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Where science meets business

Universiteit Leiden

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Mijnheer de Rector Magnificus, mijnheer de decaan en leden van het bestuur van de Faculteit Wiskunde en Natuurwetenschappen, dames en heren hoogleraren, dames en heren van de wetenschappelijke en de ondersteunende staf, dames en heren studenten en voorts gij allen die deze plechtigheid met uw aanwezigheid vereert,

Ik spreek deze tekst uit in het Engels.

The Dutch university landscape is changing. Key scientific institutions such as NWO - the national science funding organisation, are being overhauled. Moreover, the 'national science agenda' [de Nationale Wetenschapsagenda] and the 'top-sectors' policy [het top-sectoren beleid], are pushing universities ever deeper into new territories. Upcoming parliamentary elections and the formation of a new government will likely bring further changes to the status quo. One ambition that is an important driver of all these changes is to bring science and business closer together, with the purpose of strengthening innovative capabilities and the competitive position of the Dutch economy.

As a result, the questions that I will address today seem more pertinent than ever before: 'What is and should be the role of universities in supporting business?', 'How can business benefit more of relationships with science?', 'And what is the role of policy makers in supporting a productive relationship between science and business?'. How we address these questions is not only critical to the future trajectory of our economy, the types of jobs and industries we cultivate and the technological progress we will make as a nation. It also has a bearing on the work we do in our other roles as academics. The questions we ask ourselves in our research, the kind of citizens and workers we educate and the professional identities we take on ourselves. Accordingly, I applaud the Board of the University and the Faculty of Science, for creating this new Chair of Science Based Business and putting in me the faith to be its first occupier.

The intersection of science and business has been the focus of my research and teaching of the past 15 years. Thus, to answer the questions of this lecture, I will first walk you through some of my scholarly contributions. Based on these contributions, I will make the case to you today, that in the European context, broad, major Dutch research universities like ours, have a structural advantage in working with business to fuel innovation in key economic growth-sectors. I will then talk about challenges we face in capitalising on this advantage. I will focus on three stakeholder groups: policy-makers involved in science policy, managers of companies seeking to benefit of ties to academic institutions and universities facing pressure to be more actively engaged in industry innovation.

The role of fundamental research

My research has examined the interactions between science and business from different angles. First of all, focusing on universities, my research on the history of the biotechnology industry in the San Francisco region affirms the critical role of *fundamental* research - that is research, for which practical applications cannot be foreseen *ex ante*. The biotechnology industry is one of the most important new industries that emerged from university laboratories over the past decades. It finds its origins in the laboratories of biophysicists, biochemists and geneticists, who were working on questions about the molecular, genetic underpinnings of life.

Molecular biology, which finds its origins in the 1930s and 1940s, was a field of scholarship that was not associated with any significant therapeutic, commercial utility during much of its history. Advances in the early decades of the field were mostly made in the experimental context of bacteria and viruses, rather than in the context of human biology. This all changed with the development of new genetic engineering techniques during the 1970s. It was from research groups working on these techniques that the first biotechnology firms emerged during the late 1970s. These firms used genetic engineering techniques to produce protein drugs such as insulin and human growth hormone. And it was from these lines of scholarly enquiry that an industry grew that is now worth hundreds of billions of euros of annual sales.

Organisational experimentation

Second, the creation of new science-driven technological fields is often tied to the development of new epistemic logics and organizational models for producing scientific knowledge. I demonstrate that this requires universities to provide *free spaces* for processes of organisational experimentation, in which scientists for example have the freedom to develop novel research programs that build new cross-disciplinary links. My research on the history of the biotechnology industry in the San Francisco Bay Area illuminates the importance of such free spaces for organisational experimentation within universities.

I studied the role of three San Francisco-region universities in the development of the American biotechnology industry during the late 1970s and 1980s: Stanford University, the University of California at Berkeley and the University of California at San Francisco (UCSF).[1] Focusing on universities in one region allowed me to zoom in on how university-level organisational factors explain variations in the support for entrepreneurial spin-off firms. This focus allowed me to control for other factors such as the local presence of specialised financing services for entrepreneurial ventures, legal services for start-ups and cultural characteristics conducive to entrepreneurship that were available in equal measure to spin-off firms from all these three universities. In addition, I was able to account for the quality of research as the molecular biology groups at these universities were all highly regarded - for example as indicated by publication counts and their place in rankings.

The puzzle, which was the starting point of my research was that UCSF rather than Berkeley or Stanford played the leading role in spinning off pioneering firms during the early days of the biotechnology industry. When I conducted my research, I found that six of the top-10 biotechnology firms in the San Francisco biotechnology industry measured in market capitalisation were UCSF spin-offs. It was particularly surprising that Stanford didn't play a more central role in the development of the biotechnology industry. That university has been a world-leading model for technology transfer because of its sophisticated technology transfer organisation. It also has a track record of spinning off extraordinarily successful spin-off firms in the information and communications technology area. Stanford faculty and alumni played an important role in the development of firms such as HP, Google, Yahoo, Intel, Sun Microsystems and Cisco.

To understand better why scientist entrepreneurs from UCSF were better positioned than their counterparts at other universities to build up successful biotechnology firms, I first examined the distinctive organisational challenges these firms faced in developing new drugs. On the one hand, the challenge of organising research and development - R&D - at early biotechnology firms was very similar to organising academic research at top molecular biology laboratories. Using new genetic engineering techniques in developing drugs during the late 1970s and 1980s required firms to use knowledge from the very edge of the scientific knowledge frontier. Laboratories at early Californian biotechnology firms such as Genentech, Chiron and Amgen were as much focused on cutting-edge science as their academic counterparts. My research for example found that molecular biologists at the biotechnology firm Genentech out-published their counterparts at key molecular biology departments at Berkeley and Stanford in the journals *Science* and *Nature* for much of the 1980s.

On the other hand, I found notable differences in organising commercial R&D at early biotechnology firms and some of the academic molecular biology laboratories I studied. Moving forward the process of developing new biotechnological drugs required corporate R&D organisations to incorporate knowhow and skills from across a wide range of disciplines.

Successful projects ended up relying on input from researchers and collaborators with expertise and skills in fields such as biochemistry, genetics, biophysics, structure biology, chemistry, pharmacology, bioengineering, bioinformatics, in addition to the various applied clinical disciplines that were relevant to a project.

Examining the organisation of molecular biology research at Berkeley, Stanford and UCSF, I found that molecular biologists at UCSF relied to a much larger extent on interdisciplinary collaborations in their research than their counterparts at Berkeley and Stanford. Moreover, I found that UCSF scientists were able to rely on their interdisciplinary networks as a comparative advantage in advancing research and development at spin-off firms. These interdisciplinary networks were formed during the 1970s after the university had recruited William Rutter, a professor of biochemistry and biophysics, to lead new initiatives in the area of biomedicine at the university. Rutter came to UCSF with the plan to launch research programs transcending individual disciplinary agendas, focused on uncovering the genetic underpinnings of biological processes in more complex organisms such as humans. The programs that Rutter launched at UCSF differed from the more narrowly defined disciplinary research agendas pursued by molecular biologists at Berkeley and Stanford at the time. These were more oriented towards the study of biological processes in simpler organisms such as the E. coli bacterium. Over the course of the 1970s and 1980s Rutter attracted a community of scholars with different disciplinary backgrounds to UCSF's biomedical research departments with a common focus on a clinically relevant research agenda. Doctoral training programs across the biomedical research departments at UCSF were also integrated into a single program in biological sciences.

Accordingly, a community of molecular biologists developed at UCSF that was more interconnected across disciplines than the communities at Berkeley and Stanford. My analyses found that in 1979 approximately 50% of publications coming out of UCSF's main molecular biology department had authors listed from at least one other UCSF department. Less than 5% of publications of scientists of Berkeley's and Stanford's molecular biology departments had authors listed from another department at these universities. I was able to link the progression of therapeutic product development projects of several UCSF spin-off firms to the interdisciplinary networks of expertise and skills, these firms were able to rely on.

The impact of science-based business on academia
In subsequent research, I examined how the proximity of major clusters of science-based firms and the close involvement of faculty in these clusters shape the organisational development of universities.[2,3] My research has outlined three effects.

First, major campus-wide research and teaching initiatives led by faculty involved in industry tend to emphasise the value of interdisciplinarity and research agendas that are aligned with surrounding industries.

Second, I found that faculty members promoting these initiatives enjoyed significant advantages in internal political struggles for academic resources.
Some of the defining initiatives on the Berkeley, Stanford, and UCSF campuses during the decades following the birth of the biotechnology industry were led by faculty with close relationships to industry. These include:

- The launch of new initiatives at Stanford - most notably the Beckman Institute and Bio-X initiative - that brought together scholars on the Stanford campus around research agendas in health, from an ever increasing number of disciplines - including from law, the social sciences and the humanities.
- The reorganisation of the biological sciences at Berkeley and the launch of a campus-wide health sciences initiative that saw the abolishment of ten biology departments at Berkeley during the 1980s.

A third and final effect of intensifying relationships between universities and surrounding industrial clusters, is the disadvantages in struggles for resources and legitimacy that other scholarly groups face, which cannot *or cannot yet* clearly frame their research agendas in industrial terms. Both in my Berkeley and Stanford case studies I for example highlight a marginalisation of biologists that used evolution- and ecology-approaches in their research. Accordingly, my research outlines an important tension that needs to be better appreciated and managed. One that is caused by scholarly groups, which develop into central nodes in innovation networks of new industrial fields and that as a result of their success end up curtailing other scholarly groups in the development of their new, distinctive lines of scholarship.

Firms' engagement with scientific communities
My research also investigates the science-business nexus from other perspectives. From the business perspective, I have shed light on a number of trade-offs firms face in benefiting of opportunities the emergence of new science-based industries represents.[4,5] As I highlighted before, some of the successful firms located near major universities that I studied cultivated R&D organisations that were as much involved in research at the scientific knowledge frontier as laboratories at top-universities. These firms often had researchers who published in their fields' top journals, were engaged in numerous collaborations with academic laboratories and aggressively recruited faculty and students from nearby universities.

In my research I have sought to qualify and quantify some of the benefits firms enjoy by using research and development strategies that engage scientific communities. To this end, I for example conducted a comprehensive analyses of research and development strategies of 160 UK biotechnology firms during the late 1990s and 2000s. This is work I did with a former postdoctoral researcher from my lab, Kremena Slavova - currently an Associate Professor at Middlesex University.[6] In general, our results affirmed the benefits of firm strategies that directly engage scientific communities. Specifically, we found that firms that published articles in high-impact journals and firms that forged research collaborations with universities were more successful in terms of moving new medicines into clinical trials.

In addition, we found that these beneficial effects were even stronger for firms with research and development strategies focused on the development of radically innovative new medicines. We defined radically innovative medicines as medicines that had never been used in the clinic before.

These beneficial effects were less strong for research and development strategies focused on the development of incrementally innovative medicines. We defined incrementally innovative medicines as medicines that were already in clinical use but for which companies were looking to develop new clinical applications.

Science policy and industrial R&D
Finally, an important focus of my research is on science policy levers and how policy makers can use these to attract and direct private investments in new high-tech sectors. For example, I recently finished a project on how public funding for science affects decisions by companies to launch product development efforts in specific fields. I did this project together with one of my former postdoctoral researchers Hsini Huang - currently an Assistant Professor in Political Science at National Taiwan University.[7] Hsini and I focused our analyses on an episode of American science policy during the 2000s when a presidential directive by George W Bush signed in August 2001 abruptly imposed a federal funding moratorium on research on specific types of human embryonic stem cells. This moratorium remained in place throughout the presidency of George W Bush. We analysed the impact of this funding moratorium on corporate research and development activities in the global cell therapy sector. Human embryonic stem cell research was considered a particularly promising

line of scientific enquiry for this sector during this period. We compared initiation and discontinuation rates of R&D projects by US cell therapy firms before, during and after the moratorium. We also compared these with initiation and termination rates of corporate cell therapy projects by cell therapy firms outside the US. In our research we show that the government-imposed funding moratorium had a large and significant impact. It diminished the propensity of private US firms to initiate novel R&D projects in the cell therapy area and made it more difficult for firms to bring those projects to a successful completion. These findings underline the crucial role that public funding agendas for science play in shaping how science-driven industries develop.

The implications of my scholarship

So, how does my scholarship on the nexus between science and business inform current debates about the role of the state, universities and firms in shaping what happens there?

Fundamental research

Let's start with science policy. My scholarship re-affirms the important role science funding organisations such as NWO have to play in maintaining a good scientific infrastructure for fundamental research. It is on top of such an infrastructure that a national innovation ecosystem prospers.

Globally, the funding environment for science has not been bad over recent years, especially in comparison to some other areas of public expenditure. In the United States, federal funding for non-defence related research has gradually increased from US$ 55.6 billion in 2000 to US$ 70.3 billion in 2015, measured in 2016 dollars.[8] In the Netherlands, funding for science has remained fairly constant at around €2.6 billion per year measured in 2013 euros with additional increases of funding coming in via the EU.[9] It should be noted however, that while science budget appropriations were flat for the Netherlands, these had to be partially used to cover additional expenses of increased student numbers. Student numbers increased by 57% over the period 2000-2015[10], a development in which Dutch universities do not stand alone. In England, numbers of 18 year-olds entering higher education increased from 15% in 1989 to 48% for the years 2014-15.[11]

Looking closer at the distribution of science funding however, some fields of scholarship are having a harder time than other fields in the current environment. Specifically, the funding environment is becoming more difficult for scientific fields where applications of research are less clearly defined *ex ante*. There are growing pressures for universities to focus on activities, of which the social, economic value can be brought to fruition in the short-term. Universities have been incentivized to enter markets for intellectual property, have been asked to take on roles in national industrial policy agendas such as the 'top-sectors policy' and have been required to develop valorisation plans for research. These pressures are reflected in changing funding priorities. There has been a shift in emphasis away from funding for fundamental research. NWO earmarked €550 million of its €800 million budget for 2016 for so-called 'top-sectors policy'.[12]

It is probably too much to ask NWO, or any other single organisation, to maintain the nation's essential fundamental research infrastructures *and* to accommodate increased demands for foreseeable, tangible contributions by universities to economic policy initiatives such as the 'top-sectors policy'. Fulfilling these two missions within a single organisation is inherently difficult - for example because these two missions require distinctive approaches to the involvement of different stakeholders, the development and design of project calls and the organisation of review processes, as well as the definition and monitoring of project outcomes. In light of this, there is a strong case against redirecting more funding streams that flow through NWO and the Ministry of Education, Culture and the Sciences, away from fundamental research and against further diluting the fundamental research focus of organisations that control these funding streams.

The value of mission-oriented funding

While safeguarding fundamental research is imperative, I see opportunities across a range of national policy domains where engagement with our national scientific infrastructures is currently weak. Unlike countries such as the UK and US, the Netherlands does little in the way of supplementing support for fundamental research infrastructures, with support for mission-oriented programs that focus on the application of fundamental research in key policy domains. It is here that I see opportunities for policies that connect our nation's scientific research infrastructure with policy domains and areas of industrial activity, where there is currently little engagement.

Take the Ministry of Health. There resides significant value in the nation's scientific infrastructure that can be mobilised in policy domains of this ministry. This value manifests itself through work by university researchers on topics that touch on the development of new medical treatments to those who are ill, new diagnostics technologies to improve patient stratification and improved decision support systems for healthcare professionals. Ministries of health in other countries are among the most important 'users' of their nation's scientific infrastructures. In the US, the Department of Health and Human Services spends in excess of US$ 30 billion per year on scientific research that is mostly carried out at major research universities. Similarly, in the UK, the Department of Health oversees approximately £1 billion of investments per year in scientific research through the National Institutes of Health Research to improve healthcare within the National Health Service.[13]

The Dutch Ministry of Health currently *does* provide funding for the Netherlands National Institute for Public Health and the Environment (RIVM) and support for healthcare innovation *is* an important issue on the agenda of the minister, partly thanks to the ministry's involvement in the top-sectors policy. Accordingly, the ministry has demonstrated an openness towards engaging the scientific community on an *ad hoc* basis. For example, our colleague Gilles van Wezel of the Institute of Biology is playing an important role in the distribution of €6 million the minister has recently made available for research on new antibiotics drugs.

Strengthening the international competitive position of the Dutch science-business nexus in the healthcare arena, however, will require the next government to turn such *ad hoc* arrangements into more systematic and programmatic approaches of engaging the scientific community. There is a strong economic case for targeted programs in areas where there are market failures, or coordination problems that might prevent firms to take the lead in the development of R&D efforts in specific fields. I believe that the creation of a national infrastructure for precision medicine should be at the top of the list of programs that a new government should take up next year. Challenges involved in the creation of such an infrastructure currently feature as an important focus in my research.

Precision medicine refers to the implementation of new prevention and treatment strategies that take into account individual variability using ever more sophisticated methods for characterizing patients such as proteomics, metabolomics, genomics, diverse cellular assays, advanced imaging and mobile health technology. Precision medicine will have a profound impact on the clinical practice and business of healthcare. Implementing the infrastructure to deliver on the promise of precision medicine, however, is not possible without a highly integrated approach. It needs to bring together stakeholders from the healthcare arena, as well as scientists from across a wide range of disciplines. These include scientists from across the gamut of basic research disciplines working on human biology, clinical researchers, informatics people, as well as the broad range of social scientists and regulatory experts who work on issues around health system design.

Given the task at hand, governments in the UK and US have launched major precision medicine initiatives. In the UK, the ministry of health launched the Genomics England initiative - the country's effort to sequence 100,000 full genomes from patients of the UK National Health Service. Its aim is to become an international leader in the clinical practice and business of genomic medicine. In the US, president Obama launched the White House Precision Medicine Initiative in 2015. It is coordinated through the National Institutes of Health and has similar aims to those of the UK initiative. The relatively well integrated Dutch healthcare system potentially has a number of comparative advantages in capitalising on clinical and business opportunities this nascent field heralds. There is a real opportunity for the Netherlands to act as a magnet for private investment and technology commercialisation efforts in this area. Yet, until now, efforts in this area have remained fragmented across initiatives focused on individual disciplines such as genomics, themes such as 'data', or individual clinical application areas such as oncology.

Maintaining space for organisational experimentation

Turning to the role of individual universities in our national innovation ecosystem. An important challenge for universities is to maintain free spaces for experimentation with new research and teaching. We have seen a movement that represents a strong push, especially in Europe, towards increased, government-mandated external auditing and centrally coordinated control of academic work - often in the name of greater 'accountability' and 'transparency'. This takes the form of quality assurance mechanisms in education such as the European Quality Improvement System and the Dutch accreditation and visitation exercises by the Netherlands-Flemish Accreditation organisation. It extends to research as well - for example through evaluations based on the Standard Evaluation Protocol in the Netherlands and the increasingly dominant role a limited number of national and European funding programs play in shaping scientific research endeavours. Finally, 'valorisation' and/or 'impact' activities are increasingly becoming the subject of auditing exercises. In the UK, assessments by expert panels of research 'impact' accounted for 20% of the rating the UK Higher Education Funding Council used in its allocation of research grants during the last Research Assessment Exercise.

We, as an academic community should welcome scrutiny of our work. However, it is also crucial that we organise this scrutiny so that it does not stand in the way of the development of innovative organisational models for research, teaching and external engagement. In my research I highlighted the importance of free spaces within universities for scholars to recombine existing lines of enquiry and bring into the scholarly endeavour new types of questions and actors. It is this free space that plays an important role in advancing scholarship in general and the development of research programs, from which transformative business development opportunities emerge in particular.

Towards long-term partnerships between science and business

I now wish to turn my attention to new ways of thinking of the benefits businesses are able to derive that locate research and development activities close to universities. I put forward that major Dutch research universities such as Leiden that bring together the full gamut of disciplinary perspectives from across the natural sciences, medicine, law, social sciences and the humanities, enjoy a structural advantage relative to universities in countries around us in terms of building valuable engagement at the nexus between science and business.

Advancing corporate research and development in new technology fields often requires firms to tackle complex, interconnected problems from different disciplinary perspectives. Take the development of a new pharmaceutical drug. This often requires firms to gain access to cutting-edge science in biochemistry, structure biology, bio-informatics, bioengineering, pharmacology, relevant clinical expertise and so on. And that is only the discovery phase. For the development phase firms require access to project management expertise, marketing, manufacturing, regulatory, health economics expertise, insights into behavioural issues around the use of new drugs and so on. Major multinational technology firms significantly pared down internal research departments over the last decades and do not possess the resources to cultivate cutting-edge expertise across all these different fields. Increasingly, these firms are dependent on external input for product and service development activities.

In countries around us such as Germany and France fundamental research has in many areas been separated from universities and fragmented across specialised research institutes of the Max Planck Society and the National Centre for Scientific Research - CNRS. Accordingly, an environment such as that around the University of Leiden, where firms can locally tap into expertise from across the full gamut of scholarly disciplines, is potentially very attractive for businesses.

It is in building on this advantage that I see particularly promising value creation opportunities for Dutch universities in strengthening the engagement with surrounding industrial clusters. Over recent decades, technology transfer organisations such as LURIS have become increasingly savvy about managing the transfer of individual pieces of intellectual property based on university research and negotiating terms of individual research collaborations.[14,15] A next challenge for universities like ours is to broaden such collaborations beyond individual deals.

I believe that for multinational technology companies in areas such as pharmaceuticals, energy and high-end instrumentation, it is not necessarily the value of specific pockets of expertise that drives decisions about whether to locate research and development activities near a certain university. A more important factor is the disciplinary breadth of the knowledge base these companies potentially are able to gain access to. This pertinent need of corporate research and development organisations to be 'plugged in' across a wide range of scientific programs, represents an important opportunity for universities such as ours. However, capitalising on this opportunity necessitates the development of partnerships between universities and businesses that are deeper and more long-term than typical technology transfer relationships. One example of such a partnership is a recent US$ 85 million partnership between Pfizer and UCSF. The deal established Pfizer research facilities in close proximity to UCSF and created a network of UCSF and Pfizer researchers called the Center of Therapeutic Innovation. Through this network, UCSF researcher were able to bid for funding calls Pfizer created around critical scientific challenges it was facing across its drug discovery and development activities. Moreover, the partnership provided UCSF scientists access to Pfizer resources and expertise in the drug development process. Over recent years I have witnessed scientists and administrators at UCSF, and at Harvard and UCL, which I was previously affiliated with, grapple with the challenges of structuring such new - often experimental partnership models. Examining new organisational models for structuring such partnerships and the effectiveness of these models will be an important focus of my research and knowledge exchange activities here in Leiden.

In conclusion. I take on this position as Professor of Science Based Business as universities are asked to take on new, more prominent roles in innovation ecosystems. For universities, using examples from my research on the history of the biotechnology industry, I highlighted how free spaces for organisational experimentation in science have been critical in sprouting some of the most valuable contributions by universities to industrial innovation. Moreover, I put forward work on the development of deeper, more long-term partnerships between major research universities and businesses as critical to capitalising on the value that can be found at the nexus between science and business. For science policy, I used examples from my research to underline the notion that remains counterintuitive in some policy circles, that strong public institutions safeguarding the nation's fundamental research infrastructure are crucial to the dynamism of a national innovation ecosystem. And finally, I used examples from the healthcare arena to outline how a broader mobilisation of scientific resources at the national level represents an opportunity to attract and cultivate private research and development activities in the critical industries of tomorrow.

We have come to the end of this lecture. So, I wish to express my thanks to the people who have been instrumental in the creation of this chair. First of all, I thank the Board of Leiden University and the Board of the Faculty of Science for appointing me as Professor of Science Based Business, in particular Carel Stolker, Willem te Beest, Geert de Snoo and Han de Winde, whose council has been so important to me over these past months as we are navigating new waters with Science Based Business. I am also grateful for the involvement of members of so many of the different institutes of the Faculty of Science in my recruitment that took place under the leadership of Joost Kok.

I wish to acknowledge the work Harmen Jousma has done with Science Based Business over the past fifteen years. An institution in himself at the Leiden BioScience park, he has done so much to inspire students to lead and become involved in innovation, management and entrepreneurship. Also, this would not have been possible without the work of Grada Degenaars, Tim Pathuis and others who have stood with him over the years.

I am also a part of the wonderful community of the Leiden Institute of Advanced Computer Science. I particularly thank Aske Plaat and Annemart Berendse for providing Science Based Business and me such a welcoming home within this university.

I thank my students here in Leiden. It is a pleasure to teach you and get involved in your great initiatives such as the Gulliver business plan competition and the Science meets Business events. It is exciting and a privilege to develop new programs for such a diverse and smart group of students, hailing from so many different corners of the scientific endeavour.

Finally, I thank my family and above all Serena, whose love and partnership has been so all-important in the life this scholarly journey is a part of.

Ik heb gezegd.

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Advancing corporate research and development – R&D - often involves tackling complex multifaceted research problems. It requires firms to bring together multiple perspectives from different scientific and engineering disciplines, and, as R&D moves beyond the laboratory context, also from disciplines in the social sciences, humanities, law, and medicine. This is why broad research universities (as opposed to specialized institutes) that bring together all these different perspectives under one roof enjoy an advantage in fostering engagement at the nexus between science and business. Several factors are important in supporting universities in capitalising on this advantage.

First, fundamental research is critical. Some of the most impactful, disruptive innovations of modern times find their origins in research that was not geared towards commercial applications. This was the case for the birth of the chemical and pharmaceutical industries in Germany during the 19th century and the formation of firm clusters around new biomedical technologies such as CRISPR-cas9, RNAi, and next gen sequencing today.

Second, embedding scientific research more widely within the missions of government bodies will stimulate stronger engagement at the nexus between science and business. Scientific research has the potential to advance all kinds of missions these bodies are focused on. The role the US Department of Health and Human Services has played in supporting the US life sciences sector through the roughly thirty billion dollars it funnels annually into health research illustrates this.

Third, universities should (be able to) embrace their role as sanctuaries for organizational experimentation in academic research and teaching. Universities that were at the forefront of fostering disruptive innovative activity in new industries - e.g. Stanford University in the early days of Silicon Valley, the University of California at San Francisco in the case of the birth of the biotechnology industry - were also universities where research and teaching were organized in novel, unconventional ways. There is a danger that a growing emphasis in academia on government-mandated, homogenously applied bureaucratic auditing and control processes leave too little space for such experimentation.

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