A review of recent evidence on the governance of emerging science and technology

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1. Executive summary

As the UK renegotiates its relationships with Europe and the world, science and technology lie at the centre of a complex set of questions about governance, regulation, innovation and interdependence. By looking back over the past decade of experience with emerging science and technologies, we can draw important lessons, and use these to guide us as new technologies, political opportunities and uncertainties unfold.

This report is the product of a short research project that aimed to review recent evidence on the governance of and public attitudes to science and technology. We reviewed published literature and policy reports from the period 2008 to 2018. Our aim was to map systematically the state of current evidence and interpret it in the light of longer-standing debates about science and technology governance and oversight (see Appendix 2 for details of the full process).

Our **findings** are summarised in two chapters. Chapter 4 reports on evidence about the governance of emerging science and technology. Chapter 5 looks more specifically at public attitudes to emerging science and technology. To complement the literature surveyed in the mapping exercise, Chapter 5 also includes evidence from large public surveys and public dialogue exercises, in order to map what we know about public attitudes to emerging science and technology.

Our **conclusion** is that these literatures provide a useful but fragmented and partial resource in pursuit of answers to these questions. There is substantial diversity – of cases, places and governance approaches – within the literature. But there remain some jurisdictions about which relatively little is known, including large developing economies. And much of the literature is restricted to particular case studies, such as nanotechnology, which makes it harder to draw wider lessons for governance.

In particular, we draw attention to the following features of the literature:

First, the **diversity** of its objects of study, its case studies and empirical approaches. In some instances, such as with specific arguments for ethical red lines around human cloning, 'governance' is taken to mean restriction. But most analyses focussed on steering and promoting innovation in particular directions, rather than halting it altogether. In the literature we reviewed from Asia, the clear priority for steering technologies was towards economic growth. In European literature, societal goals included sustainability, equity and grand challenges such as global health or food security. The overlap between literatures on governance and public attitudes was substantial, suggesting recognition of the importance of trustworthy governance and the need for public engagement and democratic accountability in policymaking.

Second, that **there is little analysis or evidence of holistic governance strategies.** Most of the papers or policy reports consider particular governance interventions – such as risk assessment, regulation, or responsible innovation – or specific science and technology cases. There is a clear evolution of case studies during the period studies, from biotechnology to nanotechnology, to more recent consideration of machine learning, gene editing and big data. Few studies take a more systemic view to examine how these different approaches might learn from and work alongside each other, across multiple technological domains, and at multiple scales and levels of governance.

Third, that the literature is a **partial reflection of what is known – and what needs to be known – about the governance of emerging science and technology**. There is substantial knowledge, learning and experimentation within institutions that should be shared more widely. At the same time, in emerging economies, including China and India, governance is developing *de facto* in ways that remain too disconnected from governance and learning networks in Europe and America. Our study, which only looked at English-language publications, could be interpreted as magnifying this evidence gap. There are clear research needs, one of which is to compare and share alternative governance frameworks across different languages, cultures and jurisdictions.

Governance for emerging technologies involves more than just peer-reviewed evidence. There is substantial knowledge, learning and experimentation within institutions that should be shared more widely. Our review suggests two clear recommendations for improving governance:

First, **we need to recognise that the UK has developed a distinctive and comparatively sophisticated approach to the governance of emerging science and technology that commands widespread support among policymakers, publics, scientists and companies.** This includes substantial expertise and capacity to understand and broker this learning, even where it remains fragmented. **Post-Brexit, the UK has the potential to reaffirm its position as a global leader and hub for regulation, governance and deliberation over emerging science and technologies**.

Second, to realise fully this potential, **there is first a need to develop the UK's capacity for anticipatory governance and technology assessment**. This has in the past happened in a haphazard way. **The creation of UKRI provides an opportunity to make such activity more strategic** and to link it with the public dialogue activities that have built up over the last decade through programmes like Sciencewise and the engagement work of the Wellcome Trust. New issues such as data ethics and gene editing provide opportunities for the development of new and more robust models. **Policymakers should recognise that they are not starting from scratch but have solid foundations of governance, regulation, oversight and engagement on which to build.**

2. Context

As the UK renegotiates its relationships with Europe and the world, science and technology sit at the heart of a complex nexus of questions about governance, regulation, innovation and interdependence. People unfamiliar with past debates on science and innovation governance, or the evidence base behind current approaches may see Brexit primarily as an opportunity for deregulation. It is therefore important to re-examine the literature on governance in order to make decisions that do not jeopardise science, or the wider public interest. On many measures, the UK is Europe's leading scientific nation. There remain questions about the extent to which this reflects linguistic or other historical privileges, but this success may also relate in part to an enviable reputation for effective and anticipatory governance of the opportunities and uncertainties of new technologies. As Sam Gyimah MP, Minister for Universities and Science, argued in a recent speech:

> *"We have a long track record of setting world-class regulations, standards and ethical norms. If we can be take the lead on setting these standards, regulation and ethics, we have the chance to take a global lead - and to realise our vision of being a global platform."*[2]

There is a growing recognition among UK policymakers, scientists and research-intensive companies that good governance is an enabler for innovation rather than an obstacle. Looking back on the past decade of experience with emerging science and technology in the UK, we can draw important lessons (which should themselves be seen in the light of a longer history). We can use these lessons to look ahead as new technologies emerge, and political opportunities and uncertainties reveal themselves. The uncertainties of innovation mean it is likely that policymakers, researchers and innovators alike will be taken by surprise. Recent debates and controversies, such as those around Facebook's use of personal data, the possible editing of the human germline, the systemic risks from financial innovation, the testing of self-driving cars and the creation and subsequent closure of the NHS 'care.data' programme, point to the need to understand both the specificities of individual cases and the general questions raised by new science and technology.

Many relevant policy documents, including those that we review in this report, consider such challenges with respect to particular areas of science and technology such as nanotechnology, geoengineering, synthetic biology or machine learning. There have been some notable recent UK attempts to learn lessons across areas of science and technology, including reports from the Government Chief Scientific Adviser (2014) and the Nuffield Council on Bioethics (2012). But the majority of analysis is specific to one domain of science or technology. As communities and research agendas grow around these areas, they can act as a barrier to learning across cases.

Governing emerging science and technology

In this report, we take 'governance' to include the full range of processes of control and management that take place within and between states, in public agencies and private firms, and other social organisations. Governance involves directing or setting goals, selecting means, regulating their

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[2] Britain's new unique selling point (USP): the go-to place for science and innovation. Speech by Science Minister Sam Gyimah at the opening of the Schrödinger Building, Oxford Science Park. 6 July 2018

operation, and verifying results. It therefore encompasses formal, legal processes and structures of regulation, as well as forms of institutional oversight and informal processes of self-governance.

Science and technology are unpredictable, yet have a tendency to 'lock-in' to particular trajectories before there is clear evidence on which to understand their ramifications. The trajectory often becomes clear only when it is too late to change direction. David Collingridge called this challenge the 'dilemma of control'.[3] Emerging science and technology typically emerge in what Maarten Hajer, former director of the Dutch Environmental Assessment Agency, describes as an 'institutional void'.[4] When a technology like genome editing or machine learning begins to be publicly significant, it is not clear who is in charge, or what the rules should be that govern its development and use. The instinct of policymakers may be to wait until more is known about benefits and risks. Science and innovation have well-evolved systems of self-governance. But past lessons and surprises suggest that they are insufficient to secure public trust or guarantee outcomes that are in the public interest.[5]

There are important cases in which policymakers have begun proactively to fill the institutional void with timely, adaptive and anticipatory processes. For example, the UK's Human Fertilisation and Embryology Authority (HFEA) is still internationally respected for its ability to handle the myriad ethical and technical uncertainties surrounding new reproductive technologies. But there are too many examples of where governance has come too late and failed to ensure the public value and legitimacy of new technologies. And nations have become locked into unsustainable technological systems in areas such as food production, energy and transport from which their governments are now trying to extricate themselves.

The first step towards improving governance is to recognise that alternatives are available. For example, different countries can take very different approaches to governing biotechnology. Sheila Jasanoff (2011) has described how the US system for biotechnology focuses on the products of innovation, while the European approach targets the process of innovation. In some sectors and countries, the precautionary principle provides a legal basis for governance. By contrast, the software/internet sector tends to be governed in a reactive way, inheriting a model from Silicon Valley that presumes stakes are low and benefits are clear. As the scale and power of companies such as Facebook, Google and Amazon increase, governments are beginning to realise the limitations of this model.

Geoff Mulgan, the chief executive of Nesta, thinks we are seeing "a radical change in both the theory and practice of regulation with the emergence of a new field of 'anticipatory regulation'."[6] This form of governance demands a closer relationship between regulators and innovators, greater experimentation and more open dialogue. The Regulators' Pioneer fund announced by the UK government in the 2017 Budget is one response to this challenge.

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[3] Collingridge, D (1980) The social control of technology. Open University Press
[4] Hajer, M. (2003). Policy without polity? Policy analysis and the institutional void. *Policy sciences*, *36*(2), 175-195.
[5] Kaiser, D., & Moreno, J. (2012). Dual-use research: Self-censorship is not enough. *Nature*, *492*(7429), 345.
[6] Mulgan, G, (2017) Anticipatory Regulation: 10 ways governments can better keep up with fast-changing industries, https://www.nesta.org.uk/blog/anticipatory-regulation-10-ways-governments-can-better-keep-up-with-fast-changing-industries/

Public attitudes to emerging science and technology

New science and technology bring both opportunities and concerns. We should not be surprised that, as with any disruption or intervention, technological change is met with ambivalence. Members of the public understandably want to know who is likely to benefit, what the risks might be, who is making the decisions and what will happen if things go wrong.

Scientists often agonise that public trust in expert knowledge appears to be in decline. Survey evidence suggests that members of the public trust scientists and doctors more than anyone to tell them the truth. However, when questions are asked about the governance arrangements for science, public scepticism about scientists funded by, for example, business becomes more prominent. And there is some survey evidence pointing to public concern about the inequalities that may be exacerbated by innovation. (Relevant data on public attitudes is in Appendix 1). Public attitudes and governance are inextricably linked. On issues of emerging science and technology, members of the public are not just concerned with questions of risk and safety. They are also interested in matters of political economy: who is likely to win and lose?

For some areas of technology, public attitudes are relatively well understood. New technologies such as genome editing will lead to some predictable enthusiasm about disease prevention and some predictable concern with the 'designer babies'. But we should not presume to know in advance what the salient issues are. An understanding of the importance of public attitudes has over the last three decades led to important changes in public engagement with science. Whereas scientific institutions used to prioritise communication, explanation and public awareness, they now (particularly in the UK) see the need for dialogue. Formal public dialogue exercises such as those reviewed in this report are an important way for policymakers and innovators to navigate these social uncertainties.

Mapping knowledge on governance of and public attitudes to new science and innovation

This report is the final product of a short research project that aimed to map recent evidence on the governance of and public attitudes to science and innovation. We reviewed the evidence from the period 2008 to 2018 and compared it with our own knowledge of wider and older literatures, as well as with our own experience as researchers and policy advisers working on these debates. We wanted to know how well the literature engaged with the salient questions facing policymakers around science and innovation. Chapter 4 reviews recent evidence on the governance of emerging science and technology, drawing out key themes and pointing to selected sources on each. The highlighted sources were selected because they are highly-cited in the literature, represent important policy statements or offer novel approaches or findings. Chapter 5 looks more specifically at the question of public attitudes, identifying key themes from the papers reviewed as well as analysing public surveys and reviews of public dialogue exercises. Throughout the report, particular sources from the corpus of papers are referred to in the text with the first author surname and year of publication. The full bibliography of sources is in Appendix 3.

The map of recent literature that we provide is a partial record of knowledge. There is much learning contained within institutions, their memories and their ongoing experiments, that is not properly captured or evaluated in the literature. There are also gaps to do with, for example, emerging science and technology in emerging economies.

3. Methods summary

Systematic mapping was the primary methodological approach for this study (see detailed methods in Appendix 2). Systematic mapping is a process of capturing and describing relevant literature through a database search and screening process. For the purposes of this report, we used search terms relevant to both the governance of emerging technologies and public attitudes towards this governance to carry out initial searches in Web of Science and Scopus. We supplemented this with items of grey literature derived from expert-suggested literature from within the research team. Removing duplicates and screening out irrelevant items, this yielded a text corpus of 545 items. These items included 501 relevant to the governance of emerging technologies, and 73 relevant to public attitudes of the governance of emerging technologies (with some overlap). These selected items were coded in the Eppi-Reviewer 4 Platform to identify key themes and other descriptive qualities such as technologies and geographic scope of focus.

Once relevant literature had been identified, we conducted a final screening process to identify key references for each theme. This was conducted in Eppi-Reviewer by carrying out a second pass of title and abstract screening in order to assign items to a new ‘key references’ code, which were used to develop a general synthesis of the issues raised in these key references. A review of the papers’ abstracts allowed for the identification of particularly novel, relevant or interesting papers, which we highlight with key points from the text, or shortened versions of abstracts in chapter four.

4. Mapping the literature on governance

Patterns in the literature

The systematic mapping of the literature on the governance of emerging science and technologies yielded a total of 501 items. These were fairly evenly distributed over the review period from 2008 and 2018 with between 30 and 70 items published each year (Figure 4.1). Most studies focused on Europe, followed by North America and Asia (Figure 4.2).

Figure 4.1. The number of included items published each year on governance of emerging science and technology between 2008 and 2018.

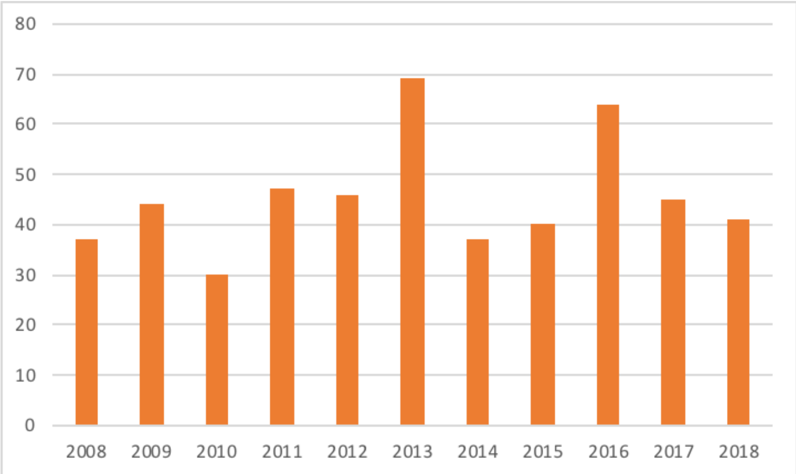
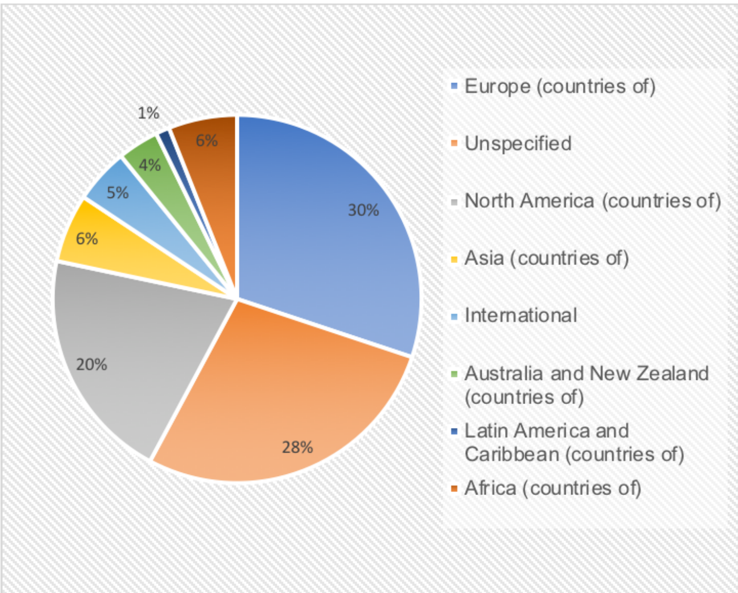


Figure 4.2. The geographic focus of included items on governance of emerging science and technology between 2008 and 2018.



Nanotechnology was the most studied case (19% of papers), followed by biotechnologies and health technologies (Table 4.1.) This reflects a spike of attention and funding for nanotechnologies in the

2000-2010 period, and expectations (not fully realised) that these might become the focus of more intense public and policy concern.

Table 4.1. The count of different kinds of science and technology considered in included items on governance of emerging science and technology between 2008 and 2018.

Science/technology	Count
generic emerging technology	185
Nanotechnology	117
generic emerging science	60
Biotechnologies	43
health technologies	41
energy technologies	28
digital technologies	27
information and communication technologies	27
synthetic biology	27
genetic engineering	17
geoengineering	13
AI and data driven tech	9
space technology	6
agricultural technologies	6
chemical technologies	5
transport technologies	5
Robotics	4
Biometrics	2

Key themes and selected sources

The systematic mapping produced a set of inductively coded 'key themes', which illustrated the different modes of governance that were considered in the included items. In the literature on governance, a total of 27 modes of governance were coded in the literature. Ranging from regulation to issues of trust, these key themes reflect the ways in which the governance of emerging science and technology are being considered in the literature.

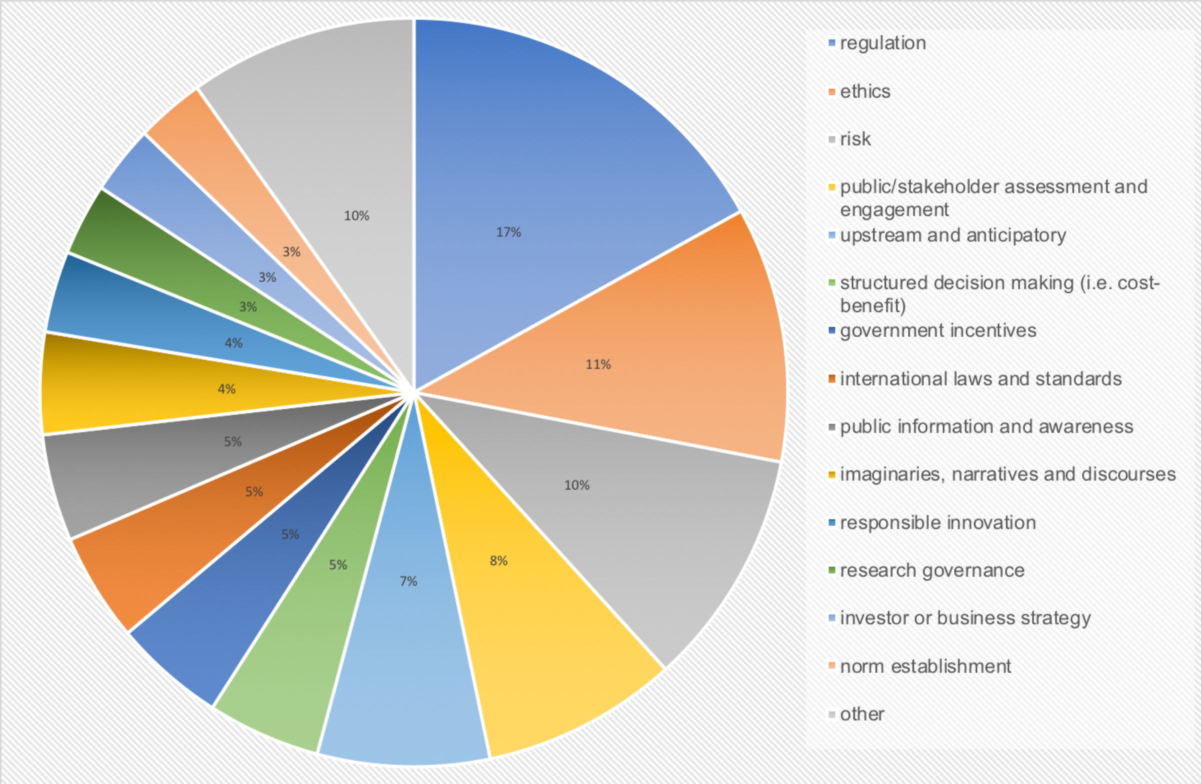
It is important to note that the systematic mapping identifying these themes was agnostic as to whether or not the literature was in favour or against each of the coded themes. So, for example, the code used for an anticipatory approach to governance was applied to items that argued for such an approach, described or analysed this approach or were critical of it.

Table 4.2 The count of different modes of governance considered in included items on the governance of emerging science and technology between 2008 and 2018.

Rank	Code	Count
1	regulation	246
2	ethics	160
3	risk	149
4	public/stakeholder assessment and engagement	123
5	upstream and anticipatory	108
6	cost-benefit, multicriteria, mapping, structured and technical-aided decision-making	71
7	government incentives	70
8	international laws and standards	68
9	public information and awareness	67
10	imaginaries, narratives and discourses	64
11	responsible innovation	51
12	research governance (e.g. interdisciplinarity)	45
13	investor or business strategy	43
14	norm establishment	43
15	precautionary	24
16	trust	21

17	university priorities and investment	13
18	laissez faire and market/consumer choice	12
19	downstream, reactive, 'regulation lag'	11
20	scientific self-governance, soft law	11
21	affect, gut response based on attitudes and values	9
22	inter-firm contractual arrangements	9
23	corporate social responsibility	8
24	technical regulation (non-human)	8
25	piloting and experiments	7
26	power and politics	5
27	expert or parliamentary committees	5

Figure 4.3 The frequency of different modes of governance considered in included items on governance of emerging science and technology between 2008 and 2018. Other includes items with frequencies < 3%.



To further explore and unpack these different modes of governance, we have subsequently grouped the 27 topics listed into ten headline themes that reflect the broad landscape of the literature.

1) **Regulation, laws & standards (1, 8)**
2) **Risk, risk assessment & cost-benefit analysis (2, 6)**
3) **Ethics (3)**
4) **Public engagement and public understanding (4, 8)**
5) **Anticipatory governance (5, 12, 14)**
6) **Government, business and university strategy and incentives (7, 11, 17)**
7) **Imaginaries, narratives (10), norms (13), values (25) and trust (16)**
8) **Self-regulation and self-governance (19, 20, 22)**
9) **Precaution (15)**
10) **Experimentation (26)**

These are discussed in turn below:

1) Regulation, laws & standards (1, 8)

There is an extensive literature (>300 items) on the regulation of emerging technologies, primarily focused on national regulatory regimes in a diverse range of countries (including India, Iran, Denmark, Brazil, Canada, Mexico, Argentina, US, France and UK).[7]

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[7] See e.g. Abbasi (2008), Ahsan and Roth (2010), Ahuja (2018), Ali and Sinha (2015), Bachu (2008), Ducas and Wilner (2017), Fatehi and Hall (2015), Freeland and Jakhu (2017), Gaxiola et al (2016), Glaser et al (2016), Harmon (2008, 2011), Medina-Arellano (2012), Sant-Anna et al (2012))[7]. Cross-national studies are dominated by comparative analysis at an EU level (E.g. Faulkner, 2009), Fieldsend (2011), Flear and Vakulenko (2010), Kloza et al. (2015), Schneider (2009))[7], with some comparative analysis of EU, US and Asia. (E.g. Howlett and Laycock (2016), Ladikas et al. (2015), Li (2011)

The literature is broadly positive about regulation as a tool for effective governance, but there is extensive discussion of the difficulties of adapting regulatory frameworks and institutions to stay ahead of rapid technological advances. There is extensive discussion of the need for anticipatory and adaptive regulation; for more experimentation in regulatory approaches; for a stronger focus on outcomes; and for greater collaboration between countries on the development and alignment of regulatory responses.

This last point is a key focus of the literature on international laws and standards, which are seen as crucial to facilitate, incentivise or navigate the risks of innovation, even though these can also be weak or slow to develop and enforce. Regulatory divergence between nations can pose challenges to trade and business efficiency (as seen now in debates over Brexit), and there is some discussion in the recent literature of more collaborative international approaches (including co-regulation and self-regulation by different industries and sectors).

Selected highlights of the literature:

Bannister and Wilson (2011) explore the relationship between emerging technologies, citizen autonomy and the regulatory state. They argue that technology already enables a significant increase in the level of governmental interference in and control of the lives of citizens. They outline two frameworks - the activating state, and the regulatory state – to analyse possible developments and their implications.

Faulkner (2009) addresses the role that regulation plays in processes of technological innovation. Using the case of the debate and development of regulatory policy for therapeutic tissue engineering in the EU's policy institutions and stakeholder networks, the paper argues that the phenomenon of 'Europe' is partly constituted by regulatory regime building, linked to new technologies. The paper provides a counter-example to the view that regulation 'lags behind' innovation.

Allyse (2010) explores emerging models of research ethics regulation, by looking at three examples: Japan's Bioethics and Biosafety Office, the UK's Human Fertilisation and Embryology Authority and the California Institute of Regenerative Medicine.

Bosso (2016) analyses papers published from 2003 through 2013 on the theme of nanotechnology and governance. It considers three points: (1) the "problem'' of nanotechnology; (2) general lessons for governance obtained; and (3) prospects for aligning the US regulatory system to the next generation of complex engineered nano-materials. A pre-existing regime shapes how policymakers perceive, define, and address the relative benefits and risks of both proximate and yet-to-be idealized nano-materials and applications. Bosso concludes that fundamental reforms in the extant regime are unlikely short of a perceived crisis.

Marchant and Allenby (2017) explore the role of soft law in governing emerging technologies, arguing that there are at least ten different reasons why nations may seek to harmonize their oversight of a specific technology. A new generation of more informal international governance tools are being explored, often grouped under the term "soft law." They include private standards, guidelines, codes of conduct, and forums for transnational dialogue.

Kuzma and Tanji (2010) consider the emerging field of synthetic biology and argue there have been few systematic analyses of the policy problems that we will likely face as this area develops. Biosecurity issues are the most defined; other societal oversight issues and implications have not been well explored. Projected applications of synthetic biology are reviewed and a typology of them is developed. The paper proposes that different categories of synthetic biology application may warrant different oversight regimes: there might not be an appropriate "one size fits all" approach.

In their analysis of synthetic biology regulation, **Trump et al. (2018)** apply multi-criteria decision analysis to a specific case of synthetic biology, a micro-robot based on biological cells called “cyberplasm”, and use data from a Delphi study to assess cyberplasm governance options and demonstrate how such decision tools may be used for assessments of synthetic biology oversight.

Tait et al. (2017) produced a report for the UK Department of Business, Enterprise and Industrial Strategy. This argues for deregulation and support for the short-term interests of businesses by making “governance systems more proportionate and adaptive to the needs of innovative technologies”. The PAGIT group proposes a responsible innovation framework tailored to companies, which presumes that companies can be certain about the risks and benefits of their products, and certain about public concerns.

Laurie et al. (2012) consider the profound uncertainties that are typical around new technologies. They note that the dominant approach during the 20th Century has been to overlook such uncertainties as technologies are rolled out. A regulatory approach that takes seriously such uncertainties should, according to the authors, make better use of ‘foresighting’ – the deliberate articulation of possible and desirable futures. The framework they propose for foresighting allows for clearer identification of legal issues around technology at an early stage.

2) Risk, risk assessment & cost-benefit analysis (2, 6)

Risk was a common theme throughout the literature and there were a large number of studies that proposed or discussed more technical approaches to decision making for emerging technologies, through some variant of cost-benefit analysis or risk assessment (e.g. Birnbaum et al (2016), Chan-Remillard et al (2008), Adenle (2017), Gazso (2016), Hong et al (2011), Kuzma and Besley (2008), Phillips and Smyth (2017), Tait and Banda (2016)). The dominant approach in these studies is based on an assessment of risks, costs and benefits, expressed in primarily economic terms. Another group of studies argue that emerging science and technologies pose fundamental challenges to traditional cost-benefit models because relevant risks and benefits are normally uncertain and impossible to calculate in advance (e.g. Devos et al (2014), Clarke (2009), EEA (2013), Felt et al (2008), Grieger et al (2012), Kastenhofer (2011), Rycroft et al (2018), Wallach et al (2018), Stirling (2010), Wallach et al (2018)).

Selected highlights of the literature:

In an influential report on *Innovation: Managing risk, not avoiding it*, the **UK’s Government Office for Science (2014)** offers a sophisticated account of how policymakers can navigate the balance between risk assessment, engagement with public and societal values, and the requirements of an effective regulatory system, able to support responsible models of innovation.

Kaebnick (2016) reviews the technology assessment literature, focussing on cost-benefit analysis and precaution. Some of the better-known formulations of a precautionary principle expressly call for combining precaution with assessment of costs and benefits. The paper examines the possible intersection of precaution and CBA. It argues that a moderate kind of CBA is a necessary part of a moderate kind of precaution.

Kastenhofer (2011) uses post-normal science to link epistemology and governance in problem situations where facts are uncertain, values in dispute, stakes high and decisions urgent. The article addresses the epistemological challenges of issues such as agricultural biotechnology and telecommunications in Germany.

Linkov et al. (2018) argue that although the existing risk-based paradigm has been essential for assessment of many chemical, biological, radiological, and nuclear technologies, a complementary approach may be warranted for the early-stage assessment and management challenges of high uncertainty technologies such as nanotechnology, synthetic biology and artificial intelligence. The paper argues for the integration of quantitative experimental information alongside qualitative insight from experts and stakeholders to characterize and balance the risks, benefits, costs, and societal implications of emerging technologies.

Mannix (2018) argues that cost-benefit analysis or ('benefit-cost analysis' in this paper) is now widely known and used, but also widely misunderstood—by many of its advocates as well as its detractors. It is designed to weigh government actions, to see whether they are in the public interest, not to evaluate private actions. The paper argues that shifting the burden of proof onto private innovators to demonstrate acceptable risks and social benefit, would have serious economic consequences.

Miller and Wickson (2015) argue that risk analysis (encompassing risk assessment, management, and communication) is touted as the most appropriate approach for governing nanomaterials. In this article, they survey existing criticisms of risk assessment as a basis for regulatory decision making on emerging technologies. They argue that risk analysis is a bad model for nanomaterial governance.

Rotolo et al. (2013) ask how scientometric mapping can function as a tool of 'strategic intelligence' to aid the governance of emerging technologies? Their paper examines the potential these techniques have to inform, in a timely manner, decision-makers about relevant dynamics of technical emergence. The analysis relies on three empirical studies of emerging technologies in the biomedical domain: RNA interference (RNAi), human papillomavirus (HPV) testing technologies for cervical cancer, and Thiopurine Methyltransferase (TPMT) genetic testing.

Stirling and Coburn (2018) critically review the design of methods for ethically robust forms of technology appraisal in the regulation of research and innovation in synthetic biology. Their report for the Hastings Centre focuses on the extent to which cost-benefit analysis offers a basis for informing decisions about which technological pathways to pursue and which to discourage. They question why mention of precaution can excite accusations of unscientific bias or irrational, "anti-innovation" extremism. The authors discuss multicriteria mapping, an appraisal method for exploring contrasting perspectives on emerging technologies.

Ferretti (2010) considers the relationship between risk and distributive justice, and argues there are certain kinds of risk for which governments, rather than individual actors, are increasingly held responsible. The paper focuses on cases of risk associated with technological and biotechnological innovation. It discusses how regulatory institutions can ensure an equitable distribution of risk between various groups such as rich and poor, and present and future generations.

3) Ethics (3)

Like risk, ethics were frequently mentioned in the literature, either as a justification for a particular approach to governance, or in a more reflective mode, as in the ways that ethical considerations shape and affect governance approaches in particular contexts and cultures. Discussion of ethics was particularly pronounced with respect to biotechnology and health technologies, reflecting the sophistication of philosophical deliberation in areas such as bioethics and reproductive technologies.

In the US context, there is a specific and identifiable strand of research on the "ethical, legal and social implications" (ELSI) of new technologies - reflecting the development and investment in this field through the 1990s, in parallel with the Human Genome Project. The same model was then extended to nanotechnology, synthetic biology and other emerging technologies, and has also been mirrored in other countries, including Canada, Finland, Netherlands and South Korea. In response to ELSI-type initiatives, there is also a more critical strand of work, suggesting that this approach can lead to a reductionist and narrow framing of public values and concerns, and play an instrumental function in limiting or ameliorating societal opposition to new technologies. A further set of studies build on an ethics-based approach to link to wider currents of anticipatory governance.

Selected highlights of the literature:

Hedgecoe (2010) looks at the role of technological expectations in bioethics. The paper presents a detailed critique of bioethicists' contribution to these debates and argues that bioethicists largely restrict themselves to reviews of possible ethical issues raised by technology rather than critiquing others' positions and arguing for specific points of view. The paper argues that bioethicists tend to: accept unquestioningly scientists' expectations about the development and ethical issues raised by pharmacogenetics; ignore contributions from bioethicists who do question these expectations; and engage in an ethical debate, the boundaries of which have been laid down and defined by academic and industry scientists.

Braun et al. (2010) analyse "governmental ethics" regimes as forms of scientific governance. Drawing from empirical research on governmental ethics regimes in Germany, France and the UK since the early 1980s, it argues that these governmental ethics regimes grew out of the technical model of scientific governance, but have departed from it in crucial ways. The article argues that governmental ethics regimes can be understood as a form of ''reflexive government''.

Edwards (2014) looks at the tensions between scientific expertise, ethical expertise, expert patient input, and lay public input in two institutions: the United Kingdom's Human Fertilisation and Embryology Authority (HFEA) and the United States' American Society for Reproductive Medicine (ASRM). The study finds that the HFEA attempts to 'balance' competing reasons but ultimately legitimizes arguments based on health and welfare concerns, while the ASRM seeks to 'filter' out arguments that challenge reproductive autonomy. Significantly for policy makers designing such deliberative committees, each method differs substantially from that explicitly or implicitly endorsed by the institution.

Mali F et al. (2012) examine the role played by policy advice institutions in the governance of ethically controversial new and emerging science and technology in Europe. The empirical analysis, which aims to help close a gap in the literature, focuses on the evolution, role and functioning of national ethics advisory bodies in Europe as "hybrid forums".

Rommetveit et al. (2013) presents an experimental methodology for empirical and participatory ethics of science and technology using the example of the "Technolife" project. This methodological approach seeks to mediate between lay ethics –whether actually existent or merely potential – and the discourse of professional ethicists. The methodology gives social and sociotechnical imaginaries a key role in the ethical framework.

Taebi B. (2017) argues that when evaluating technological risks in policymaking, there is a tendency to focus on social acceptance. Solely focusing on social acceptance may lead decision makers to overlook important ethical aspects of technological risk, particularly for technologies with transnational and intergenerational risks. This paper argues that good governance of risky technology requires analysing both social acceptance and ethical acceptability.

4) Public engagement and public understanding (4, 8) (see also next chapter)

Within a sizeable literature on the role of publics in the governance of new technologies, there is a sharp divide between those studies which focus on the need for improved *public awareness and understanding* (often of perceived benefits of the technologies in question); and those that place the emphasis on more deliberative forms of *public engagement and dialogue*. In the former category, there is often discussion of publics linked to "risk perception" or "risk communication" (e.g. Ahsan and Roth (2010), Maris (2009), Priest (2009)). The latter category tends to frame the contribution of publics in more positive terms, and much of the literature here describes specific initiatives or experiments (often small-scale) with deliberative models of engagement around particular technologies, or in specific national systems, including the use of semi-standardised formats for participation, such as citizen juries and focus groups (e.g. Sage et al (2014). Smallman (2018), Markusson (2012), Laborte et al (2009), Chilvers and Macnaghten (2011), Davies (2011).)

Evidence on public attitudes as they relate to the governance of science and innovation is discussed in more detail in chapter five of this report.

Selected highlights of the literature:

Flear and Vakulenko (2010) consider the EU's approach to citizen participation in the governance of new technologies from a human rights perspective. The article focuses on human rights as being about empowerment. Their analysis of the discourse reveals a disempowering 'deficit model' of citizens in need of education through their participation in governance. This suggests that citizen participation in EU governance of new technologies is not truly informed by human rights, but is instead used as a legitimating technique.

Jasanoff (2011) reflects on how scholars in science and technology studies have recently been called upon to advise governments on the design of procedures for public engagement. New rules for public engagement in the United Sates should take account of the history of these debates and seek to counteract some of the anti-democratic tendencies observable in recent decades.

Lövbrand et al (2011) ask how legitimate efforts to "democratise" scientific expertise really are. The authors identify a tension between principles for legitimate rule prescribed by deliberative democratic theory and the arguments for diversity and dissent. This suggests that the legitimacy of deliberative governance arrangements is justified on empirical rather than normative grounds.

Stirling (2008) argues that there are still persistently deterministic notions of technological progress. Distinguishing between "appraisal" and "commitment" in technology choice, it highlights contrasting implications of normative, instrumental, and substantive imperatives in appraisal. The paper argues for the opening up (rather than the closing down) of governance commitments on science and technology.

Macnaghten et al. (2014) conduct a meta-analysis across seventeen UK public dialogue processes and forty in-depth interviews with senior UK science-policy actors. They identify five spheres of public concern about the governance of science and technology relating to: the purposes of science; trust; inclusion; speed and direction of innovation; and equity. (The conclusions of this paper are discussed in more detail in the next chapter).

van Est (2013) analyses various attempts made by the Rathenau Instituut, the Dutch national technology assessment (TA) organization, to involve parliamentarians and policy makers in the field of nanotechnology, or broader converging technologies. The paper argued that the Rathenau Instituut relies on a trustworthy identity based on the scientific quality of its products and its quality as an organizer of participatory events.

Smallman (2018) reviews public debates on new and emerging science and technologies that have taken place in the UK over the past decade, and characterises the discourses emerging from these debates. It finds that while the public is broadly supportive of new scientific developments, they see the risks and social and ethical issues associated with them as unpredictable but inherent parts of the developments. In contrast, scientific experts and policymakers see risks and social and ethical issues as manageable and quantifiable with more research and knowledge. This helps explain why public dialogue has had limited impact on public policy.

Marris and Rose (2010) review numerous initiatives which have sought to engage members of the public in decisions concerning bioscience and biotechnologies. These initiatives have multiple motivations. In some cases, the justifications are normative – that participation is a right. In other cases, they reflect a desire to reduce conflict, (re)build trust, and smooth the way for new innovations. In others the motivations are substantive: the assumption being that participation could lead to innovations that perform better in complex real-world conditions, or that may be more socially, economically, and environmentally viable.

5) Anticipatory governance (5, 12, 14)

There is a perceptible shift in the literature over time towards a stronger focus on anticipatory or 'upstream' modes of governance and technology assessment, earlier in the cycle of research and innovation. The focus of such efforts is often university research, where questions of interdisciplinary collaboration come to the fore. Advocates of such approaches see their advantage as being the scope to inform and shape trajectories of R&D, and regulatory or other responses, at a stage when the technologies in question are still formative, and there is scope to exercise more meaningful governance (e.g. Guston 2012, 2014). Some (e.g. Tait (2017)) have criticised such approaches for putting too much emphasis on public attitudes and preferences.

From 2010 onwards, the concept of 'responsible research and innovation' (RRI) emerges as a key umbrella concept for such approaches, particularly in a European context, where RRI was given thematic prominence in Horizon 2020 funding programmes. Broadly defined, RRI draws together a range of concepts and approaches in an effort to strengthen the anticipation, inclusion, reflexivity and responsiveness of research and innovation systems. It has also featured in some UK studies, notably in areas funded by the EPSRC, the UK funder most prominently linked to an RRI approach.

Selected highlights of the literature:

Davies and Selin (2012) argue that public participation has become standard practice in both environmental communication and science and technology studies, with such engagement increasingly moving "upstream" to the early stages of technological development. This paper looks at the NanoFutures project. It draws out five tensions of the practice of deliberation on energy technologies, and discusses some of the implications of these tensions for the practice of civic engagement and deliberation.

Stilgoe et al. (2013) present a framework for understanding and supporting efforts aimed at 'responsible innovation'. The paper describes four integrated dimensions of responsible innovation: anticipation, reflexivity, inclusion & responsiveness. Although the framework for responsible innovation was designed for use by the UK Research Councils and the scientific communities they support, the authors argue that it has more general application and relevance.

Boenink (2013) argues that scenarios of the future play a significant role in anticipatory governance of new and emerging science and technologies. This paper investigates to what extent sociotechnical and techno-ethical scenario approaches might reinforce hubris around science and innovation, and whether the aim to develop plausible scenarios increases or decreases this risk.

Guston (2014) defines anticipatory governance as 'a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible'. This article reviews the early history of the National Nanotechnology Initiative in the United States. The article concludes that wider engagement can contribute to bending technoscience more towards humane ends.

Foley et al. (2016) explore how governance of technological innovation remains challenged by Collingridge's dilemma of control. Scholars are increasingly exploring responsible innovation (RI), a concept that revolves around dimensions of anticipation, reflexivity, inclusion, and responsiveness. At present, current conceptualizations of RI do not address questions of "to what end?" or "how to innovate responsibly?" Using nanotechnology as a case study, this paper informs RI with sustainability principles and proposes an alignment of activities, aspirations, and stakeholders with previously defined dimensions for RI.

Low S (2017) reports on the project Solar Radiation Management: Foresight for Governance (SRM4G), which aimed to encourage an anticipatory mode of thinking about the future of an engineered climate. SRM4G applied scenario construction to generate a set of alternative futures leading to 2030. The scenarios then provided the context for the design of systems of governance with the capacity and legitimacy to respond to those challenges, and for the evaluation of the advantages and drawbacks of different options.

Landeweerd et al. (2015) argue that in European science and technology policy, various styles have been developed and institutionalised to govern the ethical challenges of science and technology innovations. In this paper, they give an account of the most dominant styles of the past 30 years, seeking to show their specific merits and problems. They focus on three styles of governance: a technocratic style, an applied ethics style, and a public participation style.

Michelson (2016) argues that current approaches and institutions for effective technology assessment are ill suited to address the multidimensional, interconnected societal impacts of science and technology. This book offers tangible insights into the strategies deployed by well-known, high-profile organizations involved in anticipating the various societal and policy implications of nanotechnology and synthetic biology.

6) Government, business and university strategy and incentives (7, 11, 17)

These studies reflect the need and importance of promoting or incentivising the development of new science and technologies. Some explore the importance of creating environments where businesses and investors feel able to invest in innovation; others on the role of universities in creating spin-outs and start-ups. A subsection of items focus on the incentivisation of science and technology innovation in the global south, where institutional capacity-building is still a major challenge. Other studies explore softer (and non-regulatory) government incentives, or on the role of government procurement to support market development and growth of new technologies.

Selected highlights from the literature

Bussell (2011) asks what explains the different rates of adoption of new technologies for public services by governments across countries. The data on so-called 'eGovernment' show that countries with more corrupt regimes are less likely to successfully introduce new technologies than well-governed regimes.

Li and Georghiou (2016) study the use of government procurement as an innovation policy in China. This paper fits into a research agenda that considers the power of government to exert a substantial demand pull on innovation with the ability to boost and steer technological change. The Chinese example is of a government asserting its authority through the encouragement of local innovation, by accrediting particular suppliers. The authors argue that this policy risks leading to protectionism. The policy did not succeed in its own terms, but had effects on innovation that might nevertheless be seen as desirable. The success of this approach however depended on the specifics of the innovations in question and the procurement system.

Nemet (2009) also engages with the question of whether and how governments can influence innovation trajectories through 'demand pull' and 'technology push' policies. Taking the case of wind energy, Nemet asks why innovators appeared not to respond to strong demand pull policies in California, which had an overwhelming share of wind energy production in the 70s and 80s. Nemet concludes that subsidies for the technology did not boost innovation as desired because of business uncertainty about whether incentives would be long-term, the complexity of innovation systems and the range of other policies and incentives acting upon the system.

Marchant et al. (2011) ask how and at what level governments should seek to regulate technologies. Taking nanotechnology as an example, the authors challenge the received wisdom that national governments should lead and control regulatory activity. They argue that there needs to be more effort at trans-national cooperation, which would avoid some of the disadvantages of varying regulatory regimes across countries.

7) Imaginaries, narratives (10), norms (13), values (25) and trust (16)

This is broad grouping of studies which are broadly interested in how societies develop perspectives on the development of new science and technology, and the role that public norms, values and imaginaries plays in these processes. In particular, the concept of "sociotechnical imaginaries" aims to capture "collectively held, institutionally stabilized, and publicly performed visions" (Jasanoff 2015) of the relationship between scientific progress and desirable social futures. National imaginaries can be contested and at times multiple, they require stabilisation through ongoing social practice and they are hence both durable and open to transformation.

At their core they are practices of attributing value: What kind of future is desirable? Which future needs to be avoided? And what is role and value of science for this project of future making? Sociotechnical imaginaries commonly have a historical dimension, as they build on practices of remembering and reconstructing the past in the light of the present and potential futures. In national contexts, they are hence shaped by specific "technopolitical histories and identities" (Felt 2015). At the same time, they are also often transnational, as they contain interpretations and imaginations of other countries or 'the international/global' (Jasanoff (2015); Miller (2015); Lakoff (2015). While there is a burgeoning literature that explores sociotechnical imaginaries in relation to specific science fields and technologies, there is as yet little work on nation-specific socio-technical imaginaries.

Selected highlights from the literature

Roco (2008) considers the possibilities for global governance of new technologies at the convergence of 'nanotechnology, modern biology, the digital revolution and cognitive sciences'. The suggested approach would bring together disciplines and stakeholders with policymakers from various countries to support innovation, ensure responsible development, address concerns about risk and build capacity for long-term policymaking.

Von Schomberg (2013) presents responsible research and innovation as a way to align science and technology with clearly-articulated social goals, such as the values of the European Union. He describes the vision that led to RRI becoming a cross-cutting issue of Horizon 2020, the European Commission's Eighth Framework Programme for Research and Innovation. He presents RRI as a process of innovation and stakeholders becoming mutually responsive to one another. This involves new forms of public and civil society engagement, as well as more intensive use of foresight and impact assessment processes.

Rayner et al. (2013) provide a set of principles for the governance of emerging geoengineering research. The first is that geoengineering should be regulated as a public good. The second is that there should be public participation. The third is that geoengineering research and its results should be openly disclosed. The fourth is that there should be independent assessment of impacts and the fifth is that governance needs to be in place before any technology is deployed. Their paper provides a framework with which such principles could be moved forwards.

Schwarz-Plaschg (2018) looks at public debates on nanotechnology and the forms of analogy that people use to discuss new technologies. The paper argued that analogies can reflect public concerns as well as shape them. Some analogies emphasise the novelty of nanotechnology while others suggest it is more of the same. Certain analogies clearly suggest the rejection of nanotechnology, others are about acceptance. Some analogies are used to close down debate and some scientists will use analogies to claim that "nano is not nano" or at least not in the way understood by the general public.

8) Self-regulation and self-governance (19, 20, 22)

There are a variety of ways in which governance can be seen to be internalised within the science and technology development process, which can be summarised as various kinds of self-governance. One example might be the development of soft-law or norms within scientific communities. Another example is the idea of embedding some form of regulation into a technology using, for example, cryptographic blockchain approaches. There are also various forms of business self-governance, often addressed under the heading of corporate social responsibility, which emphasize the need for business to behave in ways that will be recognised as responsible or ethical to broader publics.

Selected highlights of the literature

De Bruin and Floridi (2017) consider cloud computing as a case study in ethics and self-governance. They ask what duties datacentre-providers such as Amazon might have relative to the companies that make use of cloud storage. Their argument is that hosting companies have obligations to provide and seek information regarding, for example, user privacy. The paper argues that government interference with such services is rarely justified, using an argument based on the neutrality of this technology that has influenced much of the debate about internet regulation. The companies that are using this technology should take more responsibility for governing data in the public interest.

Drew (2016) describes the UK government's approach to data ethics. This approach has been open, evidence-based and user-centred. In drawing up the policy, Government made use of a large public dialogue exercise. The paper makes the point that an ethics framework marks a start rather than an end to the necessary discussions, particularly given that new technologies will introduce new surprises.

Groves et al. (2011) discuss Corporate Social Responsibility as a response to public concerns about nanotechnology. The paper surveys existing CSR approaches of companies in the UK and argues that they tend to follow a 'do no harm' model of responsibility rather than a 'positive social force' model. The article suggests closer attention to a company's social performance rather than just its stated aims for CSR.

9) Precaution (15)

Precaution describes an approach to governance shaped by a set of questions: First, are the costs and risks of the new technology acceptable and does it have significant benefits? Second, do these benefits solve important problems and could these problems be solved in some other, less risky, way? Finally, what are the long term economic and political consequences of introducing the technology?

A significant number of studies mentioned precaution or the precautionary principle, but such discussion is often polarised. For those who assert the sufficiency of risk assessment or cost-benefit analysis techniques, it can appear that precaution involves undue compromise and a rejection of the advantages of a probabilistic calculus. Advocates of the precautionary principle argue that the uncertainties of new technologies make precaution a more rational response to the inherent uncertainties and limits of regulation.

Selected highlights of the literature

Harremoes et al. (2013) update an earlier (2000) report from the European Environment Agency to provide a number of case studies of precaution in action. Their interest is in learning what precaution can and can't do. Their cases are a set of (pre-)cautionary tales of 'major and avoidable public disasters'.

Kaebnick et al. (2016) provide an argument for precaution that draws on the National Academies study on gene drives for which the authors were working group members. They argue that precaution is not irrational, nor would it slow the development of beneficial technologies. Their approach to precaution steps away from a single high-level principle. They see precaution as an approach that needs to be worked out in particular contexts.

Kaebnick G E, and Gusmano (2018) collect a range of perspectives on the precautionary principle for their report. They argue that precaution is worth exploring because the alternative - to wait and see - is unlikely to deliver public benefit. Their report engages with the advantages and disadvantages of precaution through a close analysis of cost-benefit analysis, which they see as the dominant model in the US.

Mali (2008) discusses the importance of the precautionary principle for the governance of converging technologies (technologies using novel properties from different technological domains such as nanotechnology, biotechnology, neurotechnology etc). As part of this approach, Mali calls for increased citizen involvement in risk assessment for science and technology.

A report on nanotechnology risk by a **US Food and Drug Administration (2011)** task force does not specify precaution but its conclusions are broadly in line with a precautionary approach. There is a close analysis of uncertainty and an argument for adaptive governance and increased capacity for regulatory oversight. The report suggests that the challenges of nanotechnologies for product risk assessment are substantially similar to those of other emerging technologies, but that additional concerns may exist with the novel properties of nanoparticles.

10) Experimentation (26)

The language of experimentation as an approach to governance has risen in prominence in the literature over the past five years - often related to participatory initiatives of various kinds, designed to test and develop new, more inclusive models of governance. This also reflects a wider "experimental turn" in other aspects of government decision making - reflected for example in the UK's development of a network of "What Works" centres for evidence-informed policy, and equivalent efforts in the US, Germany and Australia.

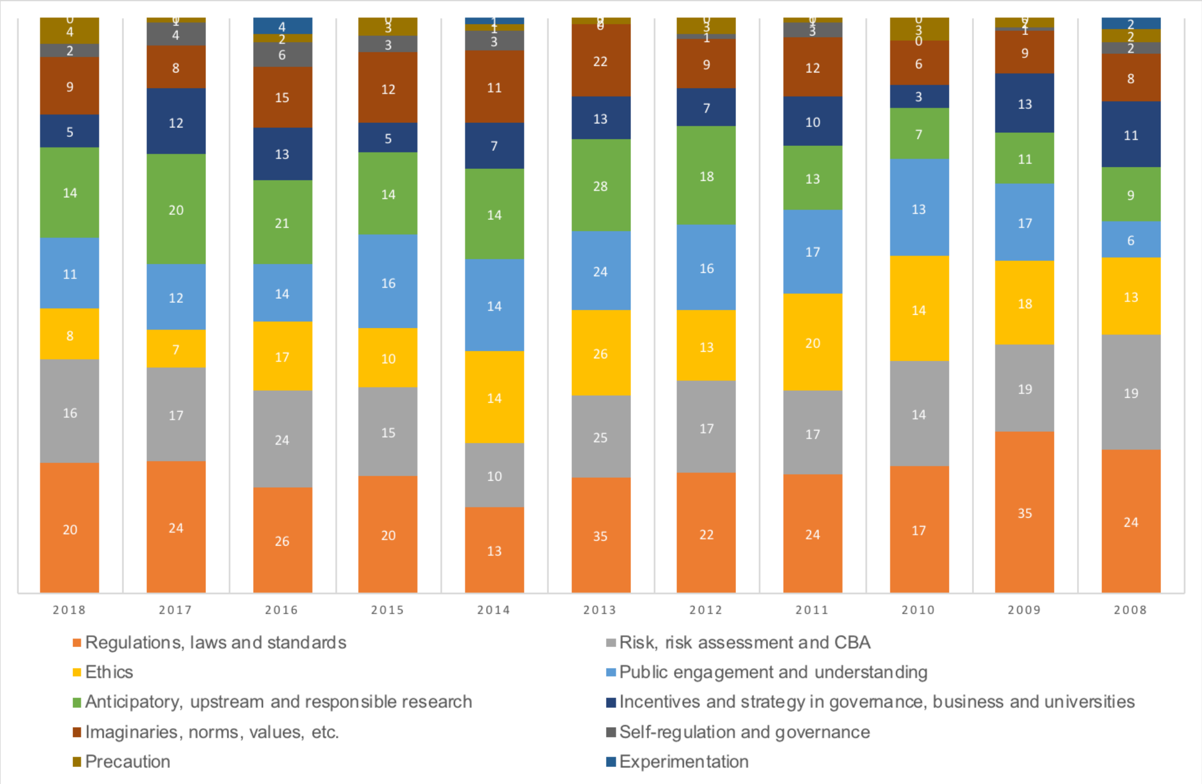
Selected highlights of the literature

Felt et al. (2008) look at the causes and implications of widely-recognised European public unease with emerging science and new technologies. The report's chapters consider innovation policy, the governance of technological risk, ethics, learning and new attempts to engage European publics in forms of dialogue around science and technology. The report calls for new forms of experimentation in both governance and science, including renewed engagement with models of open science and citizen science.

Voss and Amelung (2016) reconstruct the innovation journey of 'citizen panels', as a family of participation methods, over four decades and across different sites of development and application. A process of aggregation leads from local practices of designing participatory procedures like the citizens jury, planning cell, or consensus conference in the 1970s and 1980s, to the disembedding and proliferation of procedural formats in the 1990s, and into the trans-local consolidation of participatory practices through laboratory-based expertise since about 2000. Their account highlights a central irony: anti-technocratic engagements with governance gave birth to efforts at establishing technoscientific control over questions of political procedure.

These ten key themes have been broadly consistent in their prevalence over time in the literature between 2008 and 2018, with some increase in anticipatory approaches (Figure 4.4). Within these groupings, some terminology, such as 'anticipatory governance' or 'responsible research and innovation' has become more common over the period surveyed.

Figure 4.4. The annual frequency of the ten key themes considered in included items on governance of emerging science and technology in each year between 2008 and 2018.



5. Recent evidence on public attitudes

In this chapter, we review the recent literature on public attitudes to the governance of emerging science and technology (much of which, because of the large overlap, was discussed in the previous chapter and highlights from which were drawn out). We also consider data from recent public surveys and qualitative insights from public dialogue activities in order to derive key themes and questions as they relate to the governance of emerging science and innovation. Survey data that informs this chapter is in Appendix 1.

Patterns in the literature

The systematic mapping of the literature on public attitudes to the governance of emerging science and technology yielded a total of 73 items. The numbers are too small to discern clear publication trends (Figure 5.1.) While many of the studies did not report a geographic focus, of those that did, there was a predominant focus on public attitudes in Europe and North America (Figure 5.2.).

Figure 5.1: Number of included items published each year on public attitudes to governance of emerging science and technology between 2008 and 2018.

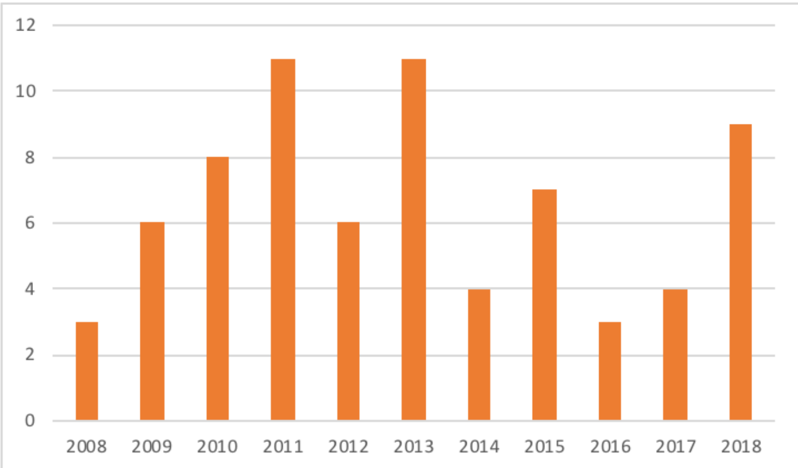
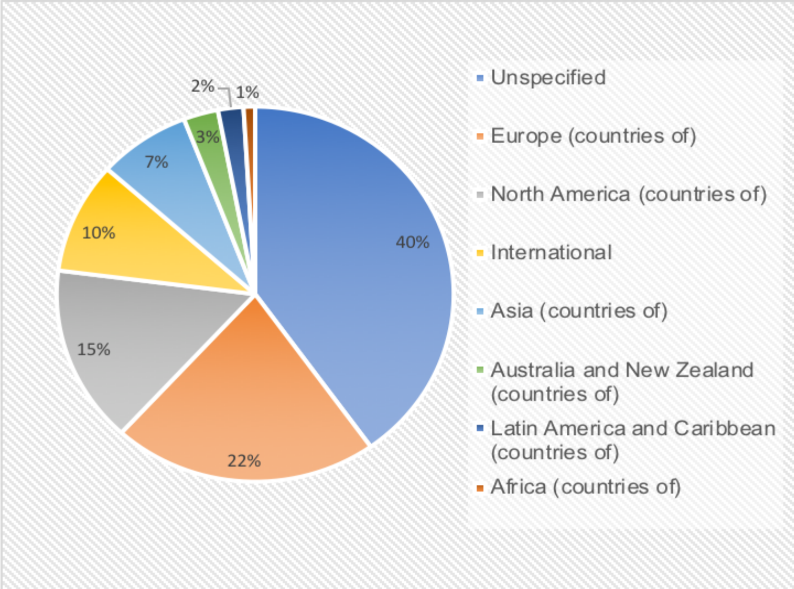


Figure 5.2. Geographic focus of included items on public attitudes to governance of emerging science and technology between 2008 and 2018.



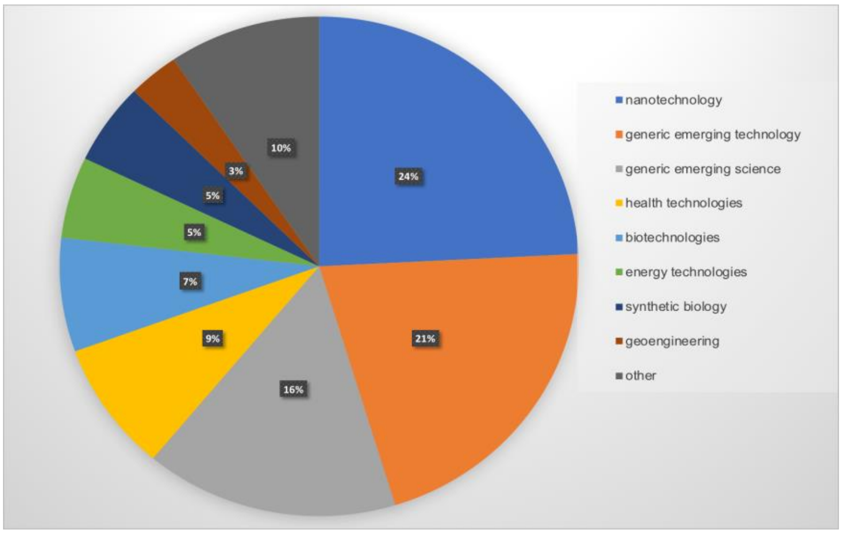
A plurality of the studies focused on nanotechnology (Table 5.3.). The prevalence of research on nanotechnology should not be interpreted as reflecting the importance of the issues raised by this case. Rather, it is a function of timing. After the public controversy surrounding agricultural biotechnology in Europe, many policymakers and researchers saw nanotechnology, which began to attract funding and interest from 2002 onwards, as an opportunity to trial more constructive forms of public engagement. Nanotechnology therefore became an important test case, particularly during the time period of our search, for deeper exploration of public attitudes to emerging science and technology.

Table 5.3. Count of different kinds of science and technology considered in included items on public attitudes to governance of emerging science and technology between 2008 and 2018.

Science/technology focus	Count
nanotechnology	23
generic emerging technology	20
generic emerging science	15
biotechnologies	7
health technologies	7
energy technologies	5
synthetic biology	5

geoengineering	3
digital technologies	2
genetic engineering	2
transport technologies	2
big data	1
information and communication technologies	1
drones	1
genomics	1

Figure 5.4. Frequency of technologies considered in included items on public attitudes to governance of emerging science and technology between 2008 and 2018. Other includes items with frequencies < 3%



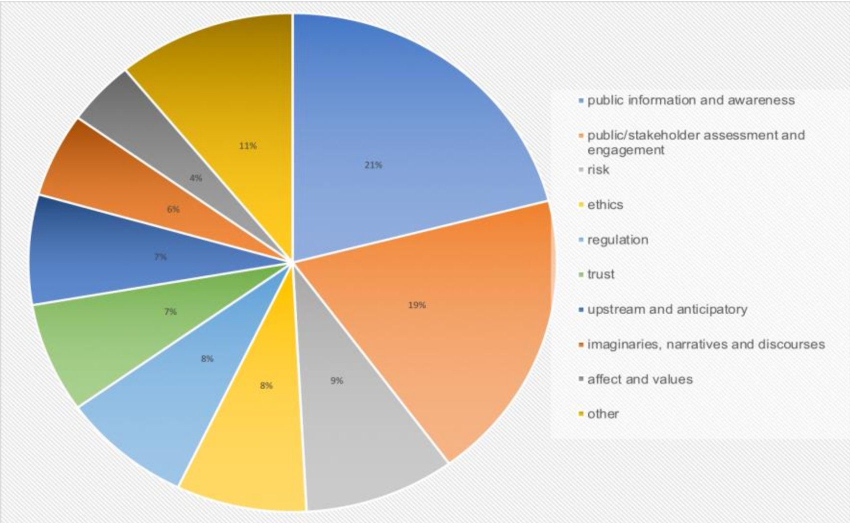
Key themes

Table 5.5. Count of different modes of governance considered in included items on public attitudes to governance of emerging science and technology between 2008 and 2018.

Rank	Code	Count
1	public information and awareness	50
2	public/stakeholder assessment and engagement	45
3	risk	22
4	ethics	19
5	regulation	19
6	trust	17
7	upstream and anticipatory	17
8	imaginaries, narratives and discourses	13
9	affect, gut response based on attitudes and values	10
10	government incentives	4
11	laissez faire and market/consumer choice	4
12	norm establishment	4
13	cost-benefit, multicriteria, mapping, structured and technical-aided decision-making	3
14	international laws and standards	2
15	research governance (e.g. need for interdisciplinarity)	2
16	responsible innovation	2
17	technical regulation (non-human)	2

18	corporate social responsibility	1
19	scientific self-governance, soft law	1
20	university priorities and investment	1

Figure 5.6. Frequency of different modes of governance considered in included items on public attitudes to governance of emerging science and technology between 2008 and 2018. Other includes items with frequencies < 3%



The themes that emerge from coding this literature have substantial overlap with those in the previous chapter. To avoid duplication, highlights from the abstracts are not repeated here. Below, we provide additional insight on public attitudes, grouping the themes into ten headings:

1) **Public awareness, public responses and public communication (1) and (9)**
2) **Public/stakeholder engagement (2)**
3) **Risk (3)**
4) **Ethics (4)**
5) **Regulation (5), government incentives (10), technical regulation (non-human) (17), cost-benefit, multicriteria mapping (13), International Laws and Standards (14)**
6) **Trust (6)**
7) **Upstream and anticipatory (7), responsible innovation (16)**
8) **Imaginaries, narratives and discourses (8)**
9) **Laissez faire and market/consumer choice (11)**
10) **Norms (12), scientific self-governance and soft law (19), corporate social responsibility (18), research governance (15), university priorities and investment (20)**

1) Public awareness, public responses and public communication (1) and (9)

This section of the literature discusses the extent of public awareness of and attitudes (positive and negative) towards the emergence of new technologies. Many of these papers are disconnected from previous evidence on public attitudes and come from countries with a less advanced dialogue on science and innovation. Some papers report the public's lack of awareness and the need for improved awareness as crucial to their acceptance (e.g. Assad et al (2014); Chen et al (2015)). These papers are based on what has become known in the US and Europe as a 'deficit model' of the public, in which public concern is assumed to be a function of public ignorance of science. The literature is predominantly based on the use of surveys and interviews with publics and stakeholders. The issues highlighted by these papers are explored in more detail in the "quantitative and qualitative insights" section below.

2) Public/stakeholder engagement (2)

These sources, mostly from the UK, US and Northern Europe, describe and analyse exercises in which public perspectives were brought into the decision-making process, either through engagement activities, or by carrying out an assessment of what publics think and feeding this back into the process. Some papers reflect on the methods of public participation and attempt to conceptualise a typology of publics. Some look at how experts imagine publics, for example around genetic testing (Braun and Schultz (2010)). Other sources focus on the ways in which members of the public talk about emerging technologies (e.g. Davies (2011)). Much of public engagement experimentation and analysis during the period surveyed took place around nanotechnologies, following the report from the Royal Society and Royal Academy of Engineering in 2004. Much of the literature compares public ambivalence with expert opinions of social issues (e.g. Bertoldo et al (2015); Barvosa (2015)). One particularly useful review (Smallman (2017)) provides a longitudinal look at how public views, as well as expert views *of* the public, have evolved over a decade. The issues highlighted by these papers are explored in more detail in the "Quantitative and qualitative insights" section below.

3) Risk (3)

A number of studies found that public responses were in many ways driven by their attitude towards risk and their awareness of risk (e.g. Priest (2009)). Risk was often connected to questions of ethics and trust (e.g. Capon et al (2015)). Risk communication and public perception of risk (e.g. Suerdem et al (2013)), research on which has a much longer history, remain important themes. As above, nanotechnology was a focus of much of this discussion (e.g. Bertoldo et al (2016)).

4) Ethics (4)

Public attitudes to emerging technology were often underpinned by ethical concerns or the trustworthiness of frameworks for ethical governance. Ethics and ethical dimensions were discussed in the literature both theoretically (for example with respect to epistemic rights) but also empirically where public responses showed ethical concerns about the implications and impacts of particular technologies, including risk of harm to publics. Ethics was frequently mentioned as an issue, either as a justification for the need for a particular approach to governance – e.g. responsible research and innovation – or thinking about how ethical considerations could be applied to the development of new science and tech. Some papers undertook a critical analysis of dominant approaches to, for example, bioethics or data ethics (e.g. Hedgecoe (2010)).

5) **Regulation (5), government incentives (10), technical regulation (non-human) (17), cost-benefit, multicriteria mapping (13), International Laws and Standards (14)**

Regulation was referred to in the literature on public attitudes, either as topic of discussion in which publics discussed positive and negative issues concerning regulation as a tool for governance (particularly in conjunction with the associated risks or incentives of innovation) or to frame the discussion and literature review which accompanied these papers and policy reports as background and context. Like regulation, government incentives, decision making including cost-benefit analyses also framed the discussion with respect to public attitudes (e.g. West et al (2018)). Reflecting the increasing globalism of the governance debate, connections were frequently made with international laws, norms and standards.

6) **Trust (6)**

Public trust was seen as an important part of public attitudes, mostly through empirical work (see survey section below and, e.g., Asaad et al (2018)) but also in theoretical contributions where trust was conceptualised, dynamics of trust are described (e.g. Adjekum et al (2017)) and suggestions on how to enhance trust are offered. Here, public attitudes were often described with respect to the amount of trust or understanding towards new emerging science or technology.

7) **Upstream and anticipatory (7), responsible innovation (16)**

These themes related to themes of trust, ethics and public engagement with science and tech. Several papers suggest frameworks for governance and set out principles for more effective engagement (e.g. Saunders (2018); Guston (2014); De Wert et al (2018)). 'Upstream' and 'anticipatory' approaches are aimed at more constructive engagement between innovators, stakeholders and the public at an early stage of innovation. Literature on responsible innovation or responsible research and innovation informs, describes and evaluates recent policy approaches by funders, including the European Commission and the Engineering and Physical Sciences Research Council in the UK, to institutionalise upstream, democratic engagement.

8) **Imaginaries, narratives and discourses (8)**

Some literature referred to public perceptions of innovation through social (sometimes identifiably national) visions of the future. This was sometimes linked to the uncertainty and ambiguity of new technologies (e.g. Flynn et al (2012)). This theme is complex but papers discussed the presence of dominant narratives and futures and the need for public views to be brought into the discussion of emerging tech through upstream engagement.

9) **Laissez faire and market/consumer choice (11)**

A small minority of literature reflected an assumption that the uncertainties of new technologies would be adequately governed by market forces. These papers interpreted public attitudes in terms of market research. Some papers drew on empirical research with consumers to identify areas in which they felt able to decide and areas that demanded regulatory intervention (e.g. Morin (2009)).

10) **Norms (12), scientific self-governance and soft law (19), corporate social responsibility (18), research governance (15), university priorities and investment (20)**

Some research on public engagement and attitudes drew connections with norms, scientific cultures and bottom-up governance (e.g. Irwin et al (2013)). Norms were referred to in papers where values and attitudes were revealed and how public perspectives were formed. Often this related to soft law and social responsibility. Some papers referred to the need to better understand public attitudes towards investment in science and research priorities.

The published literature on public attitudes should be seen alongside evidence from public surveys that may or may not have been formally published, either in primary form (as a report from Government or a science organisation) or digested form (as part of an analysis by social scientists).

Survey evidence

Surveys of public attitudes to science have a decades-long history. The US National Science Foundation began its Science Indicators surveys in the 1970s, measuring public knowledge, attitudes and rates of participation in scientific activities. Since the 1980s, these activities were given a further impetus by political concerns about an apparent crisis in public trust. Controversies around nuclear energy and agricultural biotechnology suggested a newly sceptical rather than deferential public.[8]

Appendix 1 of this report summarises recent evidence from surveys in the UK, US and EU. The headline finding is that, while support for science and scientists remains high relative to other domains and professions, public trust is contingent upon perceptions of independence. If science and technology are seen to be governed in the interests of private profit, government's own agendas or other elites, trust in science falls. This has important implications for the governance of science and technology. It suggests that the question "who benefits?" can come to dominate discussions of particular issues if they become controversial. Public surveys do not typically ask opinions about the direction of innovation. It is therefore important to supplement quantitative evidence from surveys with qualitative evidence that emerges from social research.

Quantitative and qualitative insights into public attitudes

Surveys of public attitudes to science should be understood in the context of their motivations, which, in most cases, have been to assess public support for existing science policies. They are therefore only indirectly relevant to the question of how new science and technologies should be governed.

Taken together, survey data suggest a high level of public support for science and technology in the UK, which can be read as a proxy for public support for the ways in which science and technology in general are governed. What these surveys do not reveal is the nature of public ambivalence to new science and technology. Public trust in science and technology is conditional. It is therefore valuable to combine quantitative with qualitative findings. In asking people whether they are sceptical or trusting, positive or negative, we overlook the real nature of people's concerns with science, innovation and progress. Qualitative social research over the last thirty years has revealed that public attitudes to science and technology are multidimensional and often conflicted.

[8] Research commissioned by the Wellcome Trust for the Gallup Monitor Survey provides useful background on public attitude surveys (Wellcome Global Monitor, 2018, 'Understanding what people around the world think and feel about science and key health challenges', Questionnaire development report https://wellcome.ac.uk/sites/default/files/wellcome-global-monitor-questionnaire-development-report_0.pdf)

Public ambivalence may be misconstrued by innovators as indecision, confusion or ignorance, but public attitudes are never as simple as pro- or anti-science or innovation. This complexity has been recognised in UK policymaking. Following the controversy over GM crops, the UK Government committed in its 10-year investment framework,

> *'to move the debate forward – beyond simplistic notions of the public being ignorant of science, or being either pro-science or anti-science; and beyond crude notions of a particular technology being either 'good' or 'bad'. The Government will also work to enable the debate to take place 'upstream' in the scientific and technological development process'.*[9]

Case studies suggest that ambivalence can be an active form of public engagement. Engaged members of the public can be both enthusiastic and concerned about the possibilities of innovation in general or particular technologies. Survey data is typically presented as balancing optimism against pessimism, which means balancing some people against others. Qualitative research suggests that individuals and groups will typically and simultaneously recognise pros as well as cons, opportunities as well as uncertainties. Unearthing and exploring this ambivalence has been one of the aims of deep public dialogue exercises around science and technology. The recent Monitor survey funded by the Wellcome Trust into the use of personal data in research is illustrative. In workshops, public participants offered a set of conditions for the trustworthy use of biomedical data by companies:

- "WHY: Does the activity's outcome have a provable and sufficient public benefit?"
- "WHO: Can the organisations doing this be trusted to have public interest at heart?"
- "WHAT: How anonymised and/or aggregated is the data?"
- "HOW: Does the safeguarding, access and storage protocol reassure me that the data will be safe?"[10]

The UK has, through its Sciencewise programme, built up substantial experience of conducting and learning from public dialogue since 2006. Although each exercise has had a particular science or technology focus, the themes that emerged can be seen together as a useful set of insights.

Themes from public dialogue

A review of 17 public dialogue exercises (see table 5.14) run under the aegis of Sciencewise was conducted in 2011. This review found that, in addition to concerns about the risks and ethical dilemmas presented by new science and technology, public concerns with governance could be collected under five themes (Macnaghten and Chilvers (2014)):

1. The purposes of science and innovation

When invited into dialogue on particular areas of science and technology, members of the public were often sceptical about who stood to benefit - for example, public or private sectors? Rich or poor? They were keen to know what the justification for particular technologies was and what the alternatives were. This theme helps explain why public groups have more confidence in proposed innovations

[9] HM Treasury/DTI Science & innovation investment framework, 2004
[10] Public Attitudes to the Use of Personal Data in Research: A Wellcome Trust Report, March 2016, https://wellcome.ac.uk/sites/default/files/public-attitudes-to-commercial-access-to-health-data-wellcome-mar16.pdf. Further qualitative evidence on public views on health data use is in Aitken et al. (2016).

associated with health and medicine, in which beneficiaries are well understood and institutions relatively trusted (see below).

2. The trustworthiness of institutions

Public groups were sceptical of institutions whose aims appeared not to match their own if these institutions were seen as in control of innovation. People often saw regulation as relatively weak and vulnerable to influence by private interests. Macnaghten and Chilvers note that there has been very little research on the trustworthiness of science *institutions*, while there has been plenty of research on the more abstract question of trust in science.

3. Feelings of powerlessness and exclusion

Public dialogues typically revealed a perception that science was esoteric, closed and detached. This contributed to a sense of alienation and fatalism about science and technology - the sense that innovation was being done *to* rather than *with* or *for* the public. This feeling was found not just in new technologies emerging from labs, such as synthetic biology, but also in established technological systems such as energy. People felt that they had no voice and few choices.

4. Speed and direction of science and innovation

This sense of fatalism underpins a concern that innovation may be happening too fast. However, where dialogues have explored this concern further, it is often apparent that members of the public are not concerned with the pace or quantity of innovation but rather with its direction. People seem to be intensely interested in the possibilities for redirecting innovation in more equitable, trustworthy and beneficial ways. But a lack of trust in institutions means that fatalism often dominates.

5. Ethics, trade-offs and equity

The final set of concerns related to big ethical questions of justice and how these connect with the cultures and practices of science. There was some concern among public participants in dialogue exercises that, while individual scientists are themselves responsible and ethical people, their institutions may separate these questions of ethics from their scientific research.

Table 5.14 - Sciencewise Dialogues reviewed by Macnaghten and Chilvers (2014)
Animals Containing Human Material (2010)
Big Energy Shift (2008–09)
Community X-Change (2005–08)
Drugsfutures (2006–07)
Energy 2050 Pathways (2010–11)
Forensic Use of DNA (2007–08)
Geoengineering (2010)
Hybrids and Chimeras (2006)
Industrial Biotechnology (2008)
Landscape and Ecosystem Futures (2011–)
Low Carbon Communities Challenge (2010–11)
Nanodialogues (2005–07)

Risky Business (2005–06)
Science Horizons (2006–07)
Stem Cell (2007–08)
Synthetic Biology (2009–10)
Trustguide (2005–06)

These findings accentuate the negative in part because they are looking to anticipate public concerns. It should be remembered that dialogue exercises also reveal high levels of public support and appreciation for science, particularly publicly-funded science. In response to occasional preconceptions that the public will be instinctively anti-innovation, dialogue exercises have in the past been able to reassure policymakers that well-governed science is appreciated. (This was the case with the 2007 hybrids and chimeras dialogue, for example).

The evidence from recent literature, public surveys and public dialogue exercises suggests that attitudes to the governance of science and innovation are conditional and multidimensional. While trust in science as conventionally expressed through surveys seems high, this should not be taken as a reason for complacency. If a particular issue (for example, healthcare data, vaccines or agricultural biotechnology) become publicly important, then the conditions for governance may come under scrutiny and public support may be exposed as fragile. This suggests some important lessons for governance that are the focus of the concluding chapter.

6. Conclusions

From the literatures we have reviewed, we have extracted a few headline conclusions, from which we have then drawn policy lessons of relevance to Wellcome's work.

First, the **diversity of the literature** - its objects of study, its cases and its empirical approaches. There were multiple interpretations of governance, oversight, regulation, hard law and soft law in the sources surveyed. It is clear that 'governance' goes beyond simply limiting the development of emerging science and technology; it is also about aligning it with societal values. In some instances, such as with specific arguments for ethical red lines around human cloning, 'governance' meant restriction. However, most analyses focussed on steering and promoting innovation in particular directions. In the literature we reviewed from Asia, the clear priority for steering technologies was towards economic growth. In European literature, societal goals included sustainability, equity and tackling grand challenges such as global health or food security. The overlap between literatures on governance and public attitudes was substantial, suggesting recognition of the importance of trustworthy governance and the need for democratic engagement in policymaking.

Our second conclusion is that **there is too little analysis or evidence of holistic governance strategies.** Most of papers or policy reports consider particular governance interventions, such as risk assessment, regulation, or responsible innovation, or science and technology cases. There is a clear evolution of case studies during the period identified, from biotechnology, to nanotechnology, to more recent consideration of machine learning and big data. Few studies take a more systemic view to examine how these different approaches might learn from and work alongside each other, across multiple technological domains, and at multiple levels of governance.

The third conclusion is that **the literature is a partial reflection of what is known - and what needs to be known - about the governance of emerging science and technology**. There is substantial knowledge, learning and experimentation within institutions that should be shared more widely. At the same time, in emerging economies, including China and India, governance is developing *de facto* in ways that are disconnected from governance and research on governance in Europe and America. In total, only five items focusing on governance in Africa were identified by the searches and included in the analysis. Our study, which only looked at English language publications, could be interpreted as magnifying this evidence gap. There are clear research needs, one of which is to compare and share alternative governance frameworks across different languages, cultures and jurisdictions.

Lessons for governance

This report comes at a time of uncertainty and opportunity. In the next six months, the UK is due to leave the European Union. The UK's science and innovation system is also undergoing a once-in-a-generation transformation through the creation of UKRI and ministerial promises to dramatically increase the nation's R&D intensity to 2.4% of GDP. These changes prompt a necessary debate about how best to align emerging science and technology with wider societal goals.

The literature we have surveyed suggests that, during this period of change, there are clear lessons and models of good governance that can be drawn from experience across a range of cases of emerging science and technology and from other countries and jurisdictions. The literature offers a potentially rich set of theoretical and practical resources, able to help UK decision makers to navigate the tangle of formal and informal systems that govern science and innovation.

Over the past twenty years, the UK has developed a distinctive approach to science and innovation that on the whole attracts policymaker and public support. But there is a need to avoid partisan rhetoric or complacency, and ensure that claims on behalf of the UK's governance structures are grounded in evidence. Public support for the UK's approach is conditional and relies upon ongoing dialogue for its renewal - particularly in the context of the societal divisions highlighted by the 2016 EU referendum. Post-Brexit, the UK has the potential to reaffirm its position as a global leader and hub for debate about the governance of emerging science and technologies. But this will require concerted effort and investment, and an openness to the challenges such engagement can pose.

The papers we have reviewed, seen alongside the past 25 years of experience of these debates, provide a sense of what is at stake. The implications, opportunities and uncertainties of decision making around science and innovation are typically unclear at an early stage in the R&D process. It therefore seems urgent for government to develop greater capacity for understanding and anticipating these issues. Had we done this study 20 years ago, we would have detected a stronger emphasis on themes like foresight and technology assessment. Researchers' interest in these topics has waned as governments have reduced funding and capacity to engage in such work. Academies and learned societies, such as the Royal Society or the US National Academies, have taken on some of these functions, but there are still systemic gaps.

On particular issues, such as artificial intelligence (AI), the UK government has recognised the need to build capacity for governance, such as with the Centre for Data Ethics and Innovation, but these activities need to operate at scale and keep pace with the momentum of innovation. A proposed public observatory on genome editing (Hurlbut et al, 2018) could begin the process of building technology assessment capacity for new biotechnological tools. UKRI could play a vital role in connecting technology assessment and horizon scanning with frontier research, particularly now it is home to the Sciencewise programme of public dialogue.

About the authors

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Professor James Wilsdon is Professor of Research Policy at the University of Sheffield. He is also vice-chair of the International Network for Government Science Advice (INGSA). From 2013-2017, he led the UK's Campaign for Social Science, and from 2014-2015, he chaired an independent government review of the role of metrics in the management of the UK's research system, published as The Metric Tide. Previously, he worked as Professor of Science and Democracy at the University of Sussex (2011-2015); Director of Science Policy at the Royal Society (2008-2011); Head of Science and Innovation at the think tank Demos (2001-2008). In 2015, he was elected a Fellow of the Academy of Social Sciences, and he now chairs its Policy Working Group.

Professor Andy Stirling has a background in the natural sciences, a master's degree in archaeology and social anthropology (Edinburgh) and a D.Phil in science and technology policy (Sussex). Elected a fellow of the Academy of Social Sciences in 2017, his research interests include technological risk, scientific uncertainty and issues around diversity, power and democracy in research and innovation (where he has helped develop participatory appraisal methods). He has served on several policy advisory committees, including the UK's Advisory Committee on Toxic Substances and GM Science Review Panel as well as the European Commission's Expert Group on Science and Governance. He is currently member of the EU Science Advice Mechanism working group on uncertainty.

Appendix 1 - Surveys of public attitudes to science. A summary of recent evidence

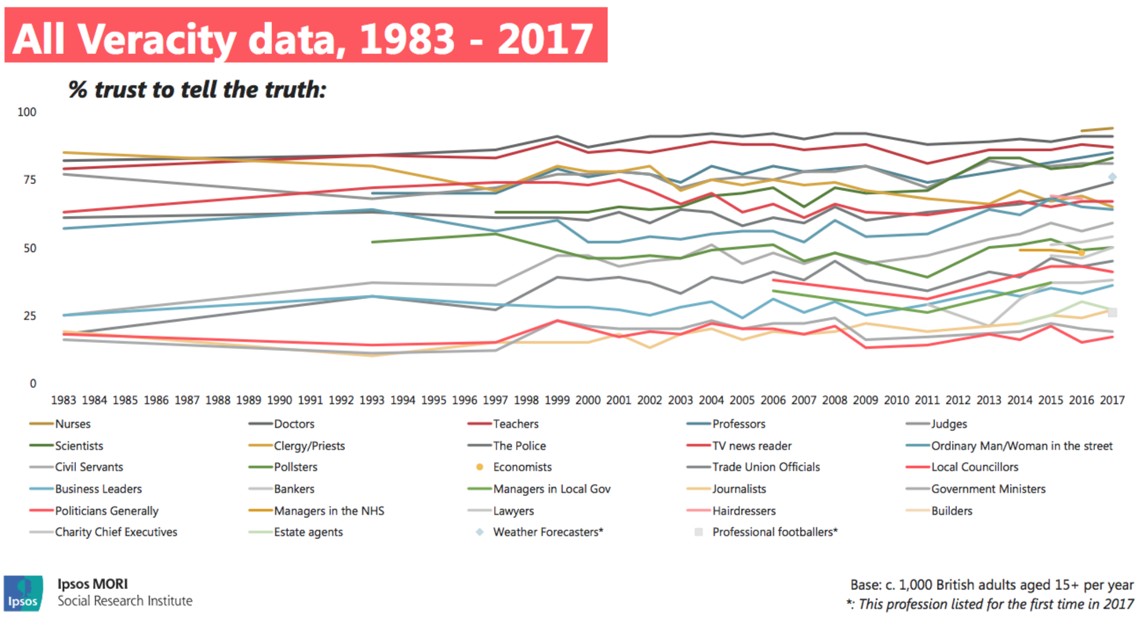
The UK Public

Contemporary surveys ask a range of questions about knowledge of and trust in science and technology. For scientific institutions, the headline findings are, in general, positive. The most recent (2014) Public Attitudes to Science survey of the UK public added qualitative and social media research to the conventional mass survey, but confirmed a stable finding that the UK public is “overwhelmingly positive about the contribution science makes to the UK economy” and “to their own lives”[11]. 81% agree that science will make people’s lives easier, and 55% think that the benefits of science outweigh any harmful effects.

The PAS survey, as with others, also asks about perceptions of scientists and engineers. These individuals are held in enormously high regard, with greater expectations of particular virtues than for other people. In 2014, 90% of the UK public thought that scientists made a positive contribution to society. Scientists were expected to have traits of honesty, ethical behaviour and open-mindedness among other qualities. 90% of people trusted that scientists working in universities would follow rules and procedures. This trust question, as with questions from other surveys on whether people trust scientists to tell the truth, illuminates some of the issue with the governance of emerging science and innovation.

Trust in scientists as a group is extremely high on these measures (and trust in journalists and politicians very low (see figure 5.7), but this trust is based on a perception of independence. In the 2014 PAS survey, 77% thought this independence is often put at risk by the interests of funders; 66% felt that scientists are too dependent on business and industry for funding.

Figure 5.7 Ipsos MORI Veracity Index

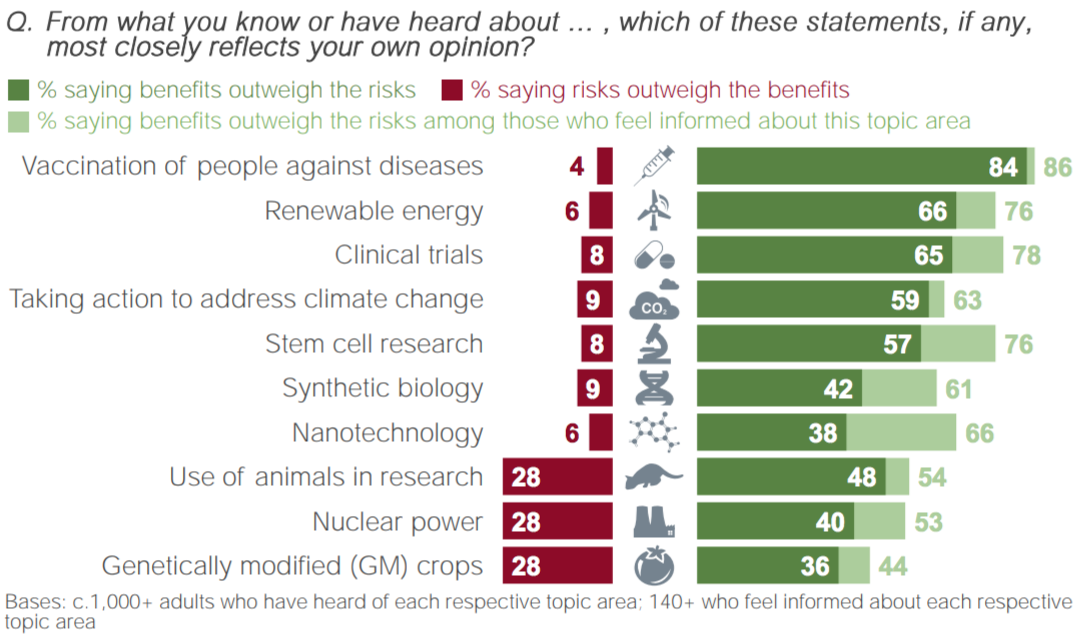


11 Public Attitudes to Science 2014: Main Report (Version 2). Available at: https://www.ipsos-mori.com/Assets/Docs/Polls/pas-2014-main-report.pdf

As can be seen from the data on whether the public trust different groups to tell the truth, trust in scientists is not only high, it is increasing, while trust in priests and the clergy to tell the truth has steadily declined. This finding is an important counter to the assumption among some scientific institutions that there is some 'crisis of trust', but the question remains whether on its own it usefully informs questions of the governance of emerging science and technology.

Questions about particular areas of science and technology are more revealing, but responses are likely to be driven by recent exposure to a particular set of issues or debates. (It is worth noting also that levels of knowledgeability vary substantially across the listed topics).

Figure 5.8 perceived risks versus benefits of specific science topics (PAS survey 2014)



The most recent PAS survey develops a segmentation model that is potentially interesting, because it allows for the investigation of ambivalence, but should not be taken as reflecting actual groups. The segments constructed are *Confident Engagers*; *Distrustful Engagers*; *Late Adopters*; *Disengaged Sceptics*; *Indifferent* and *Concerned*. This allows us to see that, for example, the level of scientific knowledge and technological uptake is not correlated with trusting, positive or negative attitudes. (Distrustful engagers are one of the most knowledgeable groups).[12]

The Wellcome Trust's own Monitor survey has found very high levels of agreement that medical research will improves the quality of life, with increasing certainty over the three waves of the survey (2009; 2012 and 2015) (Figure 5.9).

[12] Critical evaluations of the PAS approach are here: Smith, B. K., & Jensen, E. A. (2016). Critical review of the United Kingdom's "gold standard" survey of public attitudes to science. *Public Understanding of Science*, *25*(2), 154-170; Pallett, H., & Chilvers, J. (2013). A decade of learning about publics, participation, and climate change: institutionalising reflexivity?. *Environment and Planning A*, *45*(5), 1162-1183.

Figure 5.9 - Optimism about medical research[13]

Q. Please say whether you think medical research will or will not lead to an improvement in the quality of life for people in the United Kingdom in the next 20 years? Is that definitely or probably?

Base: All respondents — *Wellcome Trust Monitor*

	Monitor w1 (2009) (%)	Monitor w2 (2012) (%)	Monitor w3 (2015) (%)
Definitely will lead to an improvement	41	51	58
Probably will lead to an improvement	51	41	36
Probably will not lead to an improvement	6	4	3
Definitely will not lead to an improvement	1	1	1
Don't know	1	4	2
% Will lead to an improvement (definitely or probably)	*92*	*92*	*94*
Unweighted base:	*1,179*	*1,396*	*1,524*
Weighted base:	*1,179*	*1,396*	*1,524*

A more recent survey conducted by New Scientist of what it calls a representative sample of 2026 UK adults (the methodology and full dataset is unpublished) has been used to claim that the UK population are optimistic about the benefits of new technologies such as genetic engineering and artificial intelligence. But the framing of these questions (asking people to agree or disagree with particular statements of benefits) is problematic, and could have skewed findings.[14]

Comparisons with US and the rest of Europe

The Eurobarometer has been surveying EU member state publics since 1974. 'Special Eurobarometers' ask about knowledge, attitudes and trust with respect to science and technology.

A special Eurobarometer in 2010 asked about scientific and technological progress (Figures 5.10 and 5.11)

[13] https://wellcome.ac.uk/sites/default/files/monitor-wave3-full-wellcome-apr16.pdf
[14] https://www.newscientist.com/article/2179920-revealed-what-the-uk-public-really-thinks-about-the-future-of-science

Figure 5.10 - "Science and technology make our lives, healthier, easier and more comfortable" (Special Eurobarometer 340)

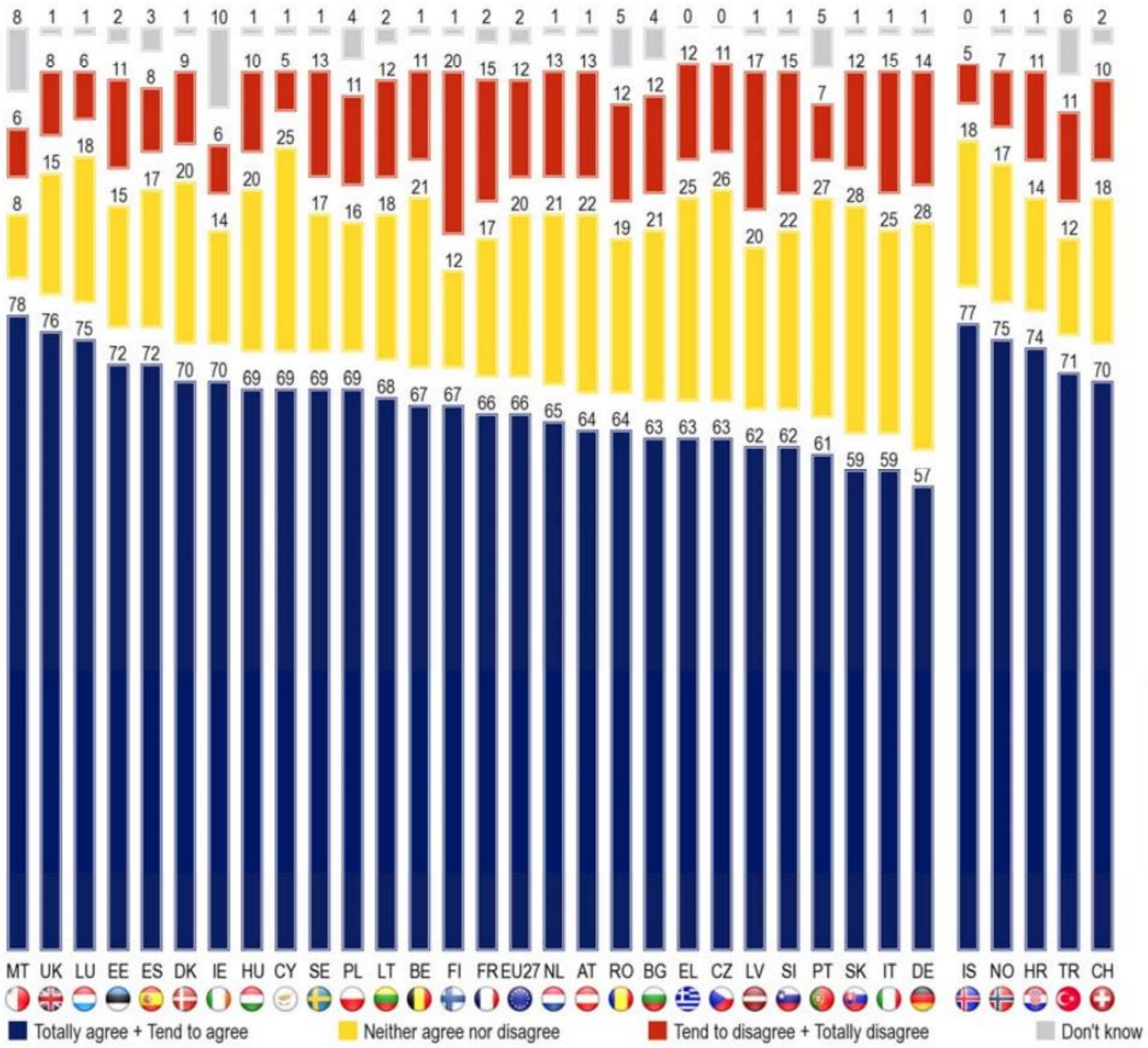
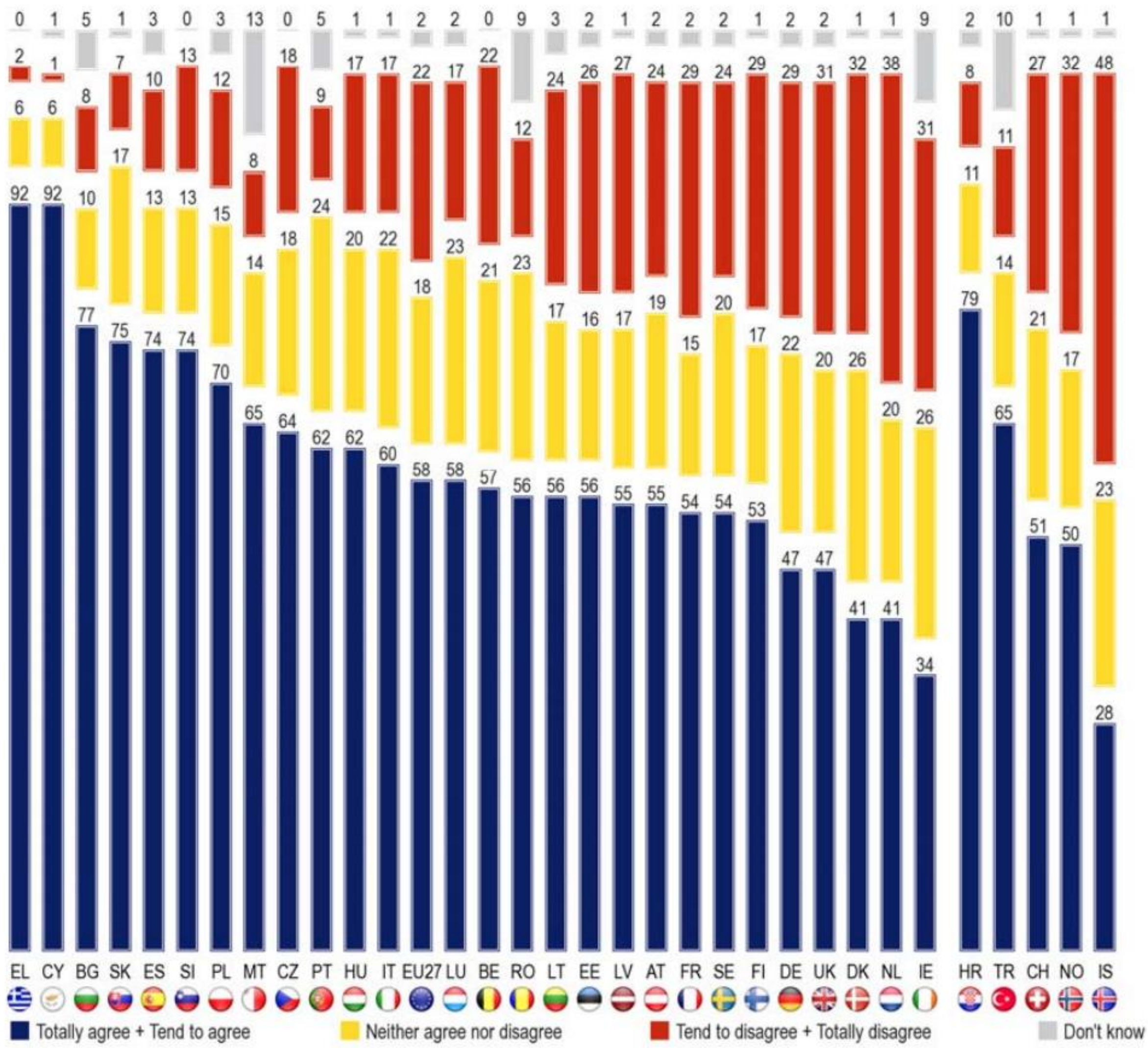


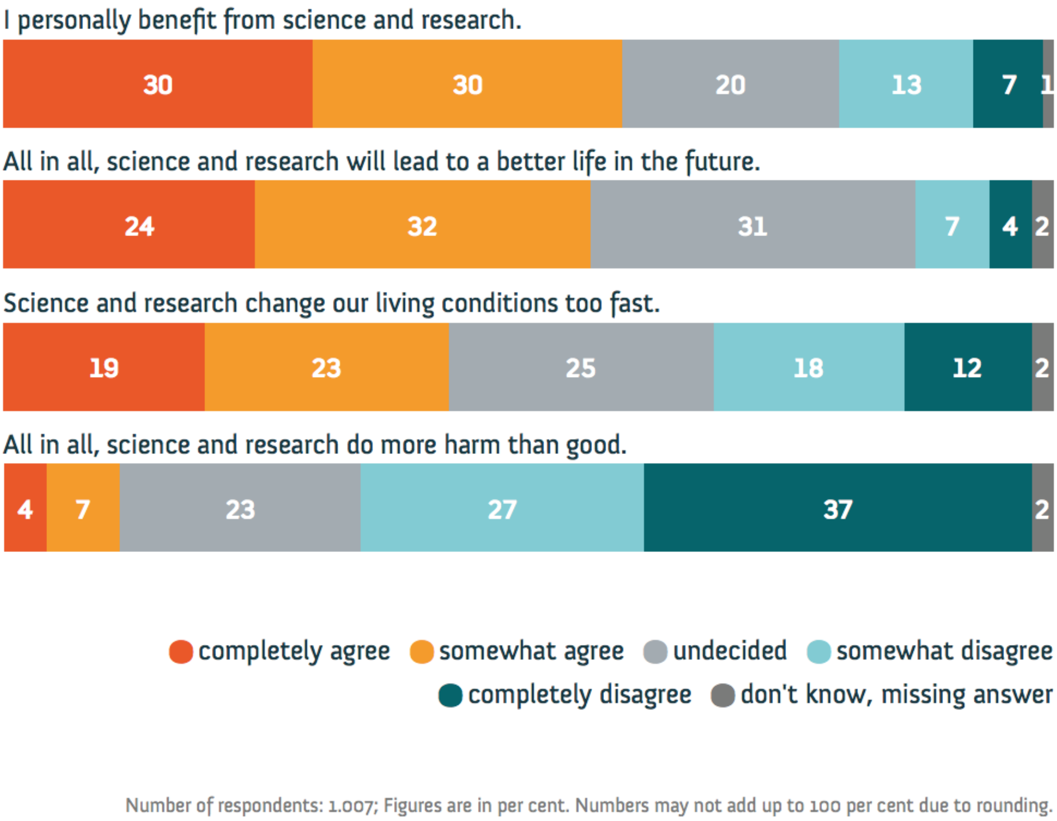
Figure 5.11 - "Science makes our way of life change too fast"



These findings suggest a UK public that is relatively comfortable with appreciating the benefits of science and living with technological change. Follow-up Eurobarometer surveys on Responsible Research and Innovation (2013) and Public Perceptions of Science, Research and Innovation (2014) suggest high public support for scientists to receive training in ethics (84% agree) and declare their funding sources and any conflicts of interest (81% agree).

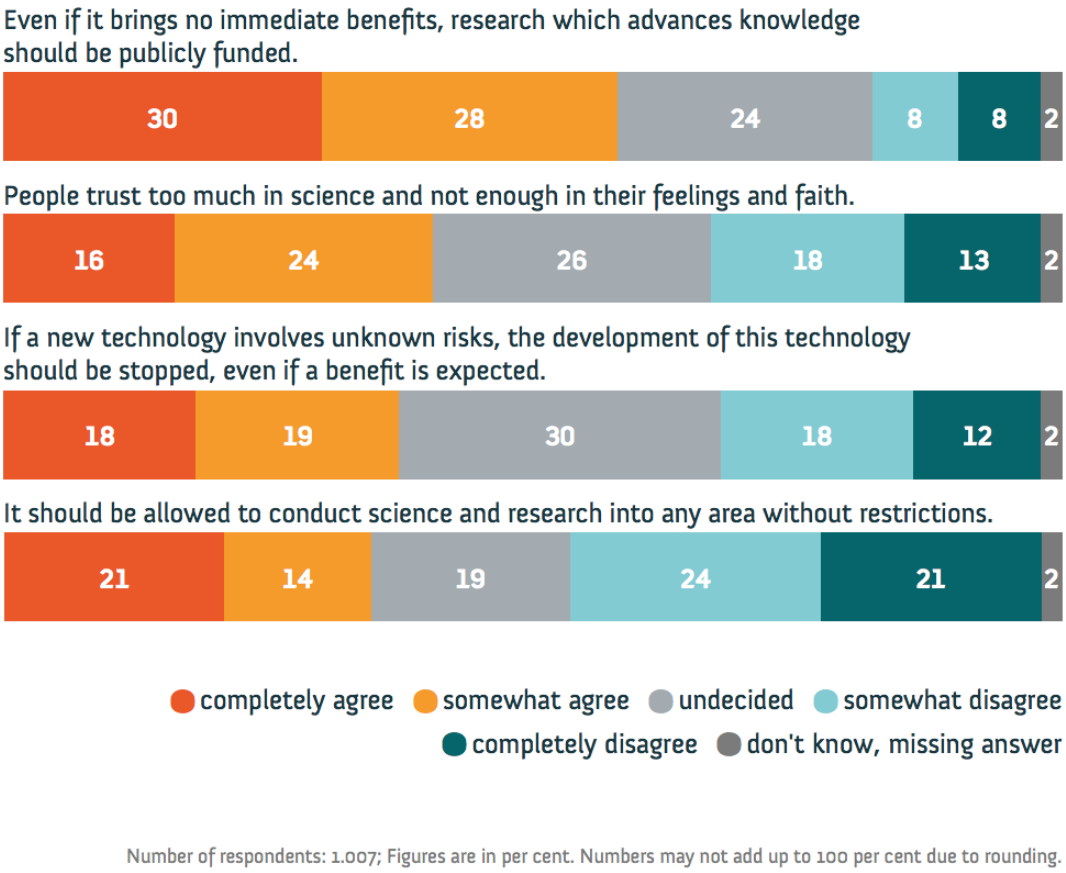
Given the apparent scepticism among the German public in 2010 (Figure X), it is worth considering the findings of a more recent survey, the German Science Barometer, which help to illustrate the nature of German public concerns.

Figure 5.12 - German Science Barometer 2017[15]



[15] https://www.wissenschaft-im-dialog.de/fileadmin/user_upload/Projekte/Wissenschaftsbarometer/Dokumente_17/Einzelgrafiken/Sciencebarometer2017_brochure_web.pdf

Figure 5.13 (German Science Barometer 2017)[16]



Further comparative information is available from large US surveys. A 2015 Pew Research Survey for the American Association for the Advancement of Science found that 79% of US adults agreed that science has made life easier for most people. This same research also pointed to declining trust in science among conservative voters and a substantial gap between scientists and publics in their understandings of issues that have become politicised and polarised such as climate change. (http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/)

The 2014 'Innovation population' survey by Nesta segmented respondents into five groups - futurists, romantics, creatives, realists and sceptics. [17] The survey and qualitative work that followed it present a more complex picture of the attitudes of diverse publics to science and its governance. It is notable that those who are more affluent are significantly more supportive of higher R&D spending. A survey by the think tank Demos found that only 16% of those surveyed thought that the benefits of technology would be shared evenly across society.[18]

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[16] https://www.wissenschaft-im-dialog.de/fileadmin/user_upload/Projekte/Wissenschaftsbarometer/Dokumente_17/Einzelgrafiken/Sciencebarometer2017_brochure_web.pdf

[17] https://media.nesta.org.uk/documents/innovation_population_wv.pdf

[18] https://www.demos.co.uk/project/public-views-on-technology-futures/

Appendix 2 - Detailed methods

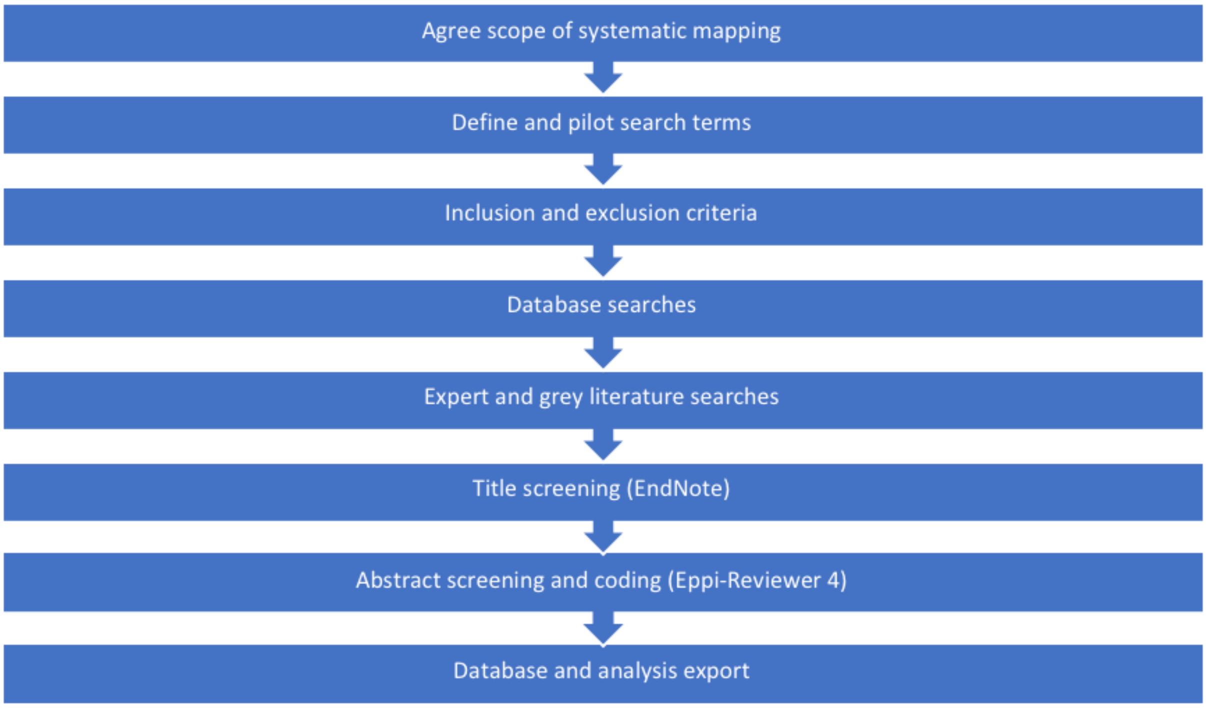
Systematic mapping

The approach adopted in the development of this report was systematic mapping. Systematic mapping is a process of capturing and describing relevant literature through a database search and screening process, followed by a coding in which to identify trends in the literature. The aim of this mapping was to provide an overall description of the key themes identified in the literature and to identify areas that have been most-researched, along with their geographical location. It differs from a systematic review approach, which attempts to extract and synthesise findings from the literature. Instead, systematic mapping can describe the kinds of work and key themes that have or have not been addressed in a particular field.

The systematic mapping methodology was developed by the Institute of Education, University of London[19], and is increasingly being applied in fields from social care[20] to environmental sciences[21].

Systematic mapping follows a series of steps (Figure 2.1).

Figure 2.1. The process of systematic mapping.



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19 Oakley, A., Gough, D., Oliver, S. and James, T. (2005) 'The politics of evidence and methodology: lessons from the EPPI-Centre', *Evidence & Policy*, vol 1, no 1, pp 5-31.
20 Bates, S., Clapton, J. and Coren, E. (2007) Systematic maps to support the evidence base in social care. Evidence and Policy. 3(4): 539-551. DOI: 10.1332/174426407782516484
21 James, K.L., Randall, N.P. and Haddaway, N.R. (2016). 'A methodology for systematic mapping in environmental sciences' Environmental Evidence. 5 (7): 1-13. DOI: 10.1186/s13750-016-0059-6

Database search and expert identification of literature

The first step in our systematic mapping of the literature was the development of search terms through which to carry out database searches. Here, we drew on the expertise of the research and commissioning teams to identify a long list of possible search terms that could be tested in pilot searches. The long list was refined through iterative discussions and testing to ensure relevant results could be maximised in the database search process.

The search terms developed as follows:

"oversight" OR "govern*"
AND
"emerging technolog*" OR "emerging scien*" OR "new technolog*"
AND
"risk" OR "anticipat*" OR "ethic*" OR "public*" OR "attitude*" OR "poll" OR "engagement" OR "trust" OR "regulat*"

In order to capture the most recent developments in this area, the date range was set for a ten-year period from 2008 to 2017, with the inclusion of the most recent studies up until the search date in September 2018.

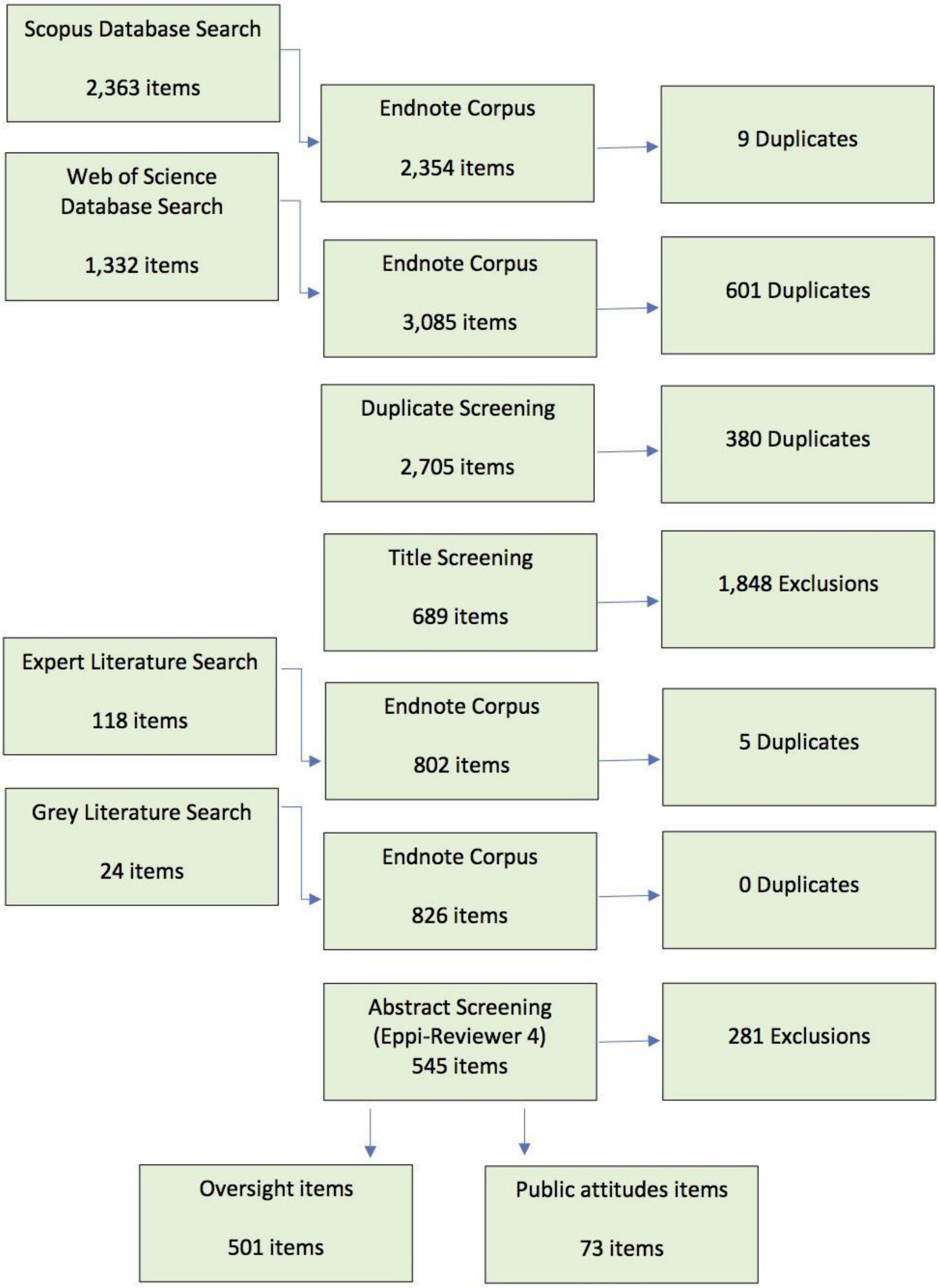
The databases selected for this project were Scopus and Web of Science. Although no database is comprehensive, these databases provide a broad spread of literature across physical, natural and social sciences. These databases were searched on 12 September 2018, and yielded an initial body of 2,363 items in Scopus and 1,332 items in Web of Science.

Members of the review and commissioning teams then identified additional literature using their expert knowledge and personal files were used to supplement material identified by the searches. Literature identified by expert members of the review team was drawn from peer reviewed journals, books, policy reports and other grey literature. This literature was then compiled in Endnote and the abstract, title and keywords of this literature was then added to the database search literature before being imported into the Eppi-Reviewer 4 platform commonly used for systematic reviews and literature reviews, narrative and meta-analyses.

Duplicate removal and inclusion screening

It was important to ensure that a thorough review of results in Eppi-Reviewer was conducted in order to remove duplicates. Additionally, the research team worked together to draw together a list of inclusion and exclusion criteria. The text corpus of both search results and expert libraries were then imported into an Endnote library. This process identified and discarded any duplicates. Additional duplicates were identified during title and abstract screening, where they were marked as excluded. The review team then carried out a title screening process in Endnote, whereby an initial assessment of the relevance of returned items was carried out. The duplicates and exclusions are set out in Figure 2.1.

Figure 2.2. Inclusion and exclusion process for developing the text corpus.



The title screening process involved the review team reading each title and determining its inclusion or exclusion according to the following exclusion protocol:

- Title does not clearly indicate relevance to governance
- Title does not clearly indicate relevance to emerging technologies

Retained items were imported into the Eppi-Reviewer 4 platform for abstract screening and coding.

Abstract screening and coding

Within the Eppi-Reviewer 4 platform, included items were subjected to coding and further abstract screening.

In order to begin this further screening process, the first stage was to develop a coding framework. An initial set of proposed codes was iteratively developed by the review and commissioning team. This included the development of a set of parent codes, which would be populated either by pre-defined deductive child codes and a set of inductive child codes.

The parent code framework was as follows:

1. Report relevance (deductive)
    a. Oversight
    b. Public attitudes
2. Type of publication (deductive)
    a. Book
    b. Book chapter
    c. Conference proceedings
    d. Journal article
    e. Policy report
3. Geographic scope of study (deductive)
    a. International
    b. Africa (and countries of)
    c. Asia (and countries of)
    d. Australasia (and countries of)
    e. Europe (and countries of)
    f. Latin America and Caribbean (and countries of)
    g. North America (and countries of)
    h. Unspecified
4. Methods of study (inductive)
5. Kind of science or technology in focus (inductive)
6. Mode of governance described (inductive)

Throughout the coding process, the frequencies of codes and co-occurrence of codes were exported to Excel for further analysis and graphical representation.

Expanding on the exclusion protocol of title screening set out above, items were subjected to an additional level of screening to ensure relevance for inclusion based on the content of their abstracts. The exclusion criteria are set out below:

- No abstract present
- Focus on the need for an emerging science or technology to overcome an identified problem or need (e.g., papers which are more attuned to debates about an impact agenda of research)
- Conference proceedings that set out a spread of papers, but do not provide details of their contents
- Focus on new technologies as a peripheral part of a problem, such as climate change
- A discussion about governance of other issues, such as data governance in the effective production of a technology
- Discussion about the potential effects of new technologies
- Discussion about the development of networks for stakeholder engagement and impact
- Public attitudes towards science in general
- Discussion about 'older' technology as opposed to newer (i.e. consideration of what is meant by 'emerging' i.e. digital/Facebook/social)
- Papers confined to discussions on the effects on a small community or organisation
- Papers which are descriptive of technology but not the governance thereof
- Reference to a situation 'where a new (replacement) technology becomes available'
- Items on public perceptions that have nothing to do with oversight
- Discussion about how new technologies will change governance or society, rather than how they can be governed.
- Papers which discuss barriers to adoption of new technology.
- Papers about trends in new technologies, without specific reference to governance

It is important to acknowledge the limitations of this approach. Specifically, one of the limitations of this approach was that we carried out a single-pass coding, so that new codes that emerged late in the coding process were not then re-applied in a second or third pass. This means that some codes will be under-reported. Additionally, title and abstract searches provided only cursory detail on the precise contents of each of these sources. In parts, the abstracts were vague or limited, with often little explicit mention of the precise methods or geographical positioning, for example. Where possible these were drawn out of the detail provided, otherwise marked as 'unspecified'.

Output analyses

Once relevant literature had been identified, the authors conducted a final screening process to identify key references for each theme. This was conducted in Eppi-Reviewer by carrying out a second pass of title and abstract screening in order to assign items to a new 'key references' code. An output of these key references was produced including full citation and abstract. This was then analysed through thematic coding to produce a general synthesis of the issues raised in these key references, which is included in this report.

Using the in-built analysis features of the Eppi-Reviewer 4 platform, a series of frequency and co-occurrence analyses were carried out. In order to identify the prevalence of literature on different technologies, their modes of governance, geographic and temporal spread.

Appendix 3 - Literature reviewed

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