ministry of Education and Culture, which receives data directly from universities that collect their own data in connection to annual reporting from a variety of information systems (e.g. the publication data system SoleCRIS and the personnel system Personec). In the staff statistics, the work input of research and teaching staff has been quantified in full-time equivalent work years and classified by university and by main discipline and discipline (main disciplines are further divided into disciplines). The data does not contain information on how the work input is divided into different production units (e.g. faculties/departments) within universities.

Our publication data from 2011–2012 is based on the report of the profile working group of the Ministry of Education and Culture, which describes the state of Finnish universities and scientific research, particularly at the beginning of the 2010s. The report analyses the volume, productivity and scientific impact of research universities, and universities are compared with each other according to discipline. The calculation of the publication scores was carried out in accordance with that which is used in the state funding model: each university participating in a publication gets the points for the whole publication (on the point division model, see also OKM 2015a, 14–16). The ministry’s paper includes calculated indicators for the quality, quantity and productivity of the research output. In this study, we have utilized the indicator “Publication Forum point average per publication”.

There is one important thing to note regarding our data sets. Classifying teaching and research staff according to discipline is different from classifying individual publications. Research staff usually publish papers belonging to their own primary discipline, but may also publish papers classified in other disciplines. For example, statisticians may be authors of sociology papers that use statistical methods and data. For this reason, the ministry's profile working group has not used staff data in its calculations of productivity figures, but instead has relied on the list of unique authors (separate names) in a given discipline's publications for the size of the research community (see OKM 2015a).

For the aims of this study, the aforementioned problem is less central than for the aims of the ministry. The number of researchers publishing in multiple disciplines is relatively small when compared to the size of the disciplinary communities in the light of our data set. For the aim of measuring the quality of publications, the participation of interdisciplinary authors is not a problem; quality is evaluated based on the set of publications classified as belonging to a selected disciplinary community, independent of the disciplines under which the authors are classified. Only in clinical medicine is there a significant difference in the number of discipline staff and the number of authors of publications; here, the discipline FTE count is, on average, around 700, and the number of unique authors is around 2000 (OKM 2015a, 44). In clinical medicine, a large number of university hospital staff participate in research work and author publications.

According to the Ministry of Education and Culture data in Vipunen, Finnish universities produced about 37 000 publications annually in the years 2011–2012, collecting a total of 51 400 PF points. In 2011–2012, a total of 27 300 unique authors featured in the publications—that included only those members of the teaching and research staff that published something during the period. According to the ministry report (OKM 2015a, 43–45), publishing activity is focused quite strongly on a relatively small number of authors in universities. According to the Finnish research publication database Juuli, there were 64 642 publications dating from 2011–2012. Based on Juuli, 65% (42 272 publications) of these belong to the classes relevant to scoring (categories A1–4 and C1), and 35% (22 370 publications) belong to other categories. The relevant publications are distributed between PF classes in such a way that 38% fall into category 0, 35% into category 1, 20% into category 2, and 8% into category 3. A more detailed breakdown of the numbers by type of publication and PF category can be found in Appendix 1.

In the selected disciplines, before undergoing the analysis, we have eliminated the disciplinary communities that seem to have staff but have no publications reported in the same discipline. Our interpretation is that in such cases the discipline serves a supporting role or provides methodological expertise within the university. The university has most likely hired academic staff in a particular field to support the work of one or many other disciplines, or this represents academic staff who primarily carry out teaching duties. The most significant FTE instances we have removed are all in Aalto University, and in the following disciplines: psychology (48.5 FTE), medical and health sciences (34.3 FTE) and political and administrative sciences (9.4 FTE).

In our analysis of the data, we utilize statistical methods and visualizations to determine the existence or lack of a statistical connection between disciplinary community size and publication quality.

### *2.3 Publication Forum, classifications and PF ratings*

Our work is based on the Publication Forum rating as a measure of the quality of Finnish university research publications. The Finnish Publication Forum classifies publications according to four quality categories (0–3). The Publication Forum was established in 2010 and operates under the auspices of the Federation of Finnish Learned Societies (TSV). The PF is a rating and classification system used to support the quality assessment of research output. It is administered by the research community and the first classification was published in 2012. The publication channel evaluation is executed by 23 discipline-specific expert panels and it has so far classified around 30 000 domestic and international publishing channels. Since 2015, the Ministry of Education and Culture has used PF ratings as a criterion in awarding basic funding to Finnish universities through the university funding model. (Niiniluoto 2015; for descriptions of the PF classification levels see Publication Forum classification criteria 2017.)

The classification of publications is also intended to encourage universities to improve the quality and impact of scientific research, which is particularly important because Finland has recently lost ground in international comparisons of research, as well as to increase the societal impact of research (Kosunen 2015).

In this study, we do not compare the PF points of publications in different disciplines to each other. Comparing different disciplines would be very problematic, since due to their differences in publishing practices, the PF classification of channels and typical PF points of disciplines in the selected time period would be strongly divergent. However, a comparison of groups of researchers in different universities within a given discipline (disciplinary communities) is possible, since the researchers within a discipline typically publish in the same channels and those channels have been classified by the relevant Publication Forum expert panel. (For a discussion of the problems of interdisciplinary comparison using PF, and changes introduced in 2015, see Niiniluoto 2015.)

Since 2015, PF classification of scientific publications has been used in calculating the research publications indicator in the university funding model through which Finnish universities receive 13% of their core funding. The funding model indicator takes into account the type of publication and the PF rating for peer-reviewed publications. In the 2015–2016 funding model, the indicator took into account the type of publication and the PF coefficients for peer-reviewed publication classes A1–A4 and C1. The 2015 version is the scoring table that has been used in this study. We have elected to use this scoring table because a scoring model is necessary to quantify the data, the model was already used by the ministry in analysing the publication data in question, and it was the first and only scoring table available at the time of writing the original draft of this article.

*Table 3: Publication Forum scoring table as of 2015*

Source: OKM 2015a, 13.

Publication type	PF level 2 & 3	PF level 1	PF level 0 or no level
A1–4 Peer-reviewed scientific articles	3	1.5	1
C1 Scientific books (monograph)	12	6	4
C2, D5, E2 Edited books, conference proceedings or special issues of journals, professional books, popularized monographs	0.4	0.4	0.4
B1–3, D1–4, E1 Non-refereed scientific articles, publications intended for professional communities, popularized articles, newspaper articles	0.1	0.1	0.1

From 2017, the ministry scoring model has changed to emphasize quality. The scoring model continues to weight the established peer-reviewed categories (A1–A4 and C1) and has also started to weight publications in category C2 (editing of scientific books) with PF coefficients. The updated coefficients for categories A1–A4 and C2 are the following (the coefficients for C1 are these quadrupled): category 0 gives coefficient 0.1; category 1 coefficient 1; category 2 coefficient 3; and category 3 coefficient 4. All non-refereed scientific articles, professional and popular articles get factors of 0.1, and books are given a factor of 0.4, regardless of the publication channel. (Publication Forum 2017.) This development of the scoring model puts more emphasis on quality and offers future researchers a more quality-differentiating model to conduct analyses similar to that of this paper.

### 3. METHODS AND DATA ANALYSIS

In this chapter, we briefly introduce our statistical methods and then go on to describe and interpret our data discipline by discipline. We will show that there is no significant statistical correlation between the size and the quality of the research of a disciplinary community.

In our study, we examine the correlation between the variables using both scatter diagrams and the Pearson correlation coefficient. We also examine the impact of the increase in the full-time equivalent (FTE) work years to the Publication Forum (PF) ratings through a linear regression model.

The correlation coefficient is a number that quantifies the strength of the linear correlation between the variables and usually refers to the Pearson product-moment correlation coefficient ( $r$ ). The value of the Pearson correlation coefficient can be anything between the values of  $-1$  and  $+1$ . The further the value diverges from zero (in one direction or another), the stronger the positive or negative linear correlation. Correspondingly, when the correlation coefficient is  $0$ , there is no linear correlation between the variables. (Taanila 2011.)

There is no univocal way to interpret the existence or nonexistence of correlation, but the literature has often settled upon the following division:

- $r < 0.3$ : there is next to no linear correlation between the variables;
- $0.3 < r < 0.7$ : there is some linear correlation between the variables;
- $r > 0.7$  there is a clear linear correlation between the variables (VirtuaaliAMK 2015).

#### 3.1 Physics

The FTE scores of universities in the discipline of physics vary quite significantly, from Lappeenranta University of Technology's FTE of 17.7 to the University of Helsinki's FTE of 598.7. Variation between the universities can also be detected when considering the PF ratings. The difference between the lowest rating (Tampere University of Technology's 1.69) and the highest rating (Lappeenranta University of Technology's 2.68) is almost one full point, and this difference is the greatest of all the disciplines included in this study. It must also be noted that the university with the lowest FTE score (LUT) also achieved the highest PF rating per publication in the examined group.

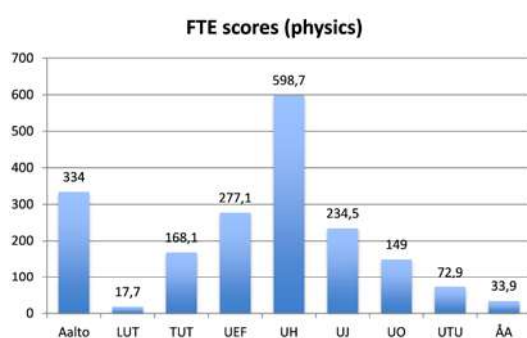


Figure 1: FTE scores in the discipline of physics, yr. 2011–2012

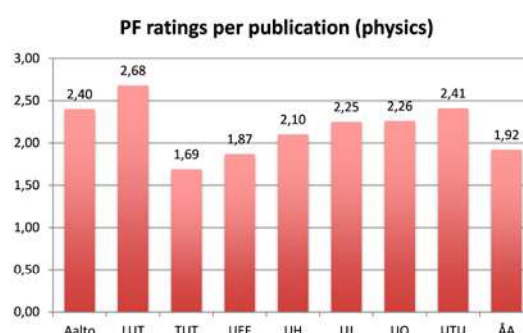
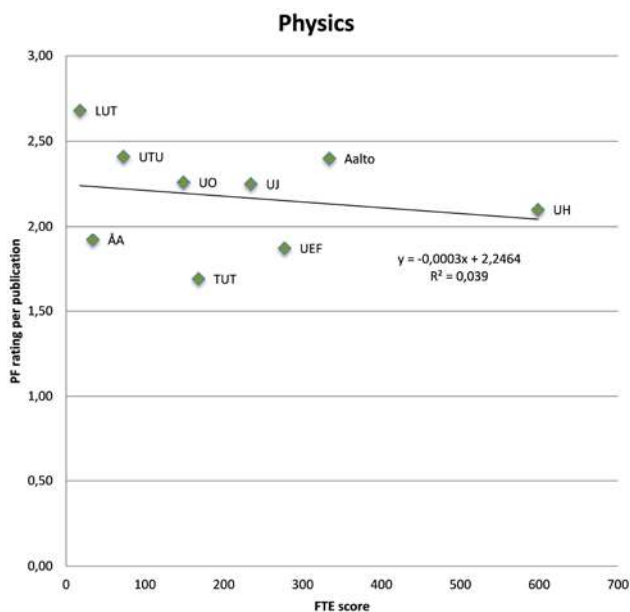


Figure 2: Publication Forum ratings per publication in the discipline of physics, yr. 2011–2012



There is no clear correlation between the PF ratings and the FTE scores visible in the data (n=9). The value of the Pearson correlation coefficient (r) in this population is -0.1975, which indicates that there is no discernible linear connection between the variables. It must also be noted that the coefficient of determination in the model is extremely small: only 3.9% of the variation between the PF ratings can be explained by changes in the FTE.

Figure 3: PF ratings per publication vs. FTE scores in the discipline of physics

### 3.2 History and archaeology

The FTE scope of the universities in the discipline of history and archaeology is divided in a more moderate way, ranging from Åbo Akademi's FTE of 23.9 to the University of Helsinki's FTE of 161.6. The range between the PF ratings is also narrower; the difference between the PF rating of 0.7 per publication for the University of Oulu and the PF rating of 1.25 per publication for the University of Jyväskylä is only slightly over one half of a point. When considering the data, it is noteworthy that the PF ratings of the university with the lowest FTE score (ÅA) and the highest FTE score (UH) are almost the same.

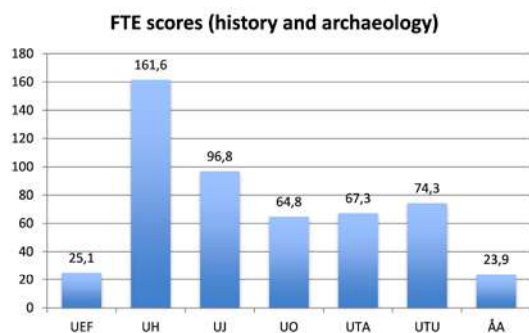


Figure 4: FTE scores in the discipline of history and archaeology, yr. 2011–2012

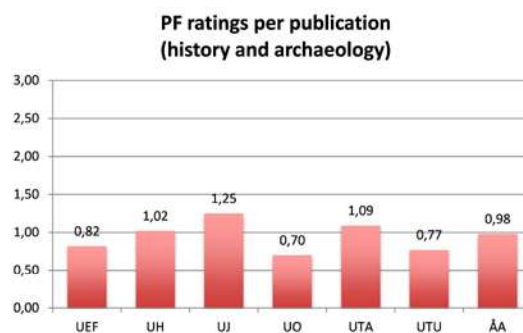
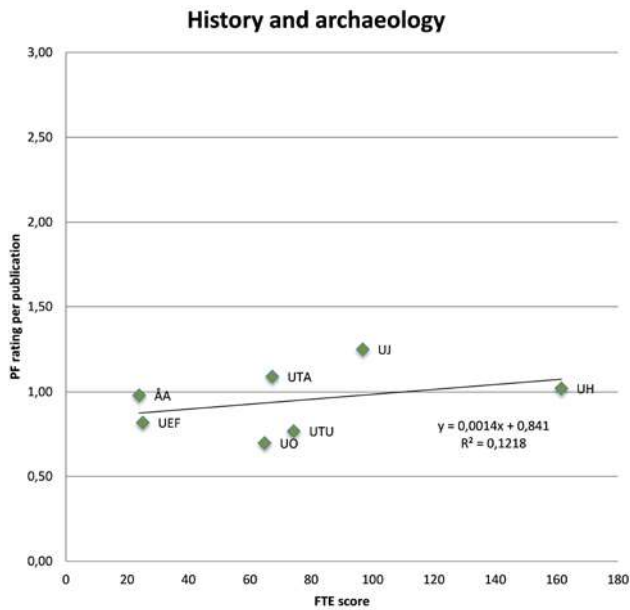


Figure 5: Publication Forum ratings per publication in the discipline of history and archaeology, yr. 2011–2012



In the discipline of history and archaeology, there is a positive correlation of a sort between the PF ratings and the FTE scores visible in the data (n=7). The value of the Pearson correlation coefficient (r) in this group is 0.3489, which indicates that there is some linear connection between the variables. Based on the slope of the regression line, it can be calculated that FTE growth of 714 units would increase the PF rating per publication by one point. However, the explanatory power of the model is weak and only 12.2% of the variation in the PF ratings can be explained by the changes in the FTE.

Figure 6: PF ratings per publication vs. FTE scores in the discipline of history and archaeology

### 3.3 Medical and health sciences

The FTE scores of universities in the discipline of medical and health sciences vary on a very large scale, ranging from Åbo Akademi's FTE of 40.9 to the University of Helsinki's FTE of 1546.3. However, it must be noted that apart from the University of Jyväskylä and Åbo Akademi, there is a university hospital operating in connection to all the universities in the examined group, which means that there is a discernible emphasis on clinical medical research in these universities' medical sub-disciplines. In addition to this, in Åbo Akademi, research is only carried out in the sub-disciplines of health sciences and pharmacy.

The variation between the PF ratings in the field of medical and health sciences is relatively small. The difference between the PF rating of 1.5 per publication in the University of Oulu and the PF rating of 1.85 per publication in the University of Turku is only 0.35 points. It must also be noted that even though the FTE scores between the universities vary significantly, the PF ratings per publication in all the universities in the field of medical and health sciences are very uniform.

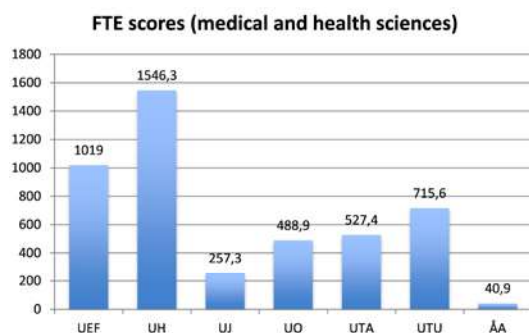


Figure 7: FTE scores in the main discipline of medical and health sciences, yr. 2011–2012

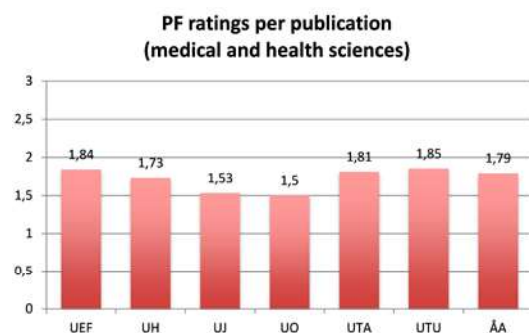
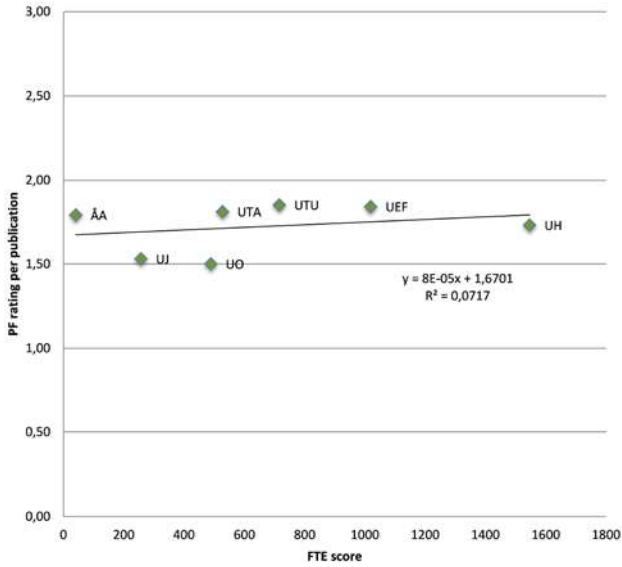


Figure 8: Publication Forum ratings per publication in the main discipline of medical and health sciences, yr. 2011–2012



### Medical and health sciences



In the field of medical and health sciences (n=7), there is no clear correlation between the PF ratings and the FTE scores. The value of the Pearson correlation coefficient (r) in this group is 0.2677, which indicates that there is no significant linear connection between the variables. The explanatory power of the model is small: only 7.2% of the variation in the PF ratings can be explained by the changes in the FTE.

Figure 9: PF ratings per publication vs. FTE scores in the main discipline of medical and health sciences

### 3.4 Mathematics and statistics

The FTE scores of universities in the discipline of mathematics and statistics is also divided on quite a large scale and vary widely from Åbo Akademi's FTE of 32.1 to the University of Helsinki's FTE of 282.7. There is also some variation between the PF ratings. For example, the difference between Tampere University of Technology's 1.43 points and the University of Oulu's 2.08 points per publication is over 0.65 points. Mathematics and statistics is the only examined discipline in which the universities with the largest FTE scores (Aalto, UH) also have the highest PF ratings.

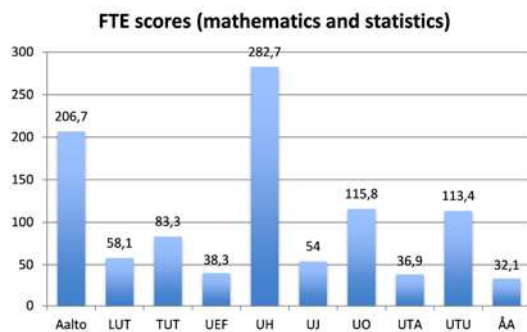


Figure 10: FTE scores in the discipline of mathematics and statistics, yr. 2011–2012

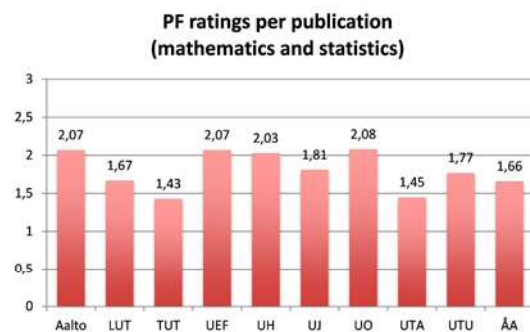
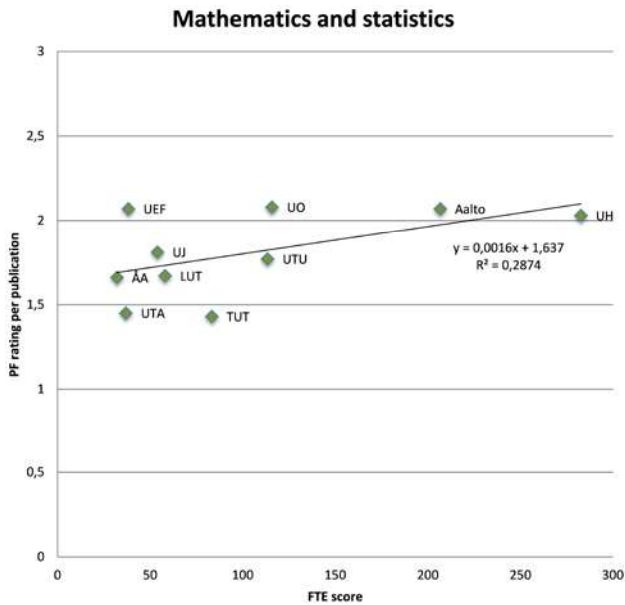


Figure 11: Publication Forum ratings per publication in the discipline of mathematics and statistics, yr. 2011–2012





Out of all the disciplines included in our study, in mathematics and statistics (n=10) there seems to be the clearest correlation between the FTE scores and PF ratings per publication. The value of the Pearson correlation coefficient (r) in this group is 0.5361, which indicates that there is some linear connection between the variables. Based on the slope of the regression line, it can be calculated that an FTE growth of about 625 units would increase the PF rating per publication by one full point. The explanatory power of the model is also the strongest of all the disciplines in our study and about one-third of the variation in the PF ratings can be explained by the changes in the FTE (28.7%).

Figure 12: PF ratings per publication vs. FTE scores in the discipline of mathematics and statistics

### 3.5 Psychology

There is moderate variation in the FTE scores of universities in the field of psychology, ranging from the University of Eastern Finland's FTE of 17.2 to the University of Helsinki's FTE of 161.3. The PF ratings are relatively uniform and there is only a one-third of a point difference between the university with the lowest PF rating (UJ) and the university with the highest PF rating (ÅÅ). Compared to the other disciplines in our study, the PF ratings of different universities in psychology are quite similar, even if the FTE scores are clearly different.

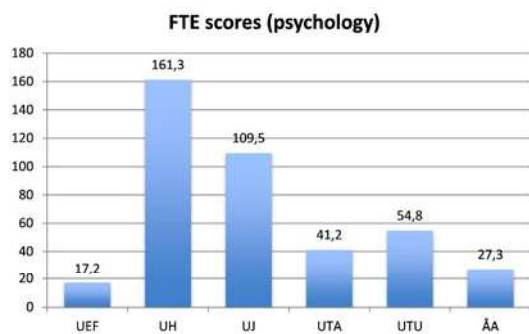


Figure 13: FTE scores in the discipline of psychology, yr. 2011–2012

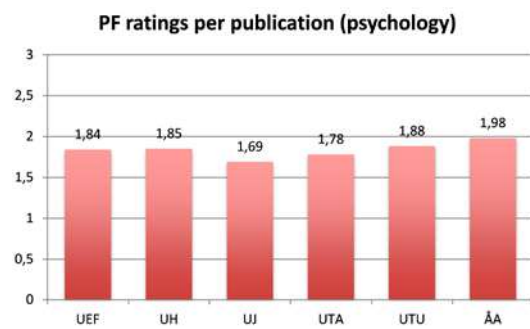
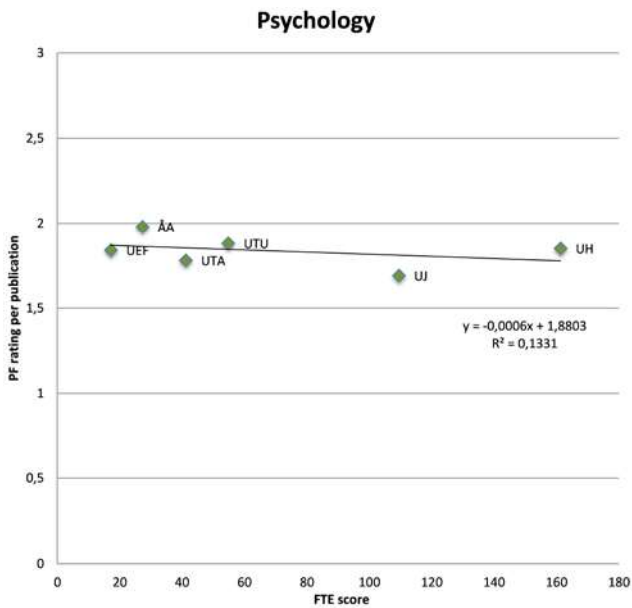


Figure 14: Publication Forum ratings per publication in the discipline of psychology, yr. 2011–2012



In psychology (n=6), there seems to be a negative correlation of a sort between the PF ratings and the FTE scores visible in the data. The value of the Pearson correlation coefficient (r) in this group is -0.3648, which indicates that there is some linear connection between the variables. This connection is negative and it seems that the growing FTE would decrease the PF rating in the examined group. However, visual observation of the regression line does not support this view, as the line is almost horizontal. It must also be remembered that the explanatory power of the model is quite weak, and only 13.3% of the variation in the PF ratings can be explained by changes in the FTE.

Figure 15: PF ratings per publication vs. FTE scores in the discipline of psychology

### 3.6 Economics

The FTE scores of universities in the field of economics (including economic science and business economics) vary on a wide scale. Aalto University's FTE of 758 is several times greater than that of other universities in the group, but the difference between the university with the smallest FTE (TUT) and the university with the largest FTE after Aalto (UTU) is also clear. In the PF ratings, the difference is not as great: the difference between the university with the lowest rating (UJ) and the university with the highest rating (Hanken) is only about 0.6 points.

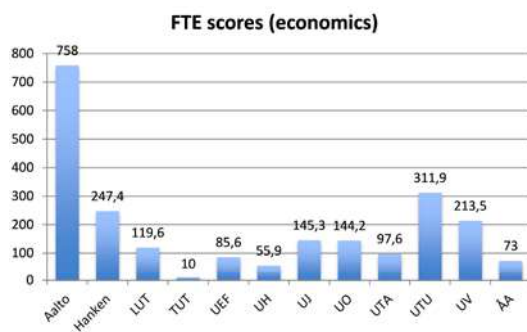


Figure 16: FTE scores in the discipline of economics, yr. 2011–2012

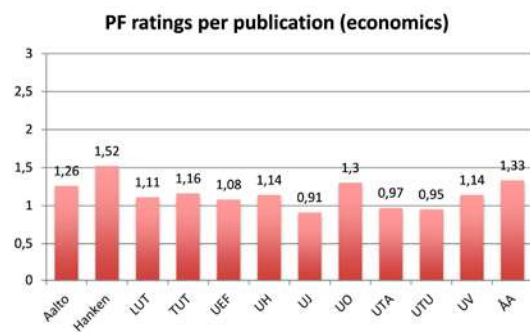
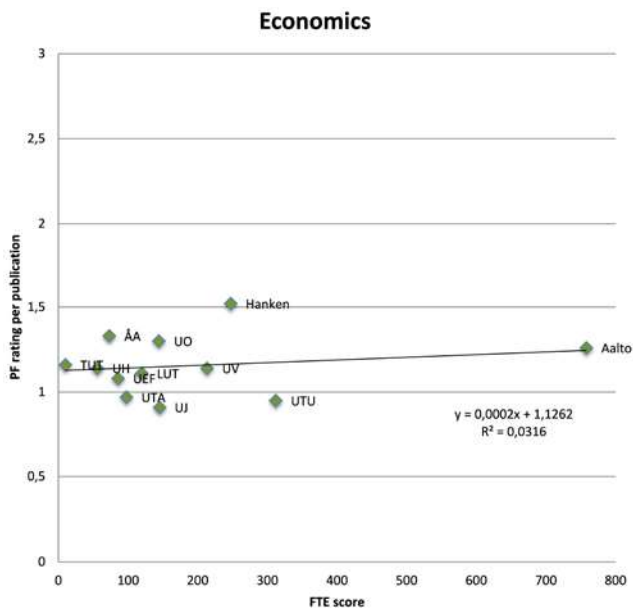


Figure 17: Publication Forum ratings per publication in the discipline of economics, yr. 2011–2012



In economics (n=12), there is no overly clear positive correlation between the PF ratings and the FTE scores. The value of the Pearson correlation coefficient ( $r$ ) in this group is 0.1778, which indicates that there is no significant linear connection between the variables. The absence of correlation can also be observed when considering the regression line, which is very nearly horizontal. The explanatory power of the model is the weakest of all the disciplines included in this study: only 3.2% of the variation in the PF ratings can be explained by changes in the FTE.

Figure 18: PF ratings per publication vs. FTE scores in the discipline of economics

### 3.7 Political and administrative sciences

The FTE of universities in the field of political and administrative sciences varies significantly from the relatively small universities of Jyväskylä, Lapland, Turku and Vaasa (average FTE of 20) to the University of Tampere's FTE of 150.1. The differences between the PF ratings are also more pronounced: the difference between the PF rating of 0.97 per publication in the University of Tampere and the PF rating of 1.66 per publication in Åbo Akademi is almost 0.7 points. A distinct observation arising from the data is that the University of Tampere, which has undisputedly the highest FTE score of all the universities in the group, also has the lowest PF ratings per publication in this discipline.

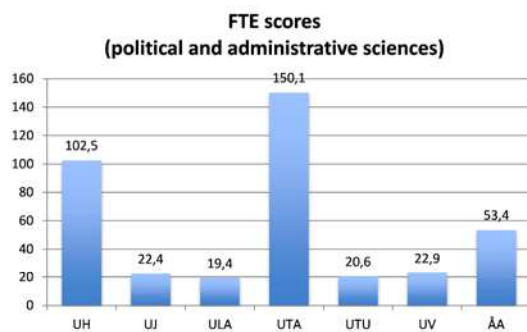


Figure 19: FTE scores in the discipline of political and administrative sciences, yr. 2011–2012

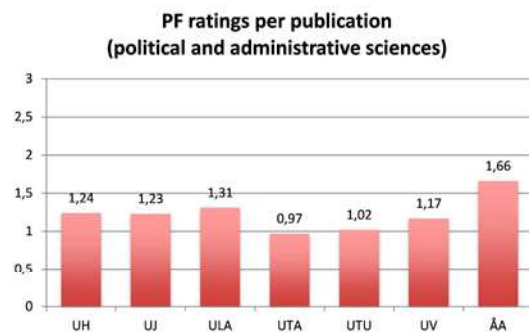
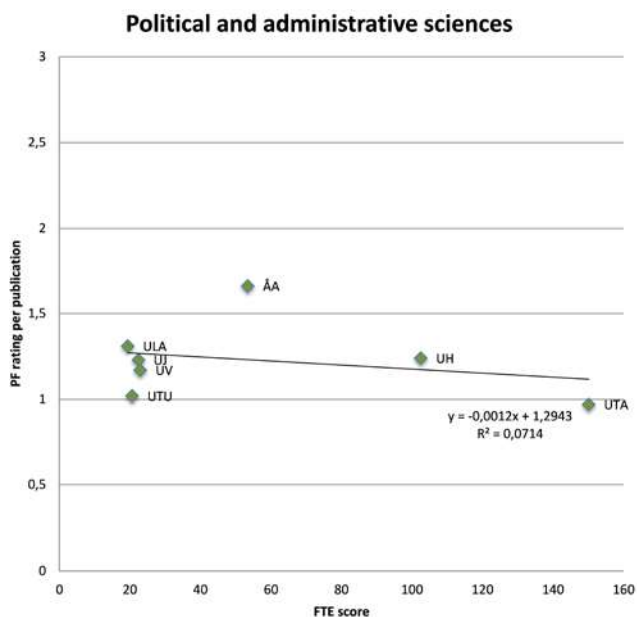


Figure 20: Publication Forum ratings per publication in the discipline of political and administrative sciences, yr. 2011–2012



There is no clear correlation between the PF ratings and the FTE scores in the field of political and administrative sciences (n=7). The value of the Pearson correlation coefficient (r) in this group is -0.2673, which indicates that there is no significant negative linear connection between the variables. This is confirmed when observing the regression line, which, similar to the field of economics, is nearly horizontal. The explanatory power of the model is relatively weak and only 7.1% of the variation in the PF ratings can be explained by changes in the FTE.

Figure 21: PF ratings per publication vs. FTE scores in the discipline of political and administrative sciences

### 3.8 Summary of the data analysis and limits to the interpretation of the results

Observing the data set as a whole, it can be stated that correlation between discipline-specific FTEs and publication forum ratings is quite insignificant. In some disciplines, there is a weak positive linear connection, and in one discipline there is a weak negative correlation (growth in FTE work years would appear to reduce research quality, as measured in PF ratings), but as a whole, there is no systematic correlation between FTE work years of research and teaching staff and PF ratings within disciplines. It must be kept in mind that in a data set with a small number of observations, there may appear to be correlations that would not persist in larger sets of observations.

When considering the correlations, it is important to keep in mind that a correlation between variables does not imply a causal relationship between them. Correlation may instead be a signal implying an external reason for the covariance of the observed variables. In this sense, the lack of correlation as observed in this paper is an easy result. We can, with reasonable certainty, state that there is no causal relationship between the observed variables, and state that the quality of the research of a discipline as measured in average PF ratings does not increase as a result of increasing the amount of FTE work years in that discipline in a given university.

We want to draw attention to two factors that limit the relevance of average PF points as a measure of quality of research. The first is that by looking at the average of PF points per publication, one does not consider how many of the publications are aimed to a wider audience in relation to those written for the research community. If one disciplinary community has published a large quantity of both top-notch scientific papers and popular/professionally oriented articles, it is not measured as being as successful (according to its average PF rating) as another disciplinary community that focuses solely on highly rated scientific publication channels. This factor may be significant as circa 38% of the publications in our data are classified as PF level 0. There may also be variation in how extensively the different disciplinary communities have reported their popular/professionally oriented publications.

The second factor to be observed is that the upper end of the PF scale does not differentiate between the quality of publications: the amount of points awarded for PF classes 2 and 3 is equal. In practice, 39% of the peer-reviewed publications in the data fell into classes 2 and 3. In some disciplines (such as physics), as many as 70% of their peer-reviewed publications were placed into these two top

classes. (Niiniluoto 2015.) Hence, the ability of the scale to differentiate between them is very weak and the number of PF points does not function well as a measure of the quality of a disciplinary community's research. Some of the problems with the PF classification have been fixed or improved in the new version of the classification that came into operation in 2015.

## 4. PREVIOUS RESEARCH ON ECONOMIES OF SCALE IN RESEARCH

In this chapter, we will review earlier research and literature on the economies of scale in research, focusing especially on research quality. We will compare the results reviewed in this part to our own results in the final chapter.

Industrial economics describes both the economies of scale and the economies of scope for given activities. The economies of scale refer to getting a proportionally greater output as the size of a production unit increases. On the other hand, economies of scope refer to advantages to the production of performing certain activities together or in cooperation, as compared to performing them in isolation. According to von Tunzelmann et al. (2003, 1), the language, concepts and methods of industrial economics have to a great extent been transferred to describing and researching universities and research institutions. In this context, research and education are described as productive activities with outputs such as scientific publications, study points and academic degrees.

According to von Tunzelmann et al. (2003, iii and 2) the most important unit of structure would appear to be the research group rather than the department or the university. A research group is typically focused on a specific sub-discipline or field of research. A department often covers a whole discipline. If the research group is of adequate size, it may produce globally leading research regardless of whether it operates in a department of 15 or 50 researchers and regardless of the size of the university. The size of the university and research productivity do not correlate in any clear way. (von Tunzelmann et al. 2003, iii.)

Previous research implies that research productivity—and possibly also research quality—increases up to a certain research group size. This critical size has in several papers been estimated to be between six to eight relatively permanent members of academic staff. Increasing research group size beyond the critical size does not result in additional increases in productivity. Some papers report lower critical sizes, and in some disciplines (e.g. some humanities subjects), there does not appear to be a critical research group size. The critical size has been observed to be larger in applied disciplines, such as clinical medicine, and smaller in theoretical disciplines, such as mathematics. (von Tunzelmann et al. 2003, iii, 8 and 11.)

The importance of the size of a research group is also addressed in a study of the quality and productivity of Dutch research programs in business and economics. In their paper, Tom Groot and Teresa García-Valderrama (2006) conclude that a larger research group size correlates with increased quality, but decreased productivity, of research. In Groot and García-Valderrama's paper, quality has been defined using bibliometric analysis and peer-review processes of research.

When researching economies of scale, one should ideally take into consideration all factors of production, not just the work of employees. The importance of human work is great in research, but in some fields—e.g. physics and medicine—research infrastructure and equipment may be central factors of production. It is practically impossible to publish in leading journals in particle physics if one's group does not have access to state of the art particle accelerators. This article, like most of the research concerning economies of scale in research, considers the work of the research and teaching staff as the sole input variable. (See also von Tunzelmann 2003, 6.) Correspondingly, research publications are only one type of output that academic staff produce: other types of output are those related to teaching (completed study credits and degrees, etc.) and those related to third stream activities (articles and lectures aimed at the general public, media appearances, meetings with interest groups, etc.). It is very possible that researchers in different universities divide their time between different activities in varied ways and value outputs

differently. Then again, in Finland, publishing in peer-reviewed research journals plays a very central role in accumulating academic merits and advancing one's career. It is a reasonable assumption that in all universities included in this study, publishing research papers is a primary activity for researchers, and aiming at publication in leading journals is both encouraged and desired.

Some of the advantages of large departments, according to Brown, are the cross-pollination of ideas, increased possibility of dividing teaching duties between researchers and according to specialization, increased chances of receiving competitive research funding for large projects, and organizing administration in more effective and productive ways. Some of the disadvantages may be decreased personal interaction and less participation in setting departmental policies. (Brown 1996, cited in von Tunzelmann et al. 2003, 10.) A report by the profile working group of the Ministry of Education and Culture of Finland states that "the size of the unit is an important factor, because in large units it is possible to bring together a large group of researchers representing different branches of the discipline and hence to diversify the interaction advancing the discipline. A large unit size is economical as the research infrastructure and the common services of the unit can be arranged in a more effective way." However, the same report continues by stating that according to empirical research, there is no correlation between the productivity and quality of research and research unit size. (OKM 2015a, 11.)

The aforementioned sources seem to imply that if large units have an advantage over smaller ones, their advantages are related to education being produced in a high-quality fashion, or effectively, or because their administration and common services are organized effectively. It is noteworthy that both sources name increased interaction between the researchers of a discipline as one of the advantages of larger units, but conclude that unit size does not have significance with regard to the quality or productivity of research. From these premises, it can be inferred that either increased interaction between the researchers of a discipline does not lead to higher quality research, or that the interaction is not in fact increased or improved in larger units.

It is also possible that the mere existence of larger departments and larger universities attracts relatively more production factors (e.g. research funding) in comparison to smaller units. Such an effect may be caused by recognizability and reputation. Robert K. Merton referred to such a self-realizing mechanism as the Matthew effect: to those that have, more shall be given. (von Tunzelmann et al. 2003, 5.) This kind of self-reinforcing pattern is likely to be at work in high quality research communities: world-leading individuals or groups in a certain discipline attract more top-quality individuals and collaborators simply as a result of their fame.

Presumably, the discussion on the advantages and disadvantages of large departments (production units) is relevant for this article since large disciplinary communities are likely to correlate with large production units. As discussed previously in this chapter, the advantages of large units seem to relate mostly to education and effective administration; advantages related directly to research are not on the list. The aforementioned ability of a unit to win competitive funding for large-scale projects may have significance for research quality, but this significance may vary according to discipline. It is possible that in some disciplines, large or multidisciplinary projects lead to better quality research, and in some other disciplines they lead to decreases in research quality.

In Finland, the ratio of competitive research funding to state basic funding might be a factor explaining the quality of research in a given disciplinary community. An increase in competitive research funding leads quite directly to an increase in disciplinary community size and enables the academic staff to use a relatively larger proportion of their time for research (vs. teaching and other duties). On the other hand, a central criterion in winning competitive research funding (e.g. Academy of Finland funding) is specifically the scientific quality of previous or planned research. Therefore, observed quality leads to new competitive funding and an increased competitive portion of the funding base, which in turn presumably increases the quality and/or quantity of publications.

Hugo Horta and T. Austin Lacy have researched (2011) the relationship between disciplinary community size and research productivity and quantity of publications in Portuguese universities. Their research showed that a larger disciplinary community increased the amount of international publications of academic staff, but did not directly affect the amount of high-quality publications. Factors contributing to the increase in international papers were more extensive international networks and the better capacity of larger disciplinary communities to engage in international collaboration. The internal variety of the research



community, the interaction of researchers in different career stages and teaching provided by postgraduate students were seen as having a positive contribution to publishing, especially in international forums. A factor seen as reducing the productivity and amount of publications was a relatively large amount of administrative and supervisory work. (Horta & Lacy 2011, 456–459.)

## 5. CONCLUSIONS

In this paper, we have studied the relationship between the size of discipline-specific research communities and the average quality of their publications. The studied data from the years 2011–2012 included research communities in Finnish universities in the disciplines of physics, history and archaeology, medical and health sciences, mathematics and statistics, psychology, economics, and political and administrative sciences.

Based on our data, our conclusion is that there is no statistical correlation between the size of the disciplinary community and research quality. The data set included heterogeneous disciplines, very small and very large disciplinary communities and very clear variations in research quality within disciplines. In some disciplines, there was a weak positive correlation and in one discipline there was a weak negative correlation. In data sets with small numbers of observations, the correlations are not significant. There are some limitations, as discussed in detail in Chapter 3.8, to interpreting the average PF points of a disciplinary community as an indicator of its research quality.

In the light of the data set observed, there are no economies of scale in research from the perspective of research quality. The results from the literature, as presented in Chapter 4, support this conclusion. The advantages of larger units or disciplinary communities over small ones may be related to effective organization of administrative and support services and the division of work related to the effectiveness or quality of education. The most important organizational unit from the perspective of research quality and productivity is the research group. In many disciplines, a research group of an adequate size, around 6–8 relatively permanent researchers, is a precondition for high-quality research. In some disciplines, there does not appear to be a critical mass for research group size.

Our results have policy implications for universities, research funding agencies and ministries of education internationally. Generally speaking, funding agencies already operate in a sound way by mainly awarding research funding to principal investigators of research groups. In Finland, some recent funding, e.g. the Academy of Finland University Profiling Funding (PROFI), has been awarded to universities. Even as research quality does not directly improve in larger departments or universities, and hence there would not appear to be a direct case (from a research quality perspective) for a stronger division of labour nationally between universities, the profiling of universities may, through the mechanisms of effective administration and providing education in larger units, enable universities to use more resources for research and thereby enable an increase in research volume and/or quality. As for universities, the implication is that there is no preset winning formula for organizing all research in a given discipline in units as large as possible. The organization should be built based on the needs of the PIs, research groups and infrastructure in given areas.

Since the beginning of 2017, the PF ratings of publications now affect the funding of Finnish universities more than ever before. With this financial steering in place, it is natural and necessary for universities to aim at increasing the quality of their publications. As our study has used data from the years 2011–2012, it is important for the research community to later observe if the improvements in the classifications and scoring models or looking at a longer time sequence lift to surface differences in research quality or correlations that have been unobservable in our data set. International comparison is also important as Finland is a small player in the global research market. Evidence-based policy does not guarantee success for any single institution or national higher education system, but considering evidence systematically gives decision-makers the best tools available in directing HE systems, steering research funding and organizing research institutions. Studies similar to this one are important in verifying the current state of Finnish research, especially in times that have already witnessed many changes in the structures of national and international higher education, and may yet witness many more.



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# APPENDIX 1: PUBLICATIONS DIVIDED BY PUBLICATION TYPE AND PF-RATING, YR. 2011–2012

Source: Juuli – Finnish Research Publications 2015; narrowed down by 2011–2012, universities.

Type of publication	PF-rating				Total	% out of all
	0	1	2	3		
A1 Journal article (refereed), original research	1 158	11 764	8 184	4 594	25 700	39.76%
A2 Review article, Literature review, Systematic review	112	905	303	138	1 458	2.26%
A3 Book section, Chapters in research books	1 533	2 418	2 263	1	6 215	9.61%
A4 Conference proceedings	4 427	3 421	157	21	8 026	12.42%
B1 Non-refereed journal articles	664	2 146	1 072	234	4 116	6.37%
B2 Book section	1 804	736	330	0	2 870	4.44%
B3 Non-refereed conference proceedings	1 126	127	8	1	1 262	1.95%
C1 Book	453	248	172	0	873	1.35%
C2 Book (editor), chapters in research books, conference proceedings or special issue of a journal	521	498	260	7	1 286	1.99%
D1 Article in a trade journal	3 122	132	9	4	3 267	5.05%
D2 Article in a professional book (incl. an introduction by the editor)	1 688	9	0	0	1 697	2.63%
D3 Professional conference proceedings	232	5	1	0	238	0.37%
D4 Published development or research report or study	1 604	5	0	0	1 609	2.49%
D5 Textbook, professional manual or guide	498	1	0	0	499	0.77%
E1 Popularised article, newspaper article	5 216	55	2	0	5 273	8.16%
E2 Popularised monograph	250	2	1	0	253	0.39%
<b>Total</b>	<b>24 408</b>	<b>22 472</b>	<b>12 762</b>	<b>5 000</b>	<b>64 642</b>	<b>100.00%</b>
% out of all	37.76%	34.76%	19.74%	7.73%	100.00%	
A1–4 and C1	7 683	18 756	11 079	4 754	42 272	65.39%
Other types	16 725	3 716	1 683	246	22 370	34.61%