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Applied and not yet applied research

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Introduction

It is a great privilege to be able to address you on the topic of applied research.

Unsurprisingly I will focus on the importance of Universities in this context and why I believe that Universities have an ever more important role in the future of research and particularly its application. Furthermore, I will try to place these comments in a more European and global context and our key role as a University.

Let me start with two assertions which I hold to deeply and yet appreciate that you may wish to explore or hold differing views in questions:

Firstly the mission statement of our University. It is very short and to the point and yet in its own way quite profound: *to **serve society** through teaching, learning and research of the highest **international** standards of **excellence***. In this context I will stress three phrases: serve society, international and excellence. With this audience, the issue of international excellence in our University probably needs no further comment from me. I am sure that we share an absolute commitment to that, but serving society, in the context of research, does mean that we are by definition committed to applying our research which again, particularly here today, does not need further exploration. But the nature of the 'society' that we aspire to serve probably does. In our ever shrinking world I am going to assert it is no longer just local, nor just regional, nor even national but has to be global.

Secondly, I am a firm believer in the quotation so often attributed to George Porter: *there are only two types of research - applied and the not-yet-applied*. My take on this is that the only reason that string theory is not yet applied is that we are not smart enough to do so but also will state with confidence that alongside all of the other fantastic fundamental or basic research we undertake someone will find an application for it in due course. The timelines for this to happen are sometimes very long - in Biomedicine it is approximately 17 years from bench discovery to clinical application but in philosophy it may centuries before a full impact is felt!

The roles and contributions of Europe's research universities

So what is the role of a research University in the wider sense that society and in particular European society should expect? They, will be the principal providers of research for Europe. Indeed, governments worldwide see universities as vital sources of new knowledge and innovative thinking, as providers of skilled personnel and credible credentials, as contributors to innovation, as attractors of international talent and business investment into a region, as agents of social justice and mobility, and as contributors to social and cultural vitality. And of course we are also warehouses of knowledge, which we pass on from one generation to another, we are cultural institutions, and we are national and regional symbols. These roles are in tension with each other to some degree - but in general the world's great universities do all of this, and we are good at it. It is no surprise that government and industry and society look to universities to help them, because we have a deep influence.

The values of a research university

If these roles constitute a job description for research universities, then what does that list have to say about our values? I suggest two key shared values for research universities: excellence, and relevance. I shall consider these values in relation to research, because it is research alongside education, rather than education alone, that shapes our unique contribution.

What is our research for?

Our research efforts are relevant, then, to the societies which we serve. If ever there was an age which contrasted ivory tower universities with 'the real world', that age is over. Serving society is at the core of what we do. We share these objectives with the authors and signatories of the Lisbon Treaty, whose aims will largely be delivered through the European Research Area. And if the work of universities is to be relevant to society, then it is natural that we focus on the problems facing society, and ask how we can contribute. The key political and societal focus at present – prominent in the German election debates and consistently the biggest concern of voters in UK and in opinion polls – is the economy. Faced with the pressing need for economic growth, how can universities help?

Our University is already making a huge economic contribution through our research: that much is obvious. Much of the research we perform is commissioned by government, business and industry through contracts and grants, with economic productivity as an expressed aim. Also, we make discoveries and inventions which, formalised in recent years as 'technology transfer', are put directly to work by the private sector to generate economic return.

What is less obvious - indeed counter-intuitive - is that universities' contribution to the economy is so effective precisely because it is not our primary objective. Economic productivity is a by-product of the teaching and research that we perform for other reasons. If it were turned into a primary objective - if universities became the Research and Development branch of Big Industry - then our distinctive contribution would be lost. This is the first point that I particularly want to emphasize. If universities are asked to do near-market research, we will do it, and do it well – but it is not our primary mission, and nor is it even the best economic contribution that we can make.

The nature of research

One reason for this is that the discoveries that make the biggest contribution economically tend to result from blue-skies, fundamental research, not applied, 'near-market' research. If a pharmaceutical company sets universities the task of improving the efficiency of a particular drug, for example, then the result will be economically and societally useful, but limited and maybe more effectively done within the company. However, a more fundamental question such as identifying a new target molecule is far better sited in a large multidisciplinary research intensive University. In such a circumstance, a university researcher primarily sets out, from curiosity, to discover how a fundamental biological process works, and the results can be unlimited - and transformative. This is what Francis Crick and James Watson did in Cambridge's Cavendish Laboratories in 1952: their discovery of the structure of DNA has had an effect on all our lives (and, as an example of economic benefit as a by-product, has generated uncountable billions of euros).

The examples are of course connected: today's applied pharmaceutical research relies on yesterday's 'blue skies' research. Although the pipeline from one to the other is long, as I have already stated based on an MRC study 'What it's worth?' it is evident that the pipeline must not be broken – the basic research we do now will be applied by our successors in the years to come. We must not leave the cupboard bare for them. Therefore there is a priority for research funders to ensure that there is sufficient resource available to sustain the 'basic or fundamental' research agenda. It does not run counter to applied research but is indeed an essential part of sustaining its viability into the future.

One further point about research: the vocabulary is understood differently in different European languages and traditions. In English the word “research” can apply to any discipline, but perhaps leans towards science. The word “scholarship” similarly can apply to any discipline, but has a definite tendency towards the arts and humanities – disciplines which suggest a single researcher rather than a team or lab group. It is important not to ignore, because of the biases of language, the contribution – cultural, economic, and societal – of arts, humanities and social science disciplines. The reason so many thousands of people come to Cambridge and other European cities each year is the “heritage industry”, which depends ultimately on these disciplines.

How to organise research to maximise benefit to society?

Once we recognise a taxonomy of different kinds of research, it becomes important to ask how to organise it in order to maximise benefit to society. I shall consider two ways in which research can be organised: firstly the kinds of institutions that perform different kinds of research; and secondly how funding organisations channel resources to support research, and how the design of funding programmes affects the outcome of the research.

First, then: where should research be done? Universities have competitors: big companies, even small ones in some sectors, can carry out their own; and research institutes are plentiful in Europe, some funded by the state, some by charities. There are plenty of successful examples, most obviously in Germany, where universities share space with Max Planck Institutes and Fraunhofer Institutes. However there are cultural reasons why the University model can be successful, even though in some, especially in universities with a strong past and present commitment to the arts and humanities, the “business-facing” attitudes necessary for innovation are sometimes viewed with suspicion.

My purpose here is not to argue that separating fundamental research from innovation is always wrong – but to argue, rather, that it is not always right, and that rigid, deliberately designed separation of these functions at country or European level would damage a diversity of approach which is fertile and fruitful. Our engagement as a University in the Cambridge Phenomenon I believe demonstrates that pure, basic research and innovation – the whole pipeline – exists productively under one roof and indeed enhances our University.

Case study: The Cambridge Phenomenon

The cluster of high-tech companies around Cambridge is a development worthy of examination. Although various actions by the University and its Colleges encouraged these companies, the “Cambridge Phenomenon” is not a process owned or managed by the University, and perhaps the most important policy that the University adopted was a policy of interfering as little as possible.

As a matter of history, in 1960, a pair of Cambridge graduates formed a company called Cambridge Consultants, starting the development of a cluster of high-tech companies around the University. This was later described as ‘the Cambridge Phenomenon’: the process by which entrepreneurial scientists created companies to take advantage of the proximity to a great research university - and, as the cluster grew, to other companies doing similar things.

To put this development into perspective you need to be aware how small Cambridge is as a city - just 100,000 people - and the surrounding area only grows this number to 600,000 or about 1% of the UK population. Despite this we now have around the city over 1,400 high-tech and bio-tech companies, from tiny recent ‘spin-outs’ from university laboratories to significant divisions of multinational companies like Microsoft. They are in diverse sectors – information technology certainly, but also bioscience, medical sciences, telecommunications, consumer goods, and industrial services. And they have brought 58,000 workers to the Cambridge region – and the regional population growth rises to 80,000 if you include their families.

Eleven companies which started in the Cambridge cluster are now valued at over 1 billion euro – including Autonomy whose business software is in use in every industry, and ARM, whose

microchips are in your mobile phone, your car and your TV. To illustrate the economic value of basic research, I only need to observe that Autonomy Corporation, which was bought by Hewlett Packard last year for \$10.2 billion US dollars, began life as the PhD thesis of one of our engineering students.

That initial spark – the foundation of Cambridge Consultants – was important of course, but it took much more than that to create the vibrant cluster of companies we see today. Along the way, Cambridge established the UK's first science park (in 1970), and the UK's first incubator for start-up businesses, the St John's Innovation Centre, in 1987. The example of the Cambridge Phenomenon argues against forcing universities down the narrow path of fundamental, blue-skies research, while leaving 'applied' research and innovation to research institutes, and private-sector R&D labs. What the University of Cambridge offers to the companies in the cluster is access to an entire spectrum of research from fundamental to applied, with the support services (technology transfer offices, science parks and incubators, seed funding) that go with it. Separating "applied" from "not-yet-applied" would certainly not be wise, and may not even be possible.

Furthermore, universities are the last institutions able to integrate knowledge from many different sources and many different disciplines. Universities can identify interesting developments in unexpected places and combine them to produce practical solutions to big problems. We can only do this because of firstly, our academic breadth, secondly because we are autonomous, and thirdly because we give freedom to our individual researchers to follow promising avenues.

I draw three conclusions:

1. Globally competitive research universities can, already do, and should drive innovation.
2. Blue skies and applied research are part of the same spectrum and both contribute directly to innovation.
3. Research policies and strategies abound from every government department and inter-governmental grouping especially in the EU. Horizon 2020 should avoid perpetuating an artificial distinction between Research and Innovation. They are not the same but innovation that drives national economies and creates jobs is largely dependent on research. Such innovation is most successful when conducted in tandem with research, especially in the University sector. I believe this will be as true of research Universities in 2020 as it is today.

Research funding models

So far, I have discussed the location of research, and in particular I have argued that research universities offer a valid home for innovation as well as for blue-skies research. I now turn to how the design of funding models can influence what sort of research you get.

Research is the dominant component of establishing universities' reputations through league tables, whether you believe that these are a useful or even helpful tool – but there are major national differences. These make the policy- and framework- making at a European level difficult. All our universities depend on winning research funding competitively. We all know that researchers will competitively seek resources to fund their work and all Universities will support them in securing such funding. However, as I noted in the 1 October speech this year, this cannot continue infinitely - we currently receive on 90p in the £1 for the real costs of research we undertake. While researchers in Cambridge are fortunate that we can maintain this subsidy, many institutions faced with the same costs are increasingly having to pre-determine where available resources can be concentrated, making central strategic rather than bottom-up determination of research the rule rather than the exception. This is one of the most worrying trends as far as I am concerned.

Therefore research funders are well aware of the importance of funding to institutions and use it to promote their strategic priorities. To avoid distorting our missions unacceptably, responsible research funding must, in its design, ensure support for novel, innovative directions, as well as

build on what is already known. The major funding bodies direct resources to research in different ways, but trends are apparent – some obvious, some subtle; some intentional, others not – which may have a significant impact on the research university of the future.

I will consider the three main funding models, each with advantages but also disadvantages – and identify trends which may predict how they could influence the future research university. The three funding models are:

1. Investigator-led, responsive-mode grants
2. Grand Challenge model
3. Awards to support individuals, rather than projects.

Investigator-led, responsive-mode grants

In this mode, an individual investigator submits a project funding proposal which is peer reviewed, and awards made on the basis of the review. Funders are encountering problems with this model which they find difficult to address:

- Demand always far exceeds supply
- Administrative costs to the funding body
- Peer review is still the gold standard used by funders and remains the best that we can do.

However, we have to be very aware of its limitations. Some of these have been highlighted recently by the journal *Science*, particularly as regards publication. It is not clear how effective peer review is at discriminating between several research projects which are all at an international level of excellence. It is arguable that peer review is good at defining whether a piece of research is “internationally excellent”, but that it cannot distinguish at a more granular level than that. When funding success rates fall below a threshold (usually <20%) this becomes a real issue. If research described in a proposal is unorthodox, it tends to get marked down by reviewers, who as a body often act conservatively. Used indiscriminately it can perpetuate the *status quo* - for example, the National Institutes of Health in the USA reported recently that most investigators were in their 40s before obtaining their first independent award. Furthermore funding agencies, such as the Wellcome Trust and NIH are only getting a 50% response rate to review requests - a worrying trend that again could undermine the validity of the only system widely recognised and trusted by investigators.

Grand Challenge model

The Bill and Melinda Gates Foundation led the way in popularising a different mode of funding: the so-called ‘grand challenge’ model which identifies an ambitious target – the eradication of malaria, for example – and funds large teams to meet that challenge.

Problems with this model:

- Universities and institutes all want a slice of these very large pies, and so configure themselves to meet the best-known challenges: meaning that they all end up focusing on the same problems. It might be more sensible in certain circumstances to direct resource at a problem that is ‘on the way to’ a grand challenge: a halfway house.
- This tends to produce thematic ‘centres’ in universities (Energy Centres, Institutes for Food Security, etc.) which attract talented researchers (and, particularly, researchers who talk a good talk) – potentially depriving the discipline-based faculties and departments of funds and people to develop and retain core skills upon which successful research relies.

Awards to support individuals, rather than projects

This is an important component of a research funded armamentarium. Its strengths are that it supports young investigators and does not lock them into particular frameworks and maintains the

freedom to change. Attractively, it also appeals because it purports to support the “brightest and best” and “lets them get on with it”!

- Investing in individuals rather than responsive-mode grants takes out of circulation a huge sum that would have gone into thematic research
- The approach also picks ‘winners’ at an early age, risks creating a demoralising two-tier system – those with individual funding and those without – and potentially leaves very able researchers without the means to set up their research group.
- There is an “unwritten rule”: even if the lion’s share of award-worthy individuals are in one department, or one institution, or one country, the unhelpful signals sent by allocating resources accordingly are often too unpalatable for the funding body, which may impose – probably without articulating it – a quota.

European Structures

Located where we are, it is important to consider the developments in EU funding, which if the budget of €70bn is confirmed, will dwarf anything our Research Councils will have on offer until 2020! The development of the European Research Area (ERA) along with Horizon 2020, and its associated funding, has significantly challenged our thinking. There are three pillars:

1. Basic science, delivered primarily through the European Research Council and/or elements of a response-mode framework largely by support for individual researchers
2. Innovation and technology transfer largely supporting applied research and interaction with industry
3. Research in support of societal challenges and infrastructure - a thematic grand challenge approach.

There are many positives in this approach, but I worry if themes are decided ‘top-down’, with limited input from the community of European research-led universities and their researchers.

Research funding models: some conclusions, and some questions

The systems-oriented changes outlined above will have a tremendous impact on research intensive universities. It leaves us with challenges, which include:

- How do we ensure that a university structure which is still largely based in discipline based units can deliver multi-disciplinary solutions?
- How do we combine grand-challenge approaches with investigator-led research, preserving the distinct benefits of both?
- Support for individuals, coupled with increased mobility of researchers and increasing requirements for costly infrastructure, increases institutional instability. How do we avoid that trap?
- As international universities we are all seeking strategic research partnerships, with academia and with the private sector, particularly in support of applied research. How do we use this changing environment of research funders to continue to promote such activity?

These new shifts and tensions in research funding carry enormous implications, with risks and opportunities in equal measure, both for funders and performers of research – but also for the wider world. We have a responsibility to get it right. My strong recommendation would be that provided national-level funding is sufficient and appropriately focused, European funding can and should concentrate on long-term, fundamental research excellence. In implementing Horizon2020, then, the EU should recognise that it is university research, in particular the “not yet applied”

variety that produces the sustainable, long-term growth and the societal contribution that Europe desperately needs.

Conclusions

So let me close by doing a little crystal ball gazing looking at the next 10 years or so. Cambridge is a member of LERU - the League of European Research Universities. I contend that Europe is fortunate to have strong, research-intensive universities which can step up to meet the challenges that we are and will continue to encounter as a society. So let me use the four words that make up the name of LERU as a framework to consider who we are, what we do, and what contribution we can and must make.

League

LERU is a voluntary association. There is no coercion or any artificial attempt at delivering uniformity. Indeed its membership is diverse and competitive – both are healthy attributes. However, we all understand the need for PARTNERSHIP. Now and for the future we must develop shared research endeavours between academic institutions, industry and society. This trend will grow because infrastructure is getting more complex and expensive and funders will demand sharing. In addition, complex problems need a multiplicity of approaches which cannot be totally confined to one institution. Here the diversity of research universities are and will continue to be our strength.

Many trends tend to drive towards uniformity - that is probably the biggest mistake that we or funds could make – ask the dinosaurs what happened when the meteorite hit! Diversity ensures adaptation and sustainability especially when the predictability of the world of tomorrow is so difficult. While competition also drives quality, research universities share values to deliver greater excellence in education and research which will be essential in the future, so collaboration alongside competition will become more important. Large industries already recognise this.

European

We are European and therefore the sphere of our operations is important: Europe is of the right scale because as globally competitive universities scale and the international dimension is key to our future success. Europe, both as member states and the Commission, must sustain competitiveness with North America and increasingly the East if we are to maintain our economic prosperity. Also as Cambridge we cannot ignore this huge funding source. We are already the top university in Europe academically, as well as the largest single body participating in Framework Programme 7 projects and the top university for ERC Awards; and if you don't think that that matters just ponder that nearly 20% of all our research income comes via Brussels!

Research

It is our research mission which allows us to develop solutions to our pressing problems. Research Universities already embrace excellence in research, its application, innovation and knowledge transfer. How are we distinctive from other research providers especially Research Institutes? Here the commitment to education of students, undergraduate and postgraduate, led through research is fundamental. We must imbue them now and in the future with those academic values that have stood the test of time and characterise our universities.

But there is something more. We have a breadth of disciplines in our institutions that allow for natural integration of arts, humanities and sciences as a basis for multidisciplinary and interdisciplinary research. This is at the heart of the 'grand challenges' that face society - in my own research the major hold up for vaccine development is so often not the technological discovery but its acceptability to policy makers and society as a whole. Therefore understanding this is not down to the biomedical disciplines alone but involving others from social sciences, psychology and political sciences.

Research-led universities are the natural home for societal challenges and must engage actively with the private as well as public sectors to ensure the benefits of research are realised as rapidly as possible. This drive will increase as policy makers and research funders increasingly measure success by outcomes and we must adapt to this. That means that certain academic disciplines will disappear and new ones will emerge - that's progress. However, we must resist the real danger that the long-term fundamental research agendas are sacrificed as well as the focus on the development of individuals working in our Universities. After all, it is their ideas that deliver the paradigm shifts that will develop the new industries of tomorrow.

Universities

Above all we are Universities. We are all committed to excellence in all aspects of our activity - a value that cannot and must not change. As I have argued, our institutions gain from the unity of teaching with research; they gain from breadth of discipline; and they gain from being a set of interconnected ecosystems, where the unexpected may happen. But our globally competitive Universities do something more than just educate a workforce and deliver research outcomes. We educate the leaders of tomorrow and that is a heavy responsibility yet one we must accept with alacrity.

But are there necessary conditions to enable us to continue to contribute to society in this positive way? In medicine, I have no idea what a clinician will be required to know in 30 years but I do know that, if she has studied with us, she will be well equipped to adapt to the future world because of our commitment to education and not just training. It follows that Universities have to plan for the long term and cannot be deflected from that by short term vicissitudes. This requires institutional autonomy. It is a strength that maintains diversity and delivers the long term perspective that is characteristic of our University.

I underlined this in a speech I made at the opening of the Competitiveness Council of EU Ministers in July last year, under the Polish Presidency. I said: *"In an economic environment of austerity and cutbacks, autonomy appears to be a luxury, and governments are tempted to create incentives for universities that are fine-grained in terms of desirable outcomes, and heavy-handed in terms of rewards and penalties. Governments know what they want: economic growth. But autonomy is not a luxury. It is an absolute and indispensable condition for excellence and every step which tends to remove the power of universities to decide who they educate and how; and what they research and why; is a step towards mediocrity and paralysis."*

Why it matters

So why does this matter and why do universities want these onerous responsibilities? The answer lies in our mission: to serve society. If ever there was a time when academia was in contrast to the 'real world', that time is surely over. Serving society is at the core of what we do. By pursuing research in all disciplines and at all points in the spectrum, from the most direct form of applied innovation to the most fundamental inquiry into the way the world works, we hold the key to growth and the wellbeing of our society now and well into the future.