

# **Does Industrial Relevance in Public Science Come at the Expense of Basic Research? Revisiting Tradeoffs in University Research.**

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## **Abstract**

The assumption that public science faces a tradeoff between basic and applied research has combined with growing pressures for industrial relevance in university research to spark concerns that universities dedicate increasing amounts of resources to applied research, at the expense of basic research. This paper suggests, however, that the very notion of a tradeoff may be the product of our use of the linear model of innovation to conceptualise research, and that this notion becomes less obvious when we apply a more nuanced typology to investigate the dynamics of knowledge production. This paper presents the preliminary findings of a study of the Technical University of Denmark (DTU), which does not indicate that the amount of applied research undertaken at DTU has a negative influence on the amount of basic research. Moreover, the data suggest a clear predominance of publications in basic research, and that much university research, which is generally classified as applied research, can be more accurately characterized as engineering research. Publications in applied research represented just 7% of the total data set. The results of the study suggest that technical universities, at least DTU, can be oriented towards industrial relevance without compromising basic scientific research activity.

## **Keywords**

Skewing problem; The science-technology distinction; Linear model; Engineering research; University research; (Technical) universities.

## Background for the study

Numerous contributions have recognized the importance of public, particularly university, research in generating and transferring knowledge and competences, which contribute to the development of industrial innovations. For example, Narin, Hamilton and Olivastro (1995, 1997) observed an increasing linkage between US technology and publicly funded science. Mansfield (1991, 1997) moreover demonstrated that more than 10 per cent of all new products and processes introduced in U.S. high technology industries between 1975 and 1994 could not have been developed in the absence of recent academic research, at least not without substantial delay.

Meanwhile, many contributions on science policy and university-industry relations rely on a fundamental assumption that public science faces a tradeoff between basic and applied research: while universities hold a comparative advantage over private science in basic research (Arrow, 1962; Nelson, 1959), they have also come under increasing pressure from governments and politicians to generate research, which is directly useful in the development of industrial innovations. Pavitt (2001, p. 768) refers to this as “the quest for greater relevance” in public research and argues that it encourages research institutions to involve the industry-based users of their findings.

Due to the limited resources available to public science, developing such practical relevance may come at the expense of long-term basic research (e.g. Gwynne & Wolf, 2000; Lee, 1996). It has been suggested that publicly funded research institutions face a “dual-orientation trade-off” (Valentin & Jensen, 2003) between basic research – which provides a window onto new scientific developments and helps guide research activities – and applied research – which ensures the industrial relevance of the research undertaken (and thus helps guarantee continued, external funding).

Fundamental developments in the research system such as the the ever-closer relationship between basic research and industrial application, and the increasing multidisciplinary and cross-fertilization of scientific and technological fields (e.g. David, Mowery & Steinmueller, 1994; Gibbons, Limoges, Nowotny, Schwartzman & Trow, 1994; Llerena & Meyer-Krahmer, 2003) – complemented by growing pressures for industrial relevance in public research, and increasing private-public research collaboration (e.g. Dasgupta & David, 1994; Etzkowitz & Leydesdorff, 1997, 2000; Pavitt, 2001) – have spawned concerns that collaboration with industry causes universities to dedicate an increasing amount of resources to the pursuit of applied research objectives, to the detriment of fundamental scientific research.

The relevance of this alleged shift in research focus – known as the “skewing problem” (Florida & Cohen, 1999) – is highlighted by the fact that recent endeavours to reform the governance of universities have placed considerable emphasis on the commercial potential and industrial usefulness of university research (Valentin & Jensen, 2003).

Nonetheless, clear and generalized evidence of such a skewing problem has yet to materialize. In contrast, two recent studies of research groups and faculty members involved in university-industry collaboration at the Catholic University in Leuven, Belgium, suggest that universities can engage in applied research *without* negatively impacting the amount of basic research undertaken (Ranga, Debackere & von Tunzelmann, 2003; Van Looy, Ranga, Callaert, Debackere & Zimmermann, 2004). On the contrary, Ranga et al. (2003, p. 301) argued that it is the “the *combination* of basic and applied publications that consolidate the [research] group’s R&D potential.”

This raises several important questions, hereunder whether the findings by Ranga, Van Looy and their colleagues can be generalized. Has the amount of applied research undertaken by universities increased and, if so, has this had any detrimental impact on the amount of basic research? Or have concerns surrounding the skewing problem been exaggerated?

This paper suggests that the very idea of a tradeoff between basic and applied research may stem from the terminology with which we describe and evaluate scientific research, rather than emanate from an actual understanding of the dynamics inherent in the process of scientific knowledge production.

The linear model of innovation – in which basic science feeds inputs into applied science, resulting in the development of new products and services – was popularized by Vannevar Bush (1945) and represented the dominant view of innovation from the end of World War II and up until the seventies. While it has long since been dismissed as unduly simplistic (see e.g. Faulkner, 1994; Wise, 1985), it continues to play a fundamental role in the development of R&D indicators and in science policy.

This paper proposes that the dichotomous nature of the linear model invites us to think about basic and applied research as opposing forces in a binary universe of scientific knowledge production, motivating the hypothesis of a tradeoff between the two.

A more nuanced conceptualization of scientific research than the distinction between basic and applied science makes the idea of a tradeoff less obvious. In this paper, we explore a related characterization of knowledge production modes proposed by Francis Narin and colleagues (Narin, Pinski & Gee, 1976; Pinski & Narin, 1976), which was also applied in the aforementioned studies by Ranga et al. (2003) and Van Looy et al. (2004). This typology distinguishes between four levels of research rather than just two: applied research (level 1), engineering and technological research (level 2), targeted basic research (level 3), and basic scientific research (level 4).<sup>1</sup> The Narin et al. typology is particularly interesting because it was developed in collaboration with the U.S. National Science Foundation and has been used in a science policy context for three decades, and therefore lends itself readily to operationalization. However, its four levels are typically aggregated into two overall categories of “basic” and “applied” research, effectively bringing us back to the research typology underlying the linear model.

Taking a critical view of the notion of tradeoffs in public science, this paper presents the initial findings of an exploratory study of the dynamic nature of scientific knowledge production and the relationship between different modes of research in a particular university, the Technical University of Denmark (DTU). Inspired in particular by the article by Ranga et al. (2003), this paper is a preliminary attempt to explore whether the findings from the studies of the Catholic University in Leuven can be extended to other universities.

The following sections introduce the design, research questions and results of the case study of the Technical University of Denmark. We conclude with a discussion of the findings and of how the exploratory study presented in this paper can be extended and developed.

## **Research design**

The empirical study undertaken in this paper is a pilot study of the joint publication record of a sample of professors from the Technical University of Denmark (DTU). Situated north of Copenhagen, Denmark, and founded in 1829, DTU is a mono-faculty university and the main institution for engineering education and research in Denmark. The university has approximately 6000 undergraduate and graduate students.

The reason why a technical university was selected as the subject of analysis for this pilot study is that engineering and technical universities are traditionally associated with a significant emphasis on application-oriented research and collaboration with industry. Thus, if there is a shift in public science towards applied research, to the detriment of basic research, this shift is likely to be particularly clear in the case of a technical university.

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<sup>1</sup> Original labels used in the Narin et al. typology are: (1) applied technology, (2) engineering science – technological science, (3) applied research and targeted basic research, and (4) basic scientific research.

The study presented here was inspired by the one performed by Ranga et al. (2003). The purpose of undertaking a similar study is to examine whether comparable results can be obtained in universities other than the Catholic University of Leuven.

As in the Ranga et al. (2003) and Van Looy et al. (2004) studies, scientific publications were used as an indicator of scientific activity. While publication data do not reflect all dimensions of the knowledge production process, they do offer an information-rich proxy for it, since publications in scientific journals are the primary means of diffusing research findings.

A sample of 40 professors from DTU, covering 38 different fields of research, has been selected at random from a total list of 127 full professors available from the university's webpage. Using the Science Citation Index (SCI) Extended database, a list was compiled of all publications in scientific journals during the period 1972-2004 for each of the professors in the sample. Only publications where DTU was listed as the author's address were included. Publications for which the author indicated another organizational affiliation may reflect research and publication practices, which are very different from DTU's practices, and were therefore not included in the data set.

A copy of the classification scheme maintained by CHI Research<sup>2</sup> has been obtained courtesy of the U.S. National Science Foundation. This classification characterizes the general level of research published in the journals covered in the SCI from 1973 to 2001, based on the Narin et al. four-level typology. The CHI classification (version 2003) was used to approximate the research level for each publication in the data set.

In seeking to understand whether Narin et al.'s four-fold typology of levels of research can provide more information on the existence (or lack) of tradeoffs between different types of research than the basic/applied distinction alone, this paper places particular emphasis on examining how the four levels are represented in the data set on an individual basis.

## Research questions

A list of four open-ended research questions guided the pilot study presented in this paper:

1. What general trends emerge over time from the publication data?
2. What relationship emerges between publications that appeared in "basic research" journals and publications in "application-oriented research" journals?
3. What relationships emerge between publications that appeared in journals oriented towards each of the four levels of research?
4. Is there a general growth in the number of "application-oriented" publications? If so, are there any indications that this has had a detrimental impact on the amount of "basic research" publications?

Based on the answers to the four research questions, the question of the possible benefits from applying a four-level instead of a binary conceptualization of knowledge production to understanding the existence (or lack) of tradeoffs in public research will also be explored.

## Findings

### *1. What general trends emerge over time from the publication data?*

The data collection exercise described earlier resulted in a total of 3111 publications. A number of the journals in which these articles were published were not classified according to the CHI classification system, based on which 206 publications were excluded from the data set, reducing the total number of observations to 2905. The excluded publications amount to just under 7% of the total number of publications in the data set. Since there are no indications

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<sup>2</sup> CHI Research is a citation research consultancy, specialized in the development of evaluation tools and indicators for science and technology analysis, and founded by Francis Narin in 1968.

of the research orientation of the journals in which they were published, it is unknown how these data might have influenced the findings.

A graph of the total number of publications (Figure 1) reveals a general increase in the overall number of articles to have been published by the professors in the sample during their employment at DTU. The graph also indicates a particularly steep increase during the 1990s and a slight drop-off in the total number of publications at the end of the 1972-2004 period. As Ranga et al. (2004) point out, this may be at least partly caused by a publication lag.

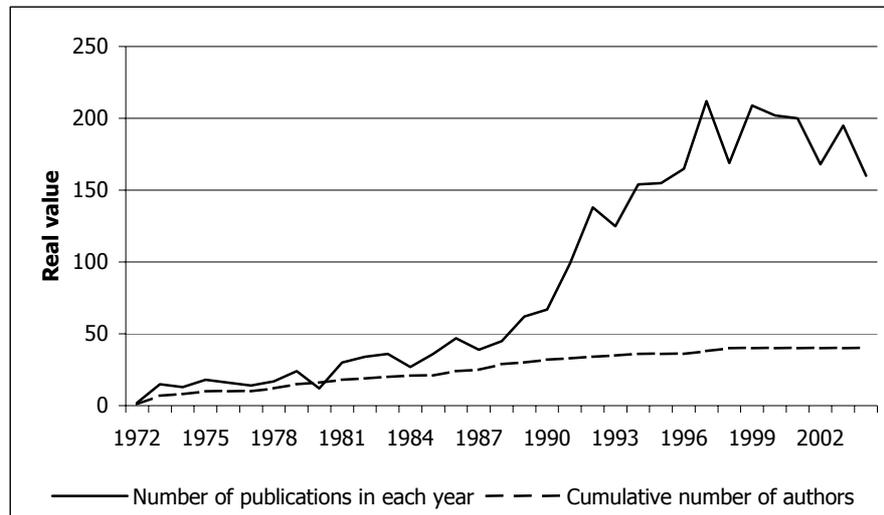


Figure 1. Number of publications in each year and cumulative number of authors (1972-2004)

Figure 1 also shows a steady increase over time in the cumulative size of the population studied. Part of the increase over time may be explained by the fact that some of the professors have started their academic careers at a later stage. However, since we are interested primarily in the relative quantities of publications at different levels of research, this does not carry vital implications for our analysis.

## 2. What relationship emerges between publications that appeared in “basic research” journals and publications in “application-oriented research” journals?

Table 1 below lists the amount of publications in the data set, in actual numbers and as a percentage of the total, distinguishing only between two levels of research. As evident from the table, a third of the number of CHI classified publications appeared in application-oriented (i.e. level 1 or 2) journals, while close to two-thirds of the publications appeared in basic research (i.e. level 3 or 4) journals.

Table 1. Publications by level of research, 1972-2004 (2 levels).

Variable	Number	Percentage of total
Total number of publications	3111	100
Excluded publications	206	7
“Applied research” (level 1 & 2) publications	1001	32
“Basic research” (level 3 & 4) publications	1904	61

This predominance of basic research – which is surprising since a technical university would be expected to engage in significant amounts of utility-oriented research – is further confirmed by a graph (see Figure 2 on the next page) of the overall trend for “basic” and

“application-oriented” research over time. We see similar growth patterns for the two groups, although publications in basic research journals appear to be growing at a slightly steeper rate.<sup>3</sup>

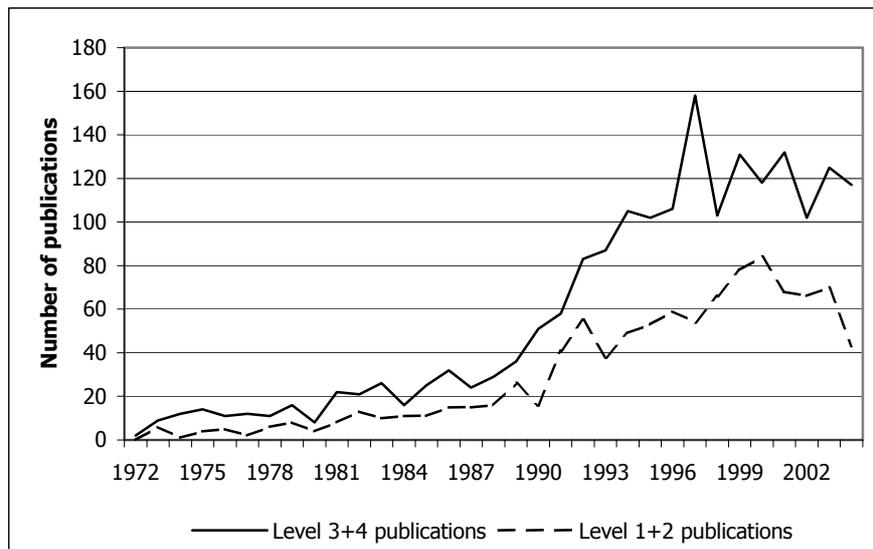


Figure 2. Publications in level 1 & 2 (“application-oriented research”) and level 3 & 4 (“basic research” journals (1972-2004)

3. What relationships emerge between publications that appeared in journals oriented towards each of the four levels of research?

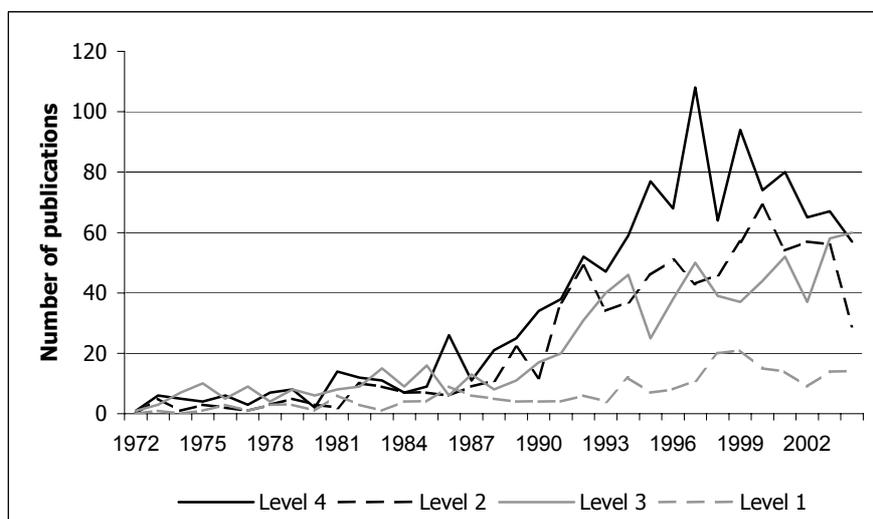


Figure 3. Publications by level of research (1972-2004)

Figure 3 above shows the distribution of publications according to the level of research ascribed by the CHI system to the journals in which they were published. This graph also indicates a majority of basic scientific research (level 4) publications. We also note a substantial amount of level 3 (applied research and targeted basic research) publications, followed closely by level 2 publications in engineering and technological science. Generally,

<sup>3</sup> An unusually high peak appears in the amount of basic scientific research (level 4) publications in 1997. An explanation for this peak requires an analysis of individual professors’ publication profiles, which is the next step planned for further analysis of the data, along with an increase in the size of the research sample.

we see a low amount of level 1 publications, in applied research, which is also the category that demonstrates the least growth over time.

Table 2 below contains information on the relative distribution of publications in each of the four levels of research across the data set. Surprisingly, in view of the fact that DTU is a technical university, level 1 (applied research) publications represent by far the smallest group at just 7% of the total data set, with 218 publications. In contrast, basic scientific research (level 4) publications dominate at 37%. Finally, 25% or 783 of the publications appeared in level 3 (engineering and technological science) journals, closely followed by 24% or 742 publications in level 2 (targeted basic research) journals.

Table 2: Publications by level of research, 1970-2004 (4 levels)

Variable	Number	Percentage of total
Total number of publications	3111	100
Excluded publications	206	7
Applied research (level 1) publications	218	7
Engineering research (level 2) publications	783	25
Targeted basic research (level 3) publications	742	24
Fundamental basic research (level 4) publications	1162	37

Based on the conceptual discussion at the start of the paper, it can be argued that level 1 (applied) research and level 2 (engineering and technological) research should be treated as two separate forms of research. If we aggregate level 3 (targeted basic) and level 4 (fundamental basic) research (see Figure 4 below), the patterns suggested by the graph in Figure 3 become even clearer. The predominance of basic research publications is still undisputed. The amount of level 1 (applied) publications is increasing over time, but only slightly. Level 2 (engineering and technological) research publications – which are also growing, although at a lower rate than basic research publications – are particularly interesting.

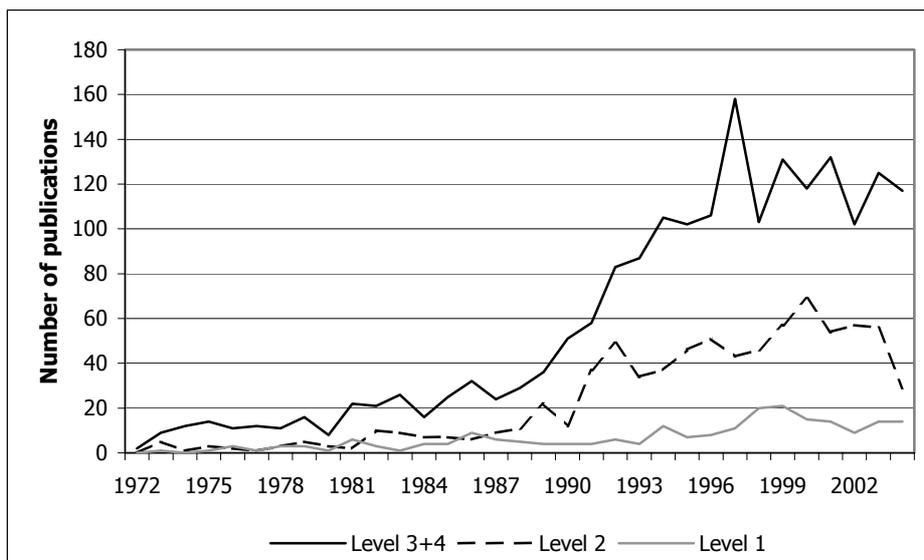


Figure 4. Publications in level 1 (applied research), level 2 (engineering research), and level 3&4 (“basic research”) journals (1972-2004)

Although fewer in numbers than basic research publications, level 2 publications account for the majority of application-oriented publications and represent a quarter of the total data set, suggesting that this level of research may deserve particular attention.

*4. Is there a general growth in the number of “application-oriented” publications? If so, are there any indications that this has had a detrimental impact on the amount of “basic research” publications?*

To confirm the trends indicated by the graphs presented above, the various publications variables have been regressed individually, as in Ranga et al. (2003), according to the model  $Y = A + B1X + B2X^2$ , where X is the independent variable Year and the dependent variable Y refers to the different publication variables (that is, publications in journals classified as level 1, 2, 3, 4, 1 and 2 combined, and 3 and 4 combined). The results of the regression analyses indicate the growth in real values of the different publication variables over time and can be seen in Table 3 below.

Table 3. Results of regressions of publication variables on the independent variable Year.

Variable	Parameter estimates <sup>4</sup>		Sign. F	R <sup>2</sup>
	Year	Year <sup>2</sup>		
Applied research (level 1) publications	0.0001	0	<.0001	0.68
Engineering research (level 2) publications	2.0488	0	<.0001	0.80
Targeted basic research (level 3) publications	1.6982	0	<.0001	0.82
Fundamental basic research (level 4) publications	2.8924	0	<.0001	0.79
“Applied research” (level 1 & 2) publications	2.5327	0	<.0001	0.83
“Basic research” (level 3 & 4) publications	4.5906	0	<.0001	0.85

The linear coefficients (B1) are all significant and confirm the trends described above. Level 3 and 4 (“basic research”) publications grow at a faster rate than level 1 and 2 (“applied research”) publications.

If we look at the growth of the individual levels, basic scientific research (level 4) publications grow at the fastest rate, followed closely by publications in engineering and technological research (level 2), and then by publications in targeted basic research (level 3). Level 1 publications, that appeared in applied research journals, grow by far at the slowest rate. Thus, neither publications in journals oriented towards level 1 or 2 research appear to have a negative impact on basic research activities.

In the following section, we discuss the findings of the pilot study and whether the Narin et al. typology of research levels generate useful information regarding the interplay between different modes of research not provided by an analysis that distinguishes solely between “basic” and “application-oriented” research. Possible implications of the findings as well as avenues for the further development of this paper and for further research are also discussed.

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<sup>4</sup> As in the regressions presented by Ranga et al. (2003), the non-linear coefficients (Year<sup>2</sup>) are set to zero because they are a linear combination of other variables in the model, because the real values of the independent variable Year are used in the regressions. Although the regressions presented here provide an indication of the rate at which the number of publications at the different levels of research grows, the model therefore cannot fully account for the development of the curves graphed in Figures 1-4.

## Discussion

Generally speaking, the data from this pilot study has revealed a much higher predominance of basic research publications than the study by Ranga et al. (2003). This may be explained by the fact that the professors in the DTU sample were picked at random, whereas the research groups examined by Ranga et al. (2003) were picked based on a known track record of collaboration with industry.

Like the Ranga et al. (2003) study, however, the preliminary findings from this study do not indicate the existence of a skewing problem. On the contrary, basic research appears to be thriving in the sample and is not negatively affected by either applied (level 1) or engineering and technological (level 2) research.

Moreover, the high degree of fundamental and targeted basic research, compared to a relatively high degree of engineering and technological research and a very low percentage of applied research, also opens up for an interesting discussion surrounding the nature of research undertaken at technical universities. Certainly the findings from this pilot study suggest that technical universities, at least DTU, can be oriented towards industrial relevance without compromising the proportion of basic research that they undertake.

The preliminary findings from the sample of professors from DTU thus do not disprove the proposition that the notion of a tradeoff between basic and applied research in public science may stem at least partly from our use of the linear model to conceptualize scientific research. The findings suggest that a more fine-grained categorization of knowledge production may provide a fruitful strategy for allaying concerns that public science engages in increasing amounts of application-oriented research at the expense of basic research. Even the simple application of the four-level typology already used in the development of R&D statistics generates significant information not provided by a two-fold distinction between basic and applied research.

If we disassociate the concept of engineering and technological science from that of applied research, the picture becomes even clearer. The preliminary analysis presented in this paper suggests that much university research, which is generally classified as applied research, can be more accurately characterized as engineering and technological research. As argued in the discussion of the conceptual background for the paper, this type of research constitutes a distinct and intermediate form of science between basic research – both fundamental and targeted – and applied research.

It is possible that level 2 research offers universities a way of delivering industrial relevance without engaging in applied research per se. If, however, engineering and technological research is seen as an independent form of science, this raises the question of whether universities have a comparative advantage in some or all forms of level 2 research, and whether their involvement in engineering and technological research is socially desirable.

This paper has attempted to take a small step towards a deeper understanding of the nature of the interplay between different modes of research, suggesting that the Narin et al. typology may indeed be a valuable tool in this and related endeavors. Naturally, there may be tradeoffs in individual decisions involving a choice between different forms of research. However, there are also great complementarities that can only be understood if we take a more nuanced conceptualization of scientific research.

There are indications that basic, engineering/technological and applied research should be seen as distinct but complementary modes of research, resulting in the production of knowledge with distinct cognitive characteristics and outputs, and that each of these categories makes an important contribution in understanding the nature of tradeoffs and complementarities in university research. Further research is needed to explore the cognitive nature of engineering and technological research vis-à-vis other forms of knowledge production. Moreover, the linear component of the Narin et al. typology – which, as

previously mentioned, has been a key weakness of the linear model – should be addressed in an effort to further our understanding of the relationship between different modes of research.

In addition to further analysis of the data presented here, the next step in the development of this paper aims to take a closer look at the publication records of individual professors, to examine how publication profiles are influenced by the length of the individual's academic career and choice of research field.

Also, not all research undertaken by university-based scientists is published. It is possible that the publication of some research activities may be delayed or entirely avoided, particularly if it was undertaken in collaboration with industry partners. Therefore, individual researchers' publication profiles will be compared with their degree of research involvement with industry (as measured by the amount of industry-held patents on which they are listed as co-inventor). This will also allow us to examine how publication profiles differ for scientists who collaborate regularly with industry and those who do not.

An analysis of individual publication profiles would also enable a study of tradeoffs and complementarities between different forms of research both at the level of the individual researchers and at the aggregated level for the university as a whole. For example, how is the general publication trend at a university influenced by the degree of research specialization of individual scientists? It would also be possible to examine how scientists with different research profiles and specializations come together in collaborative ventures, and investigate what level of research such ventures result in.

Secondly, similar studies could be repeated for a series of both mono-faculty technical universities and multi-faculty universities in Scandinavia. A study of, for example, one technical university and one multi-faculty university in each of the three Scandinavian countries, would provide an indication of the extent to which the results from this preliminary study can be generalized.

Finally, Ranga et al. (2003) advised against generalizing implications of university-industry collaboration across research fields. The relative distribution of different levels of research can be compared for different scientific fields, to explore whether patterns in knowledge production differ for various branches of the natural and technical sciences. If so, a taxonomy of patterns in the relationship between multiple levels of university-based research in a range of fields could be proposed.

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