Chapter 3

Are Some Technical Universities Better Than Others?

Mats Benner

3.1 Introduction: Are Technical Universities Birds of a Feather?

On a surface level, technical universities appear similar throughout the world: they provide professional training of engineers in the range of areas that fall under the epistemic and organisational category of ‘engineering’, sometimes aligned with adjacent areas, such as medicine, biology or the humanities. They conduct research to underpin that educational remit – and their development is closely aligned with those of its industrial and societal partners. Technical universities are education-focused but with a research function to underpin that mission, and they are strongly aligned with social forces in their evolution.

The impression is validated by an examination of the educational offerings of technical universities. They tend to have a similar core of programmes and areas irrespective of their location and history, and although they have gradually expended into other areas, the composition remains stable: mathematics, chemistry and physics, civil engineering, etc. form the foundation, and added to this, we find computer science (incepted in the 1980s), biotechnology and biosciences that emerged in the 1990s. More recently we have seen inroads into the cognitive sciences with the rise of Artificial Intelligence and other domains at the interstices of the technical and the humanistic. Most technical universities have also widened their remit and incorporated both education and research in the social sciences, with inroads also in the humanities, education and adjacent areas.

Technical universities as an organisational category have not been studied extensively, unlike their professional counterparts in the areas of business and medicine

M. Benner (✉)

Lund University, Lund, Sweden

KTH Royal Institute of Technology, Stockholm, Sweden

e-mail: mats.benner@fek.lu.se

(cf. Huzzard et al. 2017). This is somewhat of a conundrum: while specialised schools and universities in the areas of business and medicine certainly embody frictions between vocationalism and research professionalisation, and between public and private interests, that call for analytical attention, similar contradictions and tensions shape the technical universities. This notwithstanding, quite a few studies have been done of specific characteristics of technical universities, mostly with a historical bent: first and foremost as extensions of industrial interests within academic programmes (Edgerton and Horrocks 1994), later on as vehicles of national mobilization in the cold war period (Lowen 1997), or as intersections between government and corporate interests (Björck 2008), or as widely deployable infrastructures in the modernisation of local economies (Etzkowitz 2002). The most recent wave in higher education studies – of which the present anthology is a profiled example – locate technical universities at the intersection of different societal forces, which triggers organizational responses, albeit in a specific form based on the societal and cognitive specificities of technical universities.

What these studies have in common is a reading of technical universities as adaptable and embedded in society: their academic core is stable but also open to influences from areas outside that core, and that they respond to impetuses from sources and interests located outside the confines of academia. This combination of a core and an expansive periphery (both in epistemological and organisational terms) was epitomised in Clark's well-known study of "entrepreneurial universities". The very template of (and exemplars of) entrepreneurial universities was shaped by largely engineering-based higher education institutions (Clark 1998). Such entrepreneurial universities, Clark argued, were marked by "non-traditional" academic traits, such as a strong steering core, a culture of entrepreneurial achievements and a commitment to financial expansion, also in forms outside the traditional avenues of academic fundraising. The combination of strong steering and network-based enlargements was therefore epitomised in technical universities, especially those of a more recent inception (such as Twente, Warwick, Joensuu and Strathclyde in Clark's study), but also in older ones like Chalmers University of Technology, which – in Clark's reading – had been able to reinvent itself (and "steer itself" to use Clark's definition of an entrepreneurial university) despite its venerable age. Clark's analysis, which was clearly focused at the level of organisational structures and adaptations, indirectly also covered epistemic aspects of the entrepreneurial universities and their development. He inferred that the entrepreneurial trait also involves the capacity to explore and exploit interdisciplinary studies and areas that engage with issues deemed important by societal and industrial interests (Gibbons et al. 1994).

Does this mean, then, that technical universities form a specific university "species", marked by their articulated societal embeddedness and leadership forms that emulate those of their environments, and their capacity and ingrained orientation towards "new forms of knowledge production"? Or are there several subspecies of the technical university template, several different ways of interpreting and acting upon that template? These issues form the starting-point of this chapter: are technical universities with seemingly similar conditions and expectations different? And

why? To simplify the issue and to find a suitable way to highlight but also address organisational similarities and differences, the paper uses a simple empirical and analytical starting-point: the scientific impact of three technical universities. One of the universities, EPFL in Lausanne, Switzerland, counts among the most prominent universities in the world when it comes to scientific impact, and has the highest scientific impact among European technical universities, as measured in the share of its publications that is in the top 1% category. In fact, only two universities globally, Massachusetts Institute of Technology (MIT) and California Institute of Technology (Caltech), score higher than EPFL in this category. DTU is among the leading European universities in scientific impact, and ranks as number four among technical universities in Europe on this measure (after EPFL, ETH in Zurich and Delft University of Technology in the Netherlands). KTH, finally, is at a global average.

3.2 Explaining University Differences: A Brief Overview

There are different potential ways to highlight and analyse differences between different types of universities. Many contemporary studies of universities as organisations pinpoint how institutional mechanisms turn global and generic reform templates into emulations with little resonance with historical legacies and local practices (Musselin and Teixeira 2014). This juxtaposition of novelty and inertia creates organisational practices and leadership models that incorporate different institutional logics in parallel, with often ironic and unexpected outcomes. While this approach to the analysis of university governance is in many aspects laudable and intellectually clarifying, especially to decipher the often unexpected and ironic outcomes of policy reforms, a remaining analytical gap awaits to be filled, namely how we can account for variations between universities with roughly similar institutional conditions (in the sense that they are publicly funded and regulated). Why are publicly funded universities in similar political and governance settings doing this differently and with different outcomes?

For this topic, we may instead turn to another aspect of institutional theory, namely the strand which searches into divergence patterns and the continuous interplay between institutional conditions and performance (Hall and Soskice 2001). From such a perspective, similar tasks are embedded in different contexts, which leads to a variation in procedures and measures of goal attainment. Unlike the institutional studies conducted at the level of organisations, this strand is undeterred to make comparisons and judgements of the (variegated) outcomes of different institutional settings. Hence, the underlying assumption of this analytical strand is that there is a strong “institutional effect” – organisations should primarily be viewed and assessed as outcome of strong institutional determinants (e.g. Lane and Bachmann 1997). Some of the differences that are highlighted in our analysis may be relatively easily distinguishable, for instance, between private, well-endowed and small-sized universities on the one hand, and public, state-funded and large universities on the other hand – the former will most likely be predominantly

focused on reputation and selectivity whereas the latter will have accountability and access as their main characteristics (Bienenstock et al. 2014). A comparison between physics at Stanford University and Lund University (op cit.) revealed dramatic differences in scientific impact between the two, which may not be overly helpful in understanding how specific universities function in relation to goal attainment; it may, however, clarify how variations in institutional conditions produce very different organisational practices also within similar fields (history and physics, which were the cases chosen for Bienenstock et al.'s (2014) study).

In the present case we are comparing universities with similar preconditions and embedded in similar institutional systems (that is, cases that have been chosen because of their similarity, Porta 2008): publicly funded, broad in access due to public regulations, and with research-intensive counterparts in industry – and located in non-English speaking countries, which should diminish risks of skewed impact patterns (cf. Gingras and Khelifaoui 2018). To further elaborate the analytical template and to account for the differences in scientific impact, these general institutional conditions will be further refined, by investigating the following dimensions:

- Type of interaction with government, including funding profile and governance arrangements.
- Internal governance, including resource allocation and power and authority structures.
- Types of interaction with industrial and societal partners.
- Models of recruitment and promotion.

3.2.1 *The Topic*

In this chapter, I compare governance, organisation, leadership, and funding at three technical universities in Europe: the Royal Institute of Technology in Stockholm, Sweden (KTH), the Technical University of Denmark in Lyngby, Denmark (DTU), and École polytechnique fédérale in Lausanne, Switzerland (EPFL). The aim is to clarify why the technical university template, as outlined above, takes such different forms when it comes to scientific impact for universities with seemingly similar conditions. Is the template really as consistent as we have assumed, or are some institutional factors at play which influence approaches when it comes to scientific publishing? And is there a link between publication patterns and the other missions that the technical universities have? Underlying this issue is an assumption that there is a relation between modes of research practice, scientific publication patterns and scientific impact as measured by shares in high-impact (10%) publications. The validity of such measures for the analysis of individual institutions has been questioned (van Raan 2005) – such figures arguably do not take into account the considerable variations that shape and constitute higher education institutions, and risk affording a reified understanding of differences. On the other hand, such measures may be of more use if comparing universities with similar conditions when it comes

to their mission, profile, funding, and governance models. Using bibliometrics as a yardstick also enables a comparison, which has been fairly uncommon in studies of higher education institutions which instead tend to focus on specific factors or on individual case studies, thereby missing the opportunity to actually relate institutional factors to outcomes.

3.2.2 *Methods*

The article is based on a combination of sources. Interviews were conducted in 2012–2013 for DTU and EPFL, and continuously over the period 2011 to 2018 in the case of KTH (20 interviews altogether). Interviews were done primarily at the level of institutional leadership (presidents and deans) but also with individual faculty to match and map statements from formal leadership with those of teachers and researchers. In addition, secondary material has been collected in the form of strategy documents, financial reports, staff directories and minutes from leadership bodies, both to corroborate and validate interview data and to complement and update information that had provided earlier, as well as material that showcases the universities' activities and their networks, financial underpinnings, employment and promotion strategies, and other types of relevant information. Like Clark's study (1998), this study relies heavily on information provided through elite interviews; however, the discursive and potentially hyperbolic effect of depending primarily on leadership interviews has been mitigated through document studies and complementary interviews with faculty and staff. The bibliometrics is used for descriptive purposes and is derived from the publicly available Leiden Ranking database (www.leidenranking.com).

3.2.3 *Operationalisation*

In this chapter, I use a simple baseline for the performance of technical universities – their scientific impact as measured by their bibliometrical profile – and compare that to their organisational structure, forms of leadership and articulation with society.

3.2.4 *A Benchmark*

The three universities are roughly similar in size, and publish around 1000–1500 papers per year. Their respective publication patterns are also similar:

In the most recent Leiden ranking of the scientific impact of universities (covering 2012–2015), EPFL is among the most visible of universities worldwide, with a

citation level of 86% above world average for top 10% publications. DTU stands at 36% above world average. KTH, finally, is one (1) percent above world average. The pattern holds also if we extend the period under study: for 2006 to 2009, EPFL is at 73% above world average, DTU at 37% above world average, and KTH at 2%.

The three technical universities have a roughly similar scientific profile: in engineering and physics, their annual output is similar (around 800 publications annually). EPFL stands out with its significant presence in biomedicine and life sciences, about three times the size of DTU and KTH in these areas (with some 400 publications annually for EPFL). DTU and KTH have somewhat larger shares of activities in the social sciences than EPFL – even though the shares are small in comparison with those of other areas. EPFL and KTH are significantly larger than DTU in computer science and mathematics. Hence, the three technical universities have a core of engineering sciences and physics, which they combine with other areas in somewhat different proportions.

When it comes to the scientific impact of the respective areas of specialisation, the patterns are quite distinct. In engineering and physics, KTH is at the global average whereas DTU is 36% above the world average and EPFL 87% above it. In biomedicine, EPFL is over 100% above the world average for the top 10% category, while KTH, with almost 100 publications annually, is more than 40% under the world average, while DTU is 25% above it within this category. DTU is particularly strongly represented in highly cited papers within the life sciences, at around 70% above world average.

If anything can be said on the basis of the bibliometrical survey, it is that the EPFL has successfully diversified its activities into the life sciences and biomedicine. Even though those areas are still smaller in size than those of the core engineering school fields of engineering and physics, EPFL comes across as a hybrid technical university with a large and growing share of life sciences.

3.3 The National Role of the Universities

The three technical universities under study here are all “flagship” technical universities, and among the largest in their respective countries. EPFL is part of the Swiss federal structure of technical universities and belongs, together with its sister university in Zürich, ETH, to that structure. Even though the relationship between EPFL and the Swiss government can be considered as demanding, where the President is held accountable not only to the overarching ETH Council but also the Swiss Federal Council, the relationship is marked primarily by trust – “one line in the budget suffices to define the budget of the university” (Interview: EPFL leadership; cf. Kleiber 1999). The same type of relation has historically been translated into internal governance of the technical universities in Switzerland, with the ETH Board setting only rather general goals; the latitude at lower levels is therefore considerable. As Griessen and Braun (2008) have noted, there are frictions and incompatibilities in the Swiss science and technology policy system, including a divide

between the federal and the state levels, and between basic and applied research, but the ETH system occupies still a privileged zone in policy-making with limited fluctuations both financially and expectation-wise. If anything, the EPFL has been well-served by the commitment of the federal level to propel the competition between the two federal universities, and to elevate the relative position of the EPFL vis-à-vis the other technical university, ETH in Zürich, which has traditionally been far superior in rankings and international visibility.

If the Swiss system is very much based on trust and long-term commitment from the government, Danish university governance is an almost ideal-typical adoption of New Public Management, with performance indicators formalised in contracts which survey and measure the activities of its universities (Foss Hansen 2016). DTU, as all Danish universities, operates under the auspices of the Ministry of Higher Education and Science, and has its relationship with the government formalised in a multi-annual development contract. The contract covers a combination of points raised by the government and of the university itself. DTU's contract includes a combination of employability concerns and scientific measures, such as the number of indexed publications and relative citation impact with comparisons made to other "top" technical universities in Europe, such as EPFL and KTH. The contract operates in parallel with and as a non-monetary supplement to the model of funding allocation, which is based on a combination of the number of students, the scientific impact, number of PhDs produced and the size of the external funding. The Danish government has also formalised and streamlined the mechanisms of university governance considerably in the last decades, and has pushed universities in the direction of appointed leadership styles, with considerable managerial discretion, and expectations that the formalised leadership should set internal goals and performance indicators along the lines of the relationship between the government and the higher education institutions.

The Swedish governance system is the most complex of the three as it combines elements of a trust-based (historically founded) allocation of resources for research with performance-based indicators that shape a tenth of resource allocation. This mix of trust and performance is combined with a sizeable part allocated through contracts and agreements with the state. Swedish universities, especially those which are research-intensive, rely considerably on external funding of research, which in the case of KTH consists of more than 60% of the total resource basis for research – which can be compared with 20% for EPFL and 35% for DTU. External resources come in a very large plurality, ranging from European Research Council grants to commissioned studies from local authorities. The main funders are the Swedish Research Council, the European Union, the Wallenberg Foundation and the Swedish innovation agency, Vinnova. For education, Swedish universities rely on an allocation model based on a combination of admissions and degrees taken, with no guaranteed and unconditional funding. University governance reflects the complexity of the funding of universities in Sweden, with a mixture of bottom-up and top-down mechanisms, and with a general vague foundation of leadership tasks and roles (SOU 2015:92).

As to the educational profiles of the three universities, they are similar: KTH has nearly 13,000 students enrolled in 24 different educational programmes at the bachelor's and master's levels and nearly 2000 PhD students. DTU has around 11,000 students at bachelor's and master's levels in some 50 different programmes and 1300 PhD students. EPFL, finally, has around 8000 students and bachelor's and master's levels in 37 different programmes and around 2000 PhD students.

For funding, DTU has a total turnover of 5 billion DKK, and a research turnover of 3.6 billion DKK (440 million Euros), of which 53% (1.9 billion DKK or 240 million Euro) comes directly from the government. EPFL has a total turnover of almost 1 billion Swiss francs (860 million Euros) of which two thirds are for research – and of that, almost 70% comes directly from the government. KTH has an annual turnover of 5 billion SEK (500 million Euro). Of its research turnover of 2.5 billion SEK (250 million Euros), 44% comes directly from the government and the remaining 56 through third party support.

As to the structure and composition of the academic staff, KTH employs 300 full professors, DTU 240 full professors; EPFL on its side has only 350 faculty altogether, of which half (170) are full professors. EPFL, while small in size when it comes to its faculty, has a significant pool (over 1000) employed as staff scientists and post-docs, in addition to the sizable number of PhD candidates.

Another important aspect of the respective universities is their faculty composition in terms of nationalities. One straightforward reason why this is important is that has been a stated preference for DTU and EPFL to internationalise their faculty; another is the theoretical observation of an interplay between the composition of a university's faculty and its managerial models (internationalisation driving a more generic and vertically integrated leadership style; Bartell 2003).

It is difficult to ascertain the number of foreign recruits to the different universities, at least for KTH (Swedish law does not permit records of ethnic backgrounds of students or staff). Sweden and Switzerland are among the most internationalised countries when it comes to the composition of the scientific workforce, and for Switzerland it is clear that internationalisation is a characterising feature of recruitments at both the level of professors (about two thirds of the faculty is non-Swiss) and among PhD candidates and post-docs. KTH, in contrast, has the main share of its international scientists employed only at the level of PhD candidates and post-docs, but significantly fewer at the level of professors and other tenured positions. A rough estimate, provided by a member of KTH management, is that about 10% of KTH faculty is non-Swedish. DTU, finally, is again somewhere in-between: a senior member of the leadership team at DTU estimated that one third of DTU faculty is non-Danish, and DTU is also strongly oriented to international recruitments among senior members of the faculty. To sum up, then, 10% of faculty at KTH is internationally recruited, 33% are non-Danish at DTU and EPFL's is overwhelmingly international at 66% of total faculty. We assume that these differences in recruitment pattern will affect the governance and leadership of the higher education institutions.

The funding and employment patterns therefore differ significantly. KTH has a large pool of full professors, largest of all three despite the fact that is significantly smaller in economic terms, at least as concerns its research component. Part of the

explanation resides in the larger educational remit of KTH, but another and more important in the construction and constitution of the professorial position. KTH professorships are predominantly promoted professors, where internal candidates at KTH have had their qualifications tested.

EPFL and DTU also have, however, far more restrictively, the possibility of promotion. EPFL professorships are fully endowed, and come with significant additional resources: assistant professors receive generous starting-packages enabling them to form research groups on the basis of university funding, which can then be complemented by external sources. KTH, on the other hand, has no, or at best highly limited, starting packages for junior professors while senior professors receive no supplementary funding and in most cases also are expected to raise parts of their own salaries from external sources. Funding of PhD candidates and post-docs is also largely tied to external funding sources. DTU is similar to KTH in that professors have only limited extra resources attached to their positions. However, the departments are in disposal of more support staff as well as internal funding of PhD candidates.

3.3.1 Governance: Similar Issues, Different Models

Governance issues have already been touched upon briefly, as part of the contractual relationship between the state and the universities in their respective settings. We argued that governance at the level of universities in its turn is shaped by the relations that governments set up with their respective universities. In the Danish case, we depicted a New Public management-inspired model which is institutionalized through a the combination of a rather straightforward model of resource allocation intertwined with a contractual relation where the state articulates a set of specified goals, conjointly with universities which in their turn present some goals of their own. In more elaborated terms, DTU, EPFL and KTH represent three different approaches to the governance of universities and their alignment with societal missions. DTU, which started out as a strictly domestic and residual institution in a society and economy dominated by the primary sector, has been gradually transformed into a spearhead of a national developmental model taking form in the 1990s and onwards. In this model, expressed and embodied in the ideal of a “globalized, knowledge-based economy”, universities were singled out as a critical resource in the redeployment of Danish society (Benner 2003). The successive university law reforms in the 1990s and 2000s transformed the governance of Danish universities and empowered the previously mostly ceremonial roles as rector, deans and head of department. DTU was the exemplar institution in this development, with a leadership and governance model that caused enormous controversies at the time, but it also fostered a much streamlined academic organisation, with clear-cut ambitions when it came to the recruitment and promotion of staff, the modernisation of DTU’s facilities, an upgrading and modernisation of DTU’s educational offerings, and enhanced interactions with external partners (Interviews: DTU board member, DTU

leadership, DTU faculty). More specifically, that model includes a clear-cut division of labour between different management levels: the board sets general targets and strategic directions in tandem with the rector. The president operates together with a leadership group (executive team), and the president together with this group exercises a strong influence on decisions to hire senior staff and department heads. Departments, in turn, have a considerable leeway within the confines of this governance model when it comes to hiring decisions, strategic orientation, networking and alliances. A few events which have received large attention have showcased the centralisation of power around the president, for instance when individual professors have been forced to leave or when department heads have been dismissed. DTU is therefore shaped by a tension between centralisation and decentralisation, which has caused some visible strains but which seems also to have empowered an academic culture which is geared towards international visibility and networking. From the board's and the management's perspective (as well as the government's), this reorientation of DTU has paid off, and a (purportedly) myopic institution has been transformed into a global elite institution. In its most recent strategy, DTU also sets the goal to be an elite university, counted among the five best technical universities in Europe (DTU strategy 2014–2019; <http://www.dtu.dk/english/About/ORGANIZATION/Strategy>).

EPFL is founded and governed to serve as a global, elite institution, and its funding and overall directions afforded by the government are unambiguously oriented in that direction. EPFL leadership in turn has been very dedicated to streamlining the relationship with lower levels of authority and relegating tasks and authority accordingly. Deans are recruited internationally, as are – to some extent – heads of the EPFL institutes. Decisions to hire and promote are taken at the dean's levels, after considerable inputs from the departments and final vetting from the President. In this respect, EPFL has emulated a governance style similar to that of leading US universities, where the President sets the strategic directions, is in charge of relations with the patrons, does large-scale fundraising and is responsible for the hiring of faculty leaders, where the faculty leadership is tasked with the role of hiring faculty and aligning its organisation with specific conditions pertaining to the respective faculties, and where departments function as the primary site of activities with the role of the department leadership to ascertain a high level of internationally competitive research and teaching. This model marks a break with the highly decentralised way its sister university in Zürich (ETH) is governed, where the departments are the main site of power and resource allocation, without the intermediary level of faculties and schools (Interview: ETH professor). It also marks a break with the traditional way EPFL was governed, where even departments were weakly structured internally and where individual professors determined the direction of their activities and those of their professorial domains (Interview: EPFL leadership). EPFL has not been without controversies and clashes, and the highly visible and directive leadership has resulted in both considerable gains in international visibility and in internal strains; the most recent and visible example are the controversies surrounding the flagship project “Blue Brain Project” (cf. Frégnac and Laurent 2014).

KTH, finally, is a mixture of expectations and leadership roles. The university president's role is not entirely clearly defined, more than that it should serve as the ultimately responsible. The heads of school (equivalent to deans) have a clear-cut and continuous relationship with the president and university management. However, the schools are quite large and diverse, and the relationship between the school management and administrative levels below show a bewildering variety. Given KTH's broad-based and complex funding base, and the many different funding sources – each with its specific set of expectations and obligations – leadership and authority thus appears variegated and shaped by the tasks and funding available at the different divisions and departments at KTH (cf. Geschwind and Broström 2015). This does not mean that the formal leadership does not aim to make an imprint. The main expression of this has been a series of reorganisations, done mostly, critical observers note, to ensure that the university leadership exercises some power in the organisation (Interview: KTH professor). Decision-making when it comes to recruitment and promotions are nominally controlled by formal levels of authority but in many (but not all) cases tied to funding opportunities. As an example, KTH has hired a large number of professors in areas richly endowed with funding but with only small number of students: “we have five professors in the area of (X) and some 12 students at the advanced level in the same area – this does not make sense” (KTH head of school). Hence, the KTH governance model is eclectic and complex, with multiple power and authority sites and fuzzy demarcations between the different levels. While this may again be interpreted as a flexible and pragmatic stance in a national governance landscape which is more variegated than the Danish and Swiss counterparts, it risks leading into goal conflicts and also unproductive impasses when different interests try to enforce its influence: the relationship between what is decided at the level of the President, the heads of school, departments, and individual research groups seems not entirely clear to any of the actors. This shows also in the model of recruiting and promotion, which is largely tied to the supply of external funding rather than to internal considerations. Unlike DTU and EPFL, KTH does not seem to use its internal forums for systematic consultations of hiring needs, potential candidates inside or outside of Sweden, or complementarities between areas that new recruits could fill. This is, instead, largely seen as the remit of individual research groups and areas, dependent on their success with funding agencies.

3.3.2 *Industrial Relations*

A technical university has traditionally been defined by its industrial connections, with its educational profile shaped by the expectation of the industrial environment, and the research function serving as a supportive infrastructure for the educational role – and consulting and informal networks as the primary form for knowledge exchange between academia and industry.

Arguably, the current model of university governance makes the forms of industrial relations for technical universities more variegated and even more central, but in slightly different ways than in earlier periods (Geuna and Rossi 2015). Industry serves as a significant source of direct funding of research, but also as a partner in research activities, shown also in corporate support of research and education facilities, shared infrastructures and the like. All three universities under study here have extensive industrial contacts and networks, but they serve somewhat different purposes. DTU operates in a largely network-based form, and is embedded in a knowledge-intensive industry with tradition as working as supporters of academic research and academic environments. Several of these companies have afforded resources for laboratory facilities, recruitments, exchange programmes, and the like. DTU has been able to capitalise on its industrial partners, which through forms of ownership and control are largely tied to Denmark and which therefore have cultivated strong linkages with academic partners – and which therefore have welcomed the reforms of academic governance in Denmark with a more elaborated leadership structure, which they view as more conducive to industrial partnerships (Interview: Board member DTU). For DTU, this taken the form of a series of partnerships with Danish firms and the conjoined investments in new facilities in the biosciences and biotechnology.

Switzerland and EPFL have adopted an aggressive policy to obtain endowments and support from adjacent actors and organisations, witnessed in spectacular endowments for buildings but also for research centres. This reflects in part the environment of EPFL, with several large multinational firms sited in Switzerland for a variety of reasons, but also the model adopted in the governance of EPFL, namely an emulation of US private universities and their network-formation around donors and corporate beneficiaries (cf. Mathies and Slaughter 2013).

KTH, finally, has a more mixed model of interacting with its industrial partners, formalised into a series of designated “partnerships” which stipulate a number of interdependent commitments on behalf of the partners, but relatively little in terms of actual contributions for research centres, buildings or similar. What KTH has been able to capitalise on is its historical ties to the dominant ownership centre of Swedish industry, the Wallenberg family, which through one of its research foundations (Knut and Alice Wallenberg Foundation) has been very supportive of three of KTH’s pillars: research in forestry (tied to the interests of the Wallenberg family in StoraEnso), in biotechnology and genomics (tied to the family’s engagement in AstraZeneca) and in information technology and artificial intelligence, related to its large share of ownership in the telecommunications firm Ericsson. Hence, KTH relies even more strongly than DTU on bilateral relations with a very limited set of partners, and is very far from the aggressive and multipolar industrial relations strategy of EPFL. The fact that KTH’s partners are also part of a more complex ownership structure than DTU’s partners may also – from a long term perspective – hamper KTH’s possibilities to extract value from its partnerships.

3.4 Discussion

Overall, power, leadership and governance (at both the level of the political alignment and intra-university decision making) appear probable as explanations of the differences in scientific impact among the three universities. The leadership models vary between the universities – largely based in different national models for university governance. DTU is shaped by the Danish model of a high degree of centralised control to top leadership, with a tandem-like relationship between the rector level and departments when it comes to goal setting and accountability. The same applies to the relationship between the government and DTU, which is moulded by contracts between the two, specifying the goals of DTU's activities in rather elaborate detail. The contract also incorporates yardsticks – including the EPFL and KTH – when it comes to the number of indexed publications and the citation impact of DTU publications. A particularly important factor behind DTU's development seems to have been the reforms of its leadership and organisational templates, which have moved from a highly decentralised and variegated model to a streamlined ideal. EPFL is even more elaborately organised, with a clear-cut differentiation of goals and means available at the level of the President, deans and heads of departments. EPFL's model and status derives from its special relationship with the federal government: the university is lavishly funded and the relationship with the Swiss Federal Council is mediated through the ETH Council; the expectations on the ETH universities are broad and in practice focused on visibility and prestige, and the accountability of the EPFL vis-à-vis the government is therefore demanding but unambiguous. The push that EPFL experienced in the late 1990s illustrates the importance of direct governmental intervention to reinvigorate the university, and the political commitment, despite political changes elsewhere, to globally leading universities. KTH is the most complex of the three when it comes to the distribution of power and authority within the organisation: the relationship between president, dean, heads of school and department heads is not entirely clear and the responsibility for resource allocation and recruitment is divided between the different levels, with a significant input also from an advisory function. And in addition, recruitment is to a significant degree contingent upon the obtainment of external funding, which is far less common for the other two technical universities. The relationship with government is also more variegated than those of its counterparts, without the contractual foundation of the DTU and the EPFL but instead a mixture of inputs. However, the most striking difference between KTH on the one hand and DTU and EPFL on the other is the composition and structure of its financial underpinnings for research: not only does KTH receive less in total appropriations for research, it receives the main share of that funding in the form of external (third stream) funding, tied to individual projects and research groups. Despite a vociferous critique of the composition of research funding in Sweden and its (alleged) consequences on research quality and the alignment between education and research (Bienenstock et al. 2014), there are no signs of a political reorientation. The government remains committed to external funding as an important measure to direct the Swedish

universities' activities, and great stress is placed on the design and implementation of governmental research programmes and initiatives.

Industrial relations are similar between the three: all have significant direct funding from industry, at around 10% of total turnover for research. They have all secured significant private endowments for infrastructural investments, and for new facilities at significant levels for all three. The industrial partnerships are particularly broad-based for KTH, showcasing the university's strong ties with Swedish industry in its breadth ranging from forestry, biosciences over to ICT and transportation; DTU and EPFL have a somewhat narrower industrial ecosystem, which can be explained by the composition of their economies with heavy dominance of bio-related industries. Arguably, the mandate and role of KTH are more complex due to the variegated expectations of its different constituencies and eco-systems.

When it comes to the final aspect of the governance model that we have used as our analytical template, namely recruitment and promotion, we find a striking relationship between governance and funding on the one hand, and faculty promotion on the other hand. DTU, and even more strongly EPFL, identify themselves as international universities with global recruitments in particular on a senior level: EPFL recruits around two thirds of its senior staff internationally and DTU is also actively engaged in international recruitments. The number of faculty positions is also very different between the three universities: EPFL, despite being the most generously endowed of the three universities has by far the smallest number of professorial positions (but a very large number of support staff and staff scientist positions), while KTH has a significantly higher number of professorial faculty but fewer intermediary and supportive positions. DTU is in-between, but has seen a hike in the number of professorial positions more recently, where the influx of external funding has been translated into the creation of temporary professorships. The construction of professorial positions is also radically different in the three cases, with a fully supported model at EPFL with adjacent resources secured by the university including starting packages for junior professors, with DTU having a more eclectic model of supporting its faculty, while KTH relies primarily on external funding for the provision of supplementary resources for its personnel. KTH's economy is also based on the assumption that many (if not all) of its professors raise parts of their salaries through third-party funding. Even though there is not explicit policy in this direction, there seems to be considerable pressure to use parts of funding, also from prestigious sources (such as the Wallenberg foundation), to fund own salaries.

To sum up, how technical universities are governed and funded impacts on their scientific impact profile. DTU, EPFL and KTH, while sharing many characteristics, function and are organised in quite distinctly different forms. EPFL can be interpreted as an emulation of elite universities in the US, with a small, competitively selected international elite as its faculty, richly endowed in resources provided by the university and with external funding as an add-on and as a sign of the competitive standing of its faculty. KTH on its side has a largely in-house trained and recruited faculty, which relies heavily on external sources for the provision of resources and infrastructures for their research, and for the recruitment of additional staff. KTH is a national institution, even though it too increasingly hires staff

internationally, albeit primarily at the level of PHD candidates and post-docs. DTU is a blend of the two, less global and elitist than EPFL, but more selective and resourceful in relation to its recruitments than KTH, and with a much clearer and stronger steering core. They certainly share many characteristics as technical universities operating at the interstices of professional education, academic research and societal collaboration, but the way they do it and their way to enact the technical university template varies to the extent that their similarities are overshadowed by the differences.

Is one or the other of the universities better than the other? EPFL clearly comes out as the leading scientific institution of the three, based on generous endowments, streamlined governance and a recruitment policy deeply entrenched in the international labour market for elite scientists (and with salaries to match). While this strategy has certainly paid off and elevated EPFL to the status of a globally leading institution, it has come at a considerable strain, dramatically exemplified with the governance crisis of the neuroscience flagship initiative. KTH is the exemplar “civic university” (Goddard et al. 2016) or “new flagship university” (Douglass 2015) which serves many different constituencies, with only limited ambitions to compete consistently at the globally leading level. While this balancing act can be seen as successful in its own right, squaring legitimization with international visibility, it does not come without strains and contradictions, not least concerning the fuzzy expectations on university leadership, which has led to a series of stop-go policies at the level of the university president. DTU has evolved in a process described both as highly successful and traumatic, as the beacon of the Danish government’s ambition to transform its universities from insularity to global recognition. Controversies have circled around the exercise of presidential power but also a series of rather radical redeployments of resources and faculty at the level of departments. DTU’s transformation has been largely exercised from above and the main challenge for DTU is if this momentum can be reproduced over time.

A critical reading of our analysis might infer that the issue is far less complex than we have made it into and that the three universities, despite their superficially similar starting points (public universities in non-English speaking contexts), actually operate in three separated institutional settings with adjacent funding models: the Swiss which views its elite universities as global institutions which should be governed and funded accordingly; the Danish which strongly emphasises the international visibility of its universities, and which operates with a streamlined governance model with performance targets as guiding principles; and the Swedish setting, finally, which is more meagre in its funding also of research within elite universities and which views its universities as containers comprising quite distinct missions and goals which the universities are expected to somehow square and align. This, in turn, is translated into funding levels, which vary considerable between the three, with EPFL operating at the level of well-endowed private universities in the United States of America as their benchmark, DTU which is well above a European average when it comes to funding levels and which serves to protect its research mission from an overload of goals and tasks beyond those of a bare

minimum for public universities. KTH, finally, is a complex mélange of activities and funded accordingly.

While these are reasonable caveats, pointing at the relationship between inputs and outputs as a strong explanatory factor behind the differences in scientific impact, it disregards how different funding models are embedded in institutional settings. DTU is governed with a set of goals as the starting point, and organised along those lines. EPFL similarly has effected a governance model, which is relatively streamlined and it is assessed accordingly by its patron. KTH, as a contrast, operates with several different logics in parallel, which gives it, and its patrons, a higher degree of latitude but which also translates into a more complex and opaque set of expectations. This in turn has created an internal governance model, which is less stable and more prone to variations and turbulence over time. This is not entirely tied to funding but rather a more or less deliberate choice, to view the university less as a coherent organisation and more as a collection of different tasks with little alignment. When power and authority are superimposed on this, for instance, when an incoming President aims to take control over the direction of the university through reorganisations that may not serve the goals of long-term renewal or quality-enhancement but rather comes across as mere politicking.

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