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Policy Briefing

NESTA Making Innovation Flourish

Science: an engine of innovation

Science is about the discovery of new knowledge, and frequently leads to insights that form the basis of breakthrough new products and processes. Currently, the UK is improving in three important areas, but not fast enough. Expenditure on R&D lags behind international competitors, STEM graduates are increasing but demand is likely to outstrip supply, and links between businesses and universities are still challenged by university funding streams and cultural differences. In a world where the UK is competing not only with the United States and Europe but with emerging science powerhouses like China and India, science policy needs to become more prominent, but more importantly it needs to become more sophisticated.

Science generates new knowledge

Basic scientific research lays the groundwork for many innovations. It is conducted in the pursuit of knowledge, normally without a final application in mind. For example, it wasn't until many decades after the pioneering work of Faraday, Kirchhoff, Boltzmann and Planck on quantum mechanics that a range of applications such as transistors and lasers were developed.[1] As such, basic scientific research has many of the characteristics of a public good: it yields benefits that are general rather than specific to individual products, and generates economic returns which cannot be captured by any single business or entrepreneur.[2]

Applied science is also the pursuit of knowledge, but undertaken to solve a practical problem – for example, research carried out for the purpose of developing drugs to cure specific diseases. The process is initiated either through 'science-push,'[3] where new discoveries are commercialised through licences or spin-out companies, or through 'demand-pull' where businesses approach the science base to develop new products.[4]

Over the past 60 years, science policy has become an important part of economic policy

Traditional science policy is rooted in a 'linear model' of scientific discovery and commercialisation

During the 1940s and 1950s, military concerns prompted governments to undertake large-scale, resource intensive, 'big science' projects, characterised by enormous budgets, large numbers of staff and investment in hi-tech machinery. Perhaps the largest and most famous of all was the Manhattan Project. Begun in 1939 and employing 130,000 people from the US, UK and Canada, the result was the world's first nuclear weapon.[5]

In 1944, US President Roosevelt asked Vannevar Bush how wartime science and research efforts could be applied in peacetime. His landmark report, 'Science: The Endless Frontier,' essentially created the area of science policy.[6] It focused heavily on a 'linear model' characterised by heavy investment in the process of discovery and invention followed by commercialisation in the form of new processes and products.

Science has become analogous to R&D

Over time, previously distinct definitions became conflated; in particular, 'science' became analogous to 'R&D'. This has been formalised by the codification of the OECD's definition of R&D in the Frascati manual: any project to resolve 'scientific or technological uncertainty'.[7]

As science policy gained in political and economic importance, a standard toolkit of policies emerged. These included incentives to boost levels of R&D spending, increasing the number of people skilled in science, technology, engineering or maths (STEM), and mechanisms to improve knowledge transfer from universities to business.

1. Grannis, P., Brock, R. and Jackson, J. (12 November 1997), Why Support Basic Science?, available at http://www.lns.cornell.edu/~sjr/science.html
2. Llewellyn Smith, C.H. (2006), What's the Use of Basic Science?, available at the CERN website http://public.web.cern.ch/public/Content/Chapters/AboutCERN/WhatIsCERN/BasicScience/BasicScience1/BasicScience1-en.html [accessed 14 May 2007].
3. Schumpeter, J. (1942), Capitalism, Socialism and Democracy, (Harper and Brothers, New York). Schumpeter did not explicitly refer to a science-push model. Subsequent analyses of his work have argued that the generation of scientific knowledge leads to the creation of new technologies which then has impact on the economy.
4. Schmookler, J. (1966), Invention and Economic Growth, (Harvard University Press, Cambridge, MA). The demand-pull theory argues that investment and patenting have similar time correlations and so fluctuations in investment could be better explained by external events than by the course of invention, concluding that upswings in inventive activity responded to upswings in demand.
5. Hughes, J. (2003), The Manhattan Project: Big Science and the Atom Bomb, (Princeton University Press, Princeton).
6. Bush, V. (July, 1945), Science The Endless Frontier: A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development, (United States Government Printing Office, Washington).
7. OECD (2002), Frascati Manual 2002, (OECD, Paris).

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UK science policy structures now encompass innovation policy

In 1992, the Office of Science and Technology (OST) was established in the Cabinet Office to oversee the activities of the UK's science base.[8] In 1995, it became part of the Department of Trade and Industry (DTI). In 2006, the DTI Innovation Group was incorporated into the OST to become the Office of Science and Innovation (OSI).[9] The OSI is now responsible for UK science policy and for funding basic research allocated via the Research Councils.

The UK Government has targeted an increase in R&D expenditure to 2.5 per cent of GDP

In 2004, the UK Government set out a vision to 'make Britain one of the best places in the world for science, research and innovation,' principally by boosting R&D investment from 1.73 per cent of GDP to 2.5 per cent by 2014.[10] This is in addition to the target set in 2002 as part of the Lisbon Agenda to boost R&D to 3 per cent.[11]

Devolved administrations and RDAs are developing science policies

The Science Strategy for Scotland set out initiatives to promote Scotland as a 'science nation', and in 2006 the Scottish Executive consulted on a new Science and Innovation Strategy.[12] In Northern Ireland, Think, Create, Innovate[13] was followed by the more recent Action Plan detailing six areas for action, including resourcing R&D and supporting knowledge transfer.[14] The Welsh Assembly Government published a Science Policy for Wales focusing on the commercialisation of science and science education.[15]

The economic strategies of all of the English Regional Development Agencies (RDAs) include policies to boost science production.[16] They have also established Science and Industry Councils designed to bring together leaders of research communities in the public and private sectors with the wider business community.

Science ≠ innovation

Science is an important driver of innovation, but science does not equal innovation, particularly given the straitjacket of international definitions. For instance, these definitions explicitly exclude technological investments undertaken for the purposes of oil exploration and have no place for innovation that is not based on 'new-to-the-world' scientific invention – for instance, that represented by the iPod or that which takes place in financial services or in the development of low cost airlines.[17]

This is particularly important in the UK where only 2.5 per cent of the economy is concerned with hi-tech manufacturing, and where around 80 per cent is made up of businesses in the service sector. This conflation of definitions and confusion of science policy with wider innovation policy runs the distinct danger of ignoring the types of innovation that will be most important to the UK in the coming century.

Improving knowledge production

The UK Government has increased expenditure on science

Over the last ten years the science budget has doubled to £3.4bn,[18] and it is expected to continue increasing over the next few years.[19] In 2007-08, the Research Councils will invest around £2.8bn in research across all academic disciplines. This is in addition to the work carried out by the Public Sector Research Establishments that spend £1.9bn on R&D.[20]

Low investment but relatively high scientific productivity

Despite increases in funding, public sector R&D expenditure still remains comparatively low. R&D performed by the government and universities in 2004 was 0.6 per cent of GDP (down from 0.68 in 1994) compared to 0.69 per cent in the US, 0.75 per cent in Germany and 0.78 per cent in France.[21]

However, the UK appears to be efficient at converting this relatively 'low' spend into traditional measures of academic outputs. At 11.9 per cent, the UK's share of world academic citations is second only to the US.[22]

UK business R&D expenditure lags behind competitors

Over the last five years, UK business R&D expenditure has increased by 2 per cent to £13.4bn, either through in-house operations or extramural activity.[23] Forty per cent of this spend takes place in the pharmaceuticals and aerospace sectors, and is dominated by six large companies.[24] However, UK businesses still spend less on R&D than many of their international competitors.[25] Given this, it is not surprising that the UK lags behind in patenting activity.[26]

8. House of Commons Science and Technology Select Committee (Session 1999-2000), Fifth Report - Government Expenditure on Research and Development: The Forward Look, Vol.1 Report and Proceedings, Ch.4, (19 April 2000).

9. House of Commons Science and Technology Select Committee (Session 2006-07), Sixth Report - Office of Science and Innovation: Scrutiny Report 2005 and 2006, Minutes of Evidence (24 April 2006). This was designed to bring together what the government described as the 'push of science' and the 'pull of innovation'.

10. HM Treasury, DTI & DfES (2004), Science & Innovation Investment Framework 2004 – 2014, (HM Treasury, London).

11. Further information is available at http://ec.europa.eu/growthandjobs/index_en.htm

12. Scottish Executive (2001), A Science Strategy for Scotland, (Scottish Executive, Edinburgh). Scottish Executive (2006), Science and innovation strategy consultation 2006, (Scottish Executive, Edinburgh).

13. Department of Enterprise, Trade and Investment (2003), Think, Create, Innovate, (DETI, Belfast).

14. Department of Enterprise, Trade and Investment (2005), The Regional Innovation Strategy for Northern Ireland, Action Plan September 2004 to August 2006, (DETI, Belfast).

15. Welsh Assembly Government (2006), A Science Policy for Wales: The Welsh Assembly Government's Strategic Vision for Sciences, Engineering and Technology, (Welsh Assembly Government, Cardiff).

16. NESTA (2007), Innovation in UK cities, (NESTA, London).

17. For further information see NESTA (2006), The Innovation Gap: Why policy needs to reflect the reality of innovation in the UK, (NESTA, London).

18. Information from the DTI Science Funding webpage, available at http://www.dti.gov.uk/science/science-funding/index.html [accessed 16 May 2007].

19. Budget 2007 announced an early 2007 Comprehensive Spending Review settlement for both the DTI science budget and the Department for Education and Skills, which together deliver average annual growth of 2.5 per cent in real terms over the CSR period.

20. Technopolis Report to the Office of Science and Innovation (July 2006), Second Annual Survey of Knowledge Transfer Activities in Public Sector Research Establishments, Report PRZZ/016/00006P. This figure refers to 2004/05, and is considered to be the 'gross' value.

21. DTI SET Statistics: Science, engineering and technology indicators (February 2007), Figure 7.1 Trends in gross domestic expenditure on R&D (GERD) in G7 countries as a percentage of GDP, available at http://www.dti.gov.uk/files/file38816.xls#f7.1!A1 [accessed 15 May 2007].

22. Office of Science and Innovation (March 2007), PSA Target Metrics for the UK Research Base 2007, (HMSO, Norwich).

To help boost business R&D expenditure, the UK Government introduced the R&D Tax Credit in 2000. By 2006, 22,000 claims had been made, amounting to £1.8bn of support.

Increasing the supply of STEM skilled people

The UK faces a deficit of STEM skilled people

People with science, technology, engineering and maths (STEM) skills are necessary to generate new knowledge and to identify, adapt and use knowledge that is generated elsewhere and apply it for the benefit of UK business – something that will become increasingly important with the rise of new science-production centres like China and India.[27]

Numbers of STEM graduates have increased but distribution is uneven

Since 1995, the total number of STEM graduates has increased by 10 per cent.[28] However, this overall rise disguises important underlying trends – numbers of graduates in biological science, computer science and mathematical science have increased considerably, while those in engineering & technology and physical science have fallen.[29]

Most STEM graduates don't go into STEM careers

STEM graduates possess skills that are sought in many sectors of the UK economy. In fact, only 46 per cent of STEM graduates are employed in STEM occupations, with considerable variation across subject areas: 92 per cent of medicine graduates are employed in STEM occupations compared to 31 per cent of physical/environmental sciences graduates.[30] The lack of STEM graduates going into science careers is partly explained by potential earnings: qualified science and engineering graduates working in STEM careers earn around 10 per cent less than their counterparts working in other areas.[31]

Potential mismatch between demand and supply

It is estimated that by 2014, the demand for science and technology professionals will increase by one fifth, compared to an increase for all other occupations of 4 per cent.[32] Since the existence of a deep and skilled labour pool is a significant factor in multinational organisations deciding where to locate their high-value R&D, lack of STEM graduates could have significant knock-on effects for the UK's long-term economic performance.[33]

Translating knowledge into economic success

Universities have mixed results in turning research into outputs

While university licensing activity has increased over recent years and is now worth around £40m per year,[34] the total number of university spin-out companies has fallen with only 133 companies created in 2003/04.[35] The performance of universities is varied with some 'not engaged in the commercialisation of IP in any substantial way', while others 'are international benchmarks of excellence'.[36]

In recognition of this and the fact that few UK firms collaborate with universities, the UK Government set up the Lambert Review.[37] It made a number of recommendations, including the development of model collaborative research agreements for voluntary use by industry and universities.

HEIF and TTOs are targeted on increasing knowledge transfer

The Higher Education Innovation Fund (HEIF) supports commercially-relevant research and knowledge transfer from universities to business and the public sector and has led to the creation of 22 centres for knowledge exchange.[38] However, HEIF (at £238m) remains dwarfed by funding streams governed by the Research Assessment Exercise which therefore dominate university investment decisions.

While there are now 126 Technology Transfer Offices (TTOs) in the UK,[39] the Lambert Review described them as being of 'variable quality', citing particular problems with their expertise in intellectual property – a vital area for commercialisation.[40]

Other knowledge transfer initiatives have been introduced

So far, the Technology Strategy Board (TSB) has funded over 600 collaborative R&D projects between business and research communities; established 22 Knowledge Transfer Networks to transfer knowledge into businesses; and is setting up a number of Innovation Platforms in areas such as Intelligent Transport Systems and Network Security to build cross-sector interdisciplinary groups.[41] In Scotland, the SCORE and SEEKIT initiatives have also been developed to boost interaction between industry and the science base.[42] Foresight Northern Ireland has been established to encourage collaboration between academia and industry.[43]

23. Office for National Statistics (January 2007), Research and Development in UK Businesses, 2005, Business Monitor, MA14, (HMSO, Norwich). http://www.statistics.gov.uk/downloads/theme_commerce/MA14_2005.pdf

24. In ranking order, with the largest first: Pharmaceuticals – GlaxoSmithKline, AstraZeneca, Pfizer; Aerospace – BAE Systems, Rolls-Royce, Airbus.

25. OECD (2006), Main Science and Technology Indicators (MSTI): 2006/2 Edition, (OECD, Paris). This shows that expenditure by UK businesses is $538 per capita, compared to $1,063 in the US, $924 in Japan, and $1,045 in Finland.

26. OECD (2005), Main Science and Technology Indicators (MSTI): 2005/2 Edition, (OECD, Paris).

27. Leadbeater, C. and Wilsdon, J. (2006), The Atlas of Ideas: How Asian innovation can benefit us all, (Demos, London).

28. Although this compares to a rise in general graduation of 25 per cent over the same period. Comparative statistics derived from the HESA, Students and Qualifiers Data Tables: Subject of Study, 1995/96 and 2005/06, available at http://www.hesa.ac.uk/holisdocs/pubinfo/stud.htm

29. HESA (1997 – 2006), First destinations of students leaving higher education institutes, annual data volumes. From 2002-03 HESA re-worked data used in this report to incorporate omissions in the former First Destinations Supplement.

30. DTI (March 2006), Science, Engineering and Technology Skills in the UK, based on Labour Force Survey, Autumn 2004 data, available at http://www.dti.gov.uk/files/file28174.pdf

31. Roberts, G. (April 2002), SET for success: The supply of people with science, technology, engineering and mathematics skills, Final Report of Sir Gareth Roberts' Review, (HM Treasury, London). The Review cites the Labour Force Survey.

32. SSDA (January 2006), Working Futures Report 2004 – 2014, available at http://www.ssda.org.uk/PDF/Working%20Future%2020042014%20National%20Summary%20R%20060215.pdf

33. Simmie, J. (2004), Innovation Clusters and Competitive Cities in the UK and Europe, taken from Parkinson, M. and Boddy, M. (eds) (2004), City Matters: Competitiveness, cohesion and urban governance, (Policy Press, Bristol).

34. UNICO Press Release (22 November 2005), Survey Of UK University Commercialisation Shows A Doubling Of Licensing Activity In 2004, available at http://www.unico.org.uk/msurvey.doc [accessed 17 May 2007].

35. HEFCE (July 2006), Higher education, business and community interaction survey 2003-04, available at http://www.hefce.ac.uk/pubs/hefce/2006/06_25/06_25main.pdf [accessed 14 May 2007].

36. UNICO Press Release, (22 November 2005), Survey Of UK University Commercialisation Shows A Doubling Of Licensing Activity In 2004, available at http://www.unico.org.uk/msurvey.doc [accessed 17 May 2007].

Human mobility drives knowledge flow
Undergraduates undertaking placements and graduates entering the labour market take important scientific knowledge with them to their new workplace. The UK Government funds Knowledge Transfer Partnerships (KTP), whereby businesses identify a specific problem core to their strategic development and partner with a university to recruit a KTP Associate to work on it.[44] Equally important is the movement of people from industry into university. This has, for example, been recognised by the Royal Academy of Engineering, which sponsors universities to appoint senior industrialists as Visiting Professors.[45]

Knowledge exchange, not knowledge transfer
R&D intensive firms in the UK typically generate as much scientific output as a medium sized university.[46] Moreover, recent studies have demonstrated that the 'linear model' of idea production in a university and commercialisation by industry is relevant in only a very small number of cases: the reality is more about multiple exchanges of knowledge over an extended period of time.[47] Frequently, a university is not involved at all. Recognition of this more complex non-linear process is implicitly recognised by general policies, but the linear model still tends to dominate the wider policy debate.

Ensuring that UK science policy meets 21st century challenges

Ensuring that STEM supply meets demand
Efforts to boost the knowledge base in the UK will be undermined if there is an under-supply of STEM skilled people. More students need to be inspired to study these subjects, and STEM careers must present an attractive alternative to employment elsewhere.[48] This means employing teachers who can teach creatively, making the curriculum more relevant to students, and increasing the proportion of education that is based on the exciting process of discovery through experimentation.[49]

More must be done to improve the communication of the value of STEM careers to students, such as providing more advice on STEM careers or building on existing initiatives such as SETNET to bring inspiring STEM role models into schools and universities.[50]

Forge stronger links between industry and academia
Efforts to boost business demand for university R&D should be stepped up. One approach that merits attention is the Innovation Voucher scheme currently being piloted by Aston University. Based on a Dutch model, this has provided 80 high-growth SMEs with vouchers to the value of £3,000 which they are able to use to purchase academic support to improve their innovation capability.[51]

Increasing R&D expenditure is necessary but not sufficient
Meeting the 2.5 per cent target for expenditure on R&D is theoretically achievable by increasing public and business expenditure. However, this represents only an increased input into knowledge production (albeit an important one) and carries with it no guarantee of improved quality of output. As such, the target represents a necessary but not sufficient condition for improving the UK's scientific performance. Other efforts that consider quality of research and its relevance to the UK's future competitive advantage should be given equal weight in the formation of policy.

Recognising wider innovation
Science policy is critical to the UK's future economic success but should be recognised as only one part of a full innovation policy. This wider policy would recognise the different role played by science and technology in non-science-based sectors and particularly the importance of diffusing existing technologies rather than inventing new ones. Through extending existing knowledge exchange activities, it would seek to link demand in these sectors to the productive capacity of the knowledge base. Finally, it would recognise non-science-based forms of innovation such as business processes (like mass production) or social innovation (like NHS Direct).[52]

37. Lambert, R. (2003), Lambert Review of Business-University Collaboration, (HM Treasury, London).

38. Further information is available at http://www.hefce.ac.uk/reachout/heif/ [accessed 14 May 2007].

39. British Venture Capital Association (2005), Creating Success from University Spin-out, available at http://www.bvca.co.uk/publications/univspinout.pdf

40. Lambert, R. (2003), Lambert Review of Business-University Collaboration, (HM Treasury, London).

41. Further information is available at http://www.dti.gov.uk/innovation/technologystrategy/tsb/index.html [accessed 17 May 2007].

42. Further information is available at http://www.scotland.gov.uk/Topics/Business-Industry/support/16879/14127 and http://www.scotland.gov.uk/Topics/Business-Industry/support/16879/14115

43. Information from Invest Northern Ireland Foresight NI website, http://www.investni.com/index/grow/research_and_development/industrial_research/foresight_ni.htm [accessed 18 May 2007].

44. Information taken from http://www.ktponline.org.uk/default.aspx [accessed 22 May 2007].

45. Further information on RAENG Schemes for Researchers and Professional Engineers is available at http://www.raeng.org.uk/research/researcher/default.htm

46. Hicks, D. (1995), 'Published Papers, Tacit Competencies and Corporate Management of the Public/Private Character of Knowledge', Industrial and Corporate Change, 4, pp.401-424.

47. NESTA (October 2006), The Innovation Gap: Why policy needs to reflect the reality of innovation in the UK, (NESTA, London).

48. House of Commons Science and Technology Committee (Session 2004-2005), Eighth Report - Strategic Science Provision in English Universities, Vol.1 (11 April 2005), available at http://image.guardian.co.uk/sys-files/Education/documents/2005/04/06/scienceprov.pdf

49. NESTA (November 2005), Real science: encouraging experimentation and investigation in school science learning, (NESTA, London).

50. HM Treasury, DTI & DfES (2004), Science & Innovation Investment Framework 2004 – 2014, (HM Treasury, London).

51. Aston University Press Release (27 November 2006), Aston University pilots revolutionary innovation voucher scheme, available at http://www.aston.ac.uk/downloads/bpu/index2.pdf

52. For examples, see: NESTA (2006), The Innovation Gap: Why policy needs to reflect the reality of innovation in the UK, (NESTA, London), or Mulgan, G. (2007), Ready or not? Taking innovation in the public sector seriously, (NESTA, London).