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Baroness O'Neill of Bengarve: Evidence, trustworthiness and trust

Banking failure

Professor John Kay: Understanding the bigger picture
Andrew Haldane: From individual players to an interconnected system
Sir Martin Jacomb: Prudence is an essential virtue in banking

Food security

Sir John Beddington: Key challenges in feeding the world
Dr Peter Holmgren: Changing the way we view agriculture
Professor Tim Wheeler: Addressing challenges in different parts of the globe

Making science work

Sir Paul Nurse: Science and its contribution to the public good
David Eyton: Creating value in the UK economy
Dr Andy Richards: Models of economic growth
Professor Rick Rylance: The shape of future research

Select committees

The Commons Science and Technology Committee
The Lords Science and Technology Committee

Science and engineering academies

The Royal Society
The Royal Academy of Engineering

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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Hydraulic fracturing in the UK

The technology of hydraulic fracturing (often termed 'fracking') has come under the spotlight recently, particularly in terms of its safety record. A review by the Royal Society and the Royal Academy of Engineering concludes that it can be managed effectively in the UK as long as operational best practices are implemented and robustly enforced through regulation.

Professor Robert Mair FREng FRS, Chair of the review's working group said: "There has been much speculation around the safety of shale gas extraction following examples of poor practice in the USA. We found that well integrity is of key importance but the most common areas of concern, such as the causation of earthquakes with any significant impact or fractures reaching and contaminating drinking water, were very low risk."

The review examined the scientific and engineering evidence relating to the environmental and health & safety risks associated with the onshore extraction of shale gas. It found:

- hydraulic fracturing is an established technology that has been used by the oil and gas industries for many decades in the UK;
- the risk of contamination of aquifers from fractures is very low provided that shale gas extraction takes place at depths of many hundreds of metres;
- seismicity (or earth tremors) induced by hydraulic fracturing is likely to be of a smaller magnitude than the UK naturally experiences, or than is related to coal mining activities, which are, of themselves, low by world standards;
- open ponds for storing wastewater (which have been historically used in US fracking operations and carry a possible risk of leakage) are not permitted in the UK;
- well established procedures have been developed for the disposal of naturally occurring radioactive materials (which are present in the hydraulic fracturing wastewaters) by the UK's extractive industries.

A particular cause for concern is that poor cementation and casing failures of wells could lead to leakages and wider environmental contamination, as they have in some cases in the USA. Therefore, the review concludes that the priority must be to ensure the integrity of every well throughout its lifetime.
www.raeng.org.uk
http://royalsociety.org

Fukushima — 'a man-made disaster'

The official report of the Fukushima Nuclear Accident Independent Investigation Commission has been presented to the Japanese Parliament. In his introduction, the Chairman, the former President of the Science Council of Japan Kiyoshi Kurokawa, noted: "Our report catalogues a multitude of errors and wilful negligence that left the Fukushima plant unprepared for the events of March 11. And it examines serious deficiencies in the response to the accident by TEPCO [the plant operator], regulators and the Government.

"For all the extensive detail it provides, what this report cannot fully convey – especially to a global audience – is the mindset that supported the negligence behind this disaster. What must be admitted – very painfully – is that this was a disaster 'Made in Japan'.

"Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the programme'; our groupism; and our insularity."

The report uses unusually harsh language in its summary of the disaster. It says: "The TEPCO Fukushima Nuclear Power Plant accident was the result of collusion between the Government, the regulators and TEPCO, and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. Therefore, we conclude that the accident was clearly 'man-made'. We believe that the root causes were the organisational and regulatory systems that supported faulty rationales for decisions and actions, rather than issues relating to the competency of any specific individual."

The report's recommendations include new regulatory authorities, a rewriting of the law relating to nuclear installations and parliamentary monitoring of the nuclear regulatory body. The Commission's terms of reference did not include Japanese future energy policy though.
http://naiic.go.jp/wp-content/uploads/2012/07/NAIIC_report_lo_res.pdf

Access to research findings

The Government has accepted the findings of an investigation chaired by Dame Janet Finch, former Vice-Chancellor of Keele University, into improving access to research findings. The report concluded that: "The UK should embrace the transition to open access, and accelerate the process in a measured way which promotes innovation but also what is most valuable in the research communications ecosystem."

It recommends that: "the Research Councils and other public sector bodies funding research in the UK should – following The Wellcome Trust's initiative in this area but recognising the specific natures of different funding streams – establish more effective and flexible arrangements to meet the costs of publishing in open access and hybrid journals." The Government has said it looks to the Funding Councils and Research Councils to implement all of the report's recommendations.

The report, *Accessibility, sustainability, excellence: how to expand access to research publications*, is the product of a year's work by a group drawn from academia, research funders and publishing.
www.researchinfonet.org/publish/finch

National centre for universities and business

The Council for Industry and Higher Education (CIHE) has announced plans to launch a new National Centre for Universities and Business. The centre will focus on strengthening the strategic partnership between universities and business with a view to driving economic growth and recovery. The Higher Education Funding Council for England (HEFCE) will initially fund the centre, with support from other national funding bodies.

The establishment of such a centre was a key recommendation in Sir Tim Wilson's review of business-university collaboration, published in February. The development of the National Centre reflects the recognition by university and business leaders that they need to do more together to address the challenges to the UK of immediate turbulence in the global economy and of longer-term competitiveness.

A high-level steering group, chaired by Sir Richard Lambert – the former Director-General of the Confederation of British Industry (CBI) and author of the 2003 review of links between higher education and business – and Professor Anton Muscatelli, Principal of the University of Glasgow, will oversee development of a full business plan for the centre, with a view to getting a range of funders and sponsors on board to launch the centre fully in the autumn.

The centre will publish an annual 'State of the relationship report' which is intended to become the premier influence on policy development in HE-business links.

Continued on page 4

Evidence, trustworthiness and trust

Onora O'Neill

Baroness O'Neill of Bengarve CBE FBA FRS FMedSci is a professor emeritus of philosophy at the University of Cambridge, and a former President of the British Academy. She was formerly Principal of Newnham College, Cambridge and chaired the Nuffield Foundation. She is particularly well known for delivering the 2002 Reith Lectures entitled *A Question of Trust*.

Public discourse is full of claims that trust matters, that there is less of it than there used to be and that we need more of it. It is also full of claims that trust is risky and unreliable and that we should look for something more dependable, such as (supposedly) regulation or accountability. Seemingly, we both aspire to greater trust and insist that trust is undesirable. But if trust is undesirable, why seek more of it? I believe that this ambivalence reflects a widespread tendency to conflate empirical questions about others' generic attitudes of trust with practical questions about others' trustworthiness in specific matters.

The practical questions arise because trust can be misplaced: the trustworthy may be mistrusted and the untrustworthy may be trusted. Both mismatches matter to us. When we refuse to trust the trustworthy we incur needless worry and cost in trying to check them out and hold them to account, while those who find their trustworthiness wrongly questioned often feel undermined and insulted – and ultimately less inclined to be trustworthy. Yet when we trust the untrustworthy we may find our trust betrayed, and lose whatever we staked – perhaps friendship, political aims or money.

Judging trustworthiness

Most of the literature on trust focuses on trusting attitudes and simply ignores questions about the intelligent placing of trust. This seems to me perverse. Our central practical aim in placing and refusing trust is to do it well, by aligning trust with trustworthiness and mistrust with untrustworthiness. Judging trustworthiness is hard, but it is fundamental: only well-placed trust is worthwhile.

Trust is fundamentally a response made under conditions of uncertainty (uncertainty is more relevant than risk here): a matter of deciding when to rely on others' claims and commitments in the face of incomplete evidence.

Trusting without complete evidence is unavoidable, not irrational. Both in scientific inquiry and in daily life we constantly have to place and refuse belief on the basis of incomplete rather than conclusive evidence. Equally, we constantly have to place or refuse trust on the basis of incomplete rather than conclusive evidence of another's trustworthiness. However, incomplete evidence is not the same as complete absence of evidence. The central practical question we face in all areas of life is how to place trust intelligently, despite the inevitable incompleteness of evidence that others' words are true of the world and that their acts will live up to their words.

Empirical evidence and generic attitudes

When people complain about declining trust, they typically cite as evidence the generic attitudes individuals express when polled. This is not good evidence for a decline in trust, for several reasons. First, we have few time series that show generic attitudes across a long time and those that do exist typically show underlying constancy with short term fluctuations. Trust in journalists and politicians has been low for as long as pollsters have asked about it; trust in nurses and judges has been high for as long as pollsters have asked about it.

Second, empirical evidence about others' generic attitudes is useless for practical purposes. What matters to us in placing and refusing trust intelligently are not third parties' generic attitudes of trust and mistrust in types of profession or institutions. For practical purposes, we need to judge the trustworthiness of particular persons and institutions in particular matters, and third parties' generic attitudes tell us little. Others' generic attitudes may offer reasonable evidence for purchasing branded goods, or for responding to generic risks (e.g. burglaries and house fires). Here, cases can be classified by reputations or risk levels and we can do no better than assume that the case with which we have to deal is typical of a class of cases.

But things are quite different when we seek to judge the trustworthiness of particular cases, so we need to take account of their distinguishing features. If I want to work out whether a school can be trusted to provide adequate meals and exercise, or whether a garage can be trusted to service a car, or whether a colleague can be trusted to respect confidentiality, I need to judge the trustworthiness of that school, that garage or that colleague in the relevant matter – not the generic attitudes of third parties towards average or typical schools, garages or colleagues. We are not lemmings and we need to base judgments of trustworthiness on relevant evidence, rather than on evidence of others' generic attitudes.

Judging trustworthiness

Judging others' trustworthiness can be

hard, but since it matters for practical purposes the difficulty has to be addressed. Luckily we seldom need to judge the overall trustworthiness of whole professions or institutions. Typically we need to judge whether claims or commitments made by particular individuals, office holders or institutions are trustworthy. Is A's claim about an accident that damaged his car true? Is B's promise to pay for the damage reliable? In judging whether to trust others' claims or commitments we typically need, and can often find, some evidence of their honesty, reliability and competence – or lack of these – that bears on the specific practical issues. Every day we manage with some success to place trust intelligently in other motorists and pedestrians, shopkeepers and colleagues, friends and family.

In such everyday cases, the task is simplified by the fact that judgments of trustworthiness focus on specific matters. For example, in judging whether a teacher can be trusted to teach chemistry to a certain level, or a surgeon to perform a specific procedure, or a supplier to take on a complex contract, it will often be clear enough which evidence of competence is relevant.

The situation is similar in cases where judging trustworthiness depends on judging character as well as competence. In judging whether a given child can be trusted to cross a road, we judge not only competence but reliability. Is the child impetuous or steady, forgetful or organised? And yet in other cases it may be more important to judge honesty than either competence or reliability: is the other party likely to tell the truth and meet their commitments? In everyday life it is often enough to assess reliability or honesty in the specific matter; global judgements of reliability and honesty are not needed.

However, difficulties arise when we have to judge complex institutions and arcane expertise, or interact with strangers.

The standard contemporary remedy to these difficulties has been to construct systems of accountability that supposedly provide indirect ways of judging honesty, reliability and competence, which can serve when direct judgements of others' honesty, reliability or competence are not feasible. Systems of accountability have proliferated in public and professional life in the last 25 years, and until recently failures of trustworthiness were generally thought to call for more and better accountability. It is now clear that the remedy does not always work and enthusiasm for this approach is waning.

Systems of accountability work – when they do – by creating second-order obligations to provide evidence of the standards to which first-order professional or institutional obligations are discharged. In theory, this both incentivises more trustworthy performance and helps the less expert place and refuse trust with discrimination. So there are two practical questions to be asked about these systems' accountability. First, do they actually improve trustworthiness? Second, do they help individuals place and refuse trust intelligently? Unfortunately, many current approaches to accountability fail on one or both counts.

The most glaring defects occur where systems of accountability create perverse incentives and those who are held to account are pushed to 'game' the system or embrace a tick box culture at the expense of improving or maintaining standards. Lesser failures occur when systems of accountability damage or obstruct good performance by requiring office holders and professionals to follow procedures that hinder or obstruct performance of their primary tasks. In such cases, too, accountability actually damages trustworthiness.

Even systems of accountability that do not actually damage trustworthiness may not help individuals to place and refuse trust intelligently. Some still think that all that is needed in this case is to supplement accountability with increased 'transparency' about performance, thereby allowing the less expert to judge the performance of professionals and institutions. Yet transparency, too, is often less than intelligent, particularly if seen merely as a matter of putting information into the public domain.

The public domain

Putting information in the public domain does not automatically make it usable by all. The public domain is large and much of it is not accessible to those who do not know their way around. Even those who know where to find information may not find it intelligible. Those to whom it is both accessible and intelligible may still not find it assessable or usable, so may not be able to draw upon it to place or refuse trust intelligently.

Information that genuinely enables members of the public to place and refuse trust intelligently has to be communicated in ways that are not only accessible and intelligible, but also can be assessed and used. The communication of evidence of trustworthiness must take account of varied competence and understanding. Without intelligent, audience-sensitive communication of evidence and information (and this demands far more than mere transparency), intelligent placing and refusal of trust will fail beyond daily and familiar contexts. It will fail because many will be unable to judge whether others' claims are true and whether their acts are likely to live up to their commitments; they will lack the evidence for placing or refusing trust intelligently. ☐

cont from page 2

Higgs boson finally found?

At a seminar held at CERN, the European Organisation for Nuclear Research, on 2 July, teams of researchers from the ATLAS and CMS particle physics experiments presented their latest preliminary results in the search for the long-sought Higgs particle. Both experiments have observed a new particle in the mass region around 125-126 GeV.

"The results are preliminary but the 5 sigma signal at around 125 GeV we're seeing is dramatic. This is indeed a new particle. We know it must be a boson and it's the heaviest boson ever found," said Joe Incandela of CMS. "The implications are very significant and it is precisely for this reason that we must be extremely diligent in all of our studies and cross-checks."

The results presented today are labelled preliminary, being based on data collected in 2011 and 2012, with the 2012 data still under analysis. A more complete picture of the observations will emerge later this year after the Large Hadron Collider provides the experiments with more data.

"We have reached a milestone in our understanding of nature," said CERN Director General Rolf Heuer. "The discovery of a particle consistent with the Higgs boson opens the way to more detailed studies, requiring larger statistics, which will pin down the new particle's properties, and is likely to shed light on other mysteries of our universe." ☐

The banking crisis of 2008 showed how fragile the banking system can be. Are there ways to make it more robust? This question was explored at a meeting of the Foundation for Science and Technology held on 25 April 2012.

Understanding the bigger picture

John Kay

In a speech to the Global Association of Risk Professionals in 2006, the then Chairman of the Federal Reserve Bank said the following: "We are now in the midst of another wave of innovation in finance. The changes now underway are most dramatic in the rapid growth in instruments for risk transfer and risk management, the increased role played by non-bank financial institutions in capital markets around the world, and the much greater integration of national financial systems. These developments provide substantial benefits to the financial system ... These changes have contributed to a substantial improvement in the financial strength of the core financial intermediaries and in the overall flexibility and resilience of the financial system."

The speaker was Timothy Geithner. How did he get it so wrong? And why was he then promoted to become Secretary of the US Treasury, probably the most important financial and economic job in the world?

To understand how he got it so wrong, it is necessary to know something of the economics of risk and risk-taking. For the last 50 years economists have modelled risk as if it were just another commodity. There is a market where people buy and sell risks and they do so for several reasons.

The first reason is that some people have greater capacity to bear risk than others. The risk of gaining – or losing – £100 is much easier to manage for the very rich than it is for someone whose total wealth is £100. People who find risk onerous may therefore choose to sell their risks to people who find them less burdensome.

Second, initial risk exposures may differ. Events which aggravate risks for one group of individuals may reduce them for another. Hence the standard example in which ice-cream manufacturers trade with umbrella manufacturers and each reduce the risks they face. The hedge is mutually advantageous.

Both capacity and hedging provide compelling reasons for buying and selling risks. They do not reduce the overall risk in the world, but they can cut the cost of bearing those unavoidable risks.

Professor John Kay FBA FRSE is an author and columnist for the *Financial Times*. Professor Kay's interests focus on the relationships between economics and business. His career has spanned academic work and think tanks, business schools, company directorships, consultancies and investment companies. He is chairing the Review of UK Equity Markets and Long-Term Decision-Making which will report to the Secretary of State for Business, Innovation and Skills (BIS).

Third, people may have different risk preferences. Some people may like risk while others may fear it. Risk trading motivated by these reasons also has the effect of reducing the social and economic cost of managing risk – even though the aggregate risk remains the same.

Assessing risk

Yet there is a fourth reason, which is that people make different assessments of the same risk. This is a more problematic source of risk transfer because it is likely that one of the parties is right and the other is wrong – at any rate one of them is more right than the other. We may never actually know, however, who was right and who was wrong.

Looking at the financial markets, which was the dominant motive for the growth of risk trading in the last two decades? With hindsight, the reason for that explosion was motive four – different people made different assessments of the same risks. Yet, Geithner and others believed that the phenomenon was best explained in terms of motives one, two and three; there was extensive discussion about the way in which the creation of ever more complex securities had the effect of enabling people to finally match their particular holdings to their particular risk preferences.

I learnt about the fourth motive when involved in work on the reconstruction of the Lloyds insurance market during the early 1990s. Lloyds is principally a 'reinsurance market': the primary insurer takes the first tranche of a particular risk and then the reinsurer agrees to insure a further proportion. Reinsurers take on portfolios of these 'tail-risks' and manage these portfolios with large reserves. That, at least, was the traditional model of reinsurance.

However, during the 1980s, people discovered they could sell reinsurance of reinsurance. Now, if it was possible to sell reinsurance of reinsurance, then it must be possible to sell reinsurance of reinsurance of reinsurance – and so on. At each subsequent stage of these trades, though, the pattern was that people who knew a little bit about the risks they were underwriting were passing those risks to people who knew less. In the end, people who had absolutely

DISCUSSION

Predicting the impending disaster

Had anyone foreseen what would happen in 2007? It appears that while no-one had seen the peril in detail, many had forecast that the huge securitisation of risk would end in tears. There had been earlier studies criticising the use of very complex instruments. Nominal bank assets and liabilities had risen enormously, driven by inter-bank lending, and there had been warnings that this could be a source of instability.

no idea about the risks they were underwriting – rich British individuals who had been induced to become Lloyds Names – found themselves taking on the reinsurance of reinsurance of reinsurance of reinsurance.

All of this started to go wrong in 1988, when the Piper Alpha oil rig caught fire in the North Sea. At that time, this was the largest single claim to be made on the Lloyds insurance market. It then triggered the reinsurance contracts, which in turn triggered the reinsurance of reinsurance contracts.

This went on and on until people who had never heard of Piper Alpha discovered they had in fact insured it, not just once, but over and over again. That was the catalyst which caused some of the stately homes of England to be sold in order to meet the losses.

So I was relatively well-placed to understand what was happening in the early years of this century with the creation of complex securities for segmenting credit risks. In fact, I was apparently better placed than Mr Geithner!

The credit markets

If Lloyds went wrong with Piper Alpha, then the credit markets started to go wrong in the summer of 2007 when David Viniar, the Chief Financial Officer of Goldman Sachs, announced that we were experiencing 25 standard deviation moves several days in a row. The number that expresses the probability of a 25 standard deviation event has enough noughts on it to cover more than one line. These events simply do not happen. In fact, it was not that a risk had suddenly materialised which was at the extreme end of possible experience within the model. Instead, new events had occurred which were not accommodated within that particular model at all.

Imagine a model of the process in which a person arrives at a bus stop, knowing that the buses come every 10 minutes but not being sure of the exact timetable. Every minute waiting increases the probability that the bus will arrive in the next minute: after waiting for nine minutes it is absolutely certain that the bus will arrive in the next 60 seconds. We all know it is not quite like that; but the model can be extended stochastically.

After waiting 15 minutes for a bus that comes every 10 minutes, though, doubts will begin to surface. This is not because we are looking at events at the extreme ends of the probability of distribution of outcomes within the model; the doubt is due to a dawning unease about the applicability of the particular model. Only those ideologically committed to the model are likely to be waiting after half an hour!

The occurrence of extreme probabilities within a model is typically due to off-model events. Toss a coin a hundred times: if it comes down heads every time, it is of course possible that an inconceivably low probability event has occurred, but some other explanation is much more likely.

In seeking to understand why breakdowns occur in these kinds of systems, it is useful to look at the methods used to analyse extreme events in engineering systems. Charles Perrow, writing in the wake of the Three Mile Island incident, called such an event a 'normal accident'[1]. By this he meant the unanticipated interaction of multiple failures in a complex system. That is an apt description of what happened in 2007-8 and in other financial collapses.

In Perrow's analysis (which has been subsequently used by him and others to analyse similar events and failures in engineering and physical systems) such failures are generated by a combination of two factors – extreme complexity on the one hand and tight coupling on the other.

Extreme complexity is self-explanatory. Tight coupling means there is no looseness or redundancy in the system – one disastrous event quickly has consequences that spread throughout the system. Perrow made the important point that additional safety regimes, which almost inevitably add further complexity, may actually increase rather than reduce the probability of overall failure. This was true in several of the 'normal accidents' which Perrow described.

In the speech Timothy Geithner made to the Association of Risk Professionals, he discussed the risk which exists within individual financial institutions but explained nothing about the risks which were characteristic of the system as a whole. Yet it was the systemic risk, which was not effectively modelled in the mechanisms that Viniar and others were using, that caused the collapse of 2007-8.

Designers of complex engineering and physical systems have tried to reduce the probability of normal accidents (although they cannot eliminate them). The first and over-riding requirement is to reduce complexity. So, does the additional complexity added to financial systems over the last two or three decades actually serve an important purpose? If not, then a great deal of it should be stripped out.

Complex systems should have loose coupling wherever possible. That means emphasising redundancy in the system. If one element fails, there are alternative pathways to the same end. There needs to be modularity, enabling a failed element to be isolated and shut down without destroying the properties and functioning of the system as a whole. Markets have not developed in the direction of less complex, looser-coupled and modular forms, just the reverse.

A sense of the whole

Let us return to why Geithner, far from being sacked for his misjudgements, was actually promoted to handle the fallout. His value is found in his detailed knowledge of individuals and institutions within the financial system. It is possible, and common, to know a great deal about the individual parts of the system, but have little sense of it as a whole, or of its properties. Geithner's lack of understanding of the overall system was revealed by the failure to comprehend its systemic weaknesses.

We have the paradox (which can be found in engineering as well) that knowing a great deal of the detail does not necessarily equip an individual to manage or even understand the operation of the whole. That wider understanding is required to help avoid crises of the kind we experienced in 2007-8. □

1. C Perrow (1984) *Normal Accidents: Living with High-Risk Technologies*. **Princeton University Press, Princeton.**

DISCUSSION

Managers and owners

Had not Adam Smith pointed out that there could be a conflict between the interests of managers and those of owners? Current market structures seem to have exacerbated these conflicts. In fact, UK banks are very highly geared so lenders and depositors are actually absorbing a great deal of the risk. Perhaps this should be reflected in giving them more say in the running of the banks.

From individual players to an interconnected system

Andrew Haldane

To give some sense of how extraordinary the events of the last 20 years or so have been, imagine placing a hedged bet in 1900 – long on bank equities and short on non-bank equities. With a hedged bet, if banks and non-banks had performed similarly, everything would come out equal. For around 90 years that is exactly what happened.

The next 20 years saw something truly extraordinary. Up to 2006-7, the excess returns to banking cumulatively were eye-watering – it was like striking gold. As it turned out, it was Fool's Gold. The collateral damage from that bubble inflating and then popping has been enormous. To give some sense of scale, so far the cumulative output costs from the crisis are in the order of half a trillion pounds sterling in the UK – roughly a third of pre-crisis GDP (see Figure 1).

Nor is it over. Using IMF forecasts of future growth to 2018 (which if anything might be on the positive side), the figure rises to around £2 trillion – well in excess of one year's GDP. Martin Wolf at the *Financial Times* is fond of saying that the only things more costly than crises are wars. Well, as Figure 1 shows, the costs this time will be greater than those of the Great Depression and around the average of those which were incurred in the First and Second World Wars.

The cost to the UK is likely to be several multiples of annual income. The cost of reform is typically estimated to lie somewhere between 1-3 per cent of GDP. The cost-benefit case for reform is overwhelming.

Conceptual framework

It is interesting to see the change in terminology now being used – albeit slowly – by regulators and other financial professionals. On the left hand side of Table 1 are some of the terms typically used pre-crisis, on the right those to which the market is gradually moving. Take one example: pre-crisis the efficient market hypothesis assumed prices behaved in a 'random walk'. These days the term 'Levy flight' is becoming more common.

A bird foraging for food will, most of the time, seek the low-distance, low-protein food option – it will be risk averse.

Andrew Haldane is Executive Director of Financial Stability at the Bank of England. He has responsibility for developing Bank policy on financial stability issues and also for the management of the Financial Stability Area. He is a member of the Bank's Financial Stability Executive Board and of the new Financial Policy Committee. Before taking up his current role, he headed the Bank's work on systemic risk, market infrastructure and international finance.

However, when it is struggling to find any food at all, it will seek the high-protein, high-distance option. In other words, the bird gambles for resurrection when facing acute risks. It is in Levy flight.

That is exactly the behaviour exhibited by the CEOs of the world's biggest banks in 2007. Dick Fuld and Lehman Brothers essentially went for the high-risk, high-protein option. It was that, amongst other things, which brought the world to a shuddering halt.

An interconnected system

More generally, the financial world is gradually moving toward a position where it is understood and regulated as though it were a system. Seen with hindsight, one of the peculiarities of risk management and regulation pre-crisis was that it was carried out bank by bank, node by node. Risk was measured as though individual firms were islands.

The International Monetary Fund argued in 2006 that bigger ought to be better in finance because it enabled a greater diversification of risks. Bigger, more connected banks were safer and therefore could run with lower levels of insurance. The point that was missed was that even if (and it is a big 'if') the probability of failure was lower, the impact of a big connective node failing was proportionately greater.

The crisis of 2007-8 was made much worse by such connectivity and size. In its wake, it has been agreed internationally that the biggest, most connected banks will in future have larger insurance buffers, not smaller ones, to reflect their super-spreader status. This is an epidemiological lesson from the 1970s applied to modern day finance.

Pre-crisis, regulators focussed on the risks that individual firms were taking; almost none considered the links between the nodes. There was no common language for describing financial flows such as exists for the World Wide Web, for example. Yet such models of connected nodes are very common in the natural sciences: food webs are a good example.

Over the last year or two, there have been attempts to create a similar type of imaging for international finance, plotting

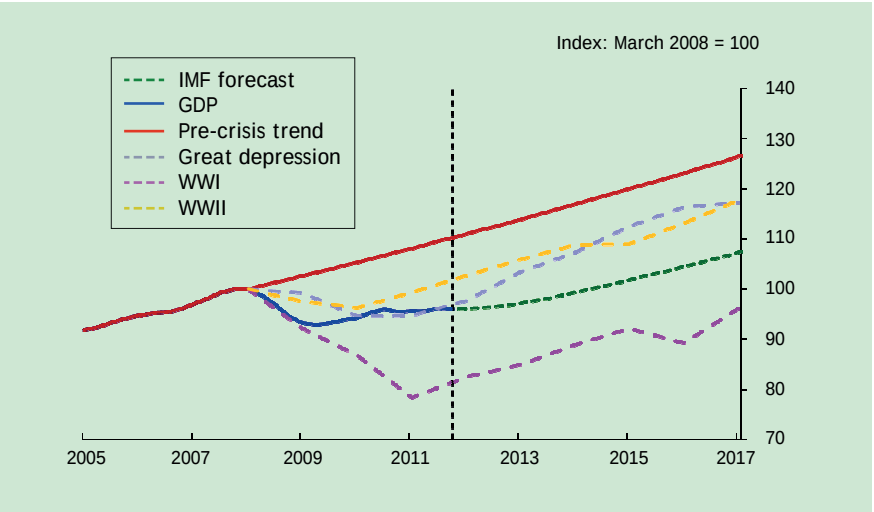

Figure 1: Crisis cost.

Table 1. An intellectual shift	
Pre-crisis	*Now*
Gauss	Pareto
Random walk	Levy flight
Fat cats	Fat tails
Representative agent	Heterogeneous agents
Idiosyncratic risk	Systemic risk
Risk	Uncertainty
Diversification	Diversity
Equilibrium	Equilibria

the contours of the international financial network. But it has not yet reached the stage where financial weather maps can be drawn, warning of incipient risks, cliff edges or rising systemic risks. Without such maps, it is difficult to consider how this network might be usefully reworked in order to make it more robust.

One initiative instigated by the G20 seeks to replace this dense, complex cat's cradle of interconnections of financial flows with a rather more simpalified 'hub and spokes' configuration where 'central counterparties' serve as the buyer to all sellers and the seller to all buyers. They sit in the middle of the web and create the hub-and-spokes configuration. This ought to make for a more robust financial web, provided the central counterparties are themselves bullet proof.

There are proposals on both sides of the Atlantic to introduce more modularity, or 'decomposability' (to use Herbert Simon's term) into banking systems of financial flows. There is a proposal by Paul Volcker, former Chairman of the Federal Reserve, to separate-off some of the banks' riskier activities. There are also proposals in the UK, by John Vickers, to ring-fence different activities that banks undertake. It is questionable whether either are, on their own, sufficient to break down completely the dense thicket of complexity that currently envelopes the financial web.

Information

Paul Volcker once said: "The only useful piece of technological innovation in banking over the past 30 years has been the ATM". This has more than a grain of truth in it. The perversity here is that if we are to believe *The Economist*, we are on the cusp of a third industrial revolution brought about by IT – information technology. As the market in finance is a market in information, so it might be expected that the financial industry would most benefit from IT.

The facts, however, tell a somewhat different story. Take the unit cost of financial intermediation in the USA over the last 130 years or so. Over that period it has increased. So, *prima facie*, finance has not fully harnessed the productivity-enhancing benefits of information technology. If anything, the unit cost of financial intermediation services is now greater than my grandfather's grandfather might have had to pay.

In some respects, banking is a peculiar industry. Up until last year, there had not been a new bank set up in the UK for a century. This indicates there is something seriously wrong in terms of barriers to entry. Of those barriers, I count unwillingness to disseminate information as among the more important. If finance is to harness the same productivity-enhancing benefits experienced by the retail and wholesale sectors, one obvious change would be to make the information currently held in-house by banks available on an open basis.

Looking at the lessons from industries as diverse as music or publishing, job searches or finding a partner, IT has revolutionised them by doing away with the middle man. Banking is the ultimate middle man – that is why it is called intermediation. IT can revolutionise this industry too. Such a transition might offer hope of not going down the same desperate path we have trodden the last three or four years ☐.

Andrew G Haldane and Robert M May (2011) Systemic risk in banking ecosystems. *Nature*, **469, 351-355 (20 January) www.nature.com/nature/journal/v469/n7330/full/nature09659.html**

Prudence is an essential virtue in banking

Martin Jacomb

In creating an efficient, safe and economical framework for a banking and financial system, there are political imperatives which stand in the way of this and have to be overcome if possible. However, the size and international scope of major banks make it difficult for individual nation states to deal with them on their own. Yet, notwithstanding a great deal of international collaboration, the UK still has to try to solve its own problems for it is UK taxpayers who are at risk.

The first political imperative is to keep the financial system from total collapse, because of the damage this would do to the economy as a whole. A more recent consideration is the need to keep retail depositors safe from loss (after all, they have votes).

Banking is an inherently risky business. A banker accepts deposits in order to lend it out. The margin on the loan pays for overheads, it services the capital invested in the business and yields the profit.

Lending money runs the risk of loans going bad. Even a prudent banker will make some loans which go bad; but if prudence rules and the banker's judgment is good, the losses will be covered by the profit. If losses outstrip profit, then they must be made good out of capital. If capital is insufficient, bankruptcy follows and depositors may not get their money back. So banks need capital both to reassure customers and create confidence that depositors will indeed get their money back. Over and above this, governments want to ensure that banks are safe, that the system will not collapse and that depositors, particularly retail depositors, will not lose money. Therefore, they introduce capital

requirements to make sure there will be enough to repay depositors in the event of disaster.

Servicing capital

Holding capital is expensive and it has to be serviced. If banks are required to hold more capital than they judge necessary, they will be tempted to cut lending rather than raise more. In any event, they will have to make more profit from their assets in order to service the extra capital. So they will take more risk to make that extra profit. It may seem paradoxical, but heavy capital requirements will thus inevitably increase the risk within the system. Those managing the banks are being nudged towards greater risk. They will know that others are doing the same and there will be a collective migration away from basic standards of prudence.

Of course, the system as a whole is inherently risky. Banks deal with each other. As they balance their books at the end of each day, some will have surplus funds, some not enough, so the former lend overnight to the latter. The scale of banks' dealings with each other is enormous. So it is unavoidable that the failure of one large bank may jeopardise the health of others. If the system is to remain secure, governments must be ready to step in and discharge the liabilities of a failed bank, or else other bank creditors may themselves collapse. This need for governments to step in with taxpayers' money to prevent or compensate for total collapse has always been there.

Given the enormous size of banks, the task of keeping the system safe is not easy. Many banks have become too big or too interconnected with others to be allowed to fail. This leads directly to moral hazard, because those running banks know that, in the event of failure, the Government will step in.

Defective regulation

Regulation, too, is very often defective. The pre-2007 Basel capital requirements were so framed that they led directly to the enormous losses caused in the securitised mortgage debt market. This was a major cause of the whole trouble, the consequences of which we now have to deal with. It is an example of bad regulation having utterly tragic consequences.

History shows that regulation, although inevitable, is almost always defective. A more authoritative and coherent critique of the proposed extension of regulation is to be found in the views of those running major banks: they really know the subject first hand and better than any regulator.

Sir Martin Jacomb is a former Deputy Chairman of Barclays and Non-Executive Director of the Bank of England. He was Chairman of the Canary Wharf Group until 2011 and Chairman of Prudential plc from 1995 to 2000. Sir Martin has also served as Chairman of the British Council and was Chancellor of the University of Buckingham. (Picture courtesy of the University of Buckingham)

Many people think that moral hazard afflicts bank managements because of the prospect of enormous bonuses. There may some truth in this: a huge bonus for giving your employer a big profit is alluring. Yet there is another much more important factor at work: banks are no longer owned by bankers. They are owned by shareholders who are, in general, not the actual beneficial owners but simply their agents: these are the fund managers who look after other people's money.

Fund managers are often interested in capital gain as much as the long term health of the business and this promotes a focus on short term gain. This is unhealthy, because it encourages riskier, higher-margin lending than a prudent bank would contemplate. Yet if it is what shareholders want, managements are likely to respond.

So there appears to be a problem with no satisfactory answer. The solution is certainly not a reversion to the *Glass Steagall Act*, i.e. splitting commercial and retail banking from the securities business. Ordinary commercial customers want banks to provide services which can only come efficiently from investment banking operations: these services include, for example, covering long term forex risks or interest rate risks, and the substitution of bond finance in place of bank lending.

In any event, the evil that *Glass Steagall* was designed to counter in the 1920s no longer exists, at least in that form. Nowadays, with modern information technology, securities can be widely distributed with full transparency and information, and are often rated by independent rating agencies.

Furthermore, Northern Rock, Bradford & Bingley, HBOS and AIG, which caused the trouble, were not universal banks. The result, though, has been heavier and more intrusive regulation. If the past is anything to go by, far from making the system safer it is a recipe for increased cost and inefficiency. Worse than this, it actually increases risk. Expensive regulation involves a great deal more capital and liquidity, plus a huge wage bill from internal regulatory work. Managers will then seek high returns from riskier business and seek ways of overcoming the barriers imposed by regulation.

Prudent management

Banks cannot be made completely safe; the best route to safety is through prudent management. Therefore it is a priority to look for ways of encouraging and incentivising prudence. Today's bank owners look for greater shorter-term profit rather than long term prudence. However, if depositors and other bank creditors have to take some risk, then they will prefer to deal with prudently-run banks. The cost of deposits will go down if a bank is run prudently and gains a reputation for prudence and therefore safety. This incentive has to come from action by depositors and other counterparties, because unfortunately it will not come from shareholders. Shareholders will not reward prudence unless and until prudence earns a decent return. My suggestion would be for all depositors to be at risk of losing, say, 10 per cent of their deposits.

Unfortunately I see little chance of political leaders adopting such an idea. Instead they will embrace an ever heavier, more cumbersome, complicated and inefficient system which will do no-one any good. Certainly not those who need bank finance. □

DISCUSSION

Modelling

There are difficulties in the modelling of these systems. They need to allow more for uncertainty as well as for measurable risk. It is also difficult to model behavioural systems. In addition, the more realistic models become, the more complicated they might be too, which is not necessarily desirable. Hedge funds, much criticised, have not seemed to contribute at all to the current crisis, nor has the insurance market.

How can the world feed its still growing population, especially in the face of challenges such as climate change? The issue was debated at a meeting of the Foundation held at the Royal Society on 25 May 2012.

Key challenges in feeding the world

John Beddington

In 2011, when the *Food and Farming Report* was published by the Foresight Group at the Government Office for Science, the world population was 7 billion, and the urban population had just exceeded the rural population for the first time. By 2025, there will be another billion people in the world, and 55 per cent of the world's population will be living in urban centres. Changes in climate between today and 2025 are already determined by the greenhouse gases now in the atmosphere.

This is the future the world faces. It means that a significantly greater amount of food has to be produced using less land, water, energy, fertilisers and pesticides, while at the same time increases in greenhouse gas emissions are avoided. The Foresight Report identified five key challenges we need to meet:

- balancing future demand and supply sustainably;
- addressing the threat of future volatility in the food system;
- ending hunger;
- meeting the challenges of a low-emissions world;
- maintaining biodiversity and ecosystem services while feeding the world.

The report had a global impact, influencing stakeholders around the world and leading to a number of new initiatives aimed at meeting each of the five challenges.

Balancing food demand and supply

New technologies and better governance are the two important drivers needed to achieve a balance between food demand and supply. Technological advances can help increase food production, while changes to international trade policies and the reduction of production subsidies can be used to increase sustainability in food production. The Foresight Report has had an impact in helping set in train projects in the UK and around the world.

The Centre for Agriculture and Biosciences International is a science-based development and information organisation that provides scientific expertise and information on agriculture and the environment. It has a global reach, with 46 member countries. As part of its work it is producing GPS plots of crop diseases to create country 'dashboards' of pests and diseases. It is also providing treatment advice to reduce pre-harvest losses.

Professor Sir John Beddington CMG FRS FRSE is Government Chief Scientific Adviser. He led the provision of scientific advice to the Government during the 2009 swine flu outbreak, the 2010 volcanic ash incident and the emergency at the Fukushima nuclear power plant in 2011. Previously he was Professor of Applied Population Biology at Imperial College. He has been adviser to the Foreign and Commonwealth Office, the Department for Environment, Food and Rural Affairs (Defra), the Ministry of Defence and the Cabinet Office.

In South America, the Brazilian Agricultural Research Corporation, Embrapa, is developing new technologies and innovations for sustainable food production in the tropics. It is supporting Brazil's aim to double its wheat production and will inform Brazil's policy on food production to 2050. Embrapa is also one of my favourite organisations – it is the only research organisation I know that not only makes its own wine, but also its own brandy!

In the UK, the Department for Environment, Food and Rural Affairs (Defra) has launched the 'Green Food Project' aimed at increasing food production while simultaneously enhancing the environment.

Managing volatility in the food system

Volatility in food prices remains a continuing challenge. 2008 saw the lowest level of food reserves for 40 years, and the result was a large spike in food prices. Commodity markets need to be managed more effectively and international trading policies designed that will reduce volatility in the food system. There must be food reserves, with safety nets. However, even if these measures are put in place, climate change means that managing volatility in the food system will remain an issue. In June 2011, the G20 made a commitment to increase food productivity and transparency in commodity markets to curb volatility in food prices.

The Foresight Report has informed the food modelling work carried out by Defra, the Organisation for Economic Cooperation and Development (OECD) and the International Food Policy Research Institute.

Ending hunger

One billion people go to bed hungry every night and a further billion are significantly malnourished. Increasing food production will help tackle this, but there are enormous issues of social equity and distribution that need to be addressed as well.

Mobile telecommunications technolo-

DISCUSSION

Eliminating obstacles to progress

There may be political obstacles to progress, especially in relation to the wider acceptance by EU member states of genetic modification of crops, as well as the elimination of subsidies and other barriers to efficient agricultural trade. The scientific community can do more to help educate the wider public to the benefits of greater use of genetic modification; the present public perception is that it offers benefits only for big business at the expense of public health. A particular problem is the readiness of some governments (including some EU member states) to base decisions on the need to strive to achieve zero risk rather than on a rational assessment of risk and benefit.

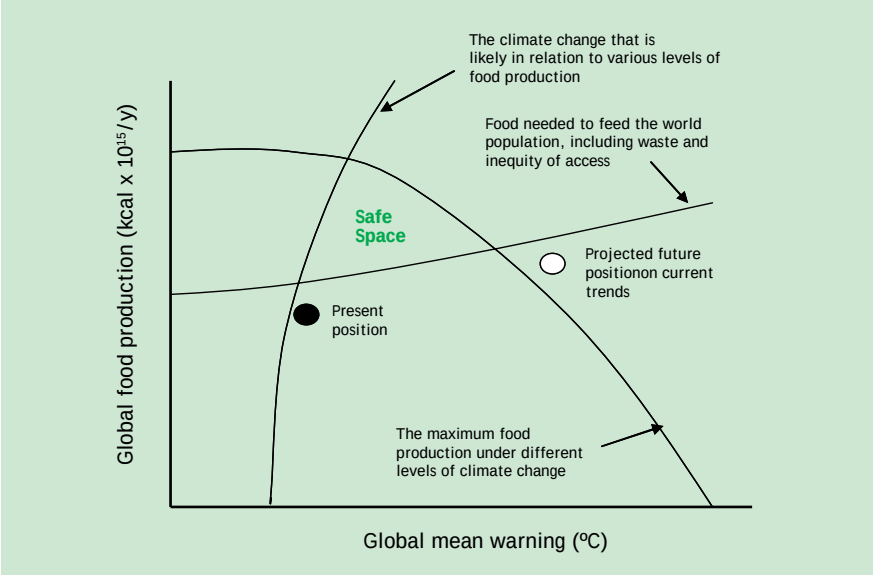

Figure 1. Climate-smart agriculture – finding the safe space for all our futures.

gies can offer innovative ways to tackle malnutrition. In Malawi, which has one of the world's highest rates of mortality in children under five, mobile SMS technology is being used to monitor the nutritional status of children across the country. Information is relayed – in real time – to their healthcare workers in the field, enabling the government and aid agencies to respond quickly if a crisis develops.

Technology could also be used to move the issue of hunger further up the public agenda and overcome the very real problem of compassion fatigue. For example, the number of people going to bed hungry every night could be displayed in Times Square in New York, instead of the temperature. The display could also carry regular updates about the effects of food prices and shortages, such as the food price spike in 2008 that moved another 100 million people into abject poverty.

A low-emissions world

To reduce overall greenhouse emissions, a strategy for carbon sequestration is needed and a programme to reduce the emissions created within the agricultural system. Innovation and adaptation need to be prioritised, as well as improvements in resource efficiency.

In the UK, Defra's 'Love Food Hate Waste' campaign led to a 13 per cent reduction in domestic waste. The National Farmers' Union aims to reduce greenhouse gas emissions by 3 million tonnes of CO_2 equivalent by 2018-22. The Technology Strategy Board, in partnership with Defra, the Biotechnology and Biosciences Research Council (BBSRC) and the Scottish Government, is running a £15 million competition as part of the Sustainable AgriFood Innovation Platform to fund projects on food processing and manufacturing efficiency. The European Commission ran a high-level seminar to address the question 'How Can Science Support Food Security?'

Maintaining biodiversity and ecosystem services

The world would be a sad place if the garden we have inherited turns into a bleak agricultural plot that produces lots of food but has lost its biodiversity. Changes in agriculture made to increase food production should not take place at the cost of lasting social, environmental and economic damage. In order to achieve this, major gaps in current knowledge have to be addressed through research and promotion of new and alternative agro-ecological approaches.

The Food and Agriculture Organisation (FAO) of the United Nations has developed a 'New World Agricultural Watch' initiative that recognises the interdependence of those policies concerned with feeding the world and those linked to conservation. The programme monitors the social, environmental and economic impacts of changes in agricultural practice. The Global Food Security Programme, which is coordinated by the BBSRC with Government and third-sector engagement, is looking at resilience, resource efficiency and sustainable production. The Foresight Report shaped much of its thinking in these areas.

The impact of the Report is also reflected in Conservation International's Food Security Strategy and the Bill and Melinda Gates Foundation's *Agricultural Development Strategy Report*.

The CSACC Report

The Commission on Sustainable Agriculture and Climate Change (CSACC), which I chaired, made a series of recommendations in 2011. The final report was published in March 2012. Its overall message, which complements that of the Foresight Report, is that we cannot continue to operate agriculture as we have in the past, not if we are to meet the dual goals of feeding the world in an equitable and sustainable way while ensuring that we do not exacerbate climate change. In other words, agriculture will not just have to adapt to climate change, it will also need to function as an agent of mitigation against climate change – a concept known as 'Climate Smart Agriculture' (Figure 1).

The CSACC Report made seven key recommendations:

- integrate food security and sustainable agriculture into global and national policies;
- significantly raise the level of global investment in sustainable agriculture and food systems in the next decade;
- sustainably intensify agricultural production while reducing greenhouse gas emissions and other negative environmental impacts of agriculture;
- target populations and sectors that are most vulnerable to climate change and food insecurity;
- reshape food access and consumption patterns to ensure basic nutritional needs are met and to foster healthy and sustainable eating habits worldwide;
- reduce loss and waste in food systems, particularly from infrastructure, farming practices, processing, distribution and household habits;
- create comprehensive, shared, integrated information systems that encompass human and ecological dimensions.

Food security is high on the international agenda this year, a focus at the G20 in Mexico, Rio+20 in Brazil and COP18 in Qatar. There is much work to do. We need to look at a variety of interventions at different levels, encompassing research, government policies, funding and socio-economics. If we do not, we face something that could be truly catastrophic. □

Achieving Food Security in the Face of Climate Change, **the Commission on Sustainable Agriculture and Climate Change (CSACC) Report, 2012. http://ccafs.cgiar.org/commission**

The Future of Food and Farming. **A Foresight Report, 2011. www.bis.gov.uk/assets/foresight/docs/food-andfarming/11-546-future-of-food-and-farming-report.pdf**

Changing the way we view agriculture

Peter Holmgren

The report of the Commission on Sustainable Agriculture and Climate Change (CSACC) is excellent: it is ambitious with a very wide scope. Its title, 'Achieving food security in the face of climate change' encompasses agricultural production, food security and food consumption. The contents reveal a strong focus on agricultural production. There is, however, less focus on non-food products and services, which play a large part in the sustainability equation: more than 10 per cent of the energy we consume comes from these sectors. Moreover, two billion people depend on bio-energy to cook their food.

Moving mountains?

The sustainable development landscape could be described as consisting of three mountains (Figure 1). Each mountain is an inter-governmental process. The first mountain is climate, the second is biodiversity and the third is food security. These are three global objectives.

At the top of the climate mountain we have United Nations Framework Convention on Climate Change (UNFCCC), which uses reduced carbon emissions as its measure of success. At the top of the biodiversity mountain is the UN Convention on Biological Diversity, which uses species as its success factor. And at the top of the food security mountain sits the World Summit on Food Security, which measures success in calories. The problem is that there is little communication between these mountains. Yet, at the base of these mountains all three issues overlap. So the result is a series of global objectives that are isolated from local realities where things need to be integrated. Hence, the development of the concept 'Climate Smart Agriculture' as a way to combine all three issues at a local level.

Dr Peter Holmgren is Director of the Climate, Energy and Tenure Division of the Food and Agricultural Organisation (FAO) of the United Nations. He is the FAO coordinator on climate change issues, with a focus on cross-cutting programmes where agriculture, forestry, fisheries and food security issues come together in the context of climate change. His research is on forest management, monitoring and economics within multiple management objectives. Before joining the FAO, Dr Holmgren worked in national forestry programme development in the Philippines, Pakistan and Kenya.

Making sustainable agriculture profitable

Agriculture must become both sustainable and profitable if current goals are to be achieved. This will mean going beyond official development assistance and public sector funds, and finding ways of attracting large-scale private finance to the sustainable agriculture agenda. Public funds will then be used for leverage and to reduce the risk for those involved. Simple measures of success in sustainable agriculture are also required, but couched in terms that business people and politicians, rather than just specialists, will understand. I would suggest three such measures: income or return on investment; the amount of biomass and organic matter in the landscape; and how much non-renewable energy is used for a given output.

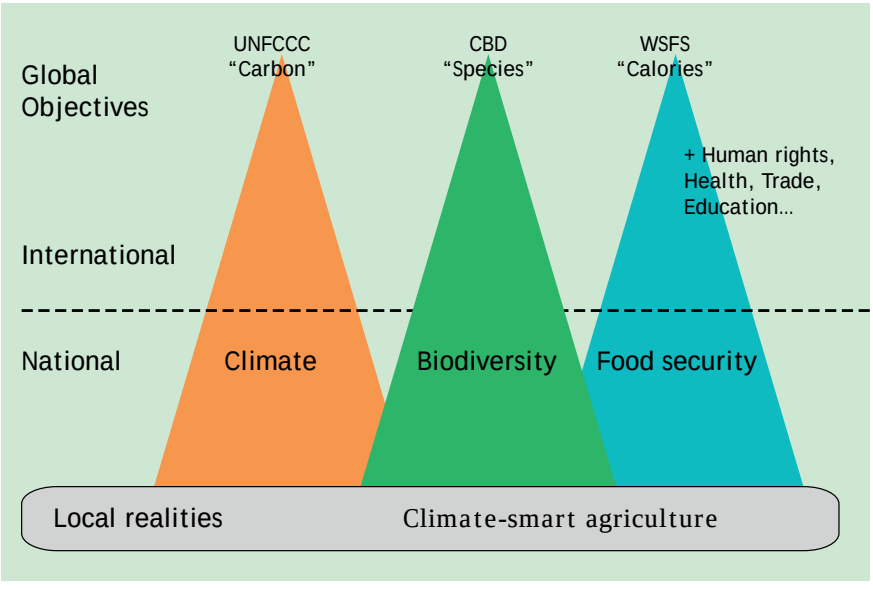

Figure 1. The sustainable development landscape

A growing urban population

Vulnerable populations must be helped to meet the challenges of climate change and food insecurity. Importantly, this needs to be achieved outside of farms as well as within them. While there may be another billion people on earth by 2025 with most of them living in cities, they are likely to have the same or similar challenges in terms of food security as people living in rural areas.

Food choices

It is vital to get across the messages that smart buying reduces impact on the environment and smart eating improves health. Public and/or private sector investment could be put towards education about choosing foods and raising awareness about the effects of food choices. The aim is to foster healthy and sustainable eating patterns while ensuring basic nutritional needs are met worldwide.

Reducing loss and waste

Reducing waste is a high priority item at the moment and has possibly the largest potential of all for reducing human impact on the environment. Food systems use 30 per cent of the energy we consume, but 80 per cent of that amount occurs beyond the farm gate. A two-pronged strategy is needed here. On the farm, there has to be a focus on reducing waste and marketing losses; while further along the consumption chain the priority is to reduce energy use and

DISCUSSION

Competition for land use

There is a general perception that there is competition for land use. Those seeking an increase in food production, those seeking to preserve forests as a means of dealing with carbon emissions and those seeking to increase non-fossil fuel sources of energy are all assumed to want the same access to the land. Such a perception may be largely misplaced. Indeed, the trade-offs between different objectives can be resolved, especially if adequate steps are taken to increase food availability and not just food production.

waste, especially in more affluent communities.

Information systems

I was very pleased to see the inclusion of information systems in the CSACC Report. Systematic, long-term, transparent and inclusive monitoring of all of the issues under discussion is crucial. Although remote sensing is suitable for some applications, it is not a very versatile tool. Increased investment in long-term monitoring by established institutions is required. In addition, participatory monitoring should be explored.

Climate-smart agriculture

Climate-smart agriculture is based on three pillars: increasing farm productivity and income; strengthening resilience both in terms of livelihoods and of ecosystems; and mitigating climate change. So the three main messages from FAO for Rio+20 were about synergies and convergence.

First, eradicating hunger and improving human nutrition are fundamental to achieving the Rio vision of sustainable development. In other words, if there is hunger, then there is no sustainable development. Second, to have healthy people and healthy ecosystems, food consumption and production must be sustainable. Third, there must be more inclusive and effective governance of agricultural and food systems.

The CSACC Report is an excellent, timely and very important contribution. There is strong alignment between it and many other reports, including those of FAO. Now is not the time to lean back and wait for intergovernmental processes. The opportunity to create new and innovative partnerships should be seized today. ☐

Addressing challenges in different parts of the globe

Tim Wheeler

Our knowledge of climate change and its effects on agriculture is increasing, but is still imperfect and uncertain. It is clear that the impacts of climate change on crop production differ across the globe (Figure 1). In Africa and many parts of Asia it results in reduced crop production, whereas in parts of the northern hemisphere production continues to increase over the coming decades. So there is inequality in the effects of climate change, but our knowledge is imperfect.

A systematic review by Cranfield University of all studies to date showed that across Africa, productivity of four major crops – wheat, maize sorghum and millet – will decrease under climate change, while maize and sorghum productivity will decrease across South Asia as well. There was no change in yield for rice.

Yet these figures conceal significant variation in the order of ±15 per cent to ±50 per cent change in crop productivity. This is a wide range of uncertainty. Can we really make decisions based on these figures? Not easily. One would argue that we can though, because sound policy-making is about risk management rather than basing it on outcomes that are certain.

Professor Tim Wheeler is Deputy Chief Scientific Adviser at the Department for International Development. He is also Professor of Crop Science at the University of Reading where he heads the Crops and Climate Group of the Walker Institute. Tim has researched the effects of climate change on agriculture for more than 20 years.

Reducing risks

There are practical ways to reduce risks in crop production. In Bangladesh and India an estimated 4 million tonnes of rice – enough to feed 30 million people – are lost due to flooding every year. In the Philippines in 2006, 50 provinces were affected by devastating typhoons and floods that cost the rice industry $65 million. Research by the International Rice Research Institute isolated the genes responsible for flood tolerance and led to the development of a flood-tolerant local rice variety, appropriately named 'scuba rice'. Scuba rice can survive being completely submerged in water for 17 days. To date six 'sub 1 mega varieties' of scuba rice have been produced.

This innovation addressed problems of climate vulnerability and reduced the production risks associated with rice. As a result, it has now been taken up by more than 1 million farmers across South Asia. Scuba rice could now move out of the research community and into the private sector, where it can be scaled up to a far greater extent. This is just one example of how some of the risks and uncertainties in agricultural production can be reduced.

What works and what does not

A review of agricultural interventions such as dairy initiatives, early efforts at bio-fortification and home gardens led by the Institute of Development Studies concluded that there was no evidence these interventions had an effect on the nutritional status of children, largely because of methodological weaknesses in the studies reviewed. This highlights the need for rigorous evaluation of research programmes to assess their true effects. In this case, it was not proved that such initiatives were ineffective; rather, that they

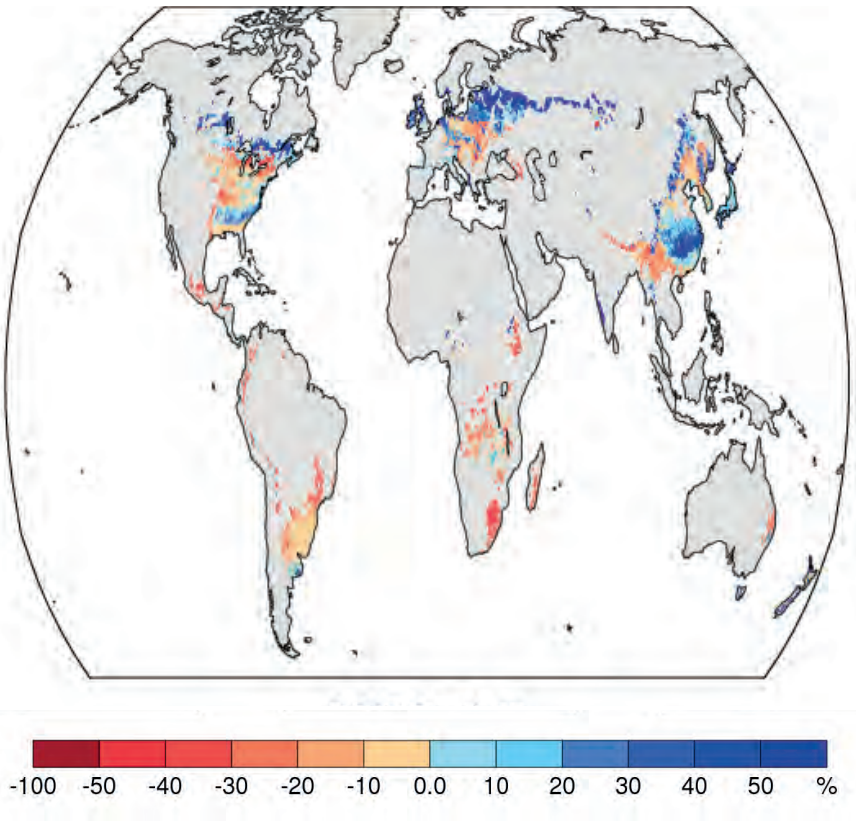

Figure 1. Changes in the yield of spring wheat under climate conditions consistent with the 2050s (Osborne, Rose and Wheeler, *Agricultural and Forest Meteorology*, in press 2012).

had serious methodological limitations.

The HarvestPlus programme, which is part of the CGIAR global research partnership for a food secure future, aims to overcome these limitations. It is now releasing bio-fortified foods into a number of farming systems within South Asia and Africa. The impact of these foods on nutrition is robustly monitored and evaluated. The researchers are investigating whether farmers will grow these biofortified crops and whether the markets will buy them. They are also determining the health and nutrition outcomes of those who eat them through sampling blood.

Information systems and data

We need timely and robust data collection and analysis to understand what the current problems are and what the future options might be.

Assimilation of data from different sources can give useful information. An example of this is a forecasting system that starts with data from the seasonal forecast in Ethiopia, where the rain gauge system is relatively sparse. The initial forecast is based on historical rainfall and a crop forecast model. As the season progresses, satellite estimates of rainfall are added to update the forecasting model and narrow the boundaries of uncertainty. As more and more data are assimilated, the boundaries of uncertainty are reduced further.

If these data can be available in time for farmers and governments to act, then uncertainty about a harvest that is yet to come can be reduced. These forecasts are just one small example of the opportunities that are made available by improvements in data and information systems.

It is interesting to compare this type of data with the perceptions of climate that farmers observe in their working lives. In one study, farmers in a number of villages in Uganda were asked whether they thought their climate was changing and, if so, in what ways. The farmers thought that the rains were starting and ending about a month earlier than in the past, that rainfall within the season was now more variable with more dry days, that there was less rain overall than before, and that the climate had become warmer.

If we compare their answers with the meteorological data available for their villages, it is clear that the rains did not start or end earlier than at any time in the past 39 years, rainfall is not more variable, and total amount of rain has not declined. The farmers' perception only matched measurements for the last item – the weather has become warmer.

This finding is important because the way farmers perceive their environment and climate determines their behaviours. We need to be aware of these behavioural and social aspects of response to climate.

Building for tomorrow

With sustainability there are trade-offs. On the small scale, for example, consider the Bolivian farmer who is battling year after year against variable rainfall, low fertility soil, and who is farming on slopes that collapse under heavy rainfall. A live grass barrier planted across the hillside would provide a low-cost solution, but the farmer must give up some of the land to accommodate this.

On a larger scale there are also trade-offs. Should biodiversity be conserved in one area while there is a concentration on agricultural growth in another? I do not think we have really got to grips with evaluating these types of trade-offs.

It is important to recognise it is not only climate that will change over the coming decades, but that agriculture also will change before 2050, 2060, or 2070. There will almost certainly be fewer farmers in many countries because developments in agriculture tend to create bigger land units with fewer farmers. Agriculture across the continent of Africa will change.

Through the efforts made by the authors of the CSACC Report and others, we have reached the stage where it is possible to formulate an accurate definition of the problems and to start implementing and delivering solutions to these many challenges. □

DISCUSSION

Urgent action needed

How can the seven key recommendations in the CSACC Report be realised, given their wide scope and the huge variety of organisations and individuals with a role to play? Dealing with the issues is so urgent that reliance on technological advances cannot be viewed as the sole solution. Speedier benefits will be derived from the application of current scientific knowledge to increase food production, investment in rural development and infrastructure, reduction of loss and waste, and innovations in the financial sector to increase the flow of funds to support agriculture and the food system.

At a special meeting of the Foundation held on 19 June 2012, the President of the Royal Society, Sir Paul Nurse, outlined his views on how science in the UK can be made to work more effectively for the good of society. His speech was followed by three formal responses.

Science and its contribution to the public good

Paul Nurse

To make science work well we need to make the right decisions about what scientific research should be supported in order to enhance our culture and to generate applications that benefit society. While 'benefit' is often considered in terms of the applications of science that follow from research, scientific knowledge also leads to a better understanding of ourselves and the natural world, an essential aspect of our civilisation. Science should not be judged solely in a utilitarian manner. This insight was captured by the American physicist Robert Wilson who, when questioned by Congress on how the Fermilab particle accelerator would help national security, answered: "It has nothing to do directly with defending our country – except to make it worth defending."

The discovery of new scientific knowledge and its application are sometimes presented as being quite different. However, scientific enquiry has always been concerned both with acquiring knowledge of the natural world and ourselves, and also with using that knowledge for the public good. Francis Bacon, the first philosopher of science, argued that: "Science improves learning and knowledge, and leads to the relief of man's estate."

This argument was reinforced by Robert Hooke at the birth of the Royal Society. He stessed how "scientific discoveries concerning motion, light, gravity, magnetism and the heavens help to improve shipping, watches, optics and engines for trade and carriage." He clearly linked science with its applications.

There is a continuum – from discovery that acquires new knowledge, through research aimed at translating scientific knowledge into applications, on to subsequent innovation. This spectrum should be considered as an interactive ecosystem, with knowledge generated at different places influencing the discovery of other knowledge upstream and new applications downstream. For example, work on improving the steam engine greatly informed the 'upstream' formulation of thermodynamics.

Sir Paul Nurse PRS FMedSci is President of the Royal Society. A geneticist who studies the division and shape of cells, he is currently Director and Chief Executive of the Francis Crick Institute. Previously he was Professor of Microbiology at the University of Oxford, Chief Executive of the Imperial Cancer Research Fund and Cancer Research UK and President of Rockefeller University New York. He was awarded the Nobel Prize for Medicine in 2001 and the Royal Society Copley Medal in 2005.

It is important to emphasise this is a continuum. Investing too heavily in one area, or erecting artificial barriers, or arguing that different parts are superior to others, should all be rejected. Science throughout the continuum shares the same values, the same skill sets and methodologies.

When choosing which scientific research to support, a key factor is the scientist carrying out that research. Major discoveries are usually associated with highly-talented individuals who have in-depth knowledge, are creative, understand the values of science, are well motivated and are effective in achieving what they set out to do.

In-depth knowledge of an area of science is essential, but this needs to be combined with what John Cadogan has called 'peripheral vision', an understanding and openness to what other sciences and traditions can contribute. It is especially required when a research problem needs multi-disciplinary and inter-disciplinary approaches, which is often the case when science is close to application.

Good scientific research is a creative activity and scientists have similarities to those pursuing other creative activities in the arts and the media. Freedom to pursue a line of investigation wherever it may lead (and even to uncover uncomfortable truths) is crucial to scientific endeavour.

Good scientists embrace the values of science, having respect for reliable and reproducible data, embracing a sceptical approach which challenges orthodoxy and scientists' own ideas, rejecting the falsification or cherry-picking of data, and being committed to the pursuit of truth.

Often this motivation is provided by a passionate curiosity about the natural world, a desire to know how things work or how they can be directed to achieve particular outcomes. Other motivations are also important, though: a desire to undertake public good through the

DISCUSSION

The Comprehensive Spending Review

With the next Comprehensive Spending Review expected in 2013, the science community needs to ensure that science is given the priority and importance it deserves, given its fundamental importance for the UK's economy. Business and academia need to provide coherent and coordinated advice to Government as well to the public generally. Yet, the scientific community needs to listen carefully as well to the concerns and views of both Government and the public and be sure it takes these on board. That is quite different though from trying to adjust its message by second guessing what Government wants to hear.

eradication of disease, to make something useful, to create economic wealth, even to become rich or famous.

But whatever the motivation, it needs to be strong because the pursuit of research is long and difficult. So in deciding what research should be supported, much attention should be paid to the scientists carrying out the work.

Decisions should be guided primarily by the effectiveness of these people. The most useful criterion for this is immediate past progress. Those that have recently carried out high quality research are most likely to continue to do so. So attention should be given to actual performance rather than planned activity (obviously such an emphasis needs to be tempered for those with only a limited recent record, such as early career researchers or those with a break in their careers).

How prescriptive?

A perennially vexing question is how prescriptive funding agencies should be when determining the research areas to be supported. There is a tension between scientists who want freedom to decide their projects, and society which supports science in order to improve the lot of humankind through specific objectives.

One possible response is for funding agencies to carry out a strategic review and identify research areas that are especially timely for future scientific advances or reflect particular needs of society. Although well-intentioned, such an approach runs the risk of wasting money and funding lower quality research. Such initiatives may attract less creative and effective scientists who simply follow the resources available.

In addition, the identification of favoured and non-favoured research areas is often made by committees made up of senior researchers, who may not be particularly research-active anymore. Better judgements are likely to be made by scientists actually carrying out specific areas of research who are much closer to the research problem being pursued.

How can this tension be resolved? There are three issues that are relevant:

- the Haldane Principle, or rather of what we understand the Haldane Principle to be;
- different approaches for programmes aimed at achieving applications or for specific goals;
- a more imaginative role for scientific leadership in influencing funding.

The Haldane Principle is usually interpreted as meaning that researchers and not politicians should decide how to spend funds, although the original Haldane Report made no reference to any specific principle. Science Minister David Willetts has recently expressed his understanding of the Haldane Principle as meaning that politicians, informed by external advice, should decide the overall science budget and the allocation between Research Councils, identifying priorities such as specific challenges or key infrastructures. Politicians should not be involved in decisions on specific funding proposals which should be made by researchers using peer review.

This is a sensible view. I would add that decisions should be made as close as possible to the researchers actually carrying out the research. Those leading research-funding bodies should focus their attention on high level priorities, avoiding the temptation to become too prescriptive and fine-grained concerning what areas should be funded. Those close to the research should decide the more detailed issues.

This can be illustrated by a metaphor derived from geographical exploration. In the nineteenth century, the Royal Geographical Society in London might decide to sponsor exploration of the Amazon basin. Which Amazon tributary should be a decision for the explorer on the ground. The funder's role should be to define the general region of interest, identify the best explorer and then properly equip that explorer so they can be most effective in the field.

Research funders today should behave in the same way. As far as possible, research funding decisions, especially at the discovery end of the spectrum, should be driven by the scientists carrying out the research because they are best placed to shape the research agenda.

Where a research programme is directed at achieving specific goals or applications, more prescriptive behaviour may be appropriate. Goal-directed research can occur anywhere in that scientific spectrum but tends to be more prevalent closer to translation and innovation (although not exclusively). Even when decisions are more prescriptive, they always need to be driven by quality, both of the researcher and also of what has been proposed.

Another issue is the role of scientific leadership. If a research funding leader decides that a particular area is important and so should receive more support, I would like to suggest he or she undertake a process of inspiring and educating researchers rather than ring-fencing resources. If the subject really is that promising, it will be easy to interest high-quality scientists and they will submit proposals. Should it not be so interesting, then they will be less impressed and less likely to submit proposals.

Permeability

Work closer to application is more likely to be multi-disciplinary and is likely to require teamwork, not only in scientific disciplines but also outside science, for example finance, market analysis and the law.

It requires effort to get individuals from such diverse backgrounds to work well together and attention needs to be paid to encouraging mutual respect and to breaking down barriers between them. This could be encouraged by greater permeability between sectors, encouraging the transfer of both ideas and people. We have too many barriers and silos that inhibit free transfer and encourage suspicion between the very people that need to be working closely together.

One problem is that increasing knowledge has led to too much specialisation, making interaction difficult between different scientists, industry, the public services and other professions. It was easier to make such contacts in the less complex society at the time of the Industrial Revolution. Take the Lunar Society for example, made up of chemists, biologists, doctors, industrialists, engineers and social reformers, regularly meeting every month to talk and exchange ideas. This included intellectuals and entrepreneurs

DISCUSSION

A waste of scientific talent

Very few women are in senior positions in science and technology. Although in biological sciences, for example, employment by women in the earlier career stages was 50 per cent, it dropped to no more than 10 per cent at more senior levels. There had been only two new female Fellows of the Royal Society elected this year in a total of 44. However, the Institute of Physics, founded in 1874, has recently had a female President and the President-Elect is also female.

such as James Watt, Josiah Wedgwood, Matthew Boulton and Erasmus Darwin. They met together in the Midlands once a month under the full moon, which illuminated them during their ride home after dinner.

It was in this atmosphere that the Industrial Revolution was born and we need to think how to reproduce this again today. Greater permeability should be promoted, starting with the young, giving them wider intellectual exposure during higher education and their research training. They need more diverse placements earlier in their careers with easy exchanges between sectors at all career stages. This is a key message: the promotion of translation and innovation requires good permeability across the sectors.

The Valley of Death

Much is said about the 'Valley of Death', the gap between the generation of new knowledge and its application, particularly through commercialisation. Usually the focus of discussion is on research support to bridge that gap but I feel attention also needs to be paid to pushing the bridgeheads further out into the valley, from both sides. There can be a problem when attempts to translate are made too prematurely, before knowledge is sufficiently reliable and complete. This is especially true in my area, the biosciences, given the complexity of living organisms. If you will forgive the pun: "To rush into translation runs the risk of becoming *lost* in translation."

A firmer bridgehead needs to be built, involving a more extended and secure knowledge base, before attempting to pass over that valley. On the other side of the valley, the bridgehead needs to be extended with more investment from industry. That investment needs to be in research that aims to capture new knowledge from the other side of the valley. Without research capacity and knowledge in industry it will be difficult to build back over the Valley of Death. Yet that is also crucial. Lose that capacity in industry and we will not recognise the science that will lead to innovation.

I should say something about impact. Researchers want their research to have impact, to increase knowledge, to contribute to culture, to generate societal benefit, to support the economy. Problems come when naïve and crude metrics of impact become an obligatory part of research funding decisions and assessments. The potential impact of research should be clearly identified if it makes sense to do so, but it does not always make sense. To demand a statement in every research proposal or assessment about societal or economic benefit will often simply result in unhelpful flights of fantasy of limited (if any) value. Impact is just one of a number of factors that may or may not need to be considered when assessing a research proposal.

Making science work well

So, how can we make sure that science works well and thrives in the UK and continues to bring benefits to our economy? The first requirement is to have a high-quality science base. The UK is very good at science and has been for centuries: it played a major role in founding modern science. The task today is to maintain, cherish and encourage scientific endeavour, and to promote its use for the public good.

Many of the features important for good science are well embedded in the UK. There is a tradition of respect for empiricism, emphasising reliable observation and experiment. Science in the UK is carried out in a culture of openness and freedom.

It is important to keep a spirit of adventure in science, to take risks and be prepared sometimes to fail, as research at the cutting edge is not always successful. When I ran Rockefeller University in New York, I saw how American entrepreneurs were prepared to be bolder and to take more risks to bring science to the marketplace.

For science to flourish, a broad portfolio of research investment is required. Funding should be given across the continuum of research, ranging from discovery science, through research aimed at translating knowledge for application, onto subsequent innovation leading to the development of new technologies.

Research often needs a longer time scale than the more short-term priorities of private business, or for that matter of politicians elected on a five-year cycle. Resolving that dilemma is crucial. Greater collaboration between publicly-funded research and private companies can reduce the risk to private companies and so move science towards applications.

Excellent scientific research requires talent. The most accomplished scientists in the world need to be attracted and trained here. This has to be reflected in the UK's immigration policy.

Citizens need an education which allows them to participate fully in a democracy that will increasingly require engagement with scientific matters. Teaching should inspire those pupils with the talent and inclination to become scientists. This will be difficult if we continue as now, as nearly all primary school teachers (over a quarter of chemistry teachers and nearly a third of physics teachers) have no specialist qualifications in science.

There should be greater attention on practical science in schools, reinforcing the fundamental principle that science is built on observation and experiment. Natural history can play an important role there – going out and mapping where spiders webs are in the garden can be very informative for an 11, 12 or 13 year old. Pupils must be inspired by the wonder of science, and need to understand why science generates reliable knowledge. At the very least, everyone leaving school should know the difference between astronomy and astrology!

There are too many barriers between scientists, technologists and engineers and these block the exchanges needed for good innovation. There are further blocks between these communities and those who lead public services and industry. It is essential to break down these barriers.

We can make science work well for our culture, our health, our quality of life, our environment and our economy. The Government is now developing an industrial strategy and it is crucial that this strategy embraces also science and innovation. Science is not only central to our culture and quality of live, it is the foundation of our economic growth. ☐

DISCUSSION

Too specialised?

Has the scientific community lost the ability to communicate intelligibly not only with the public at large but also with other scientists? Even much of *Nature*, the international weekly journal of science, is no longer accessible to non-specialist readers. Yet it had originally been launched as a magazine to inform the general reader about science.

Creating value in the UK economy

David Eyton

BP has a very strong interest in the success of UK research as it conducts over 40 per cent of its global technology development here, worth about half a billion dollars a year. We define technology in BP as the "practical application of science to manage risk, capture business value and inform strategy".

I am co-chairing with Shirley Pearce, Vice-chancellor of Loughborough University, a task force for the Council for Industry and Higher Education on making the most of research in the UK. Our latest report examines the impact of public research expenditure in the UK[1]. My sense of the work to date is as follows.

First, research is a competitive, global activity: it is in danger of becoming too fragmented in the UK. While the UK's research system is both open and excellent, as evidenced by the very large amount of inward investment, the risks are that: (a) this investment could go elsewhere as the UK's proportion of global R&D expenditure declines; or (b) the UK could increasingly be viewed as providing a higher education and research service 'at cost' to the rest of the world, while developing countries capture a growing share of business.

Second, large international companies account for the majority of the UK's business research expenditure and actually have the capacity to interface effectively with universities and funding organisations. These same companies choose to invest where they can find the best people and where they can leverage national research expenditures and infrastructure. Smaller companies account for a small fraction of R&D in the UK and often struggle to leverage the university and funding systems.

David Eyton is Group Head of Technology at BP. He is accountable for technology strategy and its implementation across BP and conducting research and development in areas of corporate renewal. In this role, he oversees the technological capability of the company. He also sits on the UK Energy Technologies Institute as well as the EU-based Science|Business Innovation Boards.

Third, commercialisation of research is one way in which value is created but it is inherently very risky. Large companies are practised at this and have the ability to manage the whole innovation pipeline, working with public research institutions. It should be noted that failures occur regularly and are to be expected. Smaller companies have fewer resources but laser-like focus: failure can be terminal and success equally dramatic.

Fourth, the impact of publicly-funded research is difficult to quantify, but is consistently assessed as strongly positive. Innovation pathways vary depending on 'clock speed' (the time from an idea to making a difference in the real world), industry structure and the significance of IP. However, the absence of an industrial strategy in the UK has resulted in offshoring of manufacturing, fewer opportunities for local leverage of our research base and a lack of strategic prioritisation of public research funding.

Last, despite having a vibrant financial services industry in the UK, inventions often end up being funded by overseas businesses.

Sir Paul said in his Richard Dimbleby lecture: "In the future we will not be able to compete on the world stage with low labour costs or by exploiting vast reserves of mineral resources. We will have to compete with our brains and with our science." I could not agree more and I worry about the longer term consequences for the UK of university fees, flat nominal budgets and limitations on capital for infrastructure.

So, how might the UK do better:

- greater confidence needs to be placed on the value of public research as a basis for the UK's success on a global stage;
- an industrial strategy, based on closer links between Government, academia and business, could target sectors and company size, in order to increase UK value-added;
- a broader notion of impact should be considered when assessing research excellence. Sir Paul mentions quality and passion and I think connectivity is also important;
- less energy should be put into competing for scarce Government funds and more into collaborating for larger programmes and global funds;
- the financial services sector should be encouraged to turn its considerable firepower onto the financing of research infrastructure and smaller companies.

1. www.cihe.co.uk/category/knowledge/publications

Models of economic growth

Andy Richards

Expectations are high that small, fast-growing companies will contribute significantly towards economic growth in this country, the model changing from one dominated by academic research and large corporations working in largely closed, secretive research centres to one of open innovation and entrepreneurs. This model describes a dynamic ecosystem, fluid and diverse, where diversity in itself is good.

I am suspicious of any homogenous approach when it comes to innovation. This is what happened in the pharmaceutical industry when it tried to industrialise the drug discovery process. Industrialisation was not in itself a problem, the fact that *everyone* did it was.

This new ecosystem, though, is a much more heterogeneous mix of small and large companies, entrepreneurs, venture capitalists, corporate venture capitalists, connected to the academic and institutional research base. However, for this to work it has to be interconnected and the barriers have to be broken down. Increasing the permeability of both people and ideas, as Sir Paul has said, is critical.

Permeability is easiest to achieve in geographical clusters like Cambridge, Oxford, London, the North West and in Scotland. A permeable cluster is a low-risk environment for an individual to

take a high risk and where the culture is empathetic to that risk. An entrepreneurial scientist can risk getting involved with a start-up and not worry so much about loss of reputation or that they might never get back onto the scientific ladder. The scientifically-literate entrepreneur can risk a technology where there is high chance of technical failure and not be judged if that occurs. It is questionable whether we can create such clusters, but we can facilitate them.

We also need more visible successes and this is a current problem as UK innovation successes tend to be sold early, often to foreign corporations.

And of course we need a robust supply of scientific entrepreneurs and entrepreneurial scientists. The quality of the people, after all, is what investors look for, much more than just the science or the business plan We do need to harness the wider enthusiasm for science, technology and innovation that does exist in this country. Evidence suggests that there is, in fact, a significant segment of students, children and adults who would love to be more involved, actively, in science. When the Raspberry Pi cut-down computer was launched earlier this year, the 10,000 target for selling these $25 computers was smashed in minutes and since then many hundreds of thousands have been sold. This is part of a growing movement of active amateurs: in its broadest sense, 'citizen science'.

Dr Andy Richards is Chairman of Abcodia. A biotechnology entrepreneur and business angel, he is currently Chairman of Altacor, Novacta, Abcodia and Ixico and a director of Arecor, Summit Corp plc, PsychologyOnline, Cancer Research Technology (commercial arm of CR-UK) and Babraham Bioscience Technology. He is a council member of the Biotechnology and Biological Sciences Research Council (BBSRC), a Trustee of the British Science Association, a founder member of the Cambridge Angels, and an advisor to several venture capital funds.

We should take note of initiatives like 'Foldit' where gamers have found the low energy states of proteins and actually ended up as authors on high ranking papers, and Galaxy Zoo and Zooniverse where planet hunters identify exoplanets from Kepler data. There is the Great Birdwatch, and OPAL, where amateur naturalists contribute through gathering data to a broader data set that is important in understanding our environment. There is also crowd-sourcing radiation data collection in Japan, which is, in many ways, superior to that generated by the state. These are just a few examples of the popularity and impact of citizen science.

I would encourage the scientific community, the Learned Societies and, yes, the Research Councils, to support this movement alongside the sterling work they are doing in facilitating translation, open innovation and impact. They all contribute to the peripheral vision that Sir Paul talked about. ☐

The shape of future research

Rick Rylance

What will the research world look like in five or 10 years' time? The increasingly tired distinction between pure and applied research will most likely have exhausted itself. Research science will be produced between a range of different organisations – not just universities – and not solely within them. Research will increasingly be funded from multi-agency points of view and there will be an accelerating international dimension. It will also be more common for knowledge to be produced at the boundaries of disciplines and in the interactions between them.

This sets challenges for funders. There is the need to stimulate translation without downplaying 'discovery research'. There are the relationships with the emerging international research powers, be they collaborative or competitive. There is a similar balance between concentration and collaboration in the way we enable domestic organisations and facilities to produce both efficiency and opportunity. There is the dividend to be gained from pooling intellectual expertise, talent and energy across the variety of disciplines.

I am not a scientist but I have worked in the history of science and I work currently with a clinical neurologist trying to understand brain functions when people read complicated texts. So I know a little about how science functions in relation to other disciplines.

Professor Rick Rylance is Chief Executive of the Arts and Humanities Research Council and Chairman of the Chief Executives' Committee of the Research Councils. Previously he was Head of the School of Arts, Languages and Literatures at the University of Exeter and before that he was Dean of Arts and Letters at the then Anglia Polytechnic University in Cambridge.

True inter-disciplinarity is easy to say and extremely hard to do. One fundamental aspect is the ability to constitute a different object of knowledge than that which exists within your current specialism. Specialist abilities are essential, but the new kind of object of knowledge will be constituted by its multi-aspected nature and its stretching demands upon time and expertise. It involves challenges at very basic levels in ways of working and the pace of research, in method, in definitions of task and ambition, in the protocols by which evidence is gathered and used, in the legitimacy of inference and conclusion and, of course, eventually in the forms of publication. One can easily find oneself 'too arty' for one journal and 'too sciencey' for another.

There are frequently low success and high mortality rates among interdisciplinary projects. Studies – such as those that followed EU Framework Programme 5 -- found fundamental reasons for this. These include underinvestment in groundwork to clarify modes of working and basic understanding among members of teams.

These replicate familiar structures. The way universities are constituted in discipline-based departments or faculties, career structures articulated around specialist skills, the training of early career researchers and postgraduates, and nature of budgets and funding structures, as well as the buildings themselves – all of these prioritise specialist rather than open-ended research.

I share Paul Nurse's vision of a new enlightenment underpinned by values of open, rational enquiry, of empiricism and respect for evidence. However, I think we are yet to have a mature conversation about the ways in which interdisciplinary work might be facilitated and encouraged. ☐

Commons Science and Technology Select Committee

Devil's Bargain? Energy Risks and the Public

Independent regulators should take a more prominent role in communicating the risks associated with energy generation and distribution because the Government is not seen as an impartial source of information, according to MPs on the Science and Technology Committee.

Public distrust of governments as providers of risk information is evident across Europe. The UK Government's position as an advocate for nuclear power makes it difficult for the public to trust it as an impartial source of information. Technically competent public bodies that are independent of Government – such as the Health & Safety Executive and Office for Nuclear Regulation – are in a much better position to engender public trust and influence risk perceptions. The Committee has called on these regulators to make greater efforts to communicate risk to the public and develop their role as trusted sources of information for lay people, in addition to providing risk information for technical audiences.

The latest report from the Committee, *Devil's Bargain? Energy Risks and the Public*, also warns that there is a lack of strategic coordination across Government when it comes to risk communication. A senior individual in Government should lead a Risk Communication Strategy team, the report argues, drawing together existing expertise within Departments and public bodies – and be visibly responsible for overseeing risk communication.

Furthermore, the decision to class the Fukushima crisis at the same 'Level Seven' magnitude as Chernobyl – despite there being significantly lower levels of radioactive material released into the atmosphere and no deaths directly attributable to the accident – demonstrates the need to revise the scale used to communicate the magnitude of nuclear accidents, according to the report.

www.publications.parliament.uk/pa/cm201213/cmselect/cmsctech/428/42802.htm

Science in the Met Office

The Met Office needs new super-computers to deliver confident extreme weather warnings, more accurate long-term forecasts and improved climate modelling, according to the Commons Science and Technology Select Committee.

It argues that scientific advances in weather forecasting and the associated public benefits – particularly in regard to severe weather warnings – are being held back by insufficient computing capacity. While recognising concerns about affordability, it believes that a new supercomputer for the Met Office could deliver as much as a ten-to-one return on investment.

Met Office weekly weather predictions have a high rate of accuracy, but there is a 'common public perception' that it does not provide reliable seasonal forecasts. Media criticism of its 'Barbeque Summer' prediction in 2009 has overshadowed the sustained improvements that the Met Office has made in forecasting.

The MPs are calling on the Met Office to continue to produce seasonal forecasts as they are useful for civil contingencies and a wide range of industries. However, the report warns that they should always be communicated carefully and accompanied by notes explaining the uncertainty. It recommends that the Met Office develops a communication strategy to improve the way it presents probabilities in its weather forecasting information.

TV and radio weather forecasts should make greater use of probabilistic risk percentages, which are employed in the USA, so that people can better understand the odds of forecasts getting it wrong.

The report recommends that the Met Office works with the Research Councils and other partners to develop a 10 year strategy for supercomputing resources in weather and climate. However, the Met Office needs assurances from Ministers. The Government must set out their minimum funding commitment to the Met Office for each year of the current Spending Review period by the end of this financial year. The report calls on BIS to complete a formal business case on supercomputing.

www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/inquiries/parliament-2010/met-office

Malware and cybercrime

Malicious software – designed to infect computers to steal bank details and identity information – poses a growing threat in the UK as more people use the internet and an increasing proportion of economic activity takes place online. MPs on the Select Committee say the Government must do more to help the public understand how to stay safe online.

The Committee has called on the Government to launch a prolonged awareness-raising campaign about personal online security. The report points out that 80 per cent of the battle against cyber-attack is 'routine IT hygiene'. Yet currently there is no single first point of advice and help for consumers while much of the online information about internet security is technical or jargon filled.

Television exposure is crucial to gain the widest possible exposure to the safety message, the MPs believe. They also want to see more done to promote and resource the existing Government website Get Safe Online. Advice from Get Safe Online should be provided with every device capable of accessing the internet and all Government websites should link to the website and highlight the latest security updates.

Many Government services are set to move to online provision either directly or through a range of providers. The Government 'digital by default' policy will increasingly require those in receipt of Government benefits and services to access these online as well.

It would be possible to impose statutory safety standards on software sold within the EU, similar to those imposed on vehicle manufacturers, but the MPs say they would prefer a solution based on self-regulation. The report calls on the industry to demonstrate that self-regulation is an effective way forward and that voluntary commitments can provide sufficient incentive for the industry to improve security in a fast moving competitive marketplace. If it cannot do so, the Government should investigate the potential for imposing statutory safety standards.

www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/inquiries/parliament-2010/malware-and-cyber-crime

Lords Science and Technology Select Committee

Science and Heritage

The House of Lords Science and Technology Committee has called upon the Department for Culture, Media and Sport (DCMS) to provide adequate leadership for heritage science.

In its report *Science and Heritage: a follow-up* the Committee cites research that heritage tourism contributes £7.4 billion a year to the UK economy and supports 195,000 full-time-equivalent jobs. The Committee argues that sustaining that contribution requires the UK to have the heritage science capacity to maintain the UK's movable and immovable heritage such as museums, libraries, archives and gallery collections as well as historic buildings. Maintaining that capacity requires greater leadership by DCMS, it says.

The recommendations made in the Committee's first report on heritage science (published in 2006) received a positive response, and their impact has been significant and lasting: the Arts and Humanities Research Council (AHRC) and the Engineering and Physical Sciences Research Council (EPSRC) have developed a joint Science and Heritage Programme, and the heritage science community have published a National Heritage Science Strategy and appointed a National Heritage Science Forum. This follow-up report welcomes these developments and says they have done much to build capacity and develop networks within the heritage science community.

The Committee, however, heard concerns that senior heritage scientist posts are being lost and that the sustainability of UK heritage science capacity is at risk. It recommends that the AHRC and National Heritage Science Forum should together measure capacity and address any issues arising.

Whilst acknowledging the role of the heritage science community and improvements in this area since 2006, the Committee remains concerned about the approach of DCMS to heritage science. As a result, the follow-up report calls on DCMS to take action to ensure that heritage science is given the priority it deserves. Recommendations in the report include:

- that DCMS should appoint a Chief Scientific Adviser without further delay. The post has been vacant since 2010 and failure to rectify this would, according to the Committee, amount to "negligent short-termism";
- that DCMS should set departmental objectives for heritage science related to its departmental responsibility to "protect our national cultural heritage". In addition, DCMS arm's length bodies (such as the national museums and galleries, and English Heritage) should set out how they will help achieve these objectives.

www.parliament.uk/business/committees/committees-a-z/lords-select/science-and-technology-committee/inquiries/parliament-2010/science-and-heritage

Strengthening the role of CSAs

The Lords Science and Technology Committee has published a report on the role and functions of departmental Chief Scientific Advisers (CSAs). The report sets out a range of recommendations to ensure that Government policy decisions are supported by the best science and engineering advice available.

The Committee concludes that the current system of CSAs has much to commend it and CSAs play a crucial role in offering science and engineering advice and evidence to inform Government policy. However, certain aspects of the system still cause concern.

The Committee received evidence of the obstacles that CSAs can encounter when seeking to offer advice to inform the policy-making process. For example, a former Home Office CSA described how the first he heard about the proposals to introduce ID Cards in the UK was on the *Today* programme. He was therefore unable to offer advice on the error margins relating to biometrics and existing technology before the policy was announced. A former CSA to the Department for Business, Innovation and Skills and the Department for Transport described how, when offshore wind policy was being developed, he lacked access to decision makers and so was not able to offer engineering advice to the relevant discussions.

The Committee identified a number of 'essential characteristics' – both institutional and personal – necessary to enable CSAs to operate effectively.

In order to ensure that CSAs are able to challenge Ministers and support departmental use of science, the Committee recommends that:

- CSAs should be recruited from outside the civil service to ensure that they have appropriate standing and authority in the scientific community. This will be vital to afford them the authority to provide advice to Government and challenge ministers;
- appointments should be part-time (but at least three days a week) and for a fixed period of three years (with the possibility of renewal) to ensure CSAs maintain critical links with academia and industry;
- CSAs should be graded at Director General or Permanent Secretary level, and have direct access to ministers, in order to ensure that they can exercise influence at the highest level;
- all CSAs should be given a seat on departmental Boards and have a formal role in policy submission sign-offs, to ensure they have oversight of their department's work;
- all CSAs should have a budget to commission advice and evidence to support policy making;
- the Government Chief Scientific Adviser should conduct an annual assessment of CSAs' performance to ensure that they are engaging effectively with their department, the scientific community, industry and with their equivalents across Whitehall.

The Committee believes these recommendations will strengthen the voice of science in Government, ensure that all CSAs play a full role in departmental policy-making and that they are given sufficient resources to carry out their role effectively.

The Committee expressed its concern that there have been extended CSA vacancies in some departments (the post is still outstanding in the Department for Culture, Media and Sports) and that the Ministry of Defence CSA post had been downgraded.

www.parliament.uk/business/committees/committees-a-z/lords-select/science-and-technology-committee/inquiries/parliament-2010/chief-scientific-advisers

The Royal Society

Science as an open enterprise

Intelligent openness about the data underpinning scientific ideas must be the default position according to a report by the Royal Society. Scientific progress can only be maximised, and scientific understanding effectively exploited in the economy and public policy, if intelligent openness is the norm.

The *Science as an Open Enterprise* report highlights the need to preserve the principle of openness and to exploit data in ways that have the potential to create a second open-science revolution. Exploring massive amounts of data using modern digital technologies has enormous potential for science and its application in public policy and business. The report maps out the changes that are required by scientists, their institutions and those that fund and support science if this potential is to be realised.

Professor Geoffrey Boulton, Chair of the Royal Society working group which prepared the report, said: "We must treat scientific data as a public rather than private resource, exploit the collective intelligence of the scientific community through collaboration and invest in the infrastructure required to make the most of the data.

Six key areas for action are highlighted in the report:

- scientists need to be more open among themselves and with the public and media;
- greater recognition needs to be given to the value of data gathering, analysis and communication;
- common standards for sharing information are required to make it widely usable;
- publishing data in a reusable form to support findings must be mandatory;
- more experts in managing and supporting the use of digital data are required;
- new software tools need to be developed to analyse the growing amount of data being gathered.

Population and consumption

Science academies around the world – including the Royal Society – have called on world leaders to take decisive action in tackling the global challenges of population and consumption.

A statement by the IAP, the global network of science academies, highlights that current patterns of consumption, especially in high-income countries, are eroding the planet's natural capital at rates that are severely damaging the interests of future generations. It urges policy makers to consider the following:

- population and consumption determine the rates at which natural resources are exploited and the ability of the Earth to meet our food, water, energy and other needs now and in the future;
- current patterns of consumption in some parts of the world are no longer sustainable;
- rapid population growth can be an obstacle to improving living standards in poor countries, to eliminating poverty and to reducing gender inequality;
- changes in population age structure resulting from declining birth and death rates can have important environmental, social and economic ramifications;
- population growth contributes to migration and urbanisation, which if unexpected and unplanned can be economically and politically disruptive and have serious environmental impacts;
- the combination of unsustainable consumption and the number of people on the planet can directly affect our capacity to support natural biodiversity.

A vital role for science and technology

National science academies of 15 countries, including the Royal Society, have called on world leaders to give greater consideration to the vital role science and technology can play in addressing the planet's most pressing challenges.

The 'G-Science' joint statements recommend that governments engage the international research community in developing systematic, innovative solutions to three global dilemmas: how to simultaneously meet water and energy needs; how to build resilience to natural and technological disasters; and how to more accurately gauge greenhouse gas emissions.

Water and energy are key considerations in global food security given the large demand agriculture places on both. However, the G-Science statements say insufficient attention is being paid to the links between energy and water. Without considering water and energy together, inefficiencies will occur, increasing shortages of both.

The cost of disasters has increased in recent years, in part because more people live in vulnerable areas with poor infrastructure and an inadequate institutional capacity to warn of, or respond to, disasters. Although recent disasters offer useful lessons, the G-Science statements emphasise that systematically assessing future risks and reducing exposure is a more effective guide to developing disaster resilience.

More accurate and standardised methods for estimating human and natural sources and sinks of greenhouse gases are needed as a prerequisite for an international climate treaty and to determine the effectiveness of national emission-reduction programs, according to the third G-Science statement.

How ice shelves melt

A new theory explaining the two different ways in which ice shelves melt has been published in *Proceedings of the Royal Society A*. This theory may help to explain satellite measurements of inland ice thinning near the coast of Antarctica. Flowing ice can respond in two entirely different ways to the encroachment of warm ocean water. Scientists at the British Antarctic Survey have discovered that the way in which ice streams melt depends on whether the force acting on them changes suddenly or gradually.

Warm ocean water can thin the ice shelves, hundreds of kilometres across and hundreds of metres thick. This force lessens the ice shelves' ability to push back against ice streams draining from the inland Antarctic ice sheet.

At low frequencies (a force once every hundred or thousand years), slope, thickness and shallow ice approximations are sufficient to explain the stress travelling upstream; it does not depend on the stress on the ice structure. At high frequencies (a force inland every 10 years or less), the force travels upstream via direct transmission through the ice structure and thus penetrates tens of kilometres inland. The speed of the flowing ice adjusts rapidly to such forcing; however, the thickness varies little. ☐

The Royal Academy of Engineering

Aerospace

The UK aerospace sector is a vibrant example of engineering design excellence coupled with world-beating advanced manufacturing. The Royal Academy of Engineering has welcomed the industry's joint initiative with Government to invest in the future of aeronautical engineering in the UK, which aims to generate more UK aerospace postgraduates with the high level skills needed by the sector.

The Government has said it is dedicated to rebalancing the UK economy, with a focus on high tech manufacturing. This scheme is an important step in investing in an industrial future. The aerospace industry is one of the country's export success stories and employs thousands of engineers, skilled technicians and scientists. The programme to fund 500 UK MSc students is designed to make a rapid, positive impact on the aerospace industry so that it can be an engine for economic recovery and growth. It draws on the world-class postgraduate training provided by key UK universities.

Philip Greenish, Chief Executive of the Academy, said: "Boosting the supply of skilled people with high-level knowledge and expertise in key areas of technology is essential for sustainable economic recovery and to ensure that the UK continues to be a leader in sectors such as aviation."

The Academy oversees the programme in partnership with the Royal Aeronautical Society.

Overcoming hearing difficulties

To ensure that hearing difficulties do not deter students, more than 100 new Engineering and Physics terms and definitions have been developed in British Sign Language.

New signs have been developed to communicate the topics of movement, the Universe, light and sight, and energy and radiation. The aim is to give 11-16 year olds with hearing difficulties a better opportunity to engage with engineering and physics.

The signs emerging from the research, which was funded by the Institute of Physics, the Institute of Physics in Engineering and Medicine, the Royal Academy of Engineering and the Royal Society, use common British Sign Language techniques to help students understand the concepts behind the phrases.

Short video clips for the 200 physics signs and their definitions on the Scottish Sensory Centre's website can be found at:
www.ssc.education.ed.ac.uk/bsl/physicshome.html

"Boosting the supply of skilled people with high-level knowledge and expertise in key areas of technology is essential for sustainable economic recovery..."

Design and Technology

Education for Engineering (E4E), the engineering profession's voice on education and skills, has welcomed a letter by the Education Secretary confirming that Design and Technology (D&T) and ICT remain in the National Curriculum for primary schools in England.

However, E4E is also urging Michael Gove to retain D&T in the secondary National Curriculum. Otherwise, it says, this will inevitably lead to schools adopting a minimal approach as they will only focus on Core and English Baccalaureate subjects.

E4E is the body through which the engineering profession offers coordinated and clear advice on education to UK Government and the devolved Assemblies. It deals with all aspects of learning that underpin engineering and is hosted by the Royal Academy of Engineering.

Chair of Education for Engineering (E4E) Dick Olver FREng said, "This is exactly the right signal that the Secretary of State should be sending to schools and we applaud his decision. We support the Government in getting the basics right, but we need much more focus on technology through all levels of education if the UK is to ensure a sustainable recovery for the economy. The UK needs to prepare young people for a future deeply embedded in technology and the provision of excellent teaching of both D&T and ICT in primary and secondary schools is crucial to this aspiration."

Sustainable building

The establishment of Centres of Excellence in integrated sustainable building design, to help the construction industry meet UK climate change policy targets, could create over £1 billion of savings by 2030 and cut carbon emissions by 3.5 million tonnes a year, according to a report by the Royal Academy of Engineering

The proposed centres would also act as a hub to educate future sustainable construction experts and share knowledge between construction companies, academics and policy makers.

The report, *The Case for Centres of Excellence in sustainable building design*, is the result of an exercise to establish the costs and benefits for the UK economy in creating a network of centres of excellence in integrated sustainable design and construction. It also evaluates the need for new skills and approaches in sustainable design in order for the construction industry to deliver low carbon buildings at the lowest cost for society.

The UK climate change policy targets an 80 per cent reduction of greenhouse gases by 2050; energy consumption in the built environment is responsible for around 45 per cent of CO_2 emissions, the principal greenhouse gas.

The report evaluated the economic benefits for UK plc in just one of the activities of the proposed centres: the provision of specialist undergraduate engineering education. Engineering graduates trained at the proposed centres would enter the construction industry equipped with skills to deliver the most cost-effective carbon abatement, informed by an integrated education bringing engineering physics, engineering, architectural and systems design together.

Seed funding of just £30 million over five years to establish four such centres of excellence would deliver cumulative savings with a net present value in excess of £1 billion by 2030 and a reduction in carbon emissions of 3.5 million tonnes of CO_2 per annum, says the Academy. By 2050 the cumulative savings could have risen to over £6 billion net present value and a reduction in emissions of nearly 11 million tonnes of CO_2 per annum. □

www.raeng.org.uk/news/publications/list/reports/Centres_of_Excellence_report.pdf

Recent dinner/discussions organised by the Foundation for Science and Technology are listed below. Summaries of these and other events – as well as the presentations and recordings of the speakers – can be found on the Foundation website at: www.foundation.org.uk

The impact of the use of social media on society and democracy

11 July 2012

Dr Mike Lynch OBE FREng, Founder of Autonomy Corporation plc
Julian Huppert, MP for Cambridge
Kathryn Corrick, digital media consultant.
Candace Kuss, Director of Planning and Interactive Strategy at Hill & Knowlton Strategies (*panellist*}.

Making science work

20 June 2012

Sir Paul Nurse PRS FMedSci, President, the Royal Society
David Eyton, Head of Technology, BP
Dr Andy Richards, Chairman, Abcodia
Professor Rick Rylance, Chief Executive, Arts and Humanities Research Council, and Chairman of the Committee of the Chief Executives of the Research Councils

Achieving food security in the face of climate change - the Climate Change, Agriculture and Food Security (CCAFS) Commission Report

23 May 2012

Sir John Beddington CMG FRS FRSE, Government Chief Scientific Adviser, Government Office for Science
Dr Peter Holmgren, Director, Environment, Climate Change and Bioenergy Division, Food and Agricultural Organisation of the UN
Professor Tim Wheeler, Deputy Chief Scientific Adviser, Department for International Development
Sir Robert Watson CMG FRS, Chief Scientific Adviser, Department for Environment, Food and Rural Affairs (*panellist*)

Reducing the risk of a systemic failure of the banking system

25 April 2012

Professor John Kay FBA FRSE, Author and Columnist for the *Financial Times*
Andy Haldane, Executive Director, Financial Stability, Bank of England
Sir Martin Jacomb, Former Deputy Chairman of Barclays and Non-Executive Director of the Bank of England
The Lord May of Oxford OM AC Kt FRS FMedSci, Department of Zoology, University of Oxford (*panellist*)

The antibody revolution; turning inventions into medicines and companies

7 March 2012

Sir Greg Winter CBE FRS FMedSci, Master Elect, Trinity College, Cambridge, and MRC Laboratory of Molecular Biology, Cambridge
Sir John Savill FMedSci FRSE, Chief Executive, Medical Research Council
Dr Neil Brewis, Vice-President of Research, Biopharm R&D, GSK

BIS Innovation and Research Strategy for Growth

1 February 2012

Sir Adrian Smith FRS, Director General, Knowledge and Innovation, Department for Business, Innovation and Skills
Sir Tim Wilson, Chair, Wilson Inquiry into University/Business Collaboration
Professor Andy Hopper CBE FRS FREng, Head, Computer Laboratory, University of Cambridge
Professor Ric Parker FREng, Director of Research and Technology, Rolls-Royce Group

Knowledge into action; development in the Arctic Region

14 December 2011

Charles Emmerson, Senior Research Associate, Chatham House
Professor Peter Harrison, Director of the School of Policy Studies (SPS), Queen's University, Kingston, Ontario, Canada

Stimulating economic growth by increasing the contribution from research, innovation and the Higher Education sector

23 November 2011

Sir Richard Lambert, Former Director General, CBI
Dr Graham Spittle CBE, Chairman, Technology Strategy Board
Catherine Coates, Director, Business Innovation, Engineering and Physical Sciences Research Council
Rt Hon David Willetts MP, Minister for Universities and Science, Department for Business, Innovation and Skills

The impact of the development of shale and tight gas reservoirs on global energy supply

9 November 2011

Malcolm Brinded CBE FREng, Executive Director, Upstream International, Royal Dutch Shell
Professor Paul Stevens, Senior Associate (Energy), Royal Institute of International Affairs, Chatham House
Professor Mike Stephenson, Head of Science, Energy Geoscience Programme, British Geological Survey

Science advice in a crisis

1 November 2011

Sir John Beddington CMG FRS FRSE, Government Chief Scientific Adviser, Government Office of Science
Professor Patrick Cunningham, Chief Scientific Adviser, Government for Ireland

Lifting barriers for career paths in Science, Technology, Engineering and Mathematics (STEM)

27 October 2011

Dame Jocelyn Bell Burnell DBE FRS FRSE FRAS FInstP, Chair, Women in STEM Inquiry, The Royal Society of Edinburgh
Dr Ellen Williams, Chief Scientist, BP
Sir Adrian Smith FRS, Director General, Knowledge and Innovation, Department for Business, Innovation and Skills

Developing adaptation policy and action for the UK in response to climate change

19 October 2011

Neil Thornton (represented by Dr Rupert Lewis), Director for Climate, Waste and Atmosphere, Department for Environment, Food and Rural Affairs
Sir Graham Wynne CBE, Deputy Chairman, Sub-Committee for Adaptation, Committee on Climate Change
Tom Bolt, Director, Performance Management, Lloyd's of London

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