CRANFIELD UNIVERSITY

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Modes of knowledge production:
Articulating coexistence in UK academic science

School of Management

PhD
Academic Year: 2014-2015

Supervisor: Professor Mark Jenkins
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ABSTRACT

The notion of Mode 2, as a shift from Mode 1 science-as-we-know-it, depicts science as practically relevant, socially distributed and democratic. Debates remain over the empirical substantiation of Mode 2. In particular, our understanding has been impeded by the mutually exclusive framing of Mode 1/Mode 2. Looking at how academic science is justified to diverse institutional interests – a situation associated with Mode 2 – it is asked, *"What happens to Mode 1 where Mode 2 is in demand?"*

This study comprises two sequential phases. It combines interviews with 18 university spinout founders as micro-level Mode 2 exemplars, and macro-level policy narratives from 72 expert witnesses examined by select committees. An interpretive scheme (Greenwood and Hinings, 1988) is applied to capture the internal means-ends structure of each mode, where the end is to satisfy demand constituents, both in academia (Mode 1) and beyond (Mode 2).

Results indicate Mode 1's enduring influence even where non-academic demands are concerned, thus refuting that means and ends necessarily operate together as a stable mode. The causal ambiguity inherent in scientific advances necessitates (i) Mode 1 peer review as the only quality control regime systematically applicable *ex ante*, and (ii) Mode 1 means of knowledge production as essential for the health and diversity of the science base. Modifications to performance criteria are proposed to create a synergy between modes and justify public investment, especially in the absence of immediate outcomes.

The study presents a framework of Mode1/Mode 2 coexistence that eases the problem with the either/or perception and renders Mode 2 more amenable to empirical research. It is crucial to note, though, that this is contingent on given vested interests. In this study, Mode 1's fate is seen through academic scientists whose imperative is unique from those of other constituents, thereby potentially entailing further struggles and negotiation.

Keywords: Mode 2, knowledge production, UK academic science, legitimacy, means-ends, causal ambiguity, social construction, opaque institutional field

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Over the years, I have been thinking of what I would say in my thesis about my supervisor, Professor Mark Jenkins. The standard disclaimer applies, of course: I thank him immensely for his guidance and all mistakes in this thesis are mine. And then there are the specifics. I am one of those who unceremoniously come up with "stuff" on a regular basis. I am grateful that I have learned how to navigate the convention without losing that somewhat wacky curiosity that I enjoy carrying in my head. With that being said, it surprises me how easy it is to overlook what's in the name. Supervisors do not just (for want of a better word) teach research; they also teach how to supervise. I was not told to pay attention, but I'm glad I did. I have had so much fun, whether Mark realised it or not, appreciating what he does (or does not) do. There is no telling if I will end up supervising my own students, but it certainly has been a privilege to be one.

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LIST OF ABBREVIATIONS

AHRC	Arts and Humanities Research Council
AURIL	Association for University Research and Industry Links
BBSRC	Biotechnology and Biological Sciences Research Council
BIS	Department for Business, Innovation and Skills
CDE	Centre for Defence Enterprise
CERN	The European Organization for Nuclear Research
CSR	Corporate social responsibility
CST	Council for Science and Technology
DIUS	Department for Innovation, Universities and Skills
Dstl	Defence Science and Technology Laboratory
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
HEIs	Higher education institutions
MIT	Massachusetts Institute of Technology
MMR	Measles-mumps-rubella (vaccine)
MOD	Ministry of Defence
MRC	Medical Research Council
MRC LMB	Medical Research Council Laboratory of Molecular Biology
NERC	Natural Environment Research Council
NGI	National Graphene Institute
NIH	National Institutes of Health
PPARC	Particle Physics and Astronomy Research Council
QC	Quality control
RBV	Resource-based view
RCUK	Research Councils UK
REF	Research Excellence Framework
S&T	Science and technology
STEM	Science, technology, engineering and mathematics
STFC	Science and Technology Facilities Council
TSB	Technology Strategy Board
TTOs	Technology transfer offices
UCSF	University of California, San Francisco
UILs	University-industry linkages

1 INTRODUCTION

1.1 Overview of the thesis

1.1.1 The third mission and changing universities

The third mission of universities reflects the role of academic knowledge in a world that is always changing. Implemented through third stream activities, the third mission involves “the generation, use, application and exploitation of knowledge and other university capabilities outside academic environments” (Molas-Gallart et al., 2002, p. 2). The designation of “third” mission implies its relative novelty compared to the first and second missions of teaching and research (Etzkowitz, 1998; Lockett, Wright and Wild, 2012). Before the third mission, the traditional view of academic research has been that of “blue skies” inquiry, driven by the agenda of advancing knowledge, and teaching as a way of developing learned and enlightened individuals. The disconnect with society in both notions suggests that universities have been granted autonomy to pursue and disseminate knowledge in the absence of immediate concerns over social development and wealth creation (Bonaccorsi, Daraio and Geuna, 2010; Jacob, 2003). The autonomy that has been afforded historically, nonetheless, can be regarded as “socially sanctioned, or at least tolerated, always provisional and subject to revision in line with social and economic change” (Harloe and Perry, 2004).

It is the change in social and economic circumstances that brings challenges to the privilege that has been granted to universities, especially in the form of public funding, (Neave, 2006). At the time of writing, research is not a protected budget in the UK, where the government has to make £30 billion in departmental cuts (Smith, 2015). The utilitarian view of universities in itself is not new. What it means in practice is that the need for social engagement is increasingly reified such that less and less leeway is allowed for universities to remain detached from their surroundings (Etzkowitz et al., 2000). The scarcity of resources available for research compounded by urgent needs to solve large-scale problems means that it is increasingly necessary for universities to participate (Lockett, Wright and Wild, 2012). In the context of science and technology, attention has been brought to the potential of innovation in fulfilling socio-economic goals, such as job creation, enhancement of well-being and investment attraction, among others (Breznitz, O'Shea and Allen, 2008; Etzkowitz and Klofsten, 2005). A recent example is the University of Manchester's £61m National Graphene Institute (NGI), opened in March 2015 to develop and commercialise Nobel Prize-winning material isolated by two Manchester professors (Geim and Novoselov, 2007). With at least 35 partner companies and 200 scientists, the "Graphene City" is expected to bring "thousands of jobs and millions of pounds to Manchester" (Cox, 2015). The message conveyed is that of an increasing accountability. Universities must now be able to produce exploitable knowledge to enhance the innovation capacity for the benefits of external stakeholders beyond the scientific community and students (Kirby, 2006). In other words, third mission is shorthand for the interaction between universities and society.

The prevalent view of the third mission rests on its connection to the second mission of research (Molas-Gallart et al., 2002), implying that it must be made more systematic for the health and wealth of society to improve more efficiently. For this purpose, the process of technology transfer is intended to help foster linkages between knowledge producers and users (Etzkowitz et al., 2000; Perkmann et al., 2013). As is the case for graphene, commercial development is often necessary for academic research to benefit end users (Markman, Siegel and Wright, 2008; Pries and Guild, 2007). One of the inventors of graphene, Sir Andre Geim, emphasised that spinouts and partner companies are essential for graphene to find its way into products used by consumers (Chakrabortty, 2013). Academic scientists have therefore engaged in entrepreneurial activities through various channels, such as contract research, consulting, patenting, licensing and spinout formation to put academic research to use (Rothaermel, Agung and Jiang, 2007).

The challenge, central to academic entrepreneurship as a field of study, is that much of the development needed to connect the second and third missions lies outside of the universities' remit (O'Shea, Chugh and Allen, 2008). Upon the emergence of entrepreneurial universities (Clark, 1998; Etzkowitz et al., 2000), scholars seek to contribute to a pressing policy question of how universities can improve their entrepreneurial performances (Siegel, Waldman and Link, 2003). Technology transfer offices (TTOs) have become a regular feature of contemporary universities as their business arm (Lockett, Wright and Franklin, 2003; Siegel, Wright and Lockett, 2007). They provide mediation and business assistance in hope of increasing the scale, scope and efficiency with which scientists interact with industry and commercialise research. The overall sentiment is captured succinctly by Di Gregorio and Shane's (2003) question in their widely cited study, "*Why do some universities generate more start-ups than others?*"

Criticisms abound for commercialisation's undue prominence as it privileges immediate outcomes of knowledge exploitation at the expense of capacity building in the long run (Molas-Gallart et al., 2002). Broadly speaking, steering of the research agenda with a view of foreseeable economic return is a potential threat to basic research, if not the standard of academic science as a whole. The pressure on academic scientists to patent, in particular, allegedly encourages secrecy which is at odds with the role of science as a public good (Nelson, 2001; Sampat, 2006). Widespread patenting is also shown to obstruct the public from otherwise freely available knowledge, thereby ironically slowing down the industrial innovation rate (Fabrizio, 2007). The answer to each of these criticisms, as we shall also find from this study, is contingent on circumstances specific to the case at hand. For each allegation of second-rate science being commercialised, there is no shortage of cases that point to the contrary (Hicks et al., 2000), including the race to commercialise graphene as mentioned earlier. The commercialisation of Cohen-Boyer's recombinant DNA technology (Cohen et al., 1973) revolutionised biotechnology both inside and outside of academia (McMillan, Narin and Deeds, 2000). It is therefore worth keeping in mind the pitfall of using a broad brush in either direction when it comes to commercialising university research.

Indeed, universities' contribution to society comes in many forms beyond commercialisation, including by advancing the knowledge base (which may be exploited in the future), developing a high-quality workforce and improving public understanding of science (Molas-Gallart et al., 2002; Salter and Martin, 2001). The other side of coupling the second and third missions by way of exploitable knowledge, therefore, is a relatively under-recognised contribution from the first mission through teaching and the second mission over the longer horizon.

1.1.2 Mode 2 knowledge production in response to multiple institutional demands

Whether the entrepreneurial trend is technically the best way forward is not of our immediate concern here, as the focus is on another angle – how the value of university research is justified to stakeholders. The progression from "third mission" to "technology transfer" and "entrepreneurship" is noteworthy for its decrease in scope and simultaneous increase in demonstrability. Commercialisation may seem narrow as a flagship of universities' engagement with the third mission. This limitation is compensated for by its readily measurable outcomes, which demonstrate market acceptance and, hence, the practical impact of academic research (Markman, Siegel and Wright, 2008) taken as being indicative of wealth creation (Breznitz, O'Shea and Allen, 2008; Etzkowitz and Klofsten, 2005). Measures or proxies are instrumental in policy decision making and public communication, although the link between academic research and knowledge spillover is notoriously difficult to pin down (Agrawal and Henderson, 2002). University TTOs readily advertise successful spinouts on their websites. The number of spinouts, however, can be problematic, as one good spinout is probably worth more than a hundred lesser ones (Lambert, 2003). Similarly, technology transfer expenditure (Lockett and Wright, 2005) does not offer much insight into how efficiently the money is spent (Langford et al., 2006). Another challenge is when revenue is generated from university intellectual property; it is very difficult to quantify the extent to which wealth is also being generated for the economy. In this situation, the more complex the linkages between scientific research and wealth creation, the more necessary proxies become (Molas-Gallart et al., 2002).

Universities' navigation in entrepreneurship reflects the recognition of a wider set of demands from different societal spheres. The demand-supply metaphor is particularly relevant. In the literature of academic entrepreneurship, universities are said to be producing "supply-side innovation" (Markman, Gianiodis and Phan, 2009). In other words, universities supply knowledge through research and teaching to various interests on the demand side. When put this way, demand-supply does not denote the quantity of a certain commodity to be bought and sold at a given price. Instead, it qualitatively represents the relationship dynamics between universities and their audiences. The dynamics are indeed complex. As a collection of demand constituents, "society" is far from homogenous. It contains a huge number of stakeholders whose demands are diverse and, at times, contradictory (Hessels, Van Lente and Smits, 2009; Muscio, 2010). In other words, there is a high level of institutional complexity (Greenwood et al., 2011) currently faced by universities.

Incompatible prescriptions come from uncoordinated constituents interested in influencing scientific research (cf. Zald, 1978). Take the geography of science funding as an example. Quality-based, geography-blind research funding works in favour of maintaining scientific excellence for those already excelling (Hicks, 2012). This further reinforces the concentration of scientific capabilities and infrastructure in a specific region, which is obviously not in the best interest of regional economic development (Flanagan, 2015; Hill, 2015). Industry, regional job creation and patient populations can all potentially benefit from science and research exploitation, although interested parties may not always align among themselves, let alone with the academic agenda.

Of special note for this study is the concept known colloquially as "Mode 2" knowledge production, first introduced in *The New Production of Knowledge* (Gibbons et al., 1994). As a departure from the science-as-we-know-it represented by Mode 1, Mode 2 fits comfortably with the university-society relationship discussed so far. Mode 2 points to an emergence of a new knowledge production system that is "socially distributed" (Gibbons et al., 1994, p. 155) beyond the confine of universities. Compared to Mode 1, it is characterised by an opposing set of five cognitive and organisational "attributes". Mode 2 knowledge production:

- is carried out in the *context of application* rather than defined by academic interests;
- is *transdisciplinary* such that it does not follow the Mode 1 disciplinary trajectory;
- involves the *heterogeneity* of participating organisations in addition to universities;
- requires *reflexivity and social accountability*, as opposed to autonomy from societal influences;
- answers to a *novel quality control* regime, which is context- and use-dependent, rather than the Mode 1 peer review community.

When put in the context of the university-society relationship, Mode 2's comprehensive list of attributes has an intuitive appeal. In the world of Mode 2, the proliferation of social involvement in how knowledge is both created and assessed subverts the exclusivity that is the case in Mode 1 and, therefore, marks the "democratisation" of science (Nowotny, 2003). Mode 2's intuitive quality is reflected in the questions directed at the role of publicly funded science, especially from universities. An upcoming review of research councils, led by Royal Society President Sir Paul Nurse, illustrates this point from the funding perspective. Questions to consider as part of the review (BIS, 2015), due in the summer of 2015, include the balancing of national interest, such as regional balance and economic impact (social accountability and novel quality control), balance between investigator-led and strategically focused initiatives (context of application), adequate support of collaborative and interdisciplinary research, and coordination with agencies funding innovation (heterogeneity). Not only does the Nurse Review indicate the contemporary relevance of issues raised by the Mode 2 diagnosis 20 years earlier, its timing also suggests some urgency in having these questions answered. The review was announced in December 2014, only months after the *Triennial Review of Research Councils* (BIS, 2014) – also dealing with "investing public money in research and innovation in the UK" (p. 6) – was published in April of the same year.

1.1.3 Research problem: Normative consequences of unresolved empirical questions

The fundamental rationale for this study is the possible normative consequences of Mode 2's assumed empirical validity, especially when and where it exerts influence on policy. The intuitive appeal of Mode 2 provides an important clue to understanding the research context. While it has demonstrated value in guiding public discussion of scientific research, much less confidence applies to the implementation of policy generated from Mode-2-type ideals. Debates remain over the empirical substantiation of Mode 2 and the consequences of applying it to science policymaking (Shinn, 2002; Weingart, 1997). Although Gibbons and colleagues (1994) insist that Mode 2 diagnosis is based on evidence and not associated with specific value judgements, it most frequently reads as a prescription endorsing the desirability of the "new" way. It seems "tinged with political commitment" (Shinn, 2002, p. 604) which implies, rightly or wrongly, that Mode 2 is the natural direction in which knowledge production systems are supposed to be heading.

There are a number of unresolved issues of descriptive validity (for review, see Hessels and Van Lente, 2008) that may indicate the reason why Mode 2 is not readily amenable to empirical research. The first issue of this study's interest comes from a well established notion that the production function of scientific research is far from straightforward. The input-output substitution is rarely, if ever, predictable with confidence (Callon, 1994; Tassey, 2005). Mode 2 as a bundle of attributes, however, incorporates both the kind of knowledge to be produced (practically relevant) and the approach by which it is achieved (socially distributed). This way, Mode 2 has been treated both as a means and outcome or an end. Furthermore, as soon as one starts to pin down each attribute or search for perfect co-presence of all five, Mode 2 becomes even more elusive. While it is safe to say that Mode 2 agrees with our common sense, attempts to demonstrate the connection between means and ends, much less the coherence of five individual features, have not been met with much success (Hessels and Van Lente, 2008). The main source of difficulty on this front is what Fuller (2000, p. xii) calls "the myth of the modes" that implies Mode 1 and Mode 2 are mutually exclusive and jointly exhaustive. The lack of appropriate language from Gibbon's diagnosis impedes our ability to tackle the issue. As a result of their landmark review of Mode 2 literature, Hessels and Van Lente (2008) suggest that Mode 2 should be disbanded altogether into five separate attributes, each of which clearly deserves attention on its own.

Another issue is whether or not Mode 2 is new, meaning that the use of the word "emergence" for Mode 2 is questionable. Critics point out that neither is the utilitarian view of Mode 2 new nor is Mode 1 the original form of knowledge production (Etzkowitz and Leydesdorff, 2000; Rip, 2000). Instead, what is new is the institutionalisation of the Mode 2 ideal and the formalisation of Mode 2 processes (Geuna and Muscio, 2009; Weingart, 1997), illustrated by earlier examples of TTOs and research commercialisation. A historical reading suggests that the individual attributes underlying Mode 1 and 2, long before they became labelled as such, may have always coexisted. Furthermore, they will continue to coexist in ways that are not captured by the Mode 2 narrative, in which the five features are bundled. On this issue, Gibbons and his co-authors point out that Mode 2 is not supplanting Mode 1, and that “Mode 1 will become incorporated within the larger system in which we have called Mode 2” (1994, p. 154). In addition to these indications, the coexistence – be it in the past, present or future – goes largely unexplained.

The motivation, however, has little to do with pedantic verification of the technical or historical accuracy of Mode 2 diagnosis. Rather, it has more to do with concern over its easy acceptance, which may cause technical and historical inaccuracies to reinforce each other. We know that both academic and practical ideals have existed for a long time (Murray, 2010), but the effects of putting labels on them may have been underestimated. What we have come to know as Mode 1 was earlier formalised by Merton (1942) to protect science from wartime political interferences (Etzkowitz and Leydesdorff, 2000; Turner, 2007), a much needed action at the time. It has since become a natural path of science with virtually no questions asked. In principle, Mode 2 could undergo a similar route along which formalisation is triggered by societal cues. As institutional demands are recognised by universities, a corollary is the need to demonstrate that said demands are met, presumably by making promises and creating new rhetoric. This way, Mode 2 assumes a life of its own as a new entity that is technically separated from Mode 1, without our awareness that its formalisation was from our own doing (cf. Berger and Luckmann, 1966; Zucker, 1977). This is not a problem in itself except that formalisation, especially in the context of the third mission, privileges a narrow view. One may say that we have started to see evidence in the proliferation of TTOs and the heavy emphasis on spinout formation as a success indicator which, in turn, further cements the necessity of TTOs themselves.

So far, Mode 2 clearly has merit in bringing attention to diverse demands that should be accounted for by contemporary universities. Our ability to say confidently what to make of it is a different matter, judging by how surprisingly little we know of Mode 2. Empirically speaking, if the individual attributes are independent, then what constitutes the emergence Mode 2? Furthermore, what constitutes Mode 2 itself? Normatively, it creates a question of whether all attributes have to be adopted, especially at the expense of their Mode 1 counterparts. Historically speaking, if Mode 1 and Mode 2 attributes have already worked together in an amalgam, what would wholesale change do to the knowledge production system (Shinn and Lamy, 2006)? The level of difficulty in merely speaking of Mode 2 has perhaps contributed to the wane of Mode 2 debates (Bartunek, 2011), preventing the concept from reaching the potential that was expected of it.

For us to move away from the rigidity of mutually exclusive framing, better articulation of coexistence between Mode 1 and Mode 2 is the aim of the study. Looking closely at the connection between the second and third missions, there are clues pointing to an unarticulated dependence of Mode 2 attributes on those already institutionalised under Mode 1 (Etzkowitz and Leydesdorff, 2000; Lenhard, Lücking and Schwechheimer, 2006; Weingart, 1997), which are taken for granted as being self-regulated by academia. The agenda of the Nurse Review provides an example of this point. Sir Paul, Chair of the review, has said, "Through this review we will seek to ensure that the UK continues to support world-leading science, and invests public money in the best possible way" (BIS, 2015, p. 3). The list of questions to consider in the review deals more explicitly with the "public money" issue, but does not feature scientific quality *per se*.

Narratives of change, by design, point to what is new, which is what the third mission (Etzkowitz and Leydesdorff, 1997; Etzkowitz, 1998), entrepreneurial universities (Clark, 1998) and Mode 2 (Gibbons et al., 1994) have in common. At this point, demands from societal constituents along with the resulting pressure and scrutiny are unmistakable (Lubchenco, 1998; Minshall et al., 2008; Neave, 2006). A peculiar fact remains that success is dependent on the knowledge production system that was formalised along Mode 1. We currently know very little of how a supposedly old system responds to new demands that are now evident and pervasive. The discussion so far shows how an assumption of simple, monolithic shift potentially brings unintended consequences by masking how the "new" is connected to the "old". For this research, a negative definition of change, i.e. the fate of the old, fits the purpose of articulating how Mode 1 and Mode 2 coexist. The question is therefore:

What happens to Mode 1 where Mode 2 is in demand?

What happens to Mode 1, in principle, is an open question. It could be found to have been obliterated, or equally its foothold could remain as firmly entrenched as we believe it was before. However, by all indications we have, both extremes are clearly not true.

1.1.4 Analytical approach and research design

Our current knowledge of Mode 2 in the context of a changing university-society relationship has informed choices made for the perspective and design of this research. The following summary highlights the choices made for the perspective used, what specifically constitutes the "supply side", how the problematic bundled form of Mode 2 is handled and what kind of data is to be collected and analysed.

Legitimacy as the central concept hinging on societal demands. The fate of Mode 1 in the presence of Mode 2 demands is examined from the perspective of legitimacy. The cue is taken from how the third mission and Mode 2 are formulated as change narratives – by adding society to the equation as demand constituents. Taken together with the struggle for science to remain adequately funded by the public, the situation fits with how legitimacy is defined and why it must be achieved and maintained. Legitimacy is defined as "a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995, p. 574). This at least partially explains why Mode 2 has attracted few questions disproportionate to its prominent visibility (Hessels and Van Lente, 2008), and despite the empirical challenges outlined earlier. The socially distributed framing of Mode 2 is highly congruent with what society demands from science, especially those visibly expressed through policy agenda. This is demonstrated by examples of the recent Triennial Review (BIS, 2014) and Nurse Review of Research Councils (BIS, 2015). In the contemporary context, the so-called tension between Mode 1 and Mode 2 (Swan et al., 2010), or academic and commercial ideals in general (Murray, 2010; Philpott et al., 2011), is not merely a matter of ideology. Legitimacy status is a valuable resource (Pfeffer and Salancik, 1978), as it convinces an audience to grant a legitimate entity freedom of pursuing activities of its choice (Deephouse and Suchman, 2008). Speaking from this perspective, legitimacy judgement from the demand side has material consequences on the viability of academic science. In this study, the main interest is to look at how these demands are being handled from the supply side.

Academic scientists as the supply side. Opposite to the demand side bestowing legitimacy is the supply side producing scientific knowledge. There is a slight twist from the usual association between Mode 2 and universities (Etzkowitz and Leydesdorff, 2000; Jansen, 2002). My interest is more specific to academic scientists as knowledge producers rather than universities as organisations managing the scientists. The notion of academic scientists transcends organisational borders between universities as they form an epistemic community. In addition, focusing on the scientific community instead of universities provides a better fit with demand-supply relations and resource considerations in the policy context. Inquiries towards scientific knowledge production are often made from the public funding perspective and addressed to research councils rather than individual universities (BIS, 2014, 2015).

Bundled "modes" rendered as means and ends. As earlier discussed, Mode 2's bundled form perpetuates the mutually exclusive framing that limits possibilities for empirical research. It also lacks the sensitivity that is needed to explain how Mode 1 and Mode 2 coexist. How this problem is tackled also comes from the focus on legitimacy that is granted by an institutional audience. Assuming the aim of achieving and maintaining legitimacy, I apply an interpretive scheme (Greenwood and Hinings, 1988) to reorganise the attributes in each mode into a set of means-ends relationships. The scheme consists of beliefs and values pertaining to (i) *raison d'être*, (ii) principles of organising and (iii) performance criteria.

In the modified rendition of each mode, the "end" is to gain positive legitimacy judgement by meeting performance criteria set by a relevant quality control audience. Therefore, Mode 1's end is to satisfy the peer review community. It is much less straightforward in Mode 2, as there is no definitive list of what constitutes the societal audience, as scientific research has many different effects on an infinite number of beneficiaries. The other four attributes are considered together as "means" – i.e. organising principles according to which the ends can be met. *Raison d'être* was previously implicit but not explicated as an attribute. In this research, it is operationalised as a mode-specific sense of purpose. The generic *raison d'être* for Mode

1 is interpreted as advancing science for science's sake. For Mode 2, it is to produce knowledge that is relevant to practical problems.

The means-ends rendition is intentionally less detailed than disbanding each mode into five individual attributes as suggested by Hessels and Van Lente (2008). In my view, the means-ends frame preserves the structure of the Mode 1/Mode 2 duality which provides a starting point to visualise the coexistence. At the same time, it leaves room for the possibility that means and ends may not necessarily match. This frees us from committing to the presumed technical accuracy of the framework whilst still acknowledging its intent.

Data combining individual Mode 2 exemplars and wider policy issues. The study comprises two sequential phases of qualitative analysis. I start Phase I with a focused interest on university spinouts. From the supply-side perspective, spinouts are the *de facto* flagship mode of academic entrepreneurship considering the level of commitment required from inventing scientists (Franklin, Wright and Lockett, 2001), and scientific breakthroughs with which they are often associated (Van Burg et al., 2008; Zucker, Darby and Brewer, 1999). From the demand side, spinouts are indicative of the impact made to beneficiaries outside of academia (Dakers, 2015), fitting with Mode 2's notion of an extended quality control audience.

The connection of spinouts to knowledge production is explored through accounts from academic founders from top-performing research universities in the UK. The results show that audiences, i.e. quality control groups, were identified very similarly to the Mode 1/Mode 2 delineation. While they make sure to produce scientifically sound research as a priority, the founders also identify directly with potential beneficiaries in wider society in a Mode 2 fashion. University-level factors do not appear to be relevant to legitimation accounts. Furthermore, pathways to spinout formation are diverse and also suggest elements of unpredictability involving elements associated with both Mode 1 and Mode 2.

Phase I results, particularly the institutional-level audiences identified by the academic founders, serve as a precursor to Phase II analysis. Interest in the science-society relationship continues as this phase entails a broader issue of how academic scientists respond to a wide range of demands from society, especially to justify continued public investment in a difficult economic climate. Emerging themes from Phase I are used to interrogate the transcripts of oral evidence sessions conducted for selected inquiries launched by science and technology committees from both the House of Commons and House of Lords. In each session, expert witnesses, most of them from an academic and/or scientific background, were summoned and examined by the committee on a range of topics. Accounts generated in the policy context have a real-life quality that is suitable for answering macro-level research questions. Phase II analysis results in further refinement of initial propositions emerging from Phase I.

1.1.5 Overview of findings and theoretical implications

The findings confirm the relevance of quality control audiences in both modes as a point of reference for academic scientists, although it refutes the necessity of all attributes operating together in a stable mode. The enduring influences of Mode 1 can be seen from three interrelated components of the narrative addressing the overall scientific needs of the Mode 2 audience. These components correspond to the interpretive scheme that was applied as an analytical framework, consisting of backing, response tactics and performance rhetoric.

The basic building blocks of backing for the supply-side perspective contain (i) a strategic imperative – to maintain the UK's privileged scientific knowledge base – and (ii) legitimacy assumptions – that knowledge accumulation is causally ambiguous, path dependent and not perfectly tradeable. This component of the narrative corresponds to the *raison d'être* that is identified in the interpretive scheme (Greenwood and Hinings, 1988). The Mode 1 quality control regime has an influence on how the challenges of building the science base, especially causal ambiguity, can be handled. Because it is difficult, if not impossible, to predict with confidence the impact on Mode 2's quality control audience, Mode 1 quality control is the only option that is systematically applicable at the onset of the process. This is considered essential for the main purpose of building the science base from which both Mode 1 and Mode 2 audiences can benefit. Backing assumptions, not previously explicated in the Mode 1/Mode 2 dichotomy, are shown to be instrumental as a connector between two otherwise separate modes.

Legitimacy assumptions inform the proposed means of organising that is needed for a knowledge base to be maintained and continuously exploited. Causal ambiguity of knowledge production means that the knowledge that benefits the Mode 2 audience can arise out of any combination of Mode 1 and Mode 2 attributes. Furthermore, the sheer variety of beneficiaries that decide on Mode 2 quality also impedes any reasonable attempt to formulate a coherent mode of knowledge production. Given the many possible combinations of Mode 1/Mode 2 attributes, Mode 1 means are permitted in the organising principles as a consequence of the dissociation between means and ends. It is therefore essential that a fuzziness of means be allowed, ideally based on expert knowledge that is also socially accountable.

Performance rhetoric serves as a device to communicate and sustain the overall narrative, especially where the value for public money is concerned. For the strategic aim of maintaining the privileged science base, Mode 1 is operationalised as synergistic to Mode 2. On the one hand, the content of Mode 1 quality is broadened to eschew the outdated equation of "excellent" and "pure", allowing for more variety to be considered legitimate by the peer community. On the other hand, the scope of the Mode 2 quality control audience – so far severely limited to businesses – is also broadened for impact to be made in a larger variety of ways without radically overturning how scientists do research. The rhetoric appeals to both Mode 1 and Mode 2 audiences, but also involves a challenge to their perception of quality.

Theoretical implications arise from how the end of satisfying the Mode 2 audience entails a blend of means from both Mode 1 and Mode 2, and prompts means fuzziness to be advocated as a response. This illustrates a challenge of how to gain and maintain legitimacy in an "opaque institutional field" where "practices, causality, and performance are hard to understand and chart" (Wijen, 2014a, p. 302). By focusing first on how to answer to the audience, this study shows that the procedural assumption of legitimacy – that compliance can be achieved by following rules and procedures (Meyer and Rowan, 1977; Oliver, 1991) – can be problematic in the presence of means-ends opacity. This is because, most importantly, a specific procedure does not exist to be followed, and neither does a clear definition of what is expected as performance. It results in a continual negotiation between supply and demand constituents (Bromley and Powell, 2012), even if they may share the same goal of "the greater good". Under this condition, the scale of classifying responses from compliant to resistant (Oliver, 1991) is not fully applicable, since knowing both tactics and intention is now obscured.

A further theoretical contribution is made as I identify three antecedents to the use of means fuzziness. Means fuzziness is more likely if (i) potential consequences of technical failure are particularly damaging, (ii) there is a lack of clarity over how demand constituents and content can be identified, and (iii) the supply side, i.e. legitimacy seekers, disproportionately commands the expert knowledge required to fulfil the ends.

1.1.6 Implications on articulating Mode 2

This study mainly contributes to an improved articulation of how otherwise separate modes of knowledge production coexist, through the application of interpretive scheme (Greenwood and Hinings, 1988) as an analytical framework. Two modifications have been made to the Mode 1/Mode 2 dichotomy as a result. First, the framework captures the internal means-ends structure of each mode. Second, it leads to the identification of strategic imperative as *raison d'être*, which bridges the otherwise disconnected modes.

The means-ends structure at least partially remedies the problem of Mode 2's internal coherence (Hessels and Van Lente, 2008; Rip, 2000). It provides an alternative to studying individual attributes separately, as recommended by Hessels and Van Lente (2008). While the complete disbanding of Mode 2 may result in a higher degree of technical accuracy, means-ends framing is more suitable for a research question located in a societal domain since the intent of Mode 2 can be acknowledged without its empirical validity being assumed.

Raison d'être, empirically identified as the strategic imperative of sustaining the privileged science base, eases the problem of mutual exclusivity between Mode 1 and Mode 2 (Fuller, 2000). The science base is believed to be important to the entire range of the audience, and thus cannot be reduced to a single mode. It provides a common ground on which responses to institutional demands can be devised.

As *raison d'être* is likely to vary for uncoordinated entities across the institutional field, it demonstrates a socially constructed character of how the coexistence is framed in response to institutional demands. It is therefore likely that the coexistence will be articulated differently according to a given interest. In addition to a number of empirical problems identified in the extant literature, the omission of this basic element may have been another reason for Mode 2's intractability as a subject of empirical research.

1.2 Thesis structure

The thesis is structured as follows:

Chapter 2: Empirical understanding of Mode 2 knowledge production

I introduce the New Production of Knowledge (Gibbons et al., 1994), also known colloquially as Mode 2. Then I review and discuss the challenges – empirical, conceptual and normative – towards the concept. Based on the literature reviewed, I identify the components that inform the research question and research design.

Chapter 3: Theoretical framework and research design

I introduce legitimacy, its socially constructed character and the means-ends interpretive scheme as an analytical framework. Based on theoretical and philosophical underpinnings, I further discuss their implications on research approach and quality criteria.

Chapter 4: Empirical study Phase I: Legitimation of university spinouts by academic founders

I start the chapter by specifying the methods – sampling logic, data collection and analysis – and report the findings from interviews with academic founders of university spinouts in themes related to legitimation of spinout/commercialisation and the processing of multiple demands for scientific research. I further put forward the initial propositions which inform the design of the next empirical phase.

Chapter 5: Empirical study Phase II: Supply-side response to the prioritisation of scientific research

I further examine the initial propositions in a policy context, specifically against the issue of strategic priority debates. Data selection and analysis are from the perspective of those representing academic science, i.e. the supply side in the knowledge production system. This phase results in a set of output propositions, further refined from the initial ones.

Chapter 6: General discussion

This chapter consists of two main parts. The first part outlines the coexistence between Mode 1 and Mode 2 by answering what happens to Mode 1 in presence of Mode 2 demands. I start by introducing *raison d'être*, empirically identified in this study as the supply side's strategic imperative, as a mode-neutral bridge between otherwise disconnected modes. I then discuss Mode 1's enduring influence according to three parts of the supply-side legitimation narrative – the backing of arguments, proposed means of organising and operationalisation of coexistence through performance rhetoric.

The second part pertains to theoretical implications arising from the supply side's insistence on maintaining flexibility and discretion over the means of knowledge production, dubbed "means fuzziness". The situation has raised some questions over our understanding of legitimacy that has so far been applicable to other contexts (Meyer and Rowan, 1977; Oliver, 1991; Suchman, 1995). Three antecedents are proposed as enablers for means fuzziness to be invoked – potentially damaging consequences of technical failure, ambiguity of demand definitions and knowledge differentials.

Chapter 7: Conclusion

I summarise the content of the study and identify contributions to knowledge in three domains – empirical, theoretical and methodological. The study mainly contributes to the empirical understanding as to how Mode 1 and Mode 2 may coexist in a legitimating context. It further raises theoretical implications on the understanding of legitimacy in the contemporary context of scientific knowledge production, as it connects the doubts over procedural assumptions of legitimacy (Oliver, 1991) and opaque institutional fields (Bromley and Powell, 2012; Wijen, 2014a). I then argue that both empirical and theoretical contributions have been made possible by the methodological contribution, i.e. the application of the interpretive scheme (Greenwood and Hinings, 1988) as an analytical framework. I also identify implications for policy and practice, limitations of the study and opportunities for future research.

2 EMPIRICAL UNDERSTANDING OF MODE 2 KNOWLEDGE PRODUCTION

The following review of literature serves the purpose of informing the research design that contributes to a better empirical understanding of the Mode 1/Mode 2 phenomenon (Gibbons et al., 1994). The notion of Mode 2 denotes a shift from traditional Mode 1 knowledge production that is university-centric, isolated from social influences and judged by an exclusive community of experts. Mode 2 proponents claim the emergence of a mission-oriented knowledge production system that is "socially distributed", involving an extended range of stakeholders in the decision of research content, process and quality judgement. The ivory tower's scientific primacy recedes and gives way to the new rigour of relevance, according to which an increasing number of parties are entitled to assess what constitutes good science.

Although Mode 2's potential merits are many (Huff, 2000; Tranfield and Starkey, 1998), and the idea that science is "democratised" upon the advent of Mode 2 resonates with popular interests (Nowotny, 2003), this study follows an important counterpoint. Mode 2 claims to be evidenced (Gibbons et al., 1994, p. 3), but is rarely substantiated by an empirical research programme (Hessels and Van Lente, 2008). The writing of Mode 2 is very easily construed as necessitating a wholesale change of scientific research to conform to Mode 2 ideals. That it offers "no questions, but lots of answers" (Shinn, 2002, p. 603) is potentially dangerous, especially as science is supported by a tremendous amount of public investment (BIS, 2004, 2014b).

This chapter starts by introducing Mode 2 in comparison to Mode 1, followed by an overview of how Mode 2 is received and debated. There are two empirical challenges that influence research questions and design. The first issue is the extent to which Mode 2 is happening. This is followed by the question of whether Modes 1 and 2 are constructed from coherent individual features. I then highlight Mode 2's potentially problematic assumption – that an institutional change necessarily entails epistemic change – by putting it in the context of university technology transfer. Furthermore, I draw on existing observations that Mode 2's acceptance is in relation to the legitimating context, notwithstanding the problems of technical accuracy. At the end of the chapter, I propose to focus on the concept of legitimacy in the investigation of the fate of Mode 1 under the institutional pressures of Mode 2.

2.1 Mode 2 as a departure from science-as-we-know-it

The demarcation between Mode 1 and Mode 2 was first introduced in a book, *The New Production of Knowledge*, in 1994 by Michael Gibbons, Helga Nowotny and colleagues. The phenomenon entails the emergence of Mode 2 out of the existing Mode 1, which represents science-as-we-know-it (Gibbons et al., 1994). If the institutionalised image of Mode 1 is science for science's sake in its own secluded ivory tower, to which the societal influence is negligible if not also potentially corrupt, then Mode 2 is diagonally different in every facet imaginable. In its literal, ideal form, Mode 2 points to "the end of disciplinary science, universities, laboratory-rooted research, and differentiations between scientific knowledge *per se* and society" (Shinn, 2002, p. 608). That is, Mode 2 diagnosis, whether taken as empirical observations or predictions, minimises the differentiation between universities, non-academic knowledge producers and users, and the lay public. Scientific referents are counter-balanced by social, political and economic ones, as science is no longer the business of truth for its own sake but that of enhancing the public well-being. This situation therefore entails "socially distributed" knowledge (Gibbons et al., 1994, p. 4) and "participatory science" (p. 148).

In the introduction to Mode 2, I draw almost exclusively from the 1994 volume. Considering the subsequent discussion on Mode 2's descriptive validity, isolating original descriptions should help maintain clarity by providing the point of reference and also give the authors sufficient justice. I also use quotations frequently, as they best illustrate the authors' use of language, which is an important reference point when normative implications are later discussed.

The cognitive and social norms that characterise each mode differ along five attributes, summarised in Table 2-1. Mode 1 and Mode 2 diverge in how problems are defined, identification with disciplinary base, range of participating organisations, the level of reflexivity involved and quality control criteria.

Table 2-1 Attributes of Mode 1 and Mode 2 knowledge production[1]

Attributes	Mode 1	Mode 2
Context of knowledge production	Academic context	Context of application
Organised nature	Disciplinary	Transdisciplinary
Participant diversity	Homogenous (university-centric)	Heterogenous (socially distributed)
Epistemic orientation	Autonomous	Socially accountable
Quality control	Peer review	"Novel" extended quality control

In Mode 1, the problems are defined and solved according to academic considerations, but in Mode 2, these activities take place in the *context of application* in which knowledge production is negotiated. Worthy research problems cannot be identified by scientific and technical criteria alone. Relevance to stakeholders in social, political or economic spheres govern the choice of research agenda, as knowledge "will not be produced unless and until the interests of the various actors are included" (Gibbons et al., 1994, p. 4). To this end, knowledge production may follow specifications identified by users, or incorporate stakeholders themselves in the working team. The intrinsic importance of demand diversifies the supply of expertise (both inside and outside of universities) that is needed to cope with various forms of demand.

Mode 1 knowledge is produced and accumulates along the academic disciplinary structure, whereas Mode 2 knowledge production is essentially *transdisciplinary*. Problems arising in the context of application escape discipline-specific frameworks. The role of the context of application here is to provide a "consensus" or a basis on which an appropriate social and cognitive form of knowledge production can be derived. Therefore, the exact mix of expertise varies from case to case but it will "normally be beyond that of any single contributing discipline" (Gibbons et al., 1994, p. 5). Gibbons specified four characteristics of "transdisciplinarity" (p. 5) as follows:

[1] Summarised from (Gibbons et al., 1994)

- Problem-solving frameworks are generated directly in the context of application, not in the universities and later applied in a different context by different groups of people.
- Problem-solving frameworks can continue to develop their own "theoretical structures, research methods and modes of practice", and possibly independently from the problems that they were originally designed to solve.
- Communication is made with participants during the process, not after or through "institutional channels" such as journal publications or conferences. This way, a stable connection can be made by the movement of diverse personnel from one context of application to another.
- Transdisciplinarity is "a problem solving capability on the move", which itself can generate further research questions, although the nature of such questions are as difficult to predict as "possible applications that might arise from discipline-based research".

Knowledge developed in the realm of transdisciplinarity normally does not belong to a specific place on a disciplinary map. Thus, according to the Mode 2 authors' reasoning, there is no need to go back to one's disciplinary home for validation.

In contrast to the universities' central importance in Mode 1, Mode 2 knowledge is marked by *heterogeneity* as it is produced on a larger number of sites. The context of application and the on-the-move property of the expertise requirement also plays an important role here. Each problem at hand requires the coming together of researchers and organisations in an equally mission-specific and transient manner. Compared to university research groups which dominate Mode 1, Mode 2 research teams are much "less institutionalised", such that they "dissolve when a problem is solved or redefined" (Gibbons et al., 1994, p. 6). The resulting organisational diversity gives rise to more significant roles of non-university knowledge producers, such as multinational firms, high-tech firms, government laboratories, think tanks and consultancies, all of which are linked by sophisticated communication networks. In sum, Jacob (2000, p. 20) reframes the scenario as a Mode 2 research team being "configured on the model of the just-in-time inventory method introduced in management in the 1980s".

Instead of maintaining the Mode 1 ideal of autonomy from societal influence, Mode 2 knowledge production requires *reflexivity and social accountability*. Researchers' awareness of social consequences of their work, and the built-in sensitivity for impact, signifies the change of the epistemic core into "socially robust knowledge" (Nowotny, Scott and Gibbons, 2001, p. 94). Again, considerations for "values and preferences of different individuals and groups that have been seen as traditionally outside of the scientific and technological system" (Gibbons et al., 1994, p. 7) are conditioned by the context of application.

Instead of peer review's primacy in Mode 1, Mode 2's *novel quality control* is more "context- and use-dependent" (Gibbons et al., 1994, p. 18), encompassing an extended range of peers added through the context of application. Society "speaks back" to science (Nowotny, Scott and Gibbons, 2001, p. 50), exerting demands for innovation. The combination of change in the epistemic core and the expanded interface between actors bring in additional criteria for quality control – political, social and economic – in addition to scientific and technical ones. On the issue of "quality" of science, the authors of Mode 2 firmly state "it does not follow that because a wider range of expertise is brought to bear on a problem that it will necessarily be of lower quality" (Gibbons et al., 1994, p. 8). "Rather traditional scientific criteria will have to be qualified by other criteria which can claim equal legitimacy" (p. 153).

In addition to the description of the five attributes, there are three important points made by Gibbons and his co-authors regarding the Mode 2 diagnosis. First, the emergence of Mode 2 is framed as empirical, and its attributes are therefore articulated as an outcome. It should be noted here, however, that the framing of Mode 2 as an empirical outcome will prove to be slippery later in the discussion. Second, Mode 2 is a large-scale phenomenon, as it is "spreading across the entire landscape of science and technology" (Gibbons et al., 1994, p. 22).

Another point worth bearing in mind is that, from the beginning of the book, the authors express their neutral stance towards Mode 2.

> No judgement is made as to the value of these trends – that is, whether they are good and to be encouraged, or bad and resisted … (Gibbons et al., 1994, p. 1)

Immediately in the same sentence, however, they also observe that Mode 2 is indeed more prevalent in the "frontier" areas of science. Depending on individual readers, associating Mode 2 with seemingly more advanced areas may lead one to question the authors' neutrality and the level of normative propensity they may carry.

> … but it does appear that they occur most frequently in those areas which currently define the frontier and among those who are regarded as leaders in their various fields. (Gibbons et al., 1994, p. 1)

2.2 Styles of Mode 2 reception

The acknowledgement of Mode 2 in academic literature has been impressive in both quantity and range (Shinn, 2002). How Mode 2 is used is perhaps a more important question. According to Hessels and Van Lente's (2008, p. 749) survey of articles citing Mode 2, approximately 80 per cent of more than 1,000 articles cite Mode 2 as an accepted account of transformation of universities and knowledge production, and often passingly in the introduction and/or conclusion. This trend has continued to this day (Broström, 2012; Feldman and Graddy-Reed, 2014; Woerter, 2012).

The attention of this study is on the articles that focus on Mode 2. The treatment of Mode 2 appears to follow one of the two styles, prescription-focused and description-focused, often depending on the author's academic discipline. Styles of Mode 2 reception are summarised in Table 2-2.

Mode 2-related articles in business and management studies are usually prescription-focused, meaning they are concerned with "what should be" in light of Mode 2 diagnosis. The utility of Mode 2, among other concepts such as "design science" (Van Aken, 2004, 2005), rests on the shared problem of the rigour-relevance (or academic-practitioner) divide (Hambrick, 1994; McGahan, 2007). The main question, posed since the Mode 2 discussion began, is "how is management research positioned to take advantage of mode 2 as it emerges?" (Tranfield and Starkey, 1998, p. 348). For this purpose, debates point to the ontological status of management research (Hodgkinson, Herriot and Anderson, 2001; Tranfield and Starkey, 1998), what constitutes the role of business schools (Grey, 2001; Starkey and Madan, 2001) and where the tensions are between Mode 1 and Mode 2 (Burgoyne and Turnbull James, 2006; Huff and Huff, 2001; Huff, 2000). How scholars answer these question leads to different responses to Mode 2's potential (Hodgkinson and Starkey, 2011; Kelemen and Bansal, 2002) and the rigour-relevance gap itself (Kieser and Leiner, 2009; Learmonth, Lockett and Dowd, 2012; Starkey, Hatchuel and Tempest, 2009).

Table 2-2 Styles of Mode 2 reception

Style	Main interests	Examples
Empirical account of "transformation"	Mode 2 used as shorthand for changes in universities and academic research	Broström (2012) Feldman and Graddy-Reed (2014)
Prescription-focused debates	How can Mode 2 help bridge the rigour-relevance gap?	Huff (2000) Tranfield and Starkey (1998)
Description-focused debates	Is Mode 2 an accurate description of change in knowledge production? Should Mode 2 be considered empirical or normative?	Jansen (2002b) Shinn (2002) Weingart (1997)

Over time, Mode 2 commentaries on management research seem not to have progressed much further from the question Tranfield and Starkey raised in 1998. Bartunek (2011, p. 557) expressed concern that the discourse has not been very productive, especially due to the lack of understanding of what happened inside universities whilst the debate was going on in academic journals. To this end, the task of researching Mode 2 seems to be a challenging one, judging from the small number of empirical studies that adopt the Mode 2 lens. MacLean, MacIntosh and Grant (2002) demonstrated that a) pure and obvious accounts of Mode 2 are rare, and b) much confusion remains around Mode 2's clarity and its use in conjunction with other terms, such as action research. Swan et al. (2010) used Mode 1 as shorthand for academic science and Mode 2 for "genetics science". They found that the Mode 1 mechanism can strengthen under Mode 2 rhetoric. Both studies show that the Mode 1/Mode 2 labels are neither neat nor readily operable as one would expect from a reading of *The New Production of Knowledge*.

The empirical dimension, or descriptive validity, is indeed the focus of the 20 per cent mentioned by Hessels and Van Lente (2008). There is little doubt over the transformation of universities, but the central question is whether Mode 2, being self-proclaimed empirical, provides an accurate description of the phenomenon. After two decades, data on Mode 2 remain scarce even as the concept is still being cited for its empirical assertions. Furthermore, the follow-up volume *Re-thinking Science: Knowledge in an Age of Uncertainty* (Nowotny, Scott and Gibbons, 2001) remains largely silent on this specific shortcoming.

This theme of debate is found in areas related to policy and sociology of science. There are possibly two main reasons for this. First, the science-society contract by itself qualifies as an empirical phenomenon of interest (Elzinga, 1997; Hessels, Van Lente and Smits, 2009; Vavakova, 1998). Another reason, which directly influenced this study, is the normative consequences of Mode 2's automatic acceptance without empirical substantiation (Godin, 1998; Weingart, 1997). Mode 2's critics appear to have converged on this concern, as policy rhetoric can create social reality (Van Lente and Rip, 1998) – a potentially grave danger, considering the high stakes involved in publicly funded science (BIS, 2004, 2014b). Academically speaking, the unfortunate lack of empirical data impedes further discussion, if not also breeding scepticism, as evidenced by the wane of Mode 2's debates (Bartunek, 2011; Romme et al., 2015) despite its conceptual merits.

In what follows, I highlight and further discuss empirical challenges surrounding Mode 2 exclusively in academic science and publicly funded scientific research. The main reason is that the existing critiques predominantly arise from such contexts. A number of management scholars (Bresnen and Burrell, 2012; Learmonth, Lockett and Dowd, 2012) have indeed referred to said critiques, especially Godin's (1998) book review of *The New Production of Knowledge*, in their discussion of Mode 2. However, I would maintain a conservative stance and keep separate the empirical domains of natural science and management research. Management research entails a distinct empirical composition such that it will likely require a different research programme and, consequently, generate different implications.

2.3 Empirical challenges

Since Gibbons and his co-authors claim that their diagnosis of change in knowledge production is value free, empirical validity is crucial as the only *explicit* basis that underpins the validity of Mode 2 itself.

> It is our contention that there is sufficient empirical evidence to indicate that a distinct set of cognitive and social practices is beginning to emerge and these practices are different from those that govern Mode 1. (Gibbons et al., 1994, p. 3)

The assertion that scientific research can be categorised into two modes is indeed a contentious one, as science is more likely known to be a "patchwork of very different activities, joined together under an umbrella label" (Rip, 1997, p. 617). Mode 2, either in the original *The New Production of Knowledge* or the follow-up, *Re-thinking Science*, does not specifically give provision for further empirical research. Unlike its contemporaries, such as the Triple Helix of university-industry-government relations (Etzkowitz and Leydesdorff, 1997), which has created its own research community, the progress to ground Mode 2 in context and articulate its limiting conditions has been severely limited (Shinn, 2002).

The following discussion on empirical challenges facing Mode 2 starts from a landmark literature review by Hessels and Van Lente (2008) who point to a major problem – Mode 2's disregard of diversity of science and historical context. In their search for responses to Mode 2 from its introduction up to 2007, they only managed to gather 13 important articles, around only half of which are empirical studies themselves – a situation that perhaps reflects the difficulty of researching Mode 2. The review resulted in a list of objections that covers the descriptive validity of individual attributes, along with critiques on Mode 2's generality, accuracy of historical perspective, conceptual coherence, theoretical underpinning, political value and the lack of a future outlook.

With a number of additions to the core set of material identified from Hessels and Van Lente's review, I discuss Mode 2's critical responses as two broad concerns that will later decide the research question. In the process, I also look into whether both the commentaries and empirical studies offer insights as to why researching Mode 2 has remained largely intractable.

2.3.1 To what extent has Mode 2 happened?

Mode 2 is framed as outcome. As indicated in *The New Production of Knowledge*, "Changes in practice provide the empirical starting point of this inquiry" (Gibbons et al., 1994, p. 3). The extent to which the outcome has manifest itself is therefore a basic question to ask. Our ability to answer such question, however, is impeded by:

- Conceptual clarity of individual attributes;
- Disagreement over Mode 2's novelty;
- Mutually exclusive framing of Mode 1 vs. Mode 2; and
- Mode 2's claimed generality.

Clarity of individual attributes. A number of empirical studies were designed to test individual claims of Mode 2. Taken together, it appears that some attributes have received more interest and are more amenable to empirical research than others. A very likely explanation is that individual features of Mode 2, perhaps with the exception of heterogeneity and quality control, are very difficult to operationalise. This observation is especially the case where the design involves the use of existing parameters, such as citation analysis. Of the five, reflexivity is the least studied (Hessels and Van Lente, 2008), although it is not clear whether it is because the attribute is well accepted or impossible to test. The difficulty with which these features, let alone the holistic notion of Mode 2 itself, can be captured empirically has limited our understanding of Mode 2 in its real-life setting.

Context of application is difficult to pin down using any measures known to researchers. Some studies have resorted to assigning labels of Mode 1 and Mode 2 to academic disciplines. To confirm the increased intensity in electronic communication, as an important Mode 2 consequence, Heimeriks, Van den Besselaar and Frenken (2008) divide the subjects into Mode 1 sciences (high energy physics, astrophysics, literature studies and psychology) and Mode 2 sciences (genetics, biotechnology, computer science and information science). Swan et al. (2010) similarly label "academic science" as Mode 1, and "genetics science" as Mode 2. It could be argued that there is no real indication that research agendas in, say, computer science or biotechnology, are categorically directed at immediate application. Furthermore, genetics has a well-established disciplinary structure. However, this approach is perhaps the most realistic way in which the context of application could factor in the research empirically.

Also implicit in the classification seen above, in addition to the "applied" nature of the so-called Mode 2 disciplines, is that they are supposedly multidisciplinary. The notion of "transdisciplinarity" is highly problematic as it is specified beyond multi- or inter-disciplinarity. That Mode 2 necessarily generates "its own distinct theoretical structures, research methods and modes of practice" and its results not being attributable to a specific discipline proves to be a challenge. Hicks and Katz (1996) test the claim that the locus of knowledge production shifts to the context of application. Their results were indecisive. They classified agriculture and materials science, among others, as disciplinary, although they admit that the choice was debatable. The specification of transdisciplinarity is an "exaggerated one", according to Jacob (2000, p. 19), such that "in order to give substance to this claim, one would have to limit it so radically as to make its impact negligible".

More importantly, Lenhard, Lücking and Schwechheimer (2006) argue that transdisciplinarity does not imply a "weakening of the disciplinary structure of science", as not all disciplines, or problems, require integration at an early stage. They argue that both early integration and late integration fields have their own ways of contributing to "social robustness", thus rejecting the claims on the privilege of early integration.

The heterogeneity of knowledge producing organisations is more visible than other attributes. Nonetheless, using surface observations to point out that the universities have lost their central importance is possibly ill-informed. To some, the heterogeneity merely indicates "the expanding role of knowledge in social, political and economic areas of activity" (Weingart, 1997, p. 596). Godin and Gingras (2000, p. 273) have indeed empirically observed "diversification of the sites of knowledge production" but "universities remain at the center of the system, while the growth of the other sectors – hospitals, industries and governments laboratories – is strongly linked to universities". Heterogeneity points to stronger interactions between these components rather than marginalising any one of them, especially universities. From the other side, Tijssen's (2004) analysis of corporate research output shows declines, as industry seems to have published less and spent more effort on securing intellectual property rights.

Quality control is possibly one of the more testable attributes, but the consensus in favour of Mode 2 has not been met. On the one hand, Hemlin and Rasmussen (2006) agree with the shift from quality "control" to "monitoring", which takes into account industry, policy, ethics and societal demand from the "lay" public. On the other hand, later studies involving actual scientists show different results, since Hemlin and Rasmussen only used selected examples at the level of universities and funding agencies. Albert, Laberge and McGuire (2012) show that academic scientists overwhelmingly assign superior value to peer review publications and low value to practitioner-oriented outlets. Hessels and Van Lente (2011) found that the effect of applied success on scientific credibility varies across sub-disciplines, subject to the influence of powerful upstream users of science.

Nonetheless, in all three cases, the authors accept that the overall picture of quality control in scientific research is changing but it is never the case of simple transition from one mode to another (Potì and Reale, 2007). The central importance of Mode 1 peer review in conferring professional and scientific legitimacy has shown no sign of subsiding.

Disagreement over Mode 2's novelty. An explanation of an "emergence" is conceptually in relation to its historical reference point. Explaining an emergence of something that is not new is therefore a difficult task.

A starting point is that the quest for "relevance" itself is not new, although the idea of how that should be achieved has changed with the perception of how science benefits the public. Hessels et al. (2009) points to the fluidity of the term "relevance". "It seems that no straightforward answer is possible to the above questions, and there is not even a common definition of societal relevance" (p. 388). They have made it clear, however, that scientific knowledge production has always related to its society in some form, based on the dominant definition of relevance at a given point in time.

It is not clear what Gibbons et al. think of Mode 2's place in the historical context, as it is omitted in their discussion of the rise of Mode 2 (Shinn, 2002). From the historical perspective, some argue that certain features of Mode 2 are neither new nor unique. Heterogeneity, as the most readily observable empirical aspect, is not unique to Mode 2 (Rip, 2000). The same applies to the joining/recombination of disciplines, according to Godin (1998), who thinks the dichotomy of disciplinarity vs. multidisciplinarity does not make a convincing division. It could also be characteristic of Mode 1 university research, which “although disciplinary in nature and performed by an individual with specific expertise, is never carried out in isolation” (p. 470-471). Weingart (1997) acknowledges that the notion of “transdisciplinarity” encompasses more than this, but the differences, if any, are “vague and ambiguous” (p. 596). And, in any case, the phenomenon of multi- or trans- disciplinarity does not signify the alteration to the fundamental basis of science.

Overall, the notion of application-oriented, mission-driven and practical research that Mode 2 claims to embody perhaps predates Mode 1. Rip’s (2002) reading of history identifies a similar logic from the Renaissance. Etzkowitz and Leydesdorff (2000) agree that Mode 1 only arrived with “academic institutionalization” in the 19th century. They argue that “Mode 1 is a construct, built upon that base in order to justify autonomy for science, especially in an earlier era when it was still a fragile institution and needed all the help it could get” (p. 116).

Mutually exclusive framing of Mode 1 vs. Mode 2. Another source of struggle in the attempt to explain the Mode 2 phenomenon is the lack of provision of limiting conditions and the language that is required to discuss them. On this matter, Fuller (2000, p. xii) states that, “The most pernicious feature of the ‘Myth of the Modes’ is that the two modes are seen as not merely mutually exclusive, but also jointly exhaustive – that is, not admitting of other possibilities”.

Elements bearing Mode 1 and Mode 2 characteristics can sometimes be found simultaneously, and this point has been demonstrated even on a conceptual level. A 2x2 taxonomy of scientific knowledge conceptualised by Stokes (1997) has two dimensions – “consideration of use” and “quest for fundamental understanding”. The two do not preclude each other. For example, Edison’s invention would be high on the former dimension and low on the latter. Louis Pasteur’s discovery would rank highly on both. To this end, the language of the Mode 1/Mode 2 dichotomy does not go into specific details of their possible coexistence.

This co-presence of Mode 1 and Mode 2 characteristics is particularly problematic if one looks at different levels of analysis. Potì and Reale (2007) found that both strategic priority setting and peer review are being reinforced at the same time, which is easily the case in transdisciplinary programmes that consist of highly traditional projects

(Weingart, 1997). It is therefore necessary to differentiate between levels of programme funding and actual research – a situation that is jointly revealed by Hemlin and Rasmussen (2006) and Albert et al. (2012) in their respective studies of quality control criteria.

Mode 2's claim of generality. Another problem is that the applicability of Mode 2, broadly speaking, varies across disciplines (Albert, 2003; Godin, 1998; Weingart, 1997) and national settings (Shinn, 2002).

Lenhard et al. (2006) point out that the equation of social robustness and participation of non-scientific actors and/or transdisciplinarity only works in "early integration science", which views "science as a part of a comprehensive problem-solving system that also includes the state and industry" (p. 341). Likewise, Weingart (1997) points to examples of "environment, health, communications, privacy and procreation" (Gibbons et al., 1994, p. 7), which all share heavy policy orientation and "value ladenness". It is extremely difficult to see how areas such as palaeontology can be affected by Mode 2's requirement of social distribution.

The importance of diversity and granularity of science continues, as Hessels and Van Lente (2011) found variations within the field of academic chemistry. Therefore, even "chemistry" is being specified; it is not sensitive enough for sub-field variations of scientific activities. Discipline-based specificity leads Heimeriks et al. (2008) to question whether Mode 2 is a helpful banner when science as a whole is being discussed.

Finally, Mode 2 is silent on the effect of national contexts, as it does not acknowledge that university, business and government all function in a national setting (Shinn, 2002, p. 610). Nation-specific characters are one of the differentiating factors in scientific disciplines, as demonstrated in other fields of literature (D'Este and Patel, 2007; Lehrer and Asakawa, 2004; Nelson, 1993).

2.3.2 Are Mode 2 attributes coherent?

To answer the first question posed (the extent to which Mode 2 has happened), the biggest challenge is the impossibility of issuing a composite score under a succinct banner of Mode 2 as originally intended for the concept. That is, the individual attributes that form a mode may not be coherent, and a stable "mode" may not exist.

Hessels and Van Lente (2008) observe that the mere fact that each attribute receives unequal criticism and/or support is a cause for concern. Rip (2002, pp. 104–105) also points out that the separate attributes are "clearly visible, but one might question their overall thesis that these add up to a new mode of knowledge production".

Regarding the issue of internal coherence, Gibbons himself acknowledges that all five attributes need not appear together in every instances of Mode 2. It is suggested that when all five attributes do appear together, they "have a coherence which gives recognisable cognitive and organisational stability to the mode of production" (Gibbons et al., 1994, p. 8). This claim is supported by MacLean et al. (2002) who, in the context of management research, demonstrate instances of all five attributes being present and their distinctiveness. However, incidents such as this are rare in the literature, to the point of being negligible.

The simultaneous acknowledgement and under-specification of partial instances of Mode 2 add to the difficulty of articulating the Mode 2 phenomenon. We do not know what "partial" Mode 2 looks like in practice. If the attributes do not necessarily appear together, when does a given instance qualify as Mode 2? How many of the attributes have to be present, and how much of each? These questions may seem mechanical, but they reveal our lack of understanding of Mode 2's descriptive quality and the lack of common ground on which conversation can be made on the topic.

Treating Mode 2 as a monolithic mass will not likely solve the puzzle. The potential incoherence may have contributed to the lack of sensitivity required to know the extent to which Mode 2 has happened, and rendered empirical research intractable. At the end of their review, Hessels and Van Lente (2008, p. 758) conclude that "the disagreement about the five attributes of Mode 2 and their relative importance shows, in the end, that there is no compelling reason why they should operate together". They suggest disbanding the modes into five separate trends, each of which clearly merits attention on its own.

2.3.3 Problematic assumption: The coupling of structural and epistemic changes

In addition to the incoherence of individual attributes, another problem is that Mode 2 implies that institutional change necessarily entails epistemic change of the same character. A general assumption is that institutional regulation, especially research funding, changes academic norms through its key role in determining reward and performance criteria (Benner and Sandström, 2000), but this usually turns out to be less than straightforward. The impact of policy is most visible at the level of higher education institutions (HEIs) or universities, and academic values or identities generally remain unperturbed by policy interventions/change in research funding (Henkel, 2005).

Different layers of outcome of policy intervention are demonstrated in academic entrepreneurship literature. Policy initiatives to create "entrepreneurial universities" (Clark, 1998; Wright et al., 2007) speak to dwindling research budgets and societal demands for innovation as a key to economic growth (Bozeman, 2000; Jacob, 2003) – a logic very similar to that of Mode 2. The results of entrepreneurial universities are typically gauged by commercial indicators such as the number of spinouts created, licensing agreements, patents filed and the income from industrial collaboration (Slaughter and Leslie, 1997). Before long, the dual demands of science and society led to the creation of technology transfer offices (TTOs) to handle the tasks that would deliver commercial outcomes (Siegel, Waldman and Link, 2003). The rate of TTO establishment quickly increased, such that now TTOs are a regular feature of universities (Lockett, Wright and Wild, 2012). The isomorphism of university technology transfer is sometimes taken as pervasive in all aspects of intellectual activities (Etzkowitz, 1998), especially for those designated "entrepreneurial academics". Focusing on said label, they are often associated with "entrepreneurial" as a qualifier rather than "academic".

But did the so-called entrepreneurial scientists really break away, *en masse*, from the tradition of science? The answer is not necessarily, if not unlikely. To begin with, scientific capabilities at both individual and university levels are positively associated with research commercialisation (Di Gregorio and Shane, 2003; Haeussler and Colyvas, 2011; Landry, Amara and Rherrad, 2006; Zucker, Darby and Armstrong, 2002). In contrast, the focus on the institutional "tension" between science and commerce suggests that academic propensity is a hindrance (Vohora, Wright and Lockett, 2004). Along this line, the resulting predictions tend to hold to a much lesser extent (Ambos et al., 2008). Indeed, scientists show a range of diverse orientations towards such tension. Lam (2010) found that scientists can fall into a category of stereotypical "traditional", "entrepreneurial" or shades of in-between hybrids. What is more, purely academic motivation is not uncommon among so-called entrepreneurial academics (Lam, 2011; Shinn and Lamy, 2006). Therefore, what appears to be dominant on the macro level may be masking the now-conflicting approaches still operating at a micro level (Townley, 2002).

The resilience of scientists' self-motivation also explains how they use the policy-generated dichotomy to their advantage. Scientists generally find little value in the basic/applied labels (Calvert, 2004), but they do adopt the terminology for the purpose of funding, knowing how it is used by policymakers, without intending to change the actual research content at all (Calvert, 2006). This scenario is not considered in the notion of Mode 2, as Albert (2003) suggests that it fails to distinguish between scientists' positions and funding agencies' agendas.

2.4 Normative dimension of Mode 2

2.4.1 Implicit normative propensity

Another question to explore here is the normative consequences and value of Mode 2 diagnosis. Although Mode 2 claims not to incorporate a normative dimension, it is typically read otherwise. It resembles a normative programme to Weingart (1997) and a performative discourse to Godin (1998). Shinn (2002) believes it is how Mode 2 should be positioned. The way Mode 2 is written, regardless of its content, comes very close to a manifesto. As it stands, "*The New Production of Knowledge* – both book and concept – seems tinged with political commitment" (p. 603). The authors appear to be convincing the readers of the desirability of the concept which, according to the series of facts they present in the process, has already taken place regardless.

An interesting juxtaposition between empirical and normative dimensions of Mode 2 is from Jansen (2002), who examines the claims based on the single case of a South

African university. Empirically, Mode 2 description is very different from the lived reality. Normatively, radical institutional changes will be necessary before anything resembling Mode 2 can be observed. Jansen has therefore identified two identities of Gibbons: “Gibbons the prophet”, who speaks of how things should change for the better, and “Gibbons the documentalist”, who observes how changes have taken place (p. 519).

Perhaps it bears repeating that “documenting” is the intended aim of the Mode 2 project, although it tends to be read differently. We do not know for certain if the normative dimension is implicit, albeit obviously unspoken, or a mere oversight. Regardless, its style shares much in common with a “polarized rhetoric” (Godin, 1998) contrasting two alternatives employed in science policy (Jacob, 2000). Vannevar Bush’s 1945 report, *Science: the Endless Frontier*, follows this style, although the stance is opposite to that of Mode 2. The main difference is that Bush, then director of the Office of Scientific Research and Development, outwardly adopted a normative orientation for the purpose of securing continued funding for scientific research.

That Mode 2 shares a writing style with policy rhetoric makes it too easy for readers to conclude that its authors are rejecting the old system of scientific research and arguing that the new system – for its sensitivity to impact, transdisciplinarity and social robustness – is definitely better (Godin, 1998; Shinn, 2002; Weingart, 1997). One of the possibilities is that Mode 2 attributes, instead of societal relevance *per se*, become the object in pursuit. Policy labels are known to induce the creation of new social realities as a result of rhetoric and promises being fulfilled (Van Lente and Rip, 1998).

2.4.2 Mode 2’s normative implications

In this section, *The New Production of Knowledge* is to be read solely for its normative implications, assuming there is no objection to its empirical content. The following discussion is based on what the scholars see as the potential consequences of Mode 2, particularly its literal wholesale implementation, on the system of scientific production. Mode 2 as discussed in the management literature (Huff, 2000; Tranfield and Starkey, 1998) are based almost entirely on a different domain.

The most important ground for criticism is perhaps the idea of "socially robust knowledge" and "democratisation of science" (Nowotny, 2003; Nowotny, Scott and Gibbons, 2001). It is not the suggested participation of non-scientific actors *per se* that is subject to contention. Rather, it is the supposed equal status between scientific and social referents of legitimacy (Shinn, 2002). Weingart (1997, p. 604) sees this assertion as rooted in the fixation on "a model of science as elitist and as a source of (authoritarian?) political power" by Gibbons, Nowotny and co-authors. He further questions the definition of "democratisation" that accompanies Mode 2 production of socially robust knowledge:

> It misses the point of democratization, which is that virtually all political groups and interests have acquired access to scientific knowledge. […] Democratization has also led to a different political treatment of the difference between privileged knowledge and lay knowledge in that those holding privileged knowledge are no longer given undue authority. But under no circumstances does this mean the abolishment of the differences between expert and lay knowledge. (Weingart, 1997, p. 604)

The supposed equal status of social and scientific referents of legitimacy also leads to perceived threats to scientific integrity and freedom. According to her reading of the new science-society contract on which Mode 2 is based, Vavakova (1998) sees the risk of science falling subservient to the corporate interest due to economic utility being dominant. Similar to Vavakova's opinion, Ziman (2003) agrees that the utilitarian propensity has to be balanced with the "non-instrumental role" of science. Mode 2 borders on privileging instrumental science that "celebrates achievement above surprise" (p. 21) as it limits itself to solving known problems and aims for results in the foreseeable future.

Contemporary policymaking is known to suffer from unrealistically high expectations of scientific research expected to be of an instrumental kind. In their analysis of advances in biotechnology, Nightingale and Martin (2004) found that knowledge and discoveries in medicinal biotechnology follow an incremental pattern on an already well established trajectory. They state that the expectations for revolutionary advances are "wildly optimistic" (p. 564). Such assumptions are dangerous because "they lead to poor investment decisions, misplaced hope and distorted priorities, and can distract us from acting on the knowledge we already have about the prevention of illness and disease" (p. 568). The slow-burning, evolutionary pattern of scientific advances aligns well with Etzkowitz and Leydesdorff's (2000) assertion of the universities' continued importance in the knowledge production system. Smaller candidates in the Mode 2 system, such as consultancies and think tanks, may have expertise but lack continuity to pursue cumulative research programmes of this kind.

From a welfare perspective, Jacob (2000) offers an interesting note on an issue that receives almost no mention – the impact of short-term contract employment. As an implication from the context of application, transdisciplinarity and the heterogeneity of participants, Mode 2 authors state that the research teams are correspondingly small, mobile and transient. Jacob discusses career difficulties and insecurities that could be the case for just-in-time contract researchers who are outside of the university system or stable organisations. There is no indication as to how these (hypothetical) individual researchers can secure continuous employment in the Mode 2 job market. He concludes that "life within this space is less than exuberant" (p. 24).

Despite or perhaps because of the political undertones that have been picked up by fellow scholars, Pestre (2003) sees the book as written in a naturalistic and apolitical way. As discussed earlier, *The New Production of Knowledge* was written as a neutral depiction of change that is inevitable, in that there is not much to do apart from recognising it. By not putting Mode 2 in a historical context, and not connecting it to social, economic and political conflicts, Gibbons and colleagues missed an opportunity to provide readers with "the tools needed for criticism and the construction of alternative ways of managing society and science" (p. 246).

2.5 Mode 2 in legitimating context

What explains the acceptance of Mode 2, notwithstanding the concerns that have been discussed throughout this chapter? Discussants of Mode 2 point to the context of legitimation for an answer. Legitimacy has always been the central component of Mode 2 debates (Lenhard, Lücking and Schwechheimer, 2006), as the newly articulated connection between science and societal stakeholders provides another source for legitimacy and works to the advantage of policymakers (Jacob, 2000; Rip, 2000).

Etzkowitz and Leydesdorff (2000) anticipate that economic contingence will be increasingly important for science to be supported. In other words, the de-differentiation between scientific and societal referents that is criticised by scholars is also the basis for Mode 2's popularity.

Weingart (1997) sees Mode 2 as politically "more correct" as a result of the "scientification" of society and the "politicization" of science (pp. 605-607). The narratives on the change of knowledge production target fields that are highly relevant to policy, such as health, energy and climate change. Policymaking in these areas is dependent on science and highly sensitive to new developments in scientific research. This scenario, along with expectations for the utility of scientific research as an engine for economic growth (Elzinga, 1997), intensifies politicisation as it helps justify the political, social and economic criteria of relevance as a counterweight to scientific legitimacy.

Science-as-we-know-it can also be framed in the historical political context, as pointed out by Etzkowitz and Leydesdorff (2000). The norms of "pure" science themselves were put forward in response to threats from the political environment at the time. Merton's (1942) essay on the normative structure of science was a bid to protect science from political manipulation and control, especially by the Nazi regime. The norms of CUDOS – communism, universalism, disinterestedness and organised scepticism – were rooted in sociology such that Merton was able to impart the message in a "politically opaque" way (Turner, 2007, p. 162). The norms later became synonymous with "traditional" science, which is the idea that also underpins Mode 1. The Bush Report entitled *Science: The Endless Frontier*, addressed to President Roosevelt, came not long after (Bush, 1945). At that time, the war had been instrumental in demonstrating science's utility and legitimating public funding. The report was to make a case for continued support for basic science as a foundation of economic welfare in peacetime (Kleinman, 1995). We have since moved far away from such conceptions (Byerly and Pielke, 1995; Lubchenco, 1998). What Etzkowitz and Leydesdorff's example illustrates is that the institutionalised norm of pure science was not necessarily naturalistic and inevitable as the lay public was led to believe.

The nature of legitimating context has important consequences for universities and scientists, especially in how they seek to secure resources. The policy agenda aiming at the role of universities propels the rise of the “entrepreneurial university” model (Hughes, 2011), which is positioned to meet society’s demand for innovation and economic growth (Jacob, 2003). Non-scientific actors therefore play a very important role in granting resources to academic science based on their perceptions of how said demand is being met. The balance between scientific legitimacy and social utility (Kinchy and Kleinman, 2003) is crucial for the availability of resources. Promises have to be made (Rip, 2004) but it is never clear how they are fulfilled. Science and innovation policy is “often based on popular and unarticulated notions of societal relevance, without a clear understanding of what these entail” (Hessels, Van Lente and Smits, 2009, p. 398).

2.6 Responding to empirical challenges: Research question

The empirical issues and critiques of Mode 2 provide a number of indications for the design of this study and the research question:

> *What happens to Mode 1 where Mode 2 is in demand?*

Difficulties in empirical research require a better way of articulating the seeming mutual exclusivity between Mode 1 and Mode 2. The contextualisation of Mode 2 popularity reveals that legitimacy is central to the reception of a potentially useful concept with contested empirical validity. However, the bundled form of a mode may lack the necessary sensitivity to operationalise the articulation. This challenge will become the focus of the next chapter in which the research approach is discussed.

The design responses in relation to specific issues derived from the literature are summarised in Table 2-3. Further explanations on the phenomenon of interest and the theoretical underpinning are also provided in sections 2.6.1 and 2.6.2, respectively.

Table 2-3 Design response to Mode 2 empirical challenges

Issues from the literature	Implications
Research question: What happens to Mode 1 where Mode 2 is in demand?	
The extent to which Mode 2 has happened	Research content: Articulation of coexistence between Mode 1 and Mode 2 Phenomenon of interest: The fate of Mode 1 in presence of demand for Mode 2 (2.6.1)
Legitimating context	Context: Legitimacy, contingent on science-society interaction, as a requirement for policy narratives Theoretical underpinning: Legitimacy in the responses to competing institutional demands (2.6.2)
Within-mode coherence of attributes	Limiting condition: The bundled form's lack of sensitivity to answer the research question Analytical framework: Interpretive schemes of means and ends (next chapter)

2.6.1 Phenomenon of interest: The fate of Mode 1 in the presence of demand for Mode 2

It can be said that the difficulties of explaining Mode 1/Mode 2 phenomena that I have listed previously converge on the lack of a language device to illustrate the coexistence of the two modes. Gibbons and colleagues have not previously suggested conditions in which this might be the case.

Instead of focusing the investigation on the so-called new logic resulting from an institutional shift, which is a more prevalent approach (Greenwood et al., 2011), I am adopting the "negative" definition of the phenomenon by focusing on the old. The positive definition tends to be useful when the new is framed, crudely speaking, as a destruction of the old (Greenwood, Suddaby and Hinings, 2002; Thornton, 2001) or where the end state is based on the rise of the new (Glynn and Lounsbury, 2005; Marquis and Lounsbury, 2007).

The indication that led to this approach is based on the reading of critiques that point to an unarticulated dependence of Mode 2 features on those already institutionalised under Mode 1 (Etzkowitz and Leydesdorff, 2000; Lenhard, Lücking and Schwechheimer, 2006; Weingart, 1997). Doubts as to the extent to which Mode 2 has arrived either suggest that Mode 2 is not new or that Mode 1 remains persistent and pervasive. More importantly, clarity of Mode 2 empirical observations remains rare, indicating the difficulty of operationalisation. Along this line, I decided to frame the phenomenon based on what remains, rather than what additions have been made to the knowledge production system.

On existing insights to be found in *The New Production of Knowledge*, the authors of Mode 2 have not specified the future outlook of Mode 1. From their analysis "it will be clear that Mode 2 is not supplanting but rather is supplementing Mode 1" (Gibbons et al., 1994, p. 14). This statement is not accompanied by further explication.

2.6.2 Theoretical underpinning: Legitimacy in responses to competing institutional demands

The preceding discussion deals with "what happens to Mode 1", whereas the theoretical underpinning now deals with "where Mode 2 is in demand". The importance of legitimating context (Etzkowitz and Leydesdorff, 2000; Rip, 2000; Weingart, 1997) means that a given version of science, Mode 2 or otherwise, has to be legitimated under the so-called science-society contract. Judging from the disputes over the advent of Mode 2, especially by empirical counterevidence, it remains an open question as to whether Mode 2 is the only justifiable thesis at the interface of science and society.

Whilst Mode 2 has been highlighted as the dominant legitimating basis of science (Jasanoff, 2003; Nowotny, Scott and Gibbons, 2001), there is no definitive conclusion that legitimacy of knowledge production is exclusive to Mode 2. Depending on the perspective taken, the merits of Mode 1 have also been leveraged to justify public investment (Gruss, 2012). This led to the positioning of Mode 1 in a context that is biased in Mode 2's favour. More specifically, this is to be investigated from the perspective of academic scientists as the supply side responding to demands for socially and economically relevant science. Some level of complexity is to be expected in the responses from academic scientists as they are known to be adept at utilising policy concepts to benefit scientific activities at their discretion, often without much regard for the spirit of policymaking (Calvert, 2004, 2006). This level of complexity is typically not observable from investigating the agenda of funding agencies or even universities themselves (see Albert, Laberge and McGuire, 2012; Hemlin and Rasmussen, 2006).

3 THEORETICAL FRAMEWORK AND RESEARCH DESIGN

The previous chapter has provided a starting point outlining the empirical understanding of Mode 1/Mode 2 phenomena, which I then proposed to examine in the legitimating context. In this chapter, I further the discussion on the theoretical lens, along with the implications it has on the research design.

The chapter starts with the definition of legitimacy as a central concept, based on a social constructionist assumption. Legitimacy is then discussed as a lynchpin of "rationalised myths" that provide ready-made accounts prescribing how to pursue an appropriate goal by appropriate means. The supposedly institutionalised relationship between means and ends is then considered in relation to competing, and potentially contradictory, demands from multiple constituents in an institutional field. The design and subsequent analysis rest on the similarity between this situation and the rise of Mode 2, itself a means-ends prescription, as an answer to demands on publicly funded science exerted by a multitude of constituents in a wider society.

3.1 Social construction of legitimacy

In this study, legitimacy is defined according to Suchman (1995, p. 574) as "a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs, and definitions". Suchman's extensive review from 1995 remains influential, as the same definition is used in a large number of studies, both empirical (Bansal and Clelland, 2004; Colyvas and Powell, 2006; Zott and Huy, 2007) and conceptual (Molinsky and Margolis, 2005; Tost, 2011).

This definition of legitimacy carries with it a requisite assumption that also underpins this study. Legitimacy is socially constructed, reflecting "a congruence between the behaviours of the legitimated entity and the shared (or assumedly shared) beliefs of some social group" (Suchman, 1995, p. 574). This means the legitimacy status is granted by a collective audience. Although a collective audience or "social group" consists of individuals, the shared belief to which an entity must align to become or remain legitimate is beyond the discretion of any one particular observer. Legitimacy status is a valuable resource (Pfeffer and Salancik, 1978), as it convinces the audience to grant to a legitimate entity freedom of pursuing activities of its choice (Deephouse and Suchman, 2008).

The intrinsically social definition of legitimacy is key to institutionalisation, the foundation of which is drawn from Berger and Luckmann's (1966) social construction of reality (Meyer and Rowan, 1977; Tolbert and Zucker, 1983; Zucker, 1977). Berger and Luckmann's work has become one of the most often cited classics in neoinstitutional theory and regarded as "one of the approach's main theoretical pillars" (Meyer, 2008, p. 519). Considering the status of legitimacy as "an anchor-point of a vastly expanded theoretical apparatus" (Suchman, 1995, p. 571), I further the discussion of legitimacy for its role in institutionalisation, how entities respond to institutional pressures and how the understanding of both is underpinned by a constructionist view.

3.1.1 Rationalised myths as ready-made accounts of means and ends

Institutionalised rules vs. efficiency criteria. According to Suchman's definition, given that a legitimate organisation is "one that is perceived to be pursuing socially acceptable goals in a socially acceptable manner" (Ashforth and Gibbs, 1990, p. 177), then there is a curious absence of technical efficiency in the description. The tension, and the possible contradiction, between institutional rules and efficiency criteria is key to Meyer and Rowan's (1977) seminal work. The adoption of socially endorsed procedures and structure serves primarily to provide legitimacy rather than to improve performance.

The connection between the espoused intention of adopting standards such as ISOs (Jiang and Bansal, 2003), structures such as the M-form (Fligstein, 1990) and diversity management (Kelly and Dobbin, 1998), and the actual working of organisations, much less the outcome, may well be a myth. The point is that myths can be institutionalised as "rationalized and impersonal prescriptions that identify various social purposes as technical ones and specify in *a rule-like way the appropriate means to pursue these technical purposes rationally*" (Meyer and Rowan, 1977, p. 343 emphasis added). The source of this seemingly logic-defying phenomenon is the discrepancy between the levels of generalisation. Institutional rules are categorically prescribed at a high and abstract level, whereas technical requirements are organisation-specific and context-dependent. The implication is that institutionalised rules can be technically unsuited to specific situations (Meyer and Rowan, 1977, p. 355).

It is in each organisation's interest to manage the inconsistency between the technical core and institutional prescriptions. In a study by Tolbert and Zucker (1983), the adoption of civil service procedures by municipalities was based on technical merit up to a certain point in time before the procedures became institutionalised and the adoption automatic. As a result, having civil service procedures in place no longer had to do with functionality. The normative quality of institutionalised elements provides legitimacy regardless of improvements in performance and efficiency. According to the preceding line of reasoning, organisations are likely to decouple the two by uniformly subscribing to socially desirable policies, but with no guarantee of implementation (Crilly, Zollo and Hansen, 2012; Westphal and Zajac, 1994). The alignment with ready-made accounts of means and ends, because of its comprehensibility to observers, protects organisations from unwanted questioning and scrutiny.

Legitimacy in taken-for-grantedness. To understand how legitimacy prescriptions become institutionalised, one "seeks to grasp *not* the universal laws that generate social practice, but the social practices that generate universal laws" (Dobbin, 1994, p. 123 emphasis in original). Social structures, practices and patterns that seem logical and true do not just exist "out there", but for any kind of legitimation to occur it is crucial that they *seem* so.

For the explanation, Zucker (1977) draws on the notion of "reification" and "objectivation" from Berger and Luckmann (1966). Reification "is the apprehension of human phenomena as if they were things" (Berger and Luckmann, 1966, p. 106). Individual actors interact based on what is socially accepted as normal. Institutionalisation happens where these actors regard certain acts as objective, based on some kind of reality that is now exterior and independent from their doings. How organisations such as schools, hospitals and modern corporations are established and run appears to be logical and natural, notwithstanding obvious imperfections. The reconstruction of subjective into "intersubjective" understanding grants the truth status, hence the acts appear valid regardless of observers. Thus, the exterior status – one that equates social views to nature – means that institutionalised acts are objective, if not factual (Luckmann, 1975). They are “potentially repeatable by other actors without changing the common understanding of the act” (Zucker, 1977, p. 728), not least for the lack of alternative interpretations. As soon as man becomes “capable of forgetting his own authorship of the human world” (Berger and Luckmann, 1966, p. 106), taken-for-grantedness is born.

Where subjective meanings “*become* objective facticities” (Berger and Luckmann, 1966, p. 30 emphasis in original), a practice has to be embedded in taken-for-granted assumptions to be taken as a ready-made account, not the other way around. Human agency is required to produce social structure that, in turn, constrains human activities (Zucker and Darby, 1997). At this point, the question is whether individuals retain “the awareness that, however objectivated, the social world was made by men – and, therefore, can be remade by them” (Berger and Luckmann, 1966, p. 106).

Collective rationality in organisational field. Myths are not rationalised randomly, and taken-for-grantedness does not materialise out of nowhere. They occur according to collective rationality residing in a given organisational field, indicating a greater degree of specification from the generalised foundation introduced earlier. Organisational field, according to DiMaggio and Powell (1983, p. 148), is “those organizations that, in aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies and other organizations that produce similar services or products”. The “totality of relevant actors” covers the entire spectrum of interconnected organisations, stakeholders and networks, instead of focusing only on similar firms or competitors (e.g. Porac and Thomas, 1990).

As a consequence of the need for legitimacy, organisations in a given domain appear increasingly similar, though not necessarily more efficient, in a process called isomorphism (DiMaggio and Powell, 1983). Isomorphism entails “conformity to values, norms, and expectations of the constituents” presented in the field of which they are members (Ashforth and Gibbs, 1990, p. 178). Put this way, organisations do not irrationally appear alike for the sake of being alike. They reflect the demands present within the field, thus appearing similar to one another in the process. The omission of “collective rationality”, suggesting that organisations isomorphise regardless of (or even despite) their fields, is probably among the most frequent misunderstandings in institutional theory (DiMaggio, 1995).

DiMaggio and Powell (1983) identify three antecedents of isomorphism: *coercive* force resulting from political or regulatory influences, *mimetic* force resulting in standard responses to uncertainty, and *normative* force exerted by professionalisation. The notion of rationalised myth (Meyer and Rowan, 1977) is especially relevant to mimetic isomorphism. The ambiguity of goals and the lack of recipes to cope with uncertainty mean the less confidence for means-ends prescription. Organisations mimic those successful few without necessarily knowing what technically caused the success, or whether adopted means would result in the desired ends. It helps, nonetheless, to be seen as similar to high performers. In a situation such as this, "organizations employ ritualized controls of credentials and group solidarity" (DiMaggio and Powell, 1983, p. 150).

Isomorphism of university technology transfer. A small note can be given here to illustrate how legitimacy and isomorphism work in a context related to this study. In the previous chapter, I mentioned isomorphism as an indicator of institutional change in which universities seek to address economic and societal demands from outside of academia, although it did not necessarily entail similar epistemic changes at the individual level.

The Cambridge Phenomenon (Segal Quince Wicksteed, 1985, 2000a, 2000b) is an example of a success case. The birth of a high-tech cluster around the University of Cambridge and the employment it has generated have contributed tremendously to the economic growth of the region. It has been an exemplar worth emulating, notwithstanding the fact that the cluster growth was bottom-up rather than micro-managed. This is not to say that the Cambridge Phenomenon was singlehandedly responsible for the commercialisation boom that came later. Rather, it is important to note that the phenomenon demonstrates what universities can achieve through entrepreneurship, both in terms of monetary gain and societal laudability (Witty, 2013). Now that technology transfer offices (TTOs) are a regular feature of British universities (Lockett, Wright and Wild, 2012), it does not mean universities are merely trying to appear similar, even to Cambridge *per se*. Establishing a dedicated commercial arm is the most visible and reasonable way of conforming to values and expectations of societal constituents. It should be noted, then, that the proliferation of TTOs is more or less in the absence of other considerations, such as science and technology capabilities of a given university (Colombo, Mustar and Wright, 2010). In line with DiMaggio and Powell's prediction, TTOs do not always lead to a better entrepreneurial outcome. Sir Gregory Winter, himself an exceptionally successful serial academic entrepreneur from Cambridge, has said that despite the best intentions, the "blundering jobsworths" in TTOs are a hindrance to the very task they are assigned to perform (Matthews, 2013).

3.1.2 Legitimacy in responses to institutional complexity

Early discussion of institutionalisation and rationalised myths assumed a singular cognitive, normative or regulative force being of influence at a given time (DiMaggio and Powell, 1983; Meyer and Rowan, 1977; Zucker, 1977). Such clarity was important as a theoretical foundation, though it also meant that most of the early work would focus on uniformity of organisations in their compliance to institutional processes (see Greenwood et al., 2008). Even so, pluralistic and contradictory nature of institutions, indicated by "inconsistency among institutionalized elements", was clearly acknowledged by Meyer and Rowan (1977, p. 356) in their groundbreaking essay. As a result, that organisations must incorporate different kinds of institutionalised elements to ensure legitimacy and improve a chance of survival has long been known even whilst uniformity and compliance were receiving a lion's share of attention in research.

Institutional complexity is the case where organisations face incompatible prescriptions from multiple institutional logics (Greenwood et al., 2011). In short, institutional logics prescribe "how to interpret organizational reality, what constitutes appropriate behavior, and how to succeed" (Thornton, 2004, p. 70). Logics can guide behaviour observed in an institutional field, as actors cohere by shared values and beliefs (Scott, 2014). Therefore, the implication is that they give rise to differences in preferences, practices, evaluations, procedures, etc. It is particularly likely in contexts that involve a large array of occupations, such as health care (Dunn and Jones, 2010), or where there exist many constituents with conflicting values and expectations, such as in education where schools can identify with various different (e.g. religious or secular) principles (Quirke, 2013). Such conditions are similar to a “polyarchic” context (Zald, 1978) in which uncoordinated parties have an interest in controlling an output of a target element.

Multiplicity of institutional logics. Our understanding of institutional complexity, plurality and change has been greatly facilitated by the institutional logics perspective (Thornton and Ocasio, 2008; Thornton, Ocasio and Lounsbury, 2012) based on the original essay by Friedland and Alford (1991). The notion of logics brings in broader cultural accounts, implying plurality of potential influences. A set of prescriptions that form a logic is generated from institutional orders that are in “mutually dependent, yet contradictory relationships” (Friedland and Alford, 1991, p. 241). Friedland and Alford first identified central institutions of contemporary Western societies as capitalism, family, bureaucratic state, democracy and Christianity (p. 249). Using DiMaggio and Powell’s term, these institutional orders are different sources of rationality. Thornton and colleagues later expanded the list as “ideal types” to include market and profession, among others. Ideal types can also be derived specifically for a particular phenomenon being studied, such as aesthetic vs. efficiency logics in architecture, and editorial vs. market logics in higher-education publishing (Thornton, 2004; Thornton, Ocasio and Lounsbury, 2012).

It can be seen that the central institutions listed above can operate simultaneously in any field, such as state logic (public health provision) and market logic (private hospitals) in health care. Such multiplicity gives rise to the institutional complexity to which organisations respond (Greenwood et al., 2011). Table 3-1overleaf shows an example of competing ideal types of institutional logics in architecture (abridged from Thornton and Ocasio, 2008, pp. 128–129).

Table 3-1 Ideal types of institutional logics in architecture (Source: Abridged from Thornton and Ocasio (2008, p. 128-129))

Characteristic	Aesthetic logic	Efficiency logic
Economic system	Personal capitalism	Managerial capitalism
Sources of identity	Architect as artist-entrepreneur	Architect as engineer-manager
Sources of legitimacy	Reputation of architect Aesthetics of design	Scale and scope of firm Efficiency and economics of design
Basis of mission	Build personal reputation Build prestige of firm	Build multidisciplinary firm Build market position of firm
Basis of attention	Resolve design problems and entrepreneurial challenges	Resolve technological and organisational challenges
Basis of strategy	Increase prestige of patron of government sponsor Win design competitions	Increase number of corporate clients Build recurring clientele Increase markets for services

Institutional prescriptions above also pertain to ends and means. They have a hold on "our process of classifying and recognizing" (Douglas, 1986, p. 3). Logics "provide the formal and informal rules of action, interaction, and interpretation that guide and constrain decision makers" (Thornton and Ocasio, 1999, p. 804). To put this in DiMaggio and Powell's (1983) discussion of fields, one can say that the field tends to be more accommodating for more powerful actors such that logics supported by these actors become dominant. Interactions of logics have generated a vibrant area of research that helps improve our understanding of institutional change (Thornton, 2004), together with the generation of new taken-for-granted practices both by powerful actors (Kitchener, 2002) and challengers (Hensmans, 2003). A large number of studies since also show various ways in which competing logics can coexist for a long period of time (Lounsbury, 2007; Marquis and Lounsbury, 2007; Reay and Hinings, 2005) or blend into a hybrid (Glynn and Lounsbury, 2005).

Although the interaction of logics *per se* is not directly relevant to this study, it is worth noting that the opposition between institutional orders is "not between rational and irrational, but between different transrational orders" (Friedland and Alford, 1991, p. 235). This also shows how institutional complexity is defined first as a function of the plurality of logics (Greenwood et al., 2011) rather than the multiplicity of constituents, although the two frequently go hand in hand. While it is possible to speak of complexity in relation to fragmented and uncoordinated constituents, it is important to remain aware that the complexity does not arise by default out of sheer numbers but rather through the actors' embeddedness in different institutional orders and societal spheres. The contestation is then less about replacing a rational structure "out there" in the environment with an irrational one, or vice versa. Rather, it has more to do with competing interests guided by different sources of rationality constructed by members of the institutional field themselves.

Sources of legitimacy and diversity of responses. As fields mature, they are more likely to be heterogeneous than homogeneous (Wooten and Hoffman, 2008). The most relevant implication from multiple logics to this study is the corresponding multiplicity of legitimacy referents. Table 3-1 shows that sources of legitimacy vary according to specific underpinning logics. Sources of legitimacy provide "a sense of order and ontological security" (Thornton and Ocasio, 2008, p. 108) to how actors behave in an institutional field.

Of particular interest here is the issue of competing stakeholder expectations in a fragmented field and the resulting responses by organisations. Fragmentation refers to "the number and distribution of organizations or social actors a focal organization is dependent upon" for legitimacy and resources (Meyer, Scott and Strang, 1987, p. 187). This suggests a situation in which there exists a diffuse audience group comprising uncoordinated constituents representing diverse logics. Influences on organisations are therefore many, and often contradictory. Along this line, organisations may be "legitimated by *multiple* mythologies" (Kraatz and Block, 2008, p. 44 emphasis in original). It is possible for actors to interpret and use the contradictions and ambiguity to their advantage. This way, behaviour is not driven by a mere existence or multiplicity of logics, it requires the consideration of identities and interests of those responding (Glynn, 2008; Kraatz and Block, 2008). By implication on the field level, since institutional stakeholders can subscribe to different logics and handle them in their own ways (albeit up to a limit), uniformed acceptance might be convenient but it is not necessarily required for a new logic to emerge (Lok, 2010).

The appearance of “conformity” changes, as there exist many legitimating referents to which, or some of which, one can respond. Organisations may communicate their commitment to a universally worthy value such as environmental sustainability (Bansal and Clelland, 2004). Otherwise it is possible that organisations can evade mainstream pressure as long as there is an audience big enough to grant a meaningful level of legitimacy. The popularity of alternative schools provides an example of selective conformity (Quirke, 2013). In other cases, organisations may be less readily able to pick a ready-to-wear model, such that they have to house different legitimated elements in a hybrid form (Battilana and Dorado, 2010; Pache and Santos, 2013). Even when the field is not as fragmented, the dominant source of legitimacy can also change over time. Using the social constructionist view of market value, Zajac and Westphal (2004) demonstrated that a company’s market value would increase upon adoption of a repurchase plan. This is despite the policy’s lack of attractiveness before the shift of logic, and also a decreasing rate of implementation after adoption, which indicates a lack of substantial effect.

Contradictions between what counts as legitimate according to different logics can also be used to advance one’s interest. Legitimating accounts using institutionalised vocabularies are possible in this context. Actors can draw from a repertoire of contradictory narratives generated from intersecting logical orientations different from one’s own to justify wrongdoing, for example (McPherson and Sauder, 2013). In a “rhetorical strategy” (Suddaby and Greenwood, 2005), one may selectively naturalise some contradictions and discredit others to steer the legitimacy definition towards one’s own agenda.

3.2 Strategic responses to institutional processes

So far, legitimacy responses have been discussed in terms of how elements of institutional logics and demands are reflected in an organisation’s structure. In this section, the emphasis shifts to specific constituents on whom organisations depend for resources, hence their significance to legitimacy (Durand and Jourdan, 2012; Pfeffer and Salancik, 1978; Raaijmakers et al., 2015). Constituents bestow legitimacy upon organisations, allowing freedom that is required for them to pursue activities as they see fit (Deephouse and Suchman, 2008). As with any social judgement, legitimacy, "like beauty, it resides in the eye of the beholder" (Ashforth and Gibbs, 1990, p. 177).

Repertoire of strategic responses. The greater prominence of a specific audience resembles the resource dependence theory, which entails a more exchange-specific, resource-driven, active choice behaviour in a task environment (Pfeffer and Salancik, 1978). In this view, organisations do not just conform through a logic of confidence and good faith as theorised by Meyer and Rowan, as responses can be calculative, manipulative and even deceptive in masking non-compliance with window dressing (Elsbach and Sutton, 1992; MacLean and Behnam, 2010). An institutional view, in comparison, expresses self-interest through conformity-led, socially driven, non-choice behaviour in an institutional environment (Oliver, 1991).

The value of a resource dependence perspective to Oliver's (1991) theorising of responses to institutional processes is in the potential to demonstrate the value of noncompliance and identify a range of tactics due to its level of specificity. Oliver delineates five strategies available for organisations to deploy.

- *Acquiescence*, or conformity, can take the form of blind adherence to taken-for-granted rules (*habit*), mimetic isomorphism (*imitation*) with more successful organisations, and conscious obedience (*compliance*) to institutional requirements such as legitimated organisational structure.
- *Compromise* is particularly likely in presence of institutional demands that limit the possibility of perfect conformity. Organisations may *balance* between competing interests, *pacify* as they partially conform to certain expectations, or *bargain* to reduce the extent of compliance.
- *Avoidance* can be achieved by *concealment* of nonconformity by way of elaborate procedures and window dressing as a disguise, *buffering* by reducing the necessity of inspection and scrutiny, or *escaping* by exiting the domain in which unwanted institutional pressure is exerted altogether.

- *Defiance* is a more active and overt form of resistance. This strategy may involve *dismissing* (ignoring) or *challenging* institutionalised rules and norms, whereas *attacking* is the most aggressive tactic of defiance.
- *Manipulation* denotes the highest level of resistance, as it involves a “purposeful and opportunistic attempt to co-opt, influence or control institutional pressures and evaluations” (Oliver, 1991, p. 157). This includes *co-opting* the sources of pressure, *influencing* public perceptions and *controlling* or dominating constituents who exerted demands themselves.

Oliver (1991, p. 160) also identified predictors of organisational resistance, referred to on a scale from low to high. The antecedents include: whether the conformity will result in social or economic fitness, how much the focal organisation is dependent on demand constituents, whether there are multiple institutional demands, whether the pressure is consistent with organisational goals, whether the pressure undermines organisational discretion, whether the pressure is legally enforced or voluntary, and how uncertain and interconnected the institutional context is.

It should be noted here that constraints of institutional fields are not taken into account, and neither are the social spheres in which an audience is embedded. Furthermore, the model is based primarily on a singular institutional pressure, which should be appreciated as it facilitates the incorporation of a resource dependence approach. Nonetheless, care should be taken not to treat legitimacy as something that is contingent solely on material exchanges and manipulation. Doing so “creates the serious risk of oversimplifying legitimacy into a matter of marketing and effective presentation rather than approaching it as a complex process of socially constructing reality” (Neilsen and Rao, 1987, p. 525).

3.3 Analytical framework: Modes of knowledge production as prescribed frames of means and ends

From the previous chapter, one of the biggest empirical challenges of Mode 2 was that the five features that form a mode were not necessarily coherent to begin with. Hessels and Van Lente (2008) also concluded upon their landmark literature review that Mode 2 should be disbanded, and each individual feature studied separately. The analytical framework for this research is slightly different from their suggestion. Complete disbanding is likely to improve the descriptive validity, which is central to the purpose of Hessel and Van Lente's review. This approach, however, does not account for Mode 2's intuitive appeal, especially in contrast to its technical inaccuracy. Despite cautions and criticisms, Mode 2 looked as if it could become a ready-made account of how to produce relevant knowledge, given its alignment with contemporary institutional demands (Weingart, 1997). This highlights the role of Mode 2 as a legitimating feature of the science-society contract (Etzkowitz and Leydesdorff, 2000; Nowotny, Scott and Gibbons, 2001; Shinn, 2002) rather than the technical description that it was designed to be.

In this study, Mode 1 and Mode 2 are treated as two distinct sets of means-ends associations, prescribed according to the institutional rules (cf. Meyer and Rowan, 1977). The word "prescribed" is significant, as it frees us from assuming Mode 2's empirical validity whilst allowing us to acknowledge its intent. This framework, for its circumvention of upfront validity assumption, is different from an institutional logics perspective although both consist of means and ends. Components of a given institutional logic have to be demonstrably rooted in a societal order (Thornton, Ocasio and Lounsbury, 2012). Although Mode 1/Mode 2 have previously been treated as logics (Swan et al., 2010), it is my view that there is not sufficient empirical ground to do so. Framing Mode 1/Mode 2 as logics is potentially incompatible with existing studies in which logics are assumed to be taken-for-granted reality. Rather, the focus is on Mode 2's role as a communication device, and its attractiveness to demand constituents in the field.

3.3.1 Socially constructed interpretive schemes

Although institutional pressures ostensibly have to do with effectiveness, rational myths "often specify extensive webs of causality, identifying some methodologies as 'science' and others as 'quackery' regardless of isolated outcomes" (Suchman, 1995, p. 580). The connection of consequential effectiveness and procedural legitimacy as means and ends is also present in "interpretive schemes" (Greenwood and Hinings, 1988; Hinings and Greenwood, 1987; Ranson, Hinings and Greenwood, 1980) which:

> contain beliefs and values about three principal and constraining vectors of activity: (1) the appropriate *domain* of operations, i.e. the broad nature of an organization's *raison d'être*; (2) beliefs and values about appropriate *principles* of organizing; and (3) appropriate *criteria* that should be used for evaluating organizational performance. (Greenwood and Hinings, 1988, p. 295)

In essence, the three components above form "a set of ideas, beliefs and values that shape prevailing conceptions of what an organization should be doing, of how it should be doing it and how it should be judged" (Greenwood and Hinings, 1988, p. 295). Each of the three is subject to some degree of institutional legitimation, where the range of available options varies in different sectors. Organisations are "driven to incorporate the practices and procedures defined by prevailing rationalized concepts of organizational work and institutionalized in society" (Meyer and Rowan, 1977, p. 340). There is not much restriction for a commercial enterprise in its choice of how it operates, as long as, for example, the business is not funded by the sales of narcotics. Its typical performance definition, however, is strictly economic. The reverse is to be expected for a public sector organisation. Whereas stronger ethical and normative pressure applies to its structure and operations, performance definition is much less specific and frequently subject to further negotiation (Hinings and Greenwood, 1987).

As an intersubjective creation (Ranson, Hinings and Greenwood, 1980), the social construction of interpretive schemes is instrumental in preserving shared understanding. Social actors commonly understand what constitutes the goal of an organisational field, and the appropriate organising principles to be employed in the pursuit (Borum, 2004). With continued interpretation and adoption, the scheme can be institutionalised as taken-for-granted assumptions (see Powell, 1991).

The three parts of the interpretive scheme provide a structure to how Mode 1/Mode 2 attributes are organised into an analytical framework.

Ends. The ends, to which knowledge production means are directed, constitute positive quality judgement by a mode-specific quality control audience. This corresponds to performance criteria, or how success is defined from the perspective of legitimacy.

Means. The means by which the ends can be achieved consist of four other attributes of knowledge production. They correspond to the organising principles in the interpretive scheme, suggesting an appropriate working context, disciplinary structure, a range of participants and the orientation towards society.

Raison d'être. The issue of domain of operations/*raison d'être* warrants further discussion. While they are treated as synonymous in the definition outlined earlier, they have been operationalised on two different bases. A sector-oriented definition based on "tasks and environments" (Hinings and Greenwood, 1987, p. 54) aligns with "domain of operations". A value-oriented definition based on "purposive values and interests" (Ranson, Hinings and Greenwood, 1980, p. 5), on the other hand, is closer to *raison d'être*. The latter definition is adopted in this research. This notion has not been specifically explicated as a Mode 2 attribute, thus giving an opportunity to account for a sense of purpose and institutional influences.

The generic *raison d'être* for Mode 1 is interpreted as advancing science for science's sake. In Mode 2, it is to produce knowledge that is relevant to practical problems. These purposes are modified slightly in the research framework to acknowledge academic entrepreneurship as a phenomenon of interest. For the purpose of this research, Mode 1 *raison d'être* more specifically has to do with basic science, and Mode 2 with exploitable knowledge.

Arguably, "context of application" may indeed qualify as the domain of operations, but only in the absence of collective institutional forces that characterise a "sector" (Hinings and Greenwood, 1987) closely resembling an organisational field (DiMaggio and Powell, 1983). This seemingly subtle difference is conceptually significant. As an attribute, the context is framed as an operational starting point aimed at mode-specific outcomes. Posing research questions in an academic context leads to Mode 1 knowledge, whereas doing so in an application context leads to a Mode 2 impact on a wider audience. Hence linkage between the "domain", conduct and success measures from Gibbons' formulation is task-oriented. The lack of provision for institutional environments from this attribute renders it ill-fitted to the assumption of interpretive schemes and, by extension, ill-fitted to stand alone as an underpinning in the analytical framework.

Another issue is whether *raison d'être,* instead of performance criteria, should be considered as ends. The answer depends on the perspective taken. In this research, legitimacy is audience-dependent. Thus, the intended outcome that supposedly flows from the organising means is that a relevant constituent is satisfied. This way, it has more to do with how success is defined according to a quality control audience rather than why a given entity exists or what overarching purpose it serves. The explication of basic science vs. exploitable knowledge, on the other hand, better captures the rationale of knowledge production and provides a better fit for the term *raison d'être*.

The interpretive scheme is applied independently of both Mode 1 and Mode 2, resulting in a two-part framework, with each part pertaining to a modified rendition of one mode. The analytical framework is depicted in Figure 3-1 below.

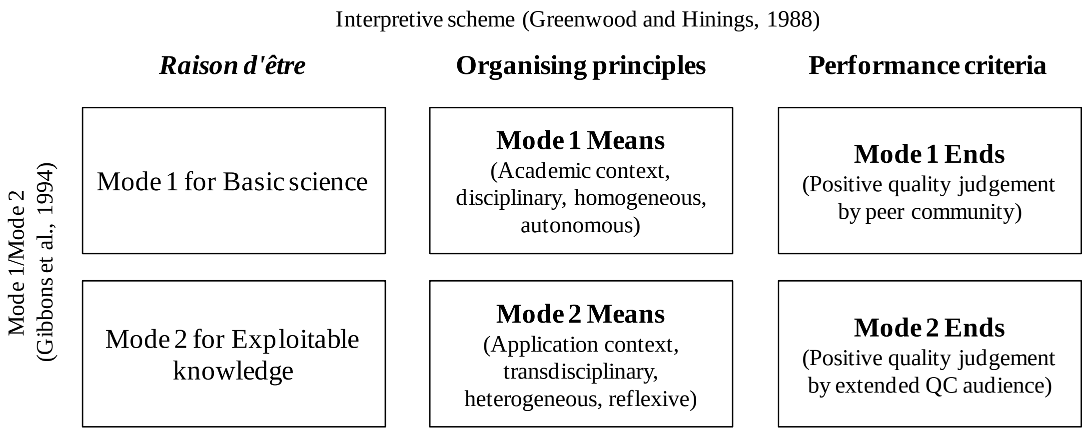

Figure 3-1 Analytical framework

3.4 Research design overview

This study consists of two sequential phases of qualitative analysis, as the results emerging from the first phase informed the second. The first phase was an exploratory study conducted with academic founders of university spinouts. The second phase set out from the respondents' reference to spinouts as a vehicle to increase research impact, addressing economic and practical considerations on the basis of being scientifically sound. The function of spinouts is therefore in line with Mode 1 and Mode 2 quality control regimes that consist of constituents such as the peer review community, businesses and technology users. It is the consideration of institutional level referents that led the study into the context of policy. To do so, I examine the accounts made on behalf of UK academic science as a sector in response to demands for improved value of publicly funded scientific research.

Figure 3-2 summarises the sequence of steps and actions taken in both phases of this study. More detailed explanations of the research design, data collection and data analysis can be found below and in specific empirical chapters.

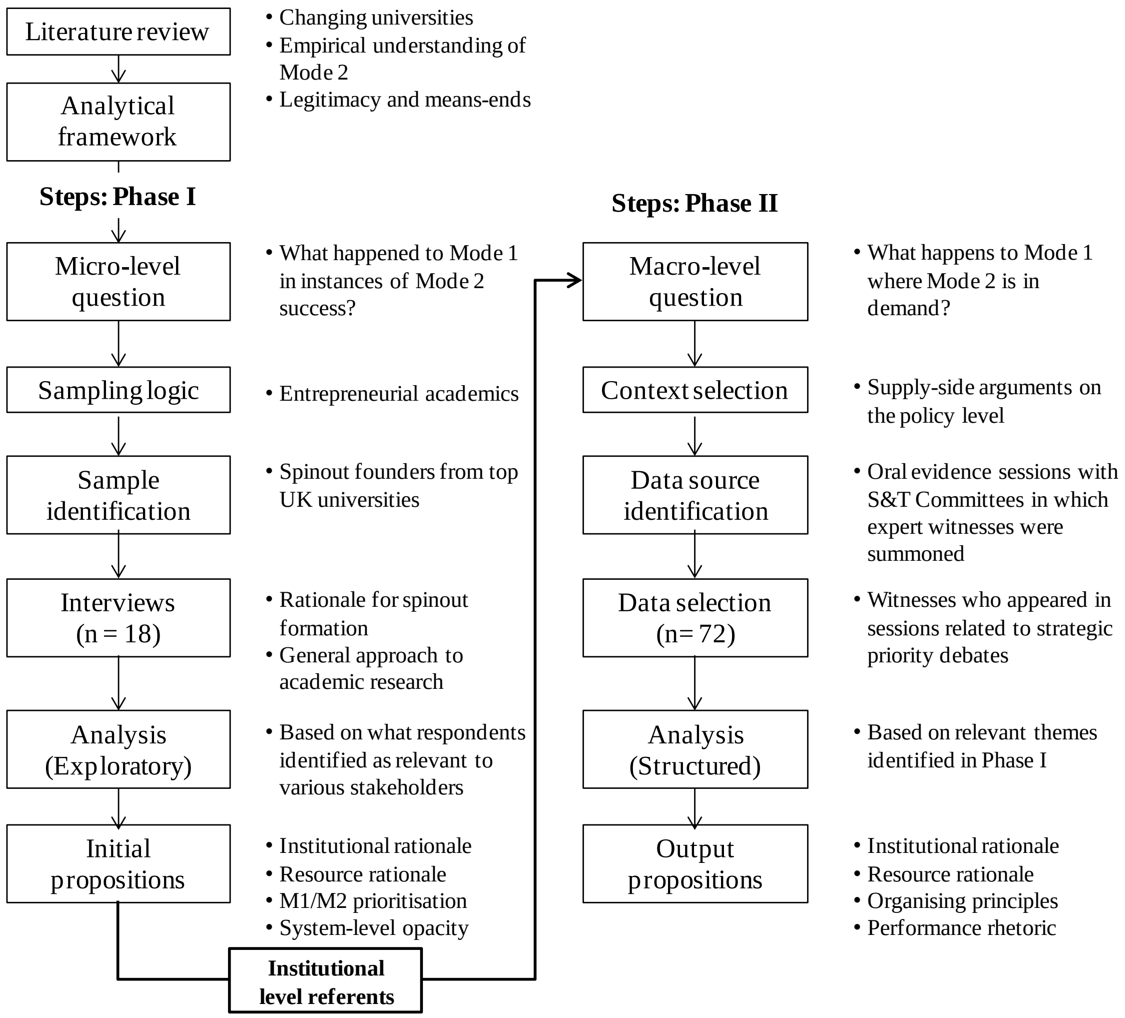

Figure 3-2 Research process overview

3.4.1 Phase I: Legitimation of university spinouts by academic founders

Phase I contains a micro-level analysis of interviews with academic founders of university spinouts, with the guiding question of: *What happened to Mode 1 in instances of Mode 2 success?* It should be noted that this is slightly different from the question identified earlier from the review of Mode 2 empirical understandings, which asks what happens to Mode 1 *where Mode 2 is in demand*, indicating a much broader phenomenon of interest.

For a highly exploratory study such as this, a narrow starting point is for the purpose of attaining a high degree of theoretical control over the sampling logic and the subsequent interpretations of findings. This specificity here aimed to give the results a strong footing on which further investigation(s) could be designed in a theoretically sound manner.

From Chapter 2, after having examined empirical studies and critiques on Mode 2, I identified the legitimating context as an essential factor contributing to a given form of knowledge production being accepted. The legitimating context, in turn, indicated the conceptual relevance of legitimacy, which has been the focus of this chapter so far. The combination of legitimacy as a central concept and the number of indications from Mode 2 critiques and academic entrepreneurship was the main input for decisions on the level of analysis and sampling logic.

Level of analysis. The micro-level starting point came from the consideration of legitimacy against a potential mismatch between institutional and epistemic change (Townley, 2002; Weingart, 1997). To recap, the narrative of institutional change, demonstrated at the structural level as a response to societal demands, often ignores the tenacity of epistemic orientation of individual actors. Policy initiatives (Bozeman, 2000) and the resulting proliferation of TTOs (Friedman and Silberman, 2003; Markman et al., 2005a) have not entailed a similar shift among academics (Lam, 2010, 2011; Shinn and Lamy, 2006).

In the context of institutional theory, universities can decouple technology transfer work (for Mode 2 audiences) from academic work (for Mode 1 audiences) by partitioning them into different organisational departments. Academic scientists, on the other hand, do not have the same option. Each has to do both at the same time. An organisational-level response in technology transfer (Lockett, Wright and Franklin, 2003; O’Shea et al., 2007), therefore, does not appear to be as problematic as the tension between ideals that is experienced by academic scientists (Ambos et al., 2008; Bercovitz and Feldman, 2008; Philpott et al., 2011). Along this line, I identified individual scientists as the principal site of knowledge production, and also the site at which multiple values and demands interact.

Sampling logic. Following from the notion of the legitimating context, in which there exist demands from constituents beyond academia, the idea was to find a Mode 2 phenomenon and trace what contributed to the outcome. To this end, research commercialisation is closest to academia's interface with a Mode 2 audience, as tellingly demonstrated by how "capitalization of knowledge" is highlighted as the third mission (Etzkowitz, 1998). More specifically, I focused on spinout formation as a commercialisation vehicle. University spinouts are often associated with scientific breakthroughs (Van Burg et al., 2008; Feldman, 2000), for which continued involvement of the academic founders (i.e. inventing scientists) is critical (Ndonzuau, Pirnay and Surlemont, 2002; Vohora, Wright and Lockett, 2004). The active willingness to engage in commercialisation, which is considered unconventional in the academic context (Franklin, Wright and Lockett, 2001), indicates the uniqueness of spinout founders in their perspective of multiple demands for scientific knowledge production.

Outcome. The consideration of the outcome was crucial, as Phase I findings directed the design of Phase II. I pursued two lines of inquiry in the interviews: the rationale for spinout formation and the approach to academic research.

The most important implication for the next phase is the level of referents on which the respondents based their accounts of why spinout formation made good sense. Mode 1 (peer review) and Mode 2 (technology users) institutional-level constituents were clearly influential on how spinout formation was rationalised. Spinouts as a vehicle for research impact functioned as a device around which the respondents recounted how they achieved usefulness from scientifically sound research. Interestingly, organisational level referents, e.g. colleagues and university management, did not seem to affect the founders' legitimacy judgement.

In terms of the Mode 1/Mode 2 framework, the quality control audience was highly relevant to legitimating accounts for both spinout formation and scientific research in general. However, its association with the other mode-specific attributes was highly questionable, as the eventual commercialisation outcome did not necessarily come from Mode-2-type research.

3.4.2 Phase II: Supply-side response to prioritisation of publicly funded science

In Phase II, the examination of responses to multiple institutional demands moved to the macro level in policy context. The most important cue taken from Phase I was the institutional level referents the respondents used to justify spinout formation.

Phenomenon of interest. In keeping with the anchor points from Phase I, Phase II also followed the supply-side perspective in addressing institutional level referents of legitimacy. The legitimation content, however, expanded from specific instances of spinout (Mode 2 success) to a more generic notion of satisfying Mode 2 demands through scientific research. Phase II was therefore guided by the main research question, *"What happens to Mode 1 in instances of Mode 2 demand?"*

The focus was on the prioritisation of publicly funded scientific research. In the policy realm, debating strategic priorities is a matter of value to the economy and the public, especially since they contribute significantly to science funding. Given the supply side's interest, this involves appeals to institutional constituents from Mode 1 and especially Mode 2. To this end, prioritisation requires consideration of how competing demands are to be resolved, and what outcomes can reasonably be expected from academic science.

Data source. Strategic priority debates have featured in a number of inquiries launched by Science and Technology Committees working in the House of Commons and the House of Lords. A general definition of select committee is:

> A cross-party group of MPs or Lords who come together to look at a particular subject and make recommendations on how things might be improved. Select committees are established by both the House of Commons and the House of Lords and have powers to summon witnesses and papers as evidence, as part of their inquiries. (House of Commons, 2011)

The main difference between Commons and Lords committees is in their respective focus. Commons committees predominantly "shadow" government departments and scrutinise government policy. Lords committees work with a larger scope, based on subject areas rather than specific government departments, using a wide-ranging expertise of Members of the Lords. For example, the Lords S&T Committee investigates issues relating to "science, health and medicine, food and the environment" (House of Commons, 2011).

Select committees gather two types of evidence – written submissions and oral evidence – to inform on a report published on a given subject. Written responses are submitted upon the committee's call for evidence. They then help the committee shape the inquiry and select witnesses who are called on to answer committee questions in the oral evidence stage (House of Commons, 2014). Transcripts of what was said in oral evidence are made publicly available on a specific committee's website[2] and as appendices in each report published.

In Phase II, I chose to focus on oral evidence for a number of reasons. The selection of witnesses by the committees was purposeful, based on written submissions and known personal expertise. Questions covered in the oral evidence sessions are also selected from written submissions as being of special interest to the committee. Moreover, live question and answer sessions provide instant feedback to responses from the witnesses and add value to the analysis. I analysed transcripts from 27 sessions related to strategic priorities. The sessions involved 72 expert witnesses, most of them from academic and scientific backgrounds, including representatives of research councils and science ministers. Transcripts were taken from the following reports:

- *Research Council Support for Knowledge Transfer* (2006)[3]
- *Putting Science and Engineering at the Heart of Government Policy* (2009)[4]
- *The Impact of Spending Cuts on Science and Scientific Research* (2010)[5]
- *Setting Priorities for Publicly Funded Research* (2010)[6]

Using previously existing data comes with both limitations and advantages. The evidence sessions were conducted in the interest of specific inquiries which are not

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[2]Commons: http://www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/publications/
Lords: http://www.parliament.uk/business/committees/committees-a-z/lords-select/science-and-technology-committee/publications /
[3]House of Commons Science and Technology Committee (2006a, 2006b)
[4]House of Commons Science and Technology Committee (2009a, 2009b)
[5]House of Commons Science and Technology Committee (2010a, 2010b)
[6]House of Lords Science and Technology Committee (2010a, 2010b)

always perfectly aligned with the phenomenon of interest. For example, research councils' support for knowledge transfer involves many issues, many of which are operational, beyond the strategic priorities. Phase I findings proved to be instrumental in giving a theoretically coherent structure for the analysis of Phase II data.

The main advantage of this approach is that it aligns with the study's interest in responses to institutional demand at a macro level. The evidence provided a real-life quality of policy discussions involving difficult-to-access key figures, including chief executives of the research councils, the president and vice-president of the Royal Society, Chair of the Russell Group and the Minister for Science and Innovation, among others. Unlike individual interviews, the sessions were a public forum in which the responses were subject to instant scrutiny by the committee members and, in some cases, fellow witnesses. Moreover, accounts from expert witnesses also informed the committees' recommendations made to the government and therefore have had practical consequences.

Analysis. Phase II analysis was structured according to the themes specified in Phase I as relevant to legitimating accounts, summarised in Figure 3-3 below. Using a guided inductive approach, propositions made at the end of Phase I generated further key questions that were then used to investigate the evidence transcripts. In addition to establishing similarities between Mode 1 and Mode 2 institutional audiences as an anchor connecting the two phases, significant extensions were made to other domains. Output propositions made at the end of Phase II improved the understanding of Mode 1's roles in how academic science, as a sector, responds to economic and practical demands from Mode 2 constituents.

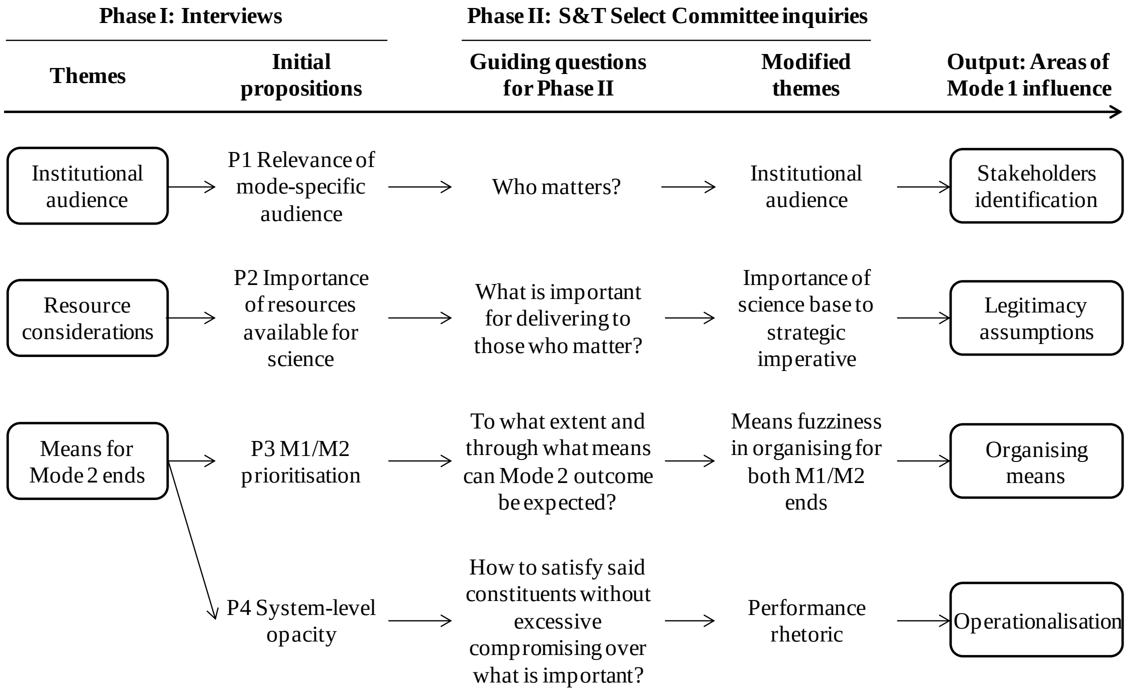

Figure 3-3 Summary of the connection between Phase I and Phase II data analysis

3.4.3 Issues of between-phase compatibility

Compatibility, based on which the two phases "talk to each other", is critical for the coherence of the entire study. In what follows, I justify the connection between phases according to four key elements listed in Table 3-2 (overleaf). The first two conceptual issues – the joining of levels of analysis, and the choice of legitimated subjects – are articulated to help "understand the degree to which ideas overlap or differ" (Suddaby, 2010, p. 352). The latter two elements have more to do with epistemological fit (Heaton, 2004) as the circumstances in which the two sets of data were generated are discussed.

Table 3-2 Issues of between-phase compatibility

Issues	Potential problems	Demonstrated compatibility
Levels of analysis	Data from two levels of analysis not converging on the same phenomenon	Institutional-level audiences as referents for both phases
Subject and content of legitimation	Spinouts (Phase I) and scientific research (Phase II) not comparable as the main subjects of legitimation	Spinouts and scientific research shown to have the same function within the phenomenon of interest Convergence of logic and structure between Phase I and Phase II despite differences in the content of legitimation
Surrounding circumstances	Context-dependent and temporal nature of data	Data from the same institutional context and historical period used for both phases
Construction of secondary data	Researcher's lack of knowledge of the specific circumstances under which data was collected	Phase II data generated publicly, and catered to the interest of a general public audience

Levels of analysis. Mode 1 and Mode 2 quality control regimes provide an anchor for the legitimation accounts made at both the individual and policy levels. Much of the justification, either for commercialisation or basic research, rests on what the respondents (Phase I) and witnesses (Phase II) see as legitimate according to given relevant constituents. From Figure 3-3, establishing the similarity of the answers as to "who matters" underpins the coherence of the study.

Subject and content of legitimation. Though similar in structure, the two phases show some qualitative differences due to the focus of two subjects of legitimation. The main concern of Phase I was why spinout formation made sense in an academic context, whereas Phase II pertained to scientific research in general. The situation warrants further discussion as to whether or not the "function" of the subject in one phase is comparable with another.

The basic idea is that the function of an entity is defined by its output (Morgeson and Hofmann, 1999). In a material sense, both spinout formation and scientific research are subject to expectation for improved practical and economic contributions. When it comes to legitimating accounts, spinout formation and scientific research function similarly as a device around which the processing of competing demands of knowledge production is articulated. Similar to the micro-macro connection above, the convergence of functions also rests on the legitimacy referents being on an institutional level.

The internal working of how each subject is legitimated, however, differs slightly, as summarised in Figure 3-4. The first difference is the specificity and the starting point of a legitimating account. Spinout founders recounted a specific incidence that occurred in the past. In comparison, expert witnesses discussed scientific research in various capacities in terms of its value to society. The two situations converge in the references made to a similar range of audiences, but the content appears in different forms. Phase I contains the spinout founders' *ex post* rationalisation of company formation, which is nominally unconventional in an academic context. Phase II, on the other hand, contains an *ex ante* justification of resource commitment from an institutional audience.

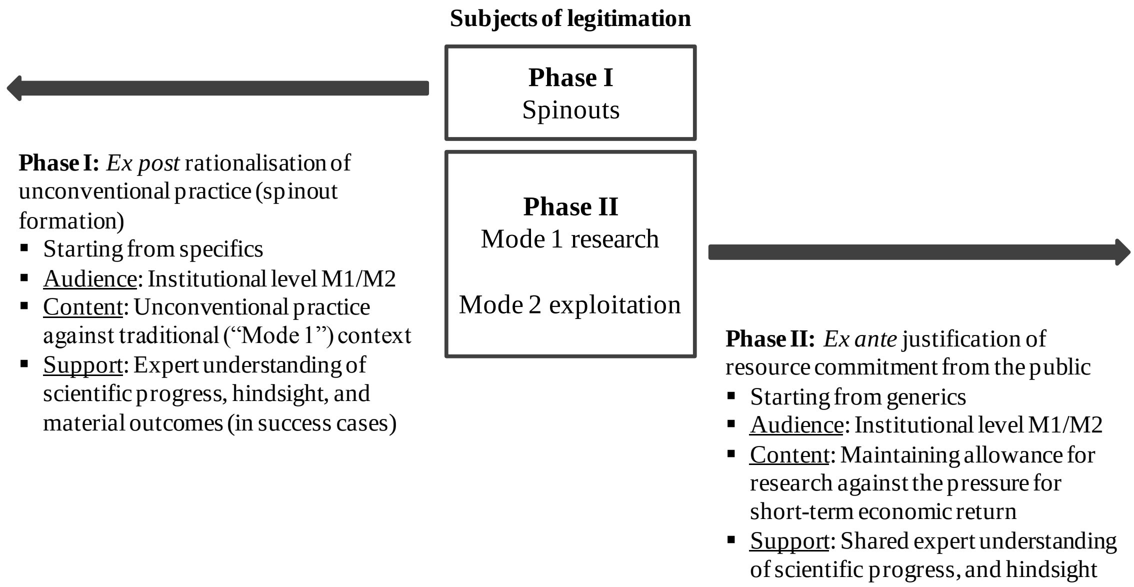

Figure 3-4 Comparison between Phase I and Phase II subjects of legitimation

The combination of generic and case-specific justifications was also influenced by the specificity of a subject and the legitimation content. To demonstrate the legitimate place of spinouts in academic science, the founders used specific consequences of the spinouts to substantiate relatively generic notions of the science-society relationship. For example, the notion of commercialisation and industrial collaboration being conducive to further scientific work, that patients benefit from university research faster through spinouts, and the various ways in which commercialisation contributes to regional development can be specifically attributed to spinout formation, and notably regardless of financial success. The same goes for the founders' ability to maintain a scientific standard which could be demonstrated by, for example, Research Excellence Framework entry.

The situation looked different in Phase II, as the witnesses were discussing more generic issues of academic science's value to society in a less-than-favourable economic climate. The significance of this in juxtaposition with Phase I was that since a large portion of the witnesses spoke on behalf of academic scientists in general, spinouts or other economic vehicles had limited applicability. Not all scientists in all disciplines would find it equally feasible to commercialise and demonstrate tangible, short-term value for tax money. The challenge in Phase II is the creativity that is required to convince the audience, largely in the absence of classical indicators such as commercialisation outcomes.

In both phases, expert understanding of scientific progress was instrumental in how the arguments were made. They converge on the characterisation of scientific research as imperfectly predictable, path dependent and untradeable. The use of these assumptions is particularly important in Phase II, in which cases had to be made for the public to continue supporting academic science even where the outcome is uncertain, in the senses of both "if" and "when".

Surrounding circumstances. Phase I and Phase II data came from the same institutional context, i.e., the UK. This is a very important point to make, given the key role of institutional constituents. While it is true that scientific research is highly international, it is likely that institutional demands vary by national contexts. The UK, US and France, for example, differ in their stances towards basic/applied research, and models of support for academic entrepreneurship (Mowery et al., 2001; Mustar and Wright, 2010; Wright et al., 2007). Data for both phases should therefore be drawn from the same context to make sure the nature of demands to which academic science responds remain comparable throughout.

Another consideration is time. Phenomena tend to be temporal, i.e. they can change over time (George and Jones, 2000; Sandberg, 2005). This is supported by the increased attention to academic entrepreneurship in recent years (Bozeman, Fay and Slade, 2013; O'Shea, Chugh and Allen, 2008; Rothaermel, Agung and Jiang, 2007). In this study, I tried to make sure that Phase I and Phase II were contemporary to one another. According to a historical analysis from 1970 to 2008 by Lockett, Wright and Wild (2012), the expansion of universities' "third mission" to incorporate economic and wider social interests took place from 2004 onwards. Both the spinout formation from Phase I and the evidence sessions from Phase II fall into this period.

Construction of secondary data. The epistemological question of how a set of existing data, i.e. oral evidence transcripts, was generated has important implications on the fit of such data with the study and, consequently, whether its use is warranted. The most relevant issue to be highlighted here is the problem of "not having been there" (Heaton, 2004, p. 60), which is common for researchers who reuse field data collected by other researchers. It is problematic because where qualitative researchers try to understand a specific phenomenon from the perspective of the people being studied, they immerse themselves in the research context, data and its relationship to theories (Miles, Huberman and Saldana, 2014). Reusing the data collected for another phenomenon of interest raises the question of whether the assumptions used in the original design can be fully accounted for by other researchers trying to answer a different question. Where data is collected in a specific interpersonal situation such as interviews, contextual and relational knowledge of such circumstances can be a cause for concern (Kvale and Brinkmann, 2009). The difficulty is compounded by our knowledge that exhaustive documentation of all implicit assumptions and tacit understanding is uncommon, if not practically impossible (Hammersley, 1997).

The use of oral evidence transcripts in Phase II is not fully subject to either of the questions. Regarding the change of phenomenon of interest, the issue of strategic priorities was already present in each of the inquiries selected for this study. I took care to select only the evidence sessions in which the strategic priorities featured as a relevant concern to preserve the S&T committees' intention in the examination of witnesses. Only after the selection did I interrogate the data based on the propositions made from Phase I. The issue of the interviewer-interviewee relationship is also not problematic, as the evidence sessions were conducted publicly in the interest of a general public audience. This is evidenced by the fact that the proceedings are carried live by webcast (www.parliamentlive.tv), attended by representatives of the press and are fully transcribed and disclosed (House of Commons, 2014). The public character of “data collection” by the select committees provides transparency that is typically difficult to attain when interviews are conducted in private.

3.4.4 Considerations for validity, reliability and generalisability

Validity and reliability are fundamentally important for any piece of research to withstand scrutiny, whereas generalisability aids the contribution to theory. For such a simple statement, there exists variety across different paradigms over the interpretations of validity, reliability and generalisability, and how they can be achieved (Hammersley, 2007).

On the surface, the three terms that together make a hallmark of research quality has a decidedly positivistic tone, resting on the assumption that it is possible to arrive at a reality that is external and independent to observers. Validity pertains to the findings instead of the measurement techniques (Hammersley, 2008), as it indicates that the findings are true (accurately representing the phenomenon of interest) and certain (backed by evidence) (Schwandt, 1997, p. 168). Based on this, the research must be replicable for any researcher to arrive at the same truth for it to be reliable. The minimal role of contextual variation, explained as residual error, means that the results are systematically generalisable to other domains. Yin’s (2009, p. 40) “tests” along four quality criteria comprising construct validity, internal validity, external validity and reliability, provide a good example of this perspective.

A constructionist assumption, e.g. this study’s view of legitimacy as socially constructed, renders a literal adoption of the above criteria problematic. As the external truth is not assumed, “there are no permanent, unvarying criteria for establishing whether knowledge can be regarded as true” (Blaikie, 2007, p. 23). For example, rationalised myths (Meyer and Rowan, 1977) are taken as a product of social interactions (Zucker, 1977), bounded by a given institutional field (DiMaggio and

Powell, 1983) and subject to further social process and change over time (Zajac and Westphal, 2004). The perceived nature of reality and the central importance of context mean that the criteria given above can be misleading and unnecessarily restrictive.

Precisely for the lack of template, however, the issues of validity, reliability and generalisability are perhaps even more important to constructionist research. Even if or especially because it is socially constructed, knowledge is located in a discipline that is nonetheless “highly systematic in its formulation” (Astley, 1985, p. 499). It is crucial that subjective meanings and interpretations can be communicated with precision and clarity (Suddaby, 2010). Keeping this in mind, I aim to demonstrate the study’s “believability” by way of “transparency” (Easterby-Smith, Thorpe and Jackson, 2008, p. 97). Transparency enables senses to be made by both researchers and audiences as to how and why the phenomenon of interest is interpreted in a certain way, what the role of theory is, and where the research overlaps with or differs from other situations.

Whereas some scholars have proposed alternative criteria, such as confirmability, credibility, transferability and dependability (Lincoln and Guba, 1985) for qualitative research, I opt to keep the well known labels of validity, reliability and generalisability for the sake of communicability. Essential to this is the caveat that the criteria are kept simple for them to be sufficiently flexible. Hammersley (2007) also similarly advises that quality criteria are to be taken as contingent guidelines rather than hard-and-fast rules. As guidelines, Easterby-Smith et al. (2008, p. 109) provide three generic questions on research quality from three different viewpoints, including constructionist. In what follows, I identify how the decisions taken in the research design and data analysis correspond to each of the points raised.

Validity. *Does the study clearly gain access to the experiences of those in the research setting?*

This question of whether the informants were “right” for the research question was the main concern of how Phase I was designed. As discussed earlier, the sampling of spinout founders followed a careful consultation with the extant literature. Based on the differences of how universities and individual scientists respond to the demand for improved economic outputs, I concluded that the fate of Mode 1 in this scenario should be better explained by scientists as the producers of knowledge rather than by their organisations. Furthermore, I limit the sampling scope strictly to spinout founders from high-performing research universities because of their uniqueness in the knowledge of the interface between Mode 1 and Mode 2 quality control regimes. As I decided to further the inquiry on a policy level, Phase II data came from expert witnesses who were summoned by the select committees for their knowledge and positions of influence on the subject.

The choice of informants and the contexts of data collection also had some bearing on what could be claimed as findings and how interpretations could be made. The data collected almost exclusively pertained to rationalisation (Phase I/II) and communication to the "publics" (Phase II). In other words, this study's interest is in what is said and how it is said, rather than the "real" practice in everyday lives. The caveat is for the readers not to take the supply side's "assumption" as objective reality. For example, the expert witnesses' claim that scientific research is causally ambiguous is not automatically taken as true. Instead, the value is in its role in substantiating specific arguments they would go on to make.

Since I have mentioned the term "convergence" a number of times, a note should be made here regarding triangulation as an approach to demonstrate validity (Denzin, 1970; Webb et al., 1966). I did not follow this approach, as it is also underpinned by the assumption of singular external reality which, in turn, violates the assumption of this study. The similar structures of Phase I and II findings were not a product of triangulation. The only by-design convergence was for Mode 1/Mode 2 audiences to be identified at the institutional, rather than organisational, level. In other words, the design tied the *ends* of the two phases together without necessarily forcing the *means*. Phase II findings were a result of guided induction, in which the guiding questions generated from Phase I were asked of Phase II. No assumption was made upfront as to whether or how such questions would be answered by Phase II data. Instead of showing that the findings were objectively true, the convergence simply demonstrated the intersubjectively shared assumptions on the supply side when confronted by multiple demands in the field. The analysis of Phase II data in relation to Phase I is to be discussed in more detail in Chapter 5.

Reliability. *Is there transparency about how sense was made from the raw data?*

Reliability is more commonly taken as whether or not a study can be replicated for the same results (Yin, 2009). The assumption is based, again, on the idea of external reality. For the research that involves a range of contextual factors and is intricately linked with a theoretical lens, the replication-based test is rather problematic. Under such conditions, it is generally advised that researchers should be transparent with the process, making sure that it is logical, traceable and documented (Lincoln and Guba, 1985).

Transparency plays an important role in research design and operationalisation. I started by clearly defining the phenomenon of interest, and relate to the extant literature for the audience to be able to follow the rationale. The same applies to the design, for which I present logical steps informing sampling, data collection and analysis. The role of the theoretical lens is instrumental in demonstrating why these steps are logical. Finally, I made sure to present the data clearly. I provide the data structure for the audience to see the connection between the organisation of findings and data analysis. I also provide a table of illustrative quotes to demonstrate how the data was coded.

Generalisability. *Do the concepts and constructs derived from this study have any relevance to other settings?*

Whether or not one is seeking an objective truth, the notion of generalisability is useful to envision a given study's place in the wider body of knowledge, although it comes in different flavours across paradigms. Especially for constructionists, careful consideration of generalisability helps prevent researchers from "confusing (own) conceptualisation with the laws of the universe" (Berger and Luckmann, 1966, p. 208). In this case, generalisability has to do with providing the grounds on which it is possible to establish the elements and the degree of similarity between cases to which the results are to be transferred (Lincoln and Guba, 1985). The precision and clarity with which this is done facilitates the "joining of the conversation" (Huff, 2002) as the findings are communicated to peers and a wider audience.

In this study, the generalisability of empirical findings is to be discussed jointly with the limitations of the research. In doing so, I present in section 7.3 a range of contextual factors that may preclude the same findings from being obtained elsewhere. Theoretical generalisability is also covered in Chapter 6 in the form of antecedents to a specific from of response to institutional demands.

4 EMPIRICAL STUDY PHASE I: LEGITIMATION OF UNIVERSITY SPINOUTS BY ACADEMIC FOUNDERS

4.1 Methods

4.1.1 Research context and sampling logic

The selection of research context and, consequently, the sampling logic are critically important to the study's conceptual fit with the main research question, along with how empirical findings can be analysed and how the study relates to the wider institutional context.

Following from my interest in examining the existence of Mode 1 features in a Mode 2-leaning phenomenon, I started by looking for a research context that would correspond as closely as possible to the conceptual framework discussed earlier. The basic idea was to maximise the possibility of finding tensions between Mode 1 and Mode 2 principles, or responding to both Mode 1 and Mode 2 constituents. The domain that contains a similar tension is academic entrepreneurship, due to its focus on universities and academics pursuing commercial activities that arise predominantly from academic research (Rothaermel, Agung and Jiang, 2007). Research commercialisation by licensing, patenting and company formation is believed to be a crucial vehicle of university technology transfer (Nelson, 2001). It allows universities to fulfil their third mission of economic development and improves societal well-being in addition to the missions of teaching and research (Etzkowitz et al., 2000; Lockett, Wright and Wild, 2012). Despite the supposed clash between academic and entrepreneurial ideals, the legitimacy of Mode 2 quality (i.e. directed to "the publics") is well established in policymaking, and in the academic entrepreneurship literature itself (Clark, 1998; Wright et al., 2007). It is the traditional ideal of "pure" science that has a tendency to impede progress (Philpott et al., 2011; Vohora, Wright and Lockett, 2004).

The nature of tensions between constituents led me to focus first on the positive outcome of university research commercialisation as a positive demonstration of Mode 2 legitimacy in a Mode 1 context. The guiding question is: *What happens to Mode 1 in instances of Mode 2 success?* In what follows, I further discuss decisions made in the design of this research. The sampling logic comprises four elements, as summarised in Table 4-1 and further discussed below.

Table 4-1 Components of sampling logic

Components	Rationale	Design choice
Generic context	Demonstration of tension between ideals	Research commercialisation
Specific mode of commercialisation	Active willingness and efforts required to commercialise	University spinout formation
Level of analysis	Site of maximum tension between commercial and academic ideals	Individual academic founders of university spinouts
Sampling context	Empirical relationship between research capabilities and commercial outcomes	Universities with superior Mode 1 performance

University spinout formation as a Mode 2 phenomenon. The investigation of what happens in instances of Mode 2 success starts with identifying such instances. For the purpose of this study, I looked to university spinout formation as a Mode 2 phenomenon. There were two main reasons for this approach considering a) spinouts' relationship with stakeholders outside of academia, and b) spinouts' conceptually focused nature compared to other means of research commercialisation.

Universities' relationship with the quality control audience is arguably the most important consideration in research design. Research commercialisation, sometimes spoken of under the banners of academic entrepreneurship or technology transfer, is perhaps the most readily visible component of how universities contribute to economic growth and public well-being (Etzkowitz et al., 2000). The same also applies to the narratives of institutional shift towards the "entrepreneurial norms" (Clark, 1998; Etzkowitz, 1998). In the process of breaking the ivory tower, commercialisation increases the real-world practical usefulness of university research that may otherwise remain unexploited (Haeussler and Colyvas, 2011). The main business of putting research to use *outside* of academia fits with the Mode 2 approach to quality control, as a wider range of stakeholders are now relevant to how science is being perceived and judged (Gibbons et al., 1994; Nowotny, Scott and Gibbons, 2001).

Although commercial activities by academics can take a number of forms, most notably technology licensing, patenting and collaborative research, spinouts are treated as the flagship mode of commercialisation (Lockett, Wright and Franklin, 2003; Wright, Birley and Mosey, 2004). Spinouts are often heralded in the policy area as the exemplar of impact and scientific relevance. Rightly or wrongly, the number of university spinouts is used as an indication of the economic impact made by academic science (Lambert, 2003).

The visibility of spinouts is perhaps connected to their distinct feature – that they are associated with how "breakthroughs" are put to use (Van Burg et al., 2008; Feldman, 2000) – hence the university research receiving greater prominence. Spinout formation is more often a case where the technology in question is in an early stage such as where the investment risk is high but there remains enough market potential if a team, generally involving the academic inventor, continues the development in a commercial setting (Markman, Siegel and Wright, 2008). Nascent breakthroughs carry some connotation regarding the expertise that is, to some extent, exclusively commanded by founding/inventing scientists (Zucker, Darby and Brewer, 1999) and cannot be easily bought or sold through licensing agreements. Spinout formation is therefore the most resource intensive form of commercialisation (Franklin, Wright and Lockett, 2001), requiring administrative, business and legal expertise as well as continued input from academic inventors (Ndonzuau, Pirnay and Surlemont, 2002; Vohora, Wright and Lockett, 2004).

Micro-level sampling of academic founders. Although a large portion of spinout literature attends to the role of universities in spinout creation (Landry, Amara and Rherrad, 2006; Lockett, Wright and Franklin, 2003; O'Shea, Chugh and Allen, 2008), this study focuses on individual academic founders. Central to the micro-level focus is the idea that individual scientists, rather than universities, are likely to be the site containing academic/commercial tensions. At the university level, academic activities can be "insulated" from commercialisation as they are decoupled by way of structuring, either by outsourcing or by establishing a technology transfer office as a separate entity (Sampat, 2006). The same kind of arrangement is not possible for scientists who are responsible for both academic and commercial outputs, hence the higher level of tension at the individual level than the organisational level (Ambos et al., 2008).

In addition to providing a highly theoretically focused sample, targeting spinout founders also has a practical advantage. By definition, the exclusivity of the founders' expertise and resource intensive nature of spinout formation indicates active willingness on the founders' part to engage in commercial activities. This further maximises the possibility of both types of ideals influencing the phenomenon of interest. The same level of confidence may not always be possible in other forms of commercialisation. For example, technology licensing requires a lesser degree of continued commitment, and collaborative research may or may not have resulted from a participating scientist's active initiation.

High-performing research universities. The interest in Mode 1 or, rather, its absence from the institutional shift narratives informs another part of the sampling criteria. After having justified the micro-level focus, the next issue to consider is the sampling context.

I decided to sample from established, high-performing research universities. This was directly influenced by my observations of the literature regarding the relationship between parent organisations (universities), inventing scientists and commercial outcomes. Universities with higher research capabilities, judged by the Mode 1 yardstick, are a good fit with this study from both an empirical and conceptual point of view.

Previous findings, especially in the resource-based stream of academic entrepreneurship literature, generally demonstrate the positive relationships between commercial outcomes and research capabilities, both at the university and individual level (Landry, Amara and Rherrad, 2006; Powers and McDougall, 2005). The positive notion runs somewhat contrary to a number of studies that focus on tensions between academic and commercial ideals, generally informed by the institutional theory. In the latter stream, the reasoning goes that since the conservatism of senior scientists is a hindrance to commercialisation, the hypotheses should be in favour of younger scientists, or those in "mid-range" universities who are more accustomed to entrepreneurial ways (Ambos et al., 2008; Bercovitz and Feldman, 2008; Haeussler and Colyvas, 2011). The results often do not confirm such hypotheses although it is clear from qualitative studies (e.g.

Jong, 2006) that the preceding reasoning is not entirely inaccurate. A conceptual implication is that research capabilities, generally measured in Mode 1 terms, can have a positive impact on overall commercialisation outcomes even though “academic norms” can indeed be at odds with entrepreneurial ideals.

4.1.2 Data collection

Sample identification and access. I identified 25 UK universities using the results of the Research Assessment Exercise (RAE) 2008, from which I considered 24 areas of submission related to science, technology and engineering. In accordance to the sampling logic, the RAE provides the most direct measures of a university’s research performance and capabilities. Unlike composite measures that are generally used to rank universities, this study does not take into account factors such as reputation. Therefore the RAE, concerning itself mainly with research activities, is more appropriate for the purpose.

The full list of selected areas is presented in Appendix A.1 and the list of universities included in this study is in Appendix A.2.

The next step was to identify spinout companies and their academic founders. Since the tension between academic and commercial ideals formed an important part of the study, my intention was to invite participants to speak in a private capacity. Therefore I chose to approach each potential participant directly without any mediation from his/her university.

I used a combination of sources to identify spinout companies that originated from each selected university, as there is no definitive database containing such information. I started from the list of spinouts compiled by the Spinouts UK Survey (http://www.spinoutsuk.co.uk/listings/company-listings). I then cross-checked with each university’s technology transfer office’s (TTO) website in order to determine whether it would be possible to identify the academic founders. It was not at all surprising that the TTO-provided lists were much more selective, as they generally contain successful or presentable companies. I also checked the Spinouts UK list using search engines and, where applicable, spinout company websites. Once I arrived at a preliminary list of academic founders, I searched for their academic profiles on the university websites to

a) obtain contact information, and b) check whether the spinouts were mentioned. The final list of potential participants only contained those who appeared on the company websites and/or explicitly mentioned the spinouts on their university profiles. I looked for specific acknowledgement to keep with the notion of "active willingness" to engage in entrepreneurial activities, which was an important design choice.

In total, invitations were sent directly to 245 academic inventors. Eighteen academic inventors from 12 universities agreed to participate in the research, as summarised in Table 4-2 below. The response rate was approximately 7 per cent. The majority of respondents are professors/emeritus professors, especially from life science disciplines. Three of the associate/assistant professors also co-founded their spinouts with professors based on collaborative projects. The predominance of academics with established, and in many cases outstanding track records based on peer review measures, may have some bearing on the findings. The possible influences of the response profile will later be discussed as a factor that may limit this study's generalisability. Further sample characteristics are presented with the findings in Table 4-3 as a result of data analysis.

Table 4-2 Interview respondents by discipline and academic position

	No. of respondents	
Disciplines	**Professor/Emeritus**	**Associate/Assistant Professor (or equivalent)**
Biosciences/medicine	7	2
Physical sciences	3	1
Computer science/Engineering	3	2

Implications of the resulting sample size. Although the resulting sample size turned out to be small, I chose to proceed with the eighteen participants. There were two alternatives to consider. The first option was to increase the sample size by expanding the sampling criteria, e.g. from other universities or other modes of commercialisation. This option implied an upfront expansion of the phenomenon of interest. The other option, which I followed, was to make further design contingent on the findings of the interviews.

The main reason came from the conceptual boundary that was drawn for the sampling logic – that the phenomenon of interest pertains to the tension between ideals that accompanies Mode 2 instances. Whilst it may be the case that scientists who have licensed their discoveries are also able to comment on such matters, the experiences informing their responses would be qualitatively much different from spinout formation. Likewise, spinout founders from universities with lower-tier research performances may have different relationships to the Mode 1 regime. Both scenarios would fare well in a comparative study but within the scope of the current research question, they could pose limits to analytical clarity. I therefore opted to keep the sampling logic relatively "pure". In this vein, the data's main utility was not to confirm facts, but rather to generate valuable leads that would inform further investigation to contribute to a better understanding of concepts that raised the research question in the first place.

Interviews. Eighteen interviews were conducted between March and December 2013 and each lasted between 40 and 80 minutes. A consequence of individual sampling was that the respondents were geographically dispersed. I managed to meet with seven of the respondents at their respective institutions. The rest of the interviews were conducted by telephone, as the respondents were physically based further away, such as in Scotland and northern parts of England. I initially focused on one line of inquiry, which was the rationale for spinout formation. After having recognised that the responses intertwined to a large extent with the respondents' general approach towards academic research, I formally incorporated the topic into the interview agenda from the eighth interview onwards. The questions therefore evolved as the data collection progressed. All interviews were recorded and transcribed verbatim.

The number of interviews (n=18) is on the small side. As a result, I retained a capacity to approach respondents as unique individuals, despite theoretical similarities that resulted from the sampling logic. I also tried, as much as possible, to obtain background information on each respondent prior to each interview and tailored some of my questions accordingly. My approach shares much in common with elite interviewing (Goldstein, 2002), where interviewees are invited because of their specific accomplishments rather than demographic characteristics or organisational membership.

I therefore focused more on opinions and perspectives than on factual details. As a result, the responses contain elements of both “what is” and “what should be”.

Other data sources were also used where possible, including previous media interviews, spinout company websites, academic CVs and articles published by universities, research councils and news agencies. The connection between the interviews and background details aided understanding of the data and, to some extent, fact checking.

4.1.3 Data analysis

The coding began with two anchor points – Mode 1 and Mode 2 quality control audiences – and built the pool of first order codes around their mentions. Figure 4-1 displays codes used for the analysis of this study. A further list of quotes not featured in the write-up is provided in Appendix B.

The first aggregate category of codes attends to the legitimacy content, i.e. why spinout formation makes sense, and according to whom. I found that the two sets of audiences, in both Mode 1 and Mode 2, played crucial roles in how respondents explained why they formed spinouts. According to the original definitions (Gibbons et al., 1994), a Mode 2 quality control audience is very loosely defined. For this study, I relied on the respondents’ identification of intended beneficiaries, including patients, engineering firms, SMEs, specific regions in the UK and society as a whole. The Mode 1 audience is already clearly defined as the peer review community.

In addition to the two modes of audiences, a few instances of tension with academic colleagues demonstrated who mattered to the respondents’ reasoning and who did not. In general, work colleagues do not influence the interviewees’ moral judgement over what is appropriate and proper in scientific research in the same way that Mode 2 beneficiaries and the Mode 1 peer review community do. Therefore, as long as the analysis concerned Mode 1/Mode 2 ideals and legitimacy judgement, I bypassed the coercive influence of universities as parent organisations.

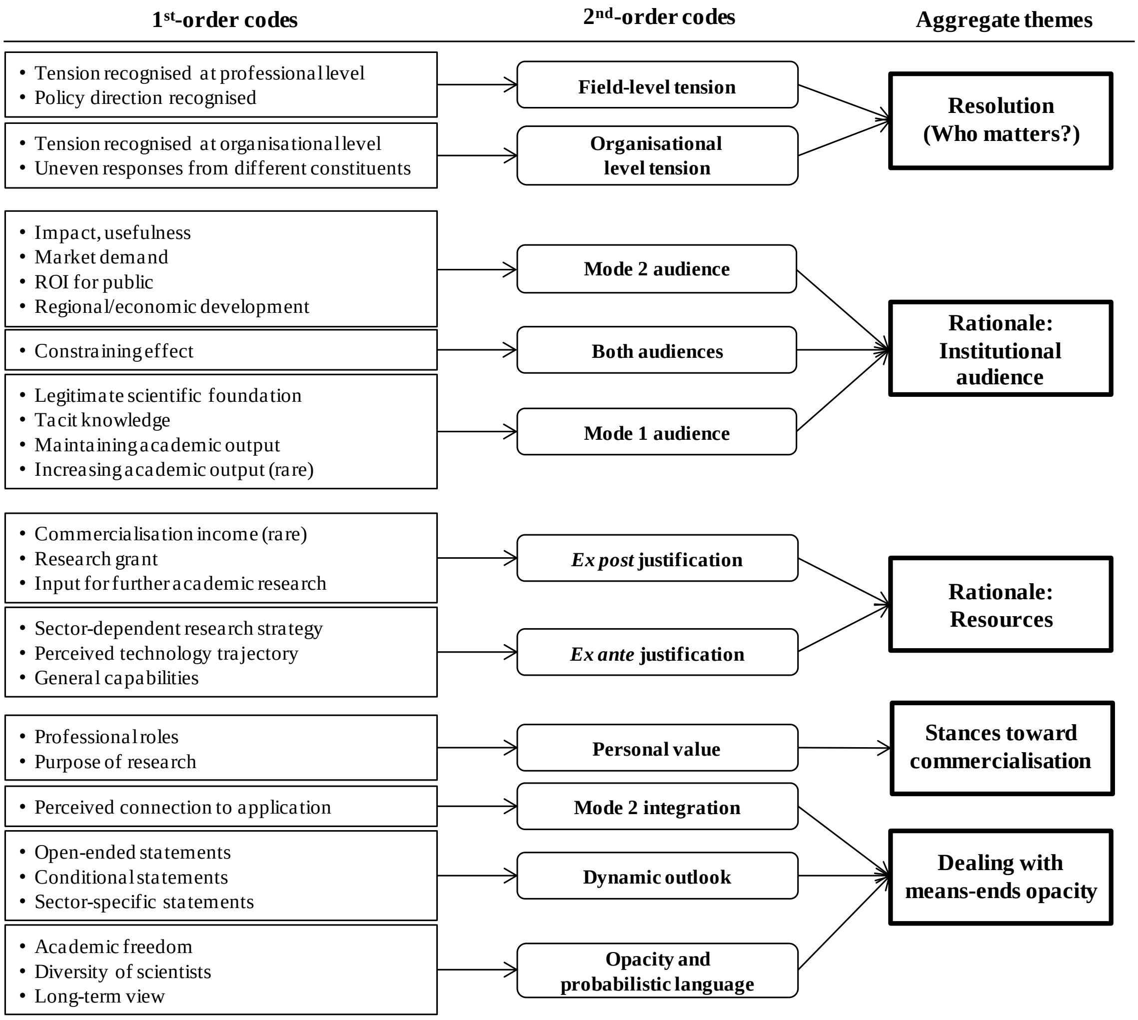

Figure 4-1 Phase I data structure

Bypassing the organisational level of analysis is admittedly very different from a sizeable proportion of academic entrepreneurship research that intentionally seeks to highlight organisational factors by using university-bound cases (Jong, 2006; Rasmussen and Borch, 2010). University-based studies, often from success cases such as MIT, UCSF and Cambridge, tend to demonstrate how entrepreneurial outcomes and attitudes of scientists are influenced by certain organisational factors such as institutional academic orientation, organisational support structure and culture. The difference may be attributable to different sampling logics. University-based sampling allows one to ask, "How do organisational factors impact entrepreneurial decisions by scientists?" Individual sampling of spinout founders, especially where disputes happen, poses a different question – "Why did an entrepreneurial outcome occur in spite of less favourable organisational condition?" – which naturally invites justification based on legitimating accounts. In any case, with or without disputes within the university, spinout founders generally identify with constituencies beyond the physical boundaries of their workplaces as an audience-based reason why their spinouts were justified.

Another series of codes emerged from the language used as respondents talked about how they, as academics, would attend to the quality requirements of two modes. In the context of means-ends, the “means” refers to the respondents’ approaches to scientific research, whereas the “end” refers to commercialisation outcome. I found that the language fell broadly into two variants, reflecting the perceived clarity of means-ends paths. On the one hand, the Mode 2 outcome might be reasonably expected from academic research. On the other hand, such commitment appeared less readily visible, as respondents opted to use conditional modifiers (e.g. research may be commercialised *“if it has the right flavour”*) and open-ended statements suggesting limited predictability of their research. The latter approach does not privilege stable formulations. Instead, it anticipates future changes and uncertainty, allowing open-ended responses to be made according to contextual or situational cues (Peng and Nisbett, 1999; Spencer-Rodgers et al., 2009). It should be noted, though, that the two variants were not coded as mutually exclusive. Some respondents indeed showed more capacity to integrate for the reason being that the context, e.g. being in a specific sector, allowed them to do so. Following from the handling of means-ends opacity, I identified the capacity to handle causal ambiguity as the crucial concern for academic science. This then led to some implications on what the respondents think the collective state of academic science should be.

Table 4-3, displayed on the next page, summarises the respondents’ academic backgrounds and the findings by coding themes.

Table 4-3 Summary of sample characteristics and findings

			Audience identification*		Addressing path ambiguity		System-level perception	
ID	**Field**	**Professor--ship**	**Mode 1 QC**	**Mode 2 QC**	**Dynamic statements**	**Mode 2 integrated**	**Pro-diversity**	**Opacity of Mode 2 success**
R01	Pharmacology	Yes	M	S				
R02	Biophysics	No	M	S	X		X	X
R03	Physics	No	M	S				
R04	Physics	Yes	S	S	X	X	X	X
R05	Neuroscience	Yes	S	S	X			
R06	Plant physiology	Yes	M	S		X		
R07	Medicine	Yes	S	S	X			
R08	Translational medicine	Yes	M	S			X	X
R09	Immunology	Yes	S	S		X	X	X
R10	Biochemistry	No	S	S				
R11	Computer engineering	Yes	S	S	X		X	X
R12	Neuroimmunology	Yes	S	S	X	X	X	
R13	Cognitive science	No	S	S	X		X	X
R14	Energy engineering	Yes	S	S	X	X	X	X
R15	Chemical engineering	No	S	S	X	X	X	X
R16	Chemistry	Yes	S	S	X		X	X
R17	Medical physics	Yes	S	S	X		X	X
R18	Genetics	Yes	S	S		X		

**M = Moderate evidence from the interview*
S = Strong evidence from the interview

Based on the summary table above, a further point should be made regarding the data pattern. The first seven and the last 11 interviews generate visibly different patterns. The identification of the Mode 1 quality control audience, along with system-level perception, appears stronger for the latter group. This is because I initially pursued only one line of inquiry (rationale for spinout formation) for the first seven interviews, as mentioned earlier in the data collection section. The system-level mentions garnered were therefore unprompted. I formally incorporated the emergent second line of inquiry, which was the general approach to academic research, from the eighth interview onward, hence the increased prominence of Mode 1 quality control and system-level opinions.

Therefore, the analysis was not based on the “count” of appearances of certain words or concepts, as the absence of data does not necessarily mean negative data. Instead, I looked for areas of convergence, as well as where the respondents might offer cautionary or opposing views (e.g. that the best science does not technically equal to the best translation) that could act as a counterweight in the analysis.

4.2 Findings

4.2.1 Basis of legitimation

The findings suggest that the rationale for legitimation follows two themes – one based on institutional audiences and another based on resource considerations. The institutional basis involves prosocial narratives addressing both Mode 1 and Mode 2 constituents. In comparison, the delineation between Mode 1 and Mode 2 audiences is much less visible in the resource-focused rationale. Instead, its focus is on potential benefits that will further contribute to research capabilities.

4.2.1.1 Identifying an audience

What counts as legitimate typically depends on whose judgement is being sought. The question of what constitutes the audience is therefore necessary to answer why and how respondents think it is legitimate to form spinouts and commercialise research despite foreseeable criticisms. Before proceeding to the actual content of legitimation, it is important to recognise layers of audiences that are involved in the responses: (i) members of immediate social context, i.e. academic colleagues, university management, university technology transfer offices (TTOs); (ii) academic peer groups, i.e. those who evaluate academic publications; and (iii) society at large, consisting of target users of research output and, in some cases, general population.

Criticisms provide a clue as to what is relevant to the legitimation of spinouts, as negative definition suggests that cognitive legitimacy is in place when questions are absent (Zucker, 1977). From the interviews, doubts and criticisms were more abundant in some places than others, even within a single university.

The struggle of spinout formation reflects the cognitive partition of academic science from other domains of activities. On the one hand, university management appears to be more accepting, probably as a result of policy pressure and perceived potential of capital gain. All of the universities represented in this study have TTOs and encourage research commercialisation. On the other hand, cognitive partitioning can be acutely more divisive when it comes to academic units. Therefore, even if a spinout is formally supported by the university, contestations can still arise out of academic concerns:

> *There was another worry that because we were all senior people, we would abuse our position within the department to feed the company. It did require the dean of medicine summoning a meeting, giving us all roundtable where there was a heated and unpleasant debate but in the end we said to the dean, "Well, look, if you can't sort this out we are going to pull out," and, of course, he stood to lose because he represents the university and if the company is not founded then the potential of that one third the university owns would be lost. (Professor of Medicine)*

Different reactions from different academic facets in a given university can also be the case. Here the respondent from biological sciences formed a spinout with an engineering professor. The extent to which research commercialisation is expected to be a part of an academic life seems to differ between the two areas:

> *I'm located in a very large faculty of biological sciences and 99% of my colleagues are engaged in fundamental curiosity-driven research. And I would say that their reaction to us forming the company was probably quite indifferent. I think the reaction in other parts of the university was more positive. So, for example, in engineering there was a very positive reaction and at the centre of the university, there was a very positive reaction. (Professor of Immunology)*

As far as legitimacy is concerned, the next question points to the ground on which respondents believe that spinout formation is called for. It is particularly important for those who faced strong opposition from within their universities. The same medical professor who had to make a "threat" to the dean reasoned that helping patients by developing new drugs transcended the semantic rigidity of the academic vs. industrial dichotomy:

> *[Medics] are conservative. So, they say, "Well, this is what the industry does, this is what the academia does," and keep the wall. They are primarily driven by their internal values, which is fine but you have to persuade me that my internal values are not necessarily the real values. In the interest of progress, I am going to change the way I think. Interact with whoever is required if that's going to deliver something good for my fellow human beings. (Professor of Medicine)*

In addition to identifying with outside entities, such as patient populations in the previous case, local doubts over the scientific capabilities of academic entrepreneurs can be countered by publications reviewed by peer communities:

> *On the whole, my academic colleagues didn't think it was real science at all and were sceptical and uninterested. They probably thought I was betraying academia. ... The universities have an assessment exercise called REF. I was entered (by the university) on the REF. Not all academics are. So, in that sense, I know that the university values the quality of my publications for its reputation. (Professor of Genetics)*

Instances of scepticism from colleagues show that the respondents were able to cope by identifying with sets of audiences further afield. The two sets of audiences are well in line with the quality control audience identified for the fifth attribute of Mode 1 and Mode 2.

4.2.1.2 Institutional basis of legitimation

The institutional basis is characterised by prosocial narratives. The manner in which the prosocial logic is expressed is related to the audience in question. Legitimation in reference to Mode 2 is active, i.e. that the spinout enhances the welfare of the targeted audience in some way. In comparison, references to Mode 1 are often made passively. The argument is not that science is expected to advance merely by having spinouts. Rather, as spinouts are vehicles to enhance research impact, the idea is that they are not supposed to diminish the science.

Respondents generally expressed that they would like their research “to be used by someone”. This statement reflects the social accountability, which has a strong association to the respondents’ perception of their dependence on public investment in scientific research.

> *I don’t fund any of my own research personally, I ask other people to fund it. So we have some responsibility to ensure that we deliver outcomes which match the funders’ demands or desires. (Professor of Chemistry)*

> *[University should be about] putting back something to society not just taking out of a society. (Professor of Plant Physiology)*

To address the practical demands of the Mode 2 audience, spinouts featured in this study typically find their roots in academic research. Initial research comes in a spectrum from basic to highly applied. The important point is that it must be of good quality and scientifically sound:

> *The spinout acts as a conduit for the research and research by definition, if it’s going to be good research, has to be scientifically novel to get funded. Things come around full circle. (Professor of Physics)*

> *By the time we’d spun out, we had several good quality academic publications as well as the three patent families which had been taken to more and more territories. (Professor of Immunology)*

Fulfilling such a broad intention of putting research to use is not an easy task, as is evidenced elsewhere (Vohora, Wright and Lockett, 2004). To address the Mode 2 quality control audience, respondents had to identify to whom their knowledge would be useful …

> *The unmet medical need was very clear because I’d been already working in this area for 20 to 30 years so I knew where the need was and that was reflected in what the market wanted. (Emeritus Professor, Pharmacology)*

… and justify whether scientifically superior propositions pass the test of practicality:

> *When you go out into the real world, they immediately start tearing you to shreds around, "Well, we just can't make this commercially. Yeah, it might be a great material. It might do everything we want but there's no way I can sell it at that price." (Professor of Chemistry)*

Agreeing with the Mode 2 approach, this is the kind of development in support of which universities by themselves do not have sufficient provision:

> *You can't develop a drug without a company and I think academically they have this pipe dream that they think they can come up with a drug and they can get it to people. (Professor of Neuroimmunology)*

Therefore, it could be argued that to achieve practical use, academic research may have to be taken out of the academic system:

> *Suppose if you did another grant or a public sector consortium, at some stage after that if you wanted it to be useful for health or wealth of the nation, eventually you'd have to develop a drug anyway. So all you'd be doing would be putting off. In the end we decided that at some point, somebody was going to have to try and make genuinely useful progress. (Associate Professor, Biophysics)*

The case for spinout is often justified on the notion that there exists substantial hindrance over the transferability of knowledge. Scientific expertise, demonstrable through Mode 1 credentials, has a role in attempts to achieve Mode 2 quality. Academic inventors have tacit knowledge over their discoveries. Being involved in the commercialisation process helps make sure that the same expertise can be used effectively to solve scientific problems that may occur:

> *The written word has limited power in preserving continuity of any story. It's the storyteller that can add strength to continuity because some of the things that we have in our heads, in our memories, we don't write them down. It's only when we are presented with a situation, ideas come to you and you would say, well, that's the solution to your problem. (Professor of Medicine)*

Another science-centric reason for being involved in a spinout is that inventors are better equipped to learn and utilise the latest scientific advancements:

> *It wouldn't be an easy task because you've established the proof of a concept with a pilot study, which we had 10 years ago, but there's an awful lot of science that's gone into it since that point. [The knowledge base] didn't stop at the time [we] started commercial exploitation. (Emeritus Professor, Medical Physics)*

As a result, these spinouts are able to claim scientific credibility:

> *It's such a small company to have three professors. [This is] not to be interpreted as arrogance, but we are the top of the pile. (Professor of Medicine)*

Academic expertise, however, tends to be narrowly defined, especially for individual academics. The notion of scientific credibility has a constraining effect on spinout activities. Business venturing for business's sake is often not advised:

> *Because of the way we work, if we think there is a better or a more appropriate way of doing it, we direct potential customers onto that. Sometimes that means business. What it does mean for us is maintaining the reputation and that is probably more important because it keeps us credible on the research side. (Professor of Physics)*

The dual roles of scientific expertise – enabling spinout formation and limiting the scope of activities – explain the specialised character of spinouts. They generally focus on core areas of expertise instead of demand-led product diversification:

> *All the venture capitalists, they were saying have you any other ideas for new companies. Although we could have said this method works on any membrane protein, in fact it works on any protein, but we thought it was actually not our expertise. So we kept it focused on the one we thought was the most valuable. (Associate Professor, Biophysics)*

Finally, institutional basis of legitimation also has some bearing on how spinout performance is rationalised. In short, money is not everything. Acknowledging the romanticised connection between advancing science and making millions, a physics professor said:

> *Having a small spinout doesn't have to be generating millions of pounds but it can actually really help when it comes to demonstrating, when you get new research funding, that there is a mechanism that does work and does deliver. (Professor of Physics)*

As is especially the case for respondents who remain full-time academics, financially unsuccessful spinouts are not spoken of as failures as the emphases are placed on what benefits accrued to diversified, extended groups of audiences.

> *None of the companies that I've been closely involved with has been hugely commercially successful. [One of the companies], although it did not make a fortune for its investors, it has created a number of very good jobs in the area and added to the local economy in significant ways. So it's had a significant impact. (Professor of Computer Engineering)*

4.2.1.3 Resource basis of legitimation

The resource rationale highlights the potential gains – both in finance and knowledge/capabilities – that are expected to help advance research in the longer term. Compared to the institutional rationale, the resource narrative makes a much less explicit connection to a specific type of audience. Instead, spinouts are connected to creating and sustaining working conditions in which both Mode 1 and Mode 2 quality can be achieved.

In rare cases, a research centre may earn substantial income from commercialisation activities, as one respondent from a prestigious group stated, *"The income is now three or four times greater than the cost of the lab"*. But such is an exception rather than the norm. A more common case would be that spinouts can be useful for future grant applications:

> *Between the end of 2008 and 2010 we won research grants to the value of about £50 million. And these were major centre fundings. Now I'm not implying that*

> *was all due to the fact that we'd spun out the company. But the fact that we could demonstrate that we could be involved in translational research, that we knew what we were doing, I'm sure played a major part in that. (Professor of Immunology)*

On a larger scale, commercialisation income, along with the economic contribution of university research, is essential for science to continue being resourced:

> *There wouldn't be any money for basic research if the country wasn't economically solvent. If you go bankrupt, you can't do research. So you have to be reasonably well balanced about it. (Associate Professor, Biophysics)*

Financially speaking, costs in certain areas of research can be prohibitive such that spinouts are integrated into the research path as they are intended to bridge stages of research and development:

> *The equipment required for research into next generation lithography systems is so expensive that no one has it, basically. The only people who have it are consortia. So there's something you can do at a university level, there's something you can do in the spinout using facilities worldwide once you've raised a bit of spinout money. And then at some stage you have to go with one of the large multinational companies because the development costs will just increase rapidly beyond what could be funded at a sensible level. (Associate Professor, Chemical Engineering)*

Scientists' beliefs regarding the future of scientific research also indicate the potential utility of spinouts to academic research:

> *I think it's quite useful to distinguish between discovery and invention. Soon we will know all the structures of all the proteins in five or 10 years. So eventually, there will be nothing left to discover. You will only be inventing things. You can invent things forever. That means that the interaction between the academic research and companies will get stronger and the boundary will become more fuzzy. (Associate Professor, Biophysics)*

Generally speaking, spinouts and interactions outside universities seem to have broadened the world views of academics:

> *[The spinout] has made me smarter, wiser, more realistic … various things … generally more educated. (Professor of Chemistry)*

4.2.2 Processing of multiple demands

4.2.2.1 Same ends, different means

Organising approaches leading up to Mode 1 and Mode 2 qualities are found to be more permeable than suggested by the original framework. It appears that as far as the focus is on the attribute of quality control, Mode 1 quality need not necessitate the isolated, or "disinterested", stance that is traditionally attached to academic science. It simply suggests that the quality of research output is approved by a certain peer community. Some respondents pointed out that Mode 2 type industrial engagement does not necessarily render research any less academically valid:

> *It is genuine research even though it is focused on industrial need. It's genuine because we have the freedom and flexibility to think of the ideas of how we are going to do it and provided we can demonstrate some progress, industry is generally very happy to give us that freedom to do it. (Professor of Physics)*

Likewise, a chemistry professor whose research interests lean on the basic side said he could still publish in high-quality academic journals even though his research ideas came from industrial problems:

> *We continue to try to do research which will be publishable in very high quality journals. There are lots of industrial needs that still require very high quality fundamental knowledge. I can get these companies to fund some of that work even though we're doing very fundamental stuff, because it gives them greater insight into how these things work, which ultimately will help them in thinking about how they redesign or optimise their products. (Professor of Chemistry)*

Equally, working from academic rationale need not preclude future commercialisation. A respondent recalled the intention he had for his research:

> *But that [the spinout] wasn't the plan. The plan was only that we should use our knowledge and skill in structure determination on membrane proteins. (Associate Professor, Biophysics)*

4.2.2.2 Stances towards research commercialisation

As "entrepreneurial academics", the respondents show varying levels of certainty over to what extent Mode 2-like quality, i.e. practical usefulness (if not commercialisation itself), can be reasonably expected from their research. Some respondents have a relatively strong preference for applied research aimed at problem solving, which is to be expected under the Mode 2 framework:

> *Science is important to me but engineering's more important because I've been bitten by the bug of problem solving. (Professor of Energy Engineering)*

Earlier, I mentioned an instance in which spinouts can be instrumental in obtaining the level of funding needed for certain types of research. Some respondents recalled their spinouts being reasonably expectable, as the nature or style of their research was not too distant from target users and applications:

> *Myself, I'm probably a translational neuroscientist and I work very closely with a clinician. So, you know, our research is really about finding things that you can translate into patient benefit. (Professor of Neuroimmunology)*

In other cases, anticipating spinouts would be much less of a certainty. Accordingly, respondents frequently speak of such opportunities in a conditional manner:

> *I stop and think, "Is this something that could be exploited?" And more often than not I come to the conclusion that there is not much that you can do about it so you publish it. It hasn't made me an opportunity-seeking animal. (Professor of Medicine)*

Open-ended statements over the future outcome of current research interests could also be the case:

> *My little group works on ions, so there are possibilities that you could [commercialise] in future ... but it's difficult to get ion channel structures, it's difficult to get serotonin. It's a bit early still to do that but then there are possibilities. (Associate Professor, Biophysics)*

A general tendency is that the Mode 2 audience is to be addressed where possible, as long as the capacity to achieve Mode 1 quality can be maintained. This tendency forms a basis of earlier conditional and open-ended statements:

> *The most fundamental motivation [academics] have is to carry out the research in their particular area and find new results and publish things that are of interest to their peer community. And stumbling across things of commercial value is kind of secondary in all of that. (Professor of Computer Engineering)*

In addition to intrinsic motivations, academic-led orientation also has to do with one's academic career:

> *If you're worrying about where your next paper's coming from, then you shouldn't be getting involved in commercialisation. (Professor of Energy Engineering)*

4.2.2.3 Academic founders on "what should be" for academic science

What explains how respondents frame their priority seems to be the value they place on the long-term view of scientific research, which is said to be dwindling in industry. As one respondent suggested, *"It can be difficult to do anything interesting in an industrial environment"*. The freedom to pursue lines of interesting inquiry, albeit up to a certain limit, means that academics do not conform to the immediacy that is required in industry:

> *It is industry's job to do the research that generates the next generation of products. It is not university's job to do that. It's university's job to be thinking*

> *further out and generating new ideas and coupling that into industry wherever there are appropriate connections. (Professor of Computer Engineering)*

Although respondents would be collectively labelled as "entrepreneurial scientists", they seemed to converge on their appreciation of long-term, even "pure" or "blue skies" research as they discussed the collective identity of academic science. The diversity of scientists, comprising *"people who try just about everything"*, is highly valued as being important for both Mode 1 and Mode 2 outputs.

Furthermore, self-professed "applied" respondents appeared to have put considerable emphasis on this point:

> *I think it's very important that our universities now are able to make this sort of applied contributions. But I wouldn't want to reduce us to problem solving factories either, you know. I'm very glad that this university has a lot of pure science departments and isn't just a technical university. (Professor of Energy Engineering)*

> *There has got to be a balance for failure. If it wasn't for that long-term view, we wouldn't be able to do the kinds of things we do. (Professor of Physics)*

A few respondents also pointed out that this idea did not always align with public (mis)understanding of science, suggesting that the Mode 2 audience could sometimes have unrealistic expectations as far as science is concerned:

> *One of the things that's least understood amongst academics, politicians and the general public is quite how long it takes to get from an initial idea through to something that's in the shops. I think that universities provide a place where this kind of long-term development can happen which simply doesn't exist in companies any more. (Associate Professor, Chemical Engineering)*

The idea, it seems, is that universities have a duty both to generate knowledge and, increasingly, to contribute to the well-being of society. However, the verdict as to by how much the latter contribution is possible, is not easy to attain. Following from the findings presented, imperfect predictability that is inherent in scientific progress plays an important role in the respondents' judgement. In essence, they are entrepreneurial academics who also argue for such elements of unpredictability to be preserved, even though they may counteract so-called entrepreneurial ideals. Whilst the idea of "balance" has been mentioned, hard-and-fast rules over what the balance should look like are elusive.

Considering two sides of unwanted consequences – wasting public investment on the one hand and the depletion of knowledge resources as a result of overexploitation on the other – respondents appeared to rely on the diversity and totality of the system. The best possible way, from a scientific point of view, is that scientists should understand that resources for truly fundamental research should be directed to the *"best possible people".* By extension, where a multitude of capabilities, interests and styles are valued, the allowance for socially relevant output should increase:

> *I'm a great believer in those people who have the intellect being allowed to conduct curiosity-driven blue skies research just to increase knowledge. I also think academic research for the majority of academics should be aimed at giving something back to the society that pays for it. I think what has happened certainly in the UK is that all academics seem to believe that they have the right to pursue their own curiosity and pursue blue skies research. However, a high proportion of them probably don't have the necessary intellect to be able to do that well. (Professor of Immunology)*

4.3 Discussion

4.3.1 Agency and the technical character of legitimation

The findings show that spinout formation, a supposed Mode 2 phenomenon, encompasses considerations for both a traditional academic audience (Mode 1) and extended groups of economic audiences (Mode 2). Generally speaking, entities "conform to environments" to gain legitimacy (Suchman, 1995, p. 587). The advice is rendered less straightforward as a result of the agency demonstrated by respondents, and the fusion of technical and social perspectives in the legitimating content. Therefore, the focus here is on the content, rather than the mechanisms, e.g. compliance, avoidance and resistance (see Kraatz and Block, 2008; Oliver, 1991), of the responses by academic founders to multiple institutional demands.

The ease with which one's environment can be identified varies, especially when universities as organisations are compared to individual academics. In the context of academic entrepreneurship, the proliferation of TTOs (Lockett, Wright and Wild, 2012) is a good indication of isomorphism, i.e. the reflection of the institutional environment, in response to societal demands and resource scarcity. Individual academics operate within the same physical environment but have been exposed to a multitude of interpretations as to what constitutes the environment and how best to respond. Entrepreneurial scientists may deal with the resulting unevenness in cognitive legitimacy by substantiating their choices through higher-level legitimating referents external to their universities, such as technology users and peer review communities.

The findings depart from the emphasis on organisational level "social learning" in the academic entrepreneurship literature. Scientists have been found to adjust their attitudes to converge with others in their immediate social settings as they try to eliminate cognitive dissonance (Bercovitz and Feldman, 2008). Differences in findings may be by design. A number of previous studies surveyed a much larger number of scientists of varying entrepreneurial and academic profiles (Ambos et al., 2008; Bercovitz and Feldman, 2008; Haeussler and Colyvas, 2011). In contrast, this study picked a small number of scientists based on a single type of entrepreneurial outcome that reveals variations in working contexts that, in turn, further reveal the agency involved in the legitimation process.

Institutional and resource rationales for spinout formation, however, suggest that these academics are not deviant by any means. The prosocial logic being used is created *within* the remit of scientific authority and the perceived technical reality of academic research. Institutional view shapes the beliefs over what constitutes good science (Mode 1), how science could and should be used (Mode 2) and how to achieve such outcomes. In response to plural demands in both Mode 1 and Mode 2, prosocial claims have to be substantiated by technical elements such that the two are not perfectly separable. Legitimacy of academic scientists is attached to their technical credibility. Although technical content is rarely accounted for in legitimacy research (Deephouse & Suchman, 2008), this study provides an example of a context in which structural arrangements and outward appearance are insufficient for gaining and maintaining legitimacy.

The intertwining of two modes can be seen from the resource explanations, as the focus shifts to maintaining and enhancing the resources and capabilities that are expected to serve *both* Mode 1 and Mode 2 audiences. This idea reinforces the respondents' emphasis on the Mode 1 audience identified in the institutional approach. Not only does it have a ceremonial value in attaining professional credibility, it also has a connection to the material value that will sustain further production and exploitation of knowledge.

An interesting character of the resource rationale is that cases of material gain (research grants and laboratory income) could be substantially more difficult to ascertain *ex ante*. In other words, it would not be wise to make such promises as a reason to form a spinout. However, this does not mean that it is not useful. *Ex post* legitimation can help add to the ammunition available for subsequent institutional legitimation, especially as case studies that are implicitly framed as transferable to other instances of spinout formation. In comparison, reasons made from generic characters of scientific progress (e.g. increasing migration from discovery to invention), are already comprehensible *ex ante*.

Despite the science-based content of legitimation, the approaches covered in this study are not necessarily the best or the most effective. It can only be said that this manner of legitimation is expected to be satisfying for a wide spectrum of audiences, based on the considerations given to society, business and science. A respondent who has been working on promoting translational research explained that scientific excellence would always be invoked in official policy narratives, which resonate with the institutional context. However, such narratives may not always reflect technical reality.

> *I think they will always use the MRC LMB[7] as the example that they would like to put forward. But if you look overall at the data that's been produced, particularly by people like the NIH,[8] they demonstrate really quite clearly that*

[7] Medical Research Council Laboratory of Molecular Biology, Cambridge
[8] National Institutes of Health

> *pouring more money into basic research doesn't really lead to more product benefit in the health care sector. (Professor of Practice)*

Therefore, an important qualification of the findings is that they are not to be interpreted in terms of technical efficacy of outcomes. Rather, the significance is in the freedom or discretion that is allowed for the respondents to pursue their chosen activities, commercial and/or academic, as a result of having satisfied relevant groups of audiences in their specific institutional context.

> ***Initial proposition 1:*** *Based on institutional audiences, academic spinouts can be legitimated by prosocial narratives directed (i) actively at the Mode 2 audience, and (ii) passively at the Mode 1 audience, irrespective of cognitive dissonance at the organisational level.*

> ***Initial proposition 2:*** *Based on resource considerations, academic spinouts can be legitimated (i)* ex post *by references to benefits accrued in favour of long-term research capabilities, and (ii)* ex ante *in relation to perceived nature of scientific research, without necessary delineation between modes of audiences.*

4.3.2 Dealing with Mode 1 and Mode 2

Respondents did not see any hostility between achieving Mode 1 and Mode 2 quality, despite acknowledgement that they could be seen by others as incompatible. For respondents still working as academics, satisfying Mode 2 quality requirements follows a manner in which the maintenance of Mode 1 capacity is privileged.

On the one hand, a connection between academic questions and problems in the context of application is evident. It allows for Mode 2 referents to be included in a research agenda. Examples would be where a respondent's academic interest corresponds to an integral part of industrial application, or where a respondent is part of a multidisciplinary research team whose expected output is defined as embodied technology. In which case, there is sufficient knowledge over what is to be expected to make a coherent formulation of a plan possible (Poole and Van de Ven, 1989; Smith and Lewis, 2011). This approach is similar to how paradoxes and contradictions should be managed according to a number of recent studies in the context of strategy making (Dameron and Torset, 2014) and organisational lives (Lüscher and Lewis, 2008), among others.

On the other hand, much less certainty can be assumed for academic research of a more speculative nature. When this is the case, respondents were found to be using language that implies uncertainty and contextual sensitivity (Peng and Nisbett, 1999; Spencer-Rodgers et al., 2009) in response to Mode 2 demand. The language involves use of conditional modifiers ("if" and "when"), and dynamic, open-ended statements anticipating uncertainty and change. Using such language, the Mode 2 audience is accounted for through contextual cues, as they will be attended to where appropriate conditions to do so exist. In this approach, a stable formulation integrating Mode 2 objectives is not privileged, as dynamics and changes are expected. To some degree, this renders *ex ante* synthesis of solutions problematic.

> ***Initial proposition 3:*** *When addressing Mode 2 quality control audiences, the use of dynamic outlook is connected to the priority of maintaining Mode 1 quality and perception of causal ambiguity.*

From the response, causal ambiguity (Dierickx and Cool, 1989; Reed and DeFillippi, 1990) seems to be an underlying rationale that induces the use of dynamic language. This type of language provides a coping mechanism for dealing with short-term policy demand from long-term, imperfectly predictable research. Therefore, the use of dynamic outlook instead of upfront commitment connects the priority of Mode 1 output and the perception of causal ambiguity to the aspiration of satisfying Mode 2 quality criteria under appropriate conditions.

Causal ambiguity also provides a connection to the responses with regards to academic research at a collective level. However much respondents may claim to be personally "applied", the traditionally forgiving character of academic research that tolerates causally ambiguous payoffs holds tremendous value to them. They emphasise the need for basic research to be done by basic scientists, even if some of them fervently disagree with the principle of academic entrepreneurship. For academics who have had entrepreneurial experiences, their defence of basic research is not in the interest of remaining pure. Instead, the value of tolerance to ambiguity is reflected in their concerns over academia's capacity to generate and accumulate fundamental knowledge to be exploited in the future. Mode 2 is largely silent on this issue.

If it is difficult to demand, or even suggest, how much Mode 2 should be incorporated into scientific knowledge production, the same perplexity carries over to what should be expected out of academic science. Also connected to causal ambiguity, respondents relied on the totality of the system and placed value on diversity of academic scientists, some of whom would produce applications, further fundamental knowledge or both. There is no easy answer as to what the combination of scientists should look like, what academic science should be collectively producing, and by how much.

The most specific suggestion aiming at the healthy rate of Mode 2 performance is to put the best scientists in the Mode 1 arena. Within this condition, from where or how much academic science can deliver Mode 2 results is highly opaque. What this means is that the need to maintain capacity for long-term fundamental research limits academia's collective ability to assess the extent to which and the manner by which Mode 2 quality requirements can be satisfied.

> ***Initial proposition 4:*** *Under the current institutional condition, there necessarily remains a high level of opacity in how to predict the collective ability of academic science to satisfy Mode 2 quality requirements.*

5 EMPIRICAL STUDY PHASE II: SUPPLY-SIDE RESPONSE TO SCIENTIFIC RESEARCH PRIORITISATION

5.1 Methods

In the design overview from Chapter 3, I have discussed the rationale for the investigation in Phase II based on the findings from Phase I. To recap, Phase II pertains to the policy-level narrative from academic science in response to the policy pressure in prioritising scientific research, especially with a view to improving science's value for taxpayers' money. This issue takes the interaction between publicly funded scientific research and society to a broader level on which competing demands are explicitly discussed. For this purpose, I identified oral evidence gathered for selected inquiries by Science and Technology Committees as a data source. In this section, I provide further relevant details on the operational steps taken to collect and analyse the data.

5.1.1 Data collection

Transcripts of oral evidence are provided as appendices in published reports and in the "publications" section of a select committee's website.[9] Transcripts are available from the sessions of 1997 (Commons) and 1995 (Lords) onwards. Given the wide range of agendas covered by the committees in both Houses, the majority of available evidence would not be relevant to this study. I used two criteria to select the data – time of inquiry and content.

Based on Lockett, Wright and Wild's (2012) historical analysis of third stream activities in UK higher education from 1970-2008, in which they identified four distinct periods, my focus was on the latest bracket (2004-2008) and beyond. This period is characterised by the active willingness of both government and the higher education sector to broaden the remit of third stream activities, defined broadly as economic development in addition to teaching and research (Etzkowitz, 1998). Conceptually, it

[9] Commons S&T Committee publications: http://www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/publications/
Lords S&T Committee publications: http://www.parliament.uk/business/committees/committees-a-z/lords-select/science-and-technology-committee/publications /

can be said that from 2004, the institutional field has expanded and become more complex with larger sets of institutional demands being incorporated in the agenda of higher education, particularly scientific research. This is also the same period in which most of the spinouts featured in Phase I were formed. Phase I and II would therefore be temporally comparable, since the informants would relate to experiences drawn from the same period and context.

Content-wise, I read reports and evidence from 2004 onward to see where the issue of strategic priorities featured. It should be emphasised that this topic is not the same as policy discussion in operational support of research commercialisation. Whilst spinouts were the main focus in Phase I, they were not used by respondents to promote academic entrepreneurship. Very little was mentioned of the business, operational or financial side of the story. Instead, spinout formation served as an artefact around which respondents discussed multiple audience groups relevant to their entrepreneurial and academic decisions. Therefore I excluded important large-scale inquiries such as *Bridging the Valley of Death: Improving the Commercialisation of Research*[10], as the requirement to support commercialisation was a given, steering the agenda into structural and operational support, rendering it ill-fitted for this study.

To be congruent with the phenomenon of interest identified in Chapter 3, selected transcripts must have some relation to the incorporation of multiple interest groups from both Mode 1 and Mode 2 spheres. As a result, I identified 27 oral evidence sessions related to strategic priorities. The sessions involved 72 expert witnesses, most of them from academic and scientific backgrounds, including representatives of research councils and science ministers. Selected transcripts were taken from the following reports:

- *Research Council Support for Knowledge Transfer* (2006)[11]
- *Putting Science and Engineering at the Heart of Government Policy* (2009)[12]
- *The Impact of Spending Cuts on Science and Scientific Research* (2010)[13]

[10] Science and Technology Committee, Eighth Report of Session 2012-2013, *Bridging the valley of death: Improving the commercialisation of research*, HC 348
[11] House of Commons Science and Technology Committee (2006a, 2006b)
[12] House of Commons Science and Technology Committee (2009a, 2009b)

- *Setting Priorities for Publicly Funded Research* (2010)[14]

A list of expert witnesses whose responses are analysed in this study is provided in Appendix C. It should be noted that the information on a specific witness's designation and affiliation is correct at the time of the session. Some of the organisations, for example the Technology Strategy Board (TSB), Particle Physics and Astronomy Research Council (PPARC), and Department for Innovation, Universities and Skills (DIUS), have since been renamed or merged with other organisations. This, however, reflects the capacity in which the witnesses were summoned for the examination. Further information on specific oral evidence sessions is available in Appendix D, and sample of evidence transcripts in Appendix E.

5.1.2 Data analysis

Interrogation of data. The guided induction approach involves the use of an *a priori* framework to guide the exploration of data. In this study, the initial propositions generated in Phase I are used for this purpose. To begin with, each of the four initial propositions provided a key question that would be used to interrogate the evidence transcripts. The connection between themes identified in Phase I, key questions they generated and outputs are illustrated in Figure 5-1.

[13] House of Commons Science and Technology Committee (2010a, 2010b)
[14] House of Lords Science and Technology Committee (2010a, 2010b)

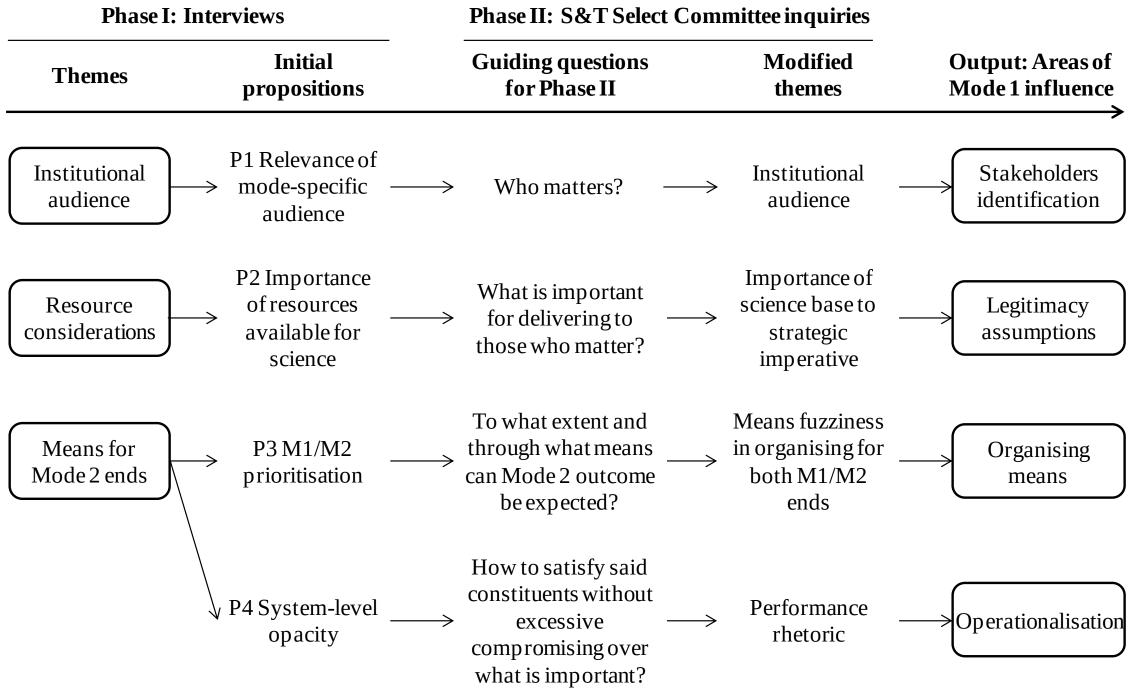

Figure 5-1 Summary of the connection between Phase I and Phase II data analysis

In what follows, I summarise how findings and propositions developed from Phase I provide a structure for data analysis in Phase II. Then I highlight some implications from adopting this approach, especially in relation to analysing interview data from Phase I.

Initial proposition 1: Legitimating audiences in the institutional sphere

> Based on institutional audiences, academic spinouts can be legitimated by prosocial narratives directed (i) actively at the Mode 2 audience, and (ii) passively at the Mode 1 audience, irrespective of cognitive dissonance at the organisational level.

The resulting question is *"Who matters"* when it comes to strategic priority debates. As a connecting point between two phases, the question of what constitutes the audience for scientific knowledge production is a crucial one. The two phases share striking similarities, as spinout founders and expert witnesses point to how the Mode 2 audience – businesses, patients, the economy, among others – can benefit from scientifically sound research that meets Mode 1 peer standards. The refinement eventually made to this proposition is therefore minimal, demonstrating a high degree of convergence which, in turn, provides coherence to this study.

Initial proposition 2: Resources and scientific capabilities

> Based on resource considerations, academic spinouts can be legitimated (i) *ex post* by references to benefits accrued in favour of long-term research capabilities, and (ii) *ex ante* in relation to the perceived nature of scientific research, without necessary delineation between modes of audiences.

The resulting question is: *What is important for delivering to those who matter?* According to Phase I findings, this is where the interests of Mode 1 and Mode 2 quality control audiences are perceived to be intertwined through the fundamental importance of the science base. In Phase II, the maintenance of the science base is framed as a strategic imperative for the overall system of knowledge production. Furthermore, expert witnesses specify some characteristics of knowledge production – causal ambiguity, path dependence and untradeability – as assumptions underlying what should be done for the science base to remain in good health. These assumptions also have important implications on competitiveness. Without the privileged position being preserved, it is reasoned, the system's ability to serve the Mode 2 audience is likely to erode.

Initial proposition 3: Conditions on which Mode 2 demands can be handled – Individual/project level

> When addressing Mode 2 quality control audiences, the use of dynamic outlook is connected to the priority of maintaining Mode 1 quality and perception of causal ambiguity.

The resulting question is: *To what extent and through what means can a Mode 2 outcome be expected?* The important caveat is, of course, that the strategic imperative must not be jeopardised. In Phase I, spinout founders used a dynamic outlook (conditional and open-ended) to express their commitment to social accountability on the condition that the scientific quality of their work would not suffer. The same sentiment, along with the dynamic framing, carries over to Phase II, although the content is broadened to reflect a more generic nature of the inquiries. In this phase, expert witnesses discuss the need to maintain a balance between multiple tasks of knowledge production. In doing so, the elusive nature of "balance" plays a significant role, leading to the means from *both* Mode 1 and Mode 2 being recommended in service of the wider society which, by itself, counts as the Mode 2 audience.

Initial proposition 4: Degree to which Mode 2 demands can be satisfied – System level

> Under the current institutional condition, there necessarily remains a high level of opacity in how to predict the collective ability of academic science to satisfy Mode 2 quality requirements.

The resulting question is: *How to satisfy the audience without excessive compromising over what is important?* There is no denying that demands from societal spheres are relevant, but the challenge is to set realistic expectations while keeping in mind the strategic imperative. How this is done depends a great deal on the assumption of causal ambiguity previously identified from Theme 2. From Phase I, we learned that there is a high level of opacity that impedes our ability to quantify the amount of Mode 2 output to be expected from scientific research as a whole. In Phase II, amendments are recommended to expand both the content and the scope of quality control, forming a basis for performance rhetoric that captures the synergy and co-dependence between quality control regimes in both modes.

The connection between Phases I and II is summarised in greater detail in Table 5-1 (overleaf).

Implications on coding and analysis. Guided induction entails a slightly different approach to coding compared to the previous exploratory phase. Instead of looking for emerging themes or categorising related concepts, Phase II coding aimed mainly at answering the four questions set out in Phase I. Only the first-order codes that contributed to the aim were reported and subsequently grouped into themes corresponding to guiding questions. The data structure is displayed in Figure 5-2.

What this means is that the coding process relied more on the data's relevance to the guiding questions rather than pre-defined keywords or theoretical constructs. Take the question of "who matters" as an example. I started seeking out codes from scratch, without specifying the constituents already identified by spinout founders in Phase I, such as SMEs, patients or one's native region. Following this line of thinking, one might be able to anticipate a general "direction of travel" of the results, even if based on common sense. In principle, however, the results could be different from Phase I owing to the open-ended nature of the guiding questions.

This approach is therefore useful for expanding and refining exploratory insights, and also examining logic from one setting in another comparable context. What should be noted here is that while the two phases agree in this particular research, it does not mean that guided induction is necessarily suitable for triangulation or qualitative theory testing. For triangulation, the sequential interpretation is not technically the same as using multiple data sources, methods, researchers, etc. in answering the same question (Denzin, 1970) that, speaking in this study's language, should be contained in the same phase. For theory testing, the inductive nature of the analysis, even if it is "guided" or "structured", may obscure the clarity needed for the purpose, especially where open-ended questions are used as guidance.

Table 5-1 Connection between Phases I and II

Phase I		Phase II		
Themes	**Phase I propositions**	**Phase II analysis based on Phase I implications**	**Modified themes**	**Output propositions**
Institutional basis of legitimation	P1: Based on institutional audiences, academic spinouts can be legitimated by prosocial narratives directed (i) actively at the Mode 2 audience, and (ii) passively at the Mode 1 audience, irrespective of cognitive dissonance at the organisational level.	Examine whether Phase II data are based upon similar legitimating audiences in Mode 1 and Mode 2, in order to establish the relationship between both phases	**Audience identification** Outcome: Very similar constituents are identified as audiences, suggesting that Phase II policy discussions are founded on the same principles as those of Phase I	**Output P1:** Research exploitation and scientific research aimed broadly at Mode 2 beneficiaries are legitimated by (i) prosocial narratives directed at the Mode 2 audience, and (ii) defence of scientific integrity communicated to the Mode 1 audience.
Resource basis of legitimation	P2: Based on resource considerations, academic spinouts can be legitimated (i) *ex post* by references to benefits accrued in favour of long-term research capabilities, and (ii) *ex ante* in relation to perceived nature of scientific research, without necessary delineation between modes of audiences.	Examine whether or not, and the manner in which, the importance of resource/capabilities are in use	**Strategic imperative of knowledge production** Outcome: Significant extension from Phase I findings, though based on similar ideas, as heavy emphasis is placed on the importance of *sustaining privileged asset position* as the strategic imperative that enables the supply side to answer to both Mode 1 and Mode 2 audiences	**Output P2A:** Scientific research, with or without foreseeable applications, is legitimated for its contribution to the system's maintenance of privileged asset position from which both creation and exploitation of knowledge are expected, hence no evident delineation of mode-specific audiences. **Output P2B:** The supply side's shared perception of (i) causal ambiguity, (ii) limited tradeability of knowledge and (iii) path dependence contributes to the legitimacy assumptions justifying scientific research, with or without foreseeable applications, aimed at the system's maintenance of privileged asset position.

Phase I		Phase II		
Themes	**Phase I propositions**	**Phase II analysis based on Phase I implications**	**Modified themes**	**Output propositions**
Prioritisation of Mode 1 and Mode 2 delivery	P3: When addressing Mode 2 quality control audiences, the use of dynamic outlook is connected to the priority of maintaining Mode 1 quality and perception of causal ambiguity.	Examine the certainty at which and the ways in which Mode 2 outcomes could be delivered to the Mode 2 audience, especially subject to the strategic imperative and its underlying assumptions (i.e. causal ambiguity, limited tradeability and path dependence)	**Organising knowledge production in means-ends opacity** Outcome: Significant extension from the dynamic/integrative handling of Mode 2 quality outcomes, as the fusion of Mode 1 and Mode 2 organising principles (i.e. means) are discussed in relation to the strategic imperative that underlies the system's capacity to deliver to both Mode 1 and Mode 2 audiences	**Output P3A:** Both Mode 1 and Mode 2 quality outcomes can be achieved through multiple combinations of otherwise mode-specific attributes. **Output P3B:** Based on the strategic imperative and legitimacy assumptions, where *ex ante* incorporation of Mode 2 beneficiaries is problematic, open-ended and conditional statements are used to acknowledge possibility of economic and social outcomes being realised.
Academic science's capacity to deliver Mode 2 outcomes	P4: Under the current institutional condition, there necessarily remains a high level of opacity in how to predict the collective ability of academic science to satisfy Mode 2 quality requirements.	Examine the extent to which Mode 2 outcomes could be expected from academic science, subject to the defence of strategic imperative, and opacity of means-ends connections	**Performance rhetoric** Outcome: Significant extension from the previous conception using probabilistic language by Phase I respondents, as Mode 1 and Mode 2 performance definitions are discussed based on how means-ends opacity influences the expectations and articulation of the knowledge production outcomes	**Output P4A:** Based on the strategic imperative and legitimacy assumptions, Mode 1 performance may be maintained by broadening the scope of what constitutes a Mode 2 quality control audience and, consequently, the ways in which an impact can be made. **Output P4B:** Based on the strategic imperative and legitimacy assumptions, Mode 2 performance may be enhanced by broadening the content of what constitutes Mode 1 scientific excellence. **Output P4C:** Based on the strategic imperative the legitimacy assumptions, justifying resource allowance for scientific research involves a combination of *ex post* and *ex ante* articulation of impact towards the Mode 2 audience.

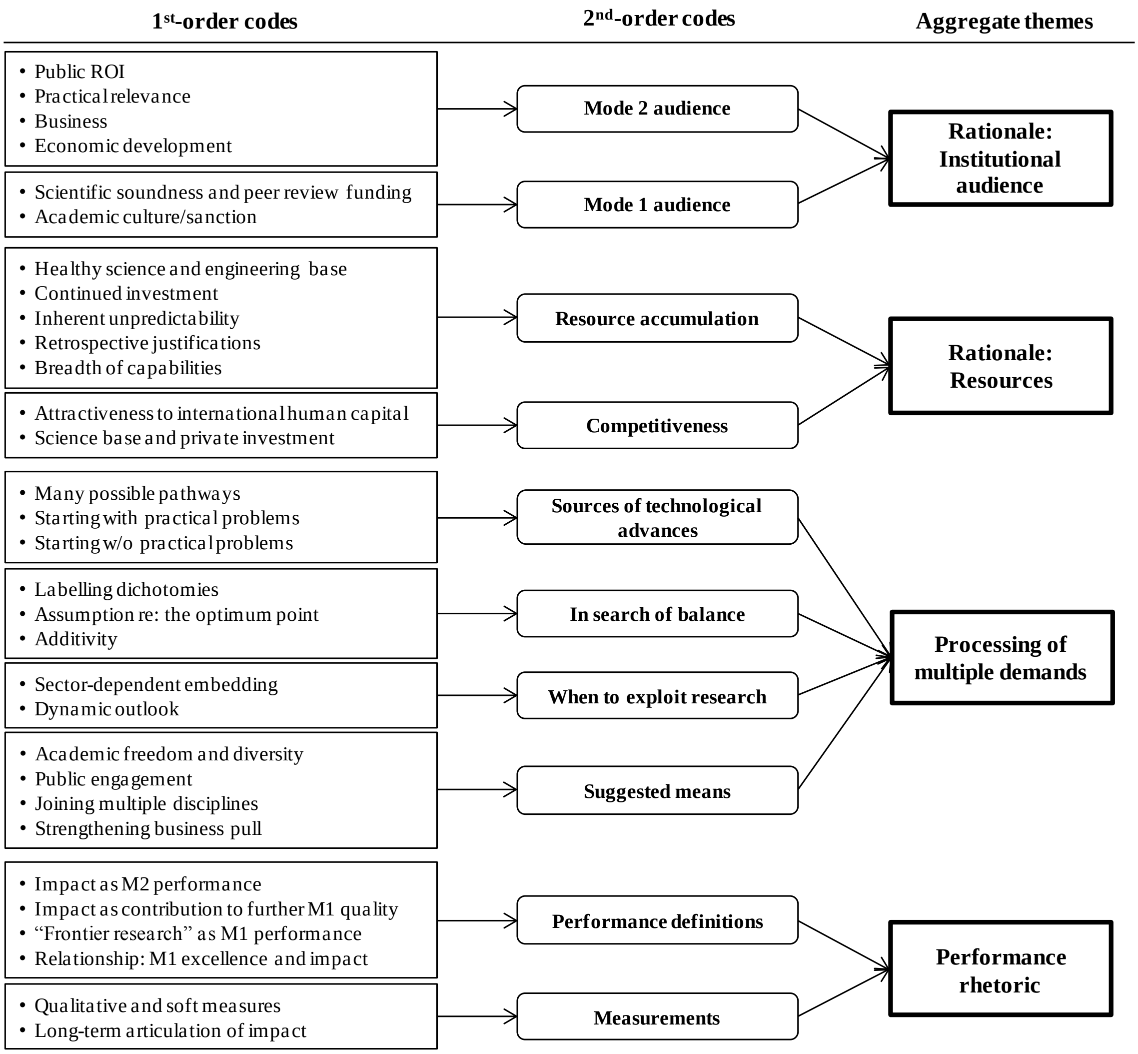

Figure 5-2 Phase II data structure

A list containing examples of extended quotes and exchanges between witnesses and committee members is provided in Appendix G. As the data were not uniformly structured by an interview protocol, illustrated quotes displayed in the findings (next section) are typically a part of a larger set of texts dealing simultaneously with multiple issues. As a reference, extended quotes provide a context surrounding the edited quotes, and show how the witnesses see the connection of different topics and how they draw on their experiences and/or other examples to substantiate the points. Information of this kind has provided value to how sense was made from the data, although the restriction of space and format would preclude much from making its way into the formal presentation.

The issue of frequency. Based on a difference between how interview data and oral evidence were collected, a brief note should be made regarding what is considered "worthy" of reporting as a result of qualitative analysis. In Table 4-3 from Phase I, I provided a list of respondents and their responses on specific points, for example, whether or not a given respondent identified with a Mode 2 audience. Implicit in this way of data presentation is that I was determining whether the respondents converged on the points of interest as a way to substantiate the propositions. This logic does not fully apply to Phase II data due to the circumstances in which the evidence sessions were conducted. To begin with, expert witnesses were not asked the same set of questions in the same way interviewees were. Instead, committee members would pick the most relevant witness(es) based on their background knowledge and/or written submissions. Furthermore, once the committee was satisfied with the answer, the examination would move on to other areas without obtaining more of the same views because of time constraints.

This highly selective nature of questioning might help with the quality of responses, but it also means that tally-based checking as in Phase I was no longer appropriate. Instead, I relied on the reaction of the committee members and fellow witnesses present in the same session and made sure to include in the report where disagreement arose.

5.2 Findings

5.2.1 Legitimating audiences for research exploitation

5.2.1.1 Mode 2

Consideration of a Mode 2 audience is formally acknowledged by universities through a performance management framework that specifies two broad outputs known colloquially as Output 1 and Output 2, denoting scientific excellence and better exploitation outcomes respectively:

> *The first [output] is improving the international excellence of the science that we undertake in the UK; and the second output is improving the exploitation of that science for both the public good, health outcomes, national security and*

> *economic benefits. (Prof Sir Keith O'Nions, Director General of the Research Councils)*[15]

The material rationale of having two outputs has to do with *"the fact that departmental R&D spending has stagnated over the last 10 years".*[16] A specialist in science history, Prof David Edgerton, pointed to *"a certain disillusion with large scale departmental programmes like Concorde and the AGR",*[17] such that there was a feeling that research, which was directly concerned with the well-being of people and the strength of the economy, was not yielding the results that it should. The research councils that had been funding a small proportion of the total government research budget found themselves funding more and, consequently, found themselves being subject to an increasingly diverse range of demands:

> *For that reason there was increased emphasis on trying to justify that kind of research in relation to the broader objectives, so you get <u>a rather odd situation where people are expecting basic science in the universities to translate directly</u> into economic benefits or social quality of life benefits for the British people in the short term. (Prof David Edgerton, Imperial College London)*[18]

The imperative is therefore to understand "*the value of independent research in a world which is always changing"*.[19] The range of constituents that make up a Mode 2 audience covered by the expert witnesses is strikingly similar to that identified previously from Phase I interviews. In sum, the publicly funded research may benefit Mode 2 audiences in the following ways:

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[15] Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 4, Q20)
[16] Mr Nick Dusic, Campaign for Science and Engineering (*Putting Science and Engineering at the Heart of Government Policy*, Ev 33, Q173)
[17] Advanced gas-cooled reactor
[18] Prof David Edgerton, Imperial College London (*Putting Science and Engineering at the Heart of Government Policy*, Ev 33, Q173)
[19] Prof David Fisk, Imperial College London (*Putting Science and Engineering at the Heart of Government Policy*, Ev 15, Q62)

Return on taxpayers' investment. Much like the interview respondents, the witnesses agree that improvements should be made over "*the practical applications of the research that [the research councils are] being funded for".*[20]

> *I think the days are gone when we can just throw £2 to £3 billion into the university sector on the basis that we hope something useful will come out of it. (Prof John Murphy, Chairman, External Challenge Panel)*[21]

The most straightforward response to the question of return on investment is expectedly to point out how much money has been generated, naturally as a result of commercialisation. University spinouts, in particular, can be used to demonstrate the financial returns in a tangible way:

> *Over the last two years, university spinout companies that have entered the stock market, their capitalisation as of February this year was £1 billion. […] That is a huge contribution. (Prof Sir Keith O'Nions, Director General of the Research Councils)*[22]

Whether return on taxpayers' investments has to be demonstrate in monetary terms is a contentious issue, so much so that the form of value for money of publicly funded scientific research is crucial throughout this study. The notion of value for money underpins the debates over strategic priorities such that there is a general consensus that it has to be improved, but not nearly as much on how that value should be achieved.

One of the ways in which scientific research can be of value to taxpayers is through its role in tackling the scientific needs of the nation, which are addressed as "grand challenges" through various programmes such as climate change, food and water security, energy, counter-terrorism and ageing. Ultimately, innovation can be influenced

[20] Prof Diana Green, Vice-Chancellor, Sheffield Hallam University (*Research Council Support for Knowledge Transfer*, Ev 11, Q67)
[21] Prof John Murphy, Chairman, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 18, Q111)
[22] Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 3, Q15)

by science, but the direct trail from universities is not always obvious and the monetary return not always deducible.

> *Science, we believe, has all sorts of benefits that are often underestimated: iPods, cash machines, people even accept too easily the benefits of medical health. (Prof Sir Martin Taylor, the Royal Society)*[23]

Contribution to business. The university-industry linkages (UILs) are perhaps the classical definition of academic science's contribution to, or "impact" on, society. The earlier chapter, which documents discussion with university spinout founders, is dedicated to business creation through scientific research. Here, UILs constitute an important indication that *"business recognises the value of engaging at that early stage in [the] frontier activities and being part of a channel for it to flow through and get taken up".*[24]

From the business perspective, UILs have an important role in helping create technology and new products, especially where such products require scientific input that is prohibitively costly and risky. This could be true for small companies without *"the luxury of separate R&D departments",*[25] as well as firms as large as Rolls Royce:

> *Typically, a new material will take 20 years to go from a sticky black mess in a test tube to something that we can fly around the sky. It is a hugely competitive environment on a global stage and certainly for the first 10 or 15 years of that research you are not sure if there are going to be any benefits. <u>So it is quite hard to convince, in a normal economic cycle, that we should put that level of effort in</u> when it may fail. (Mr Colin Smith, Rolls Royce)*[26]

A similar relationship with universities is also the case for the Ministry of Defence, whose Defence Science and Technology Laboratory (Dstl) also experienced budget

[23] Prof Sir Martin Taylor, the Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)
[24] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 37, Q223)
[25] Prof Christopher Snowden, Vice-Chancellor, University of Surrey (*Research Council Support for Knowledge Transfer*, Ev 14, Q80)
[26] Mr Colin Smith, Rolls Royce (*Setting Priorities for Publicly Funded Research*, 217, Q347)

cuts. Although some of the most effective military equipment originated from long-term research from 20 years ago,[27] the Dstl could not retain within the laboratory "*highly speculative programmes on cyber and space that were not significantly aligned with current military requirements".* Therefore,

> *With MoD R&D spend we cannot do a lot of fundamental work – in fact we do very little fundamental work – so it is crucial to us that we engage with UK academia … (Prof Mark Welland, Ministry of Defence)*[28]

Economic development. The most prominent example of academic science's contribution to the economy is through regional development, especially when it comes to clusters. Spinouts and small companies tend to cluster around academic institutions where world-leading research is being done. The phenomenon also includes the flow of talent of the students graduating from such institutions who move into these companies. Therefore, *"the choice of the areas that basic research is done in dictates an awful lot about how the whole economy works".*[29] The most famous example in the UK is arguably the Greater Cambridge area, which has a combined effect of having world-class universities, science parks and venture capital:

> *[There] are 3,500 hi-tech companies employing 150,000 people, and you will know that the population of Cambridge itself is only just about 100,000, with a commercial worth of about £1 billion. (Prof Sir Keith O'Nions, Director General of the Research Councils)*[30]

The challenge in this area, save for a handful of exemplars, is that, "*While the science base has been strong and getting stronger, our science-based industry has been getting weaker and weaker"*.[31] To put it in simple terms, the remedy requires more success in

[27] Prof Mark Welland, Ministry of Defence (*Setting Priorities for Publicly Funded Research*, 48, Q79)
[28] Prof Mark Welland, Ministry of Defence (*Setting Priorities for Publicly Funded Research*, 47, Q77)
[29] Ms Anne Glover, Amadeus Capital Partners (*Setting Priorities for Publicly Funded Research*, 218, Q356)
[30] Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 4, Q23)
[31] Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 3-4, Q1)

"seeing the translation of that scientific excellence from pure research through to commercial application to drive jobs and growth".[32]

5.2.1.2 Mode 1

Similar to the views expressed in Phase I, there remains an emphasis that the drive for improved exploitation outcomes must not run counter to scientific excellence, however defined by peer review community. The so-called tension between Output 1 and Output 2 often comes to the fore when funding and support, especially by research councils, are discussed against the backdrop of increasing demands for value for money from science investment. Research funding is determined by the peer review process, which is a separate matter from knowledge transfer and research exploitation issues, such that *"you are not going to get anything funded on the back of a good knowledge transfer plan unless the science is great".*[33] To be fair, the science primacy is not solely in the prodigal interest of scientists. Assurance of continued excellence in scientific research is also in the interest of the Select Committee, who expressed worries over the possibility of funds being diverted away from fundamental research. In such a context, the assertion of science primacy is almost rule-like in expression:

> *The primary differentiator is the excellence of the research. That is the primary criterion, always has been and, as far as I am concerned, always will be. (Prof Alan Thorpe, Chair, Research Councils UK)*[34]

Still in the context of funding, the peer review community (the Mode 1 audience) seems to hold the key to the upstream part of knowledge production, as they are granted the authority to decide what science gets done. Thus, "it is not for ministers to tell the scientific community these are [priority] areas".[35] This is the case even in an unfavourable economic condition that involves spending cuts:

[32] Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 81, Q246)
[33] Prof Keith Mason, Chief Executive, PPARC (*Research Council Support for Knowledge Transfer*, Ev 38, Q226)
[34] Prof Alan Thorpe, Chair, Research Councils UK (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 17, Q77)
[35] Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 86, Q272)

> *[Prioritisation] is the role of the academic community, through peer review, through the research councils, under the Haldane Principle, having been asked to think by the government of what these priorities should be, for them to provide that advice. (Rt Hon Lord Drayson, Minister for Science and Innovation)*[36]

Given the discretion that the peer review community has at the upstream of knowledge production, the *"cultural issue amongst the people who are creating the new knowledge"* [37] is perhaps a subtle but more enduring and effective way that requires the legitimacy of Mode 2 quality to be reinforced in the Mode 1 peer review community:

> *One of the risks in driving knowledge transfer too hard in its own right is that within universities or within organisations knowledge transfer is set up as a separate entity on the side of the university and it is not fully integrated with these very special people who have the ability to create the knowledge. (Prof John Murphy, Chairman, External Challenge Panel)*[38]

5.2.1.3 Proposition 1

The identification of legitimating audiences both inside and outside of academia almost mirrors that from Phase I, as they converge on a similar logic. Informants from both phases acknowledge social accountability as positive, as long as scientific soundness is upheld. Looking more specifically at Phase II, despite the expanded context and agenda that now cover a more generic notion of scientific research, it corresponds to Phase I almost point by point. Accounts justifying individual instances of spinout formation and those connecting scientific research to the wider societal context both point to returns on public investment, contribution of technological advances to businesses and economic and regional development.

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[36] Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 86, Q272)
[37] Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 1, Q3)
[38] Prof John Murphy, Chairman, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 20, Q117)

The narrative becomes slightly more restrained compared to Phase I, in which the communication is directed at the Mode 1 audience. Within the context of satisfying the Mode 2 audience, the message focuses on ensuring a Mode 1 quality standard rather than the prospect of improving it. In comparison, a number of interviewees from Phase I were able to recount specific benefits their spinouts had on scientific research. The source of this subtle variation is the differences between spinout formation, being a specific incident occurring in the past and a more generic forward-looking notion of achieving better Mode 2 quality through publicly funded research. It is understandable that the benefits of spinouts to university-based research are readily discernible retrospectively. Much less confidence is warranted for generalising such linkage in the policy context.

> ***Output proposition 1:*** *Research exploitation and scientific research aimed broadly at Mode 2 beneficiaries are legitimated by (i) prosocial narratives directed at the Mode 2 audience, and (ii) defence of scientific integrity communicated to the Mode 1 audience.*

On the one hand, the high level of similarity means there is not much to be added to the previous findings. On the other hand, the similarity serves a more important role of establishing compatibility between the two phases. The interviewees and the expert witnesses, speaking from micro and macro levels respectively, share the same perception of an institutional environment surrounding how scientific knowledge is created and utilised.

The compatibility indicates that the interview findings are likely to be relevant and useful as “leads” in the interrogation of data from a higher level of analysis.

5.2.2 Strategic imperative and legitimacy assumptions

In this section, I present the components of the imperative, along with its implications, that informs the legitimating narrative from the supply side. Addressing Mode 1 and Mode 2 audiences is a matter of strategy. The *“excellence that exists within science and engineering within the United Kingdom is one of [the UK’s] core strengths*”, as it gives "*a competitive advantage against other countries*".[39] The underpinning logic of how academic science can address either Mode 1 or Mode 2 demands is intimately tied to the strategic imperative – that the UK's privileged position in scientific research capabilities must be maintained:

> *We are about one per cent of the world's population but we get something like 14 per cent of the top citations. Fifteen per cent of those that travel the world to do a PhD come to the United Kingdom, and in drug production, of the leading drugs, 25 per cent of them come from Britain. (Prof Sir Martin Taylor, the Royal Society)*[40]

The arguments put forward in the knowledge production debates therefore hinge on the sense of purpose, which dictates what could and should be done with UK's lead in scientific capabilities:

> *... you start off by what you are trying to achieve, and if [it] is a preservation of international competitiveness and the sustainability of the top research universities and institutions, that might drive one to particular conclusions in particular financial circumstances. (Prof Adrian Smith, Director General, Science and Research, BIS)*[41]

For the vision to "*strengthen the UK's position as a hub for global science",*[42] the first consideration is how such an objective can be achieved. The general emphasis on the health of the science and engineering base indicates a need for the pool of scientific resources and capabilities to be maintained, if not enhanced, despite adverse economic conditions. Central to the issue of how the science base develops is its inherent unpredictability, which in turns highlights the state of means-ends opacity and significantly influences the rhetoric that follows.

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[39] Mr Nick Dusic, Campaign for Science and Engineering (*Putting Science and Engineering at the Heart of Government Policy*, Ev 29, Q148)
[40] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 290, Q457)
[41] Prof Adrian Smith, Director General, Science and Research, BIS (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 75-76, Q218)
[42] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 291, Q458)

The strength of the science base, or the signal it gives, has two important self-reinforcing functions. It attracts the most essential ingredient in knowledge production – human capital – which is required for further sustaining and improving the privileged position. The commitment to maintaining the privileged science base also attracts investment decisions, even in the presence of an unknown future, generating more capital gains for the economy.

5.2.2.1 Maintenance of the science and engineering base

Continued investment in scientific research. The issue is especially salient during times of economic downturn, which is the central premise of the reports *The Impact of Spending Cuts on Science and Scientific Research* and *Setting Priorities for Publicly Funded Research.* In this line of argument, investment in science and innovation *"is not an intellectual luxury for a developed country"* but *"an economic and social necessity and an indispensable ingredient of economic success".*[43]

Science is *"one of the best investments, along with education"* that warrant investment for the future, especially in times of recession, in order to *"hit the ground running"* when the economy recovers:[44]

> *And the idea that science has had a good run in the last decade so it is perhaps time to tighten the belt is a mistaken one, because <u>what science needs, leading to engineering, leading to wealth creation</u>, is <u>continuity</u> and delivery of programmes over very long periods of time. (Sir Peter Williams, Vice-President, the Royal Society)*[45]

The economic value of neurosciences and cardiovascular disease, for example, has shown a phenomenal rate of return, amounting to *"the best value thing that Britain ever*

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[43] Rt Hon David Lammy, MP, Minister of State for Higher Education and Intellectual Property, BIS (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 82, Q248) quoting *Higher Ambitions* (BIS, 2009, p. 55)
[44] Sir Peter Williams, Vice-President, Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 5, Q10)
[45] Sir Peter Williams, Vice-President, Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 5, Q8)

does, much more than you would get from a railway or a road",[46] according to the Medical Research Council's analysis:

> *[The analysis] basically allows you to say to the Chancellor of the Exchequer, "Chancellor, you do not invest in anything in this country which will give you a return of 40p in the pound by treasury rules in perpetuity as a result of public investment." (Prof Sir Leszek Borysiewicz, MRC)*[47]

Behind the phenomenal returns is the contribution of basic research to exploitation. Although Output 1 (better research) and Output 2 (better exploitation) were delineated as if they were separable, it is not possible to divert public investment to activities that directly yield foreseeable results:

> *… we need a healthy base before we can get the better exploitation and yet you can immediately see the relevance of that through to better exploitation. (Prof John O'Reilly, Chief Executive, EPSRC)*[48]

Not having a strong science base potentially results in the lack of *"feed-through from the basic research into clinical practice".*[49] In the same vein, there is a reminder of the role of basic research that is overlooked where translational research gets mentioned:

> *Everybody recalls Cooksey*[50] *and talks about translational research. They forget the shortest sentence in the Cooksey Report, [which] actually says that [Britain's excellence] is driven through that basic, biomedical science. (Prof Sir Leszek Borysiewicz, MRC)*[51]

Another example can be found in the space industry which, at the time of the session, seemed to have been unaffected by the recession, as it had been growing at 9 per cent

[46] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 163, Q272)
[47] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 163, Q272)
[48] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 45, Q269)
[49] Dr Tony Peatfield, Director of Corporate Affairs, MRC (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 23, Q126)
[50] A review of UK health research funding by Sir David Cooksey, known as "The Cooksey Review" (Cooksey, 2006)
[51] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 170, Q292)

for approximately a decade. Ten per cent of the global market share meant a potential for 100,000 jobs being created.[52] Expectedly, the main contributing factor to achieving such potential would be the world-leading expertise from the investment *"made to maintain the fundamental science … and make sure that that is translated into success in the economy"*.[53] Lord Drayson, the then Minister for Science and Innovation, cited Surrey Satellites as exemplary in this area:

> *The best example I would give of success in doing this is Surrey Satellites. Out of one of our leading universities, a world lead that we have now in small satellites, Surrey Satellites just having won a major contract for the supply of the Galileo System. 500 million, I think, is the number, half of which will be coming to the UK. (Rt Hon Lord Drayson, Minister for Science and Innovation)*[54]

Still within the context of public spending, there is a concern over the UK's level of investment, that *"we are punching above our weight"*, [55] with a low level of research when compared with other competing countries – 1.8 per cent of GDP for the UK vs. 2.7 per cent for the US. Moreover, the US and also Japan, Germany, India and China initiated stimulus packages for research and development in the midst of recessions: [56]

> *Our research funding system is, by its outputs, a very efficient and a very effective one, but, with a lower proportion of funding going in than our competitors, that position must be fragile. If we wish to hold our position of second in the world […], then I can see a peril over the next two or three years. (Prof Roger Kain, British Academy)*[57]

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[52] Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 86, Q272)
[53] Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 86, Q272)
[54] Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 86, Q272)
[55] Prof Roger Kain, British Academy (*Setting Priorities for Publicly Funded Research*, 207, Q330); Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 289, Q456)
[56] Prof Roger Kain, British Academy (*Setting Priorities for Publicly Funded Research*, 207, Q330)
[57] Prof Roger Kain, British Academy (*Setting Priorities for Publicly Funded Research*, 207, Q330)

Inherent unpredictability of scientific progress. Causal ambiguity is the name of the game. At the heart of the argument for continued investment in scientific research is the general consensus that planning towards certain outcomes is at best problematic, due to the imperfect predictability that is inherent to the enterprise. Over directing is not likely to give the intended results, and poor quality science is a more realistic outcome.[58] The best illustration of scientific advancements was given by Professor Lord John Krebs:

> *I pointed to a very nice study that was described by Sir William Paten a few years ago in his book Man and Mouse in which he looked at <u>10 key advances in cardiovascular medicine</u> and he traced back <u>where those key advances came from</u> and he identified about 600 papers in the literature that led to these key medical developments. <u>Over 40% of them had nothing to do with cardiovascular medicine at all</u> and many of them were not carried out in medical departments or medical faculties; they were carried out in departments of chemistry, engineering, physics, botany, agriculture, zoology, et cetera. (Prof Lord John Krebs, a Member of the House of Lords, University of Oxford)*[59]

On the whole, expert witnesses appeared not to be in favour of prioritising in the upstream part of the research, i.e. *"you do not make choices about the sorts of thing you study",*[60] otherwise researchers *"miss the opportunities that randomly come up".*[61] Therefore, it is not surprising that *"the Foresight activities and other activities to try to pick those areas have been quite unsuccessful in seeing where science will lead us in the future".*[62] It is a common occurrence for a research programme, many of which *"create value for the country",* [63] to pan out in a very different direction from what is originally expected:

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[58] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 280, Q449)
[59] Prof Lord John Krebs, Member of the House of Lords, University of Oxford (*Putting Science and Engineering at the Heart of Government Policy*, Ev 11, Q41)
[60] Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 205, Q326)
[61] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 280, Q449)
[62] Mr Nick Dusic, Campaign for Science and Engineering (*Setting Priorities for Publicly Funded Research*, 208, Q333)
[63] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 280, Q449)

> *I can recall a discussion with Professor Weiss who has received huge amounts of research funding from the Medical Research Council and EPSRC and he has come up with lots of wonderful science, but often that science bore very little resemblance to what he originally bid for. (Dr Paul Nightingale, Science Policy Research Unit)*[64]

Scientists play an important role in coming up with novel ideas for research as *"many of the areas that science will bring for the future are ones that we have not thought about yet".*[65] The only indication that a bet should be placed on a scientific project, including that with a view of eventual application, is how it answers scientific questions at the upstream rather than exploitation demanded at the downstream:

> *If you have something like gravitational waves, what is the exploitation for that? Maybe we will have weightless machines in 50 years' time or 100 years' time, who knows, but we are not going to have that today. […] You should be making the decision dependant solely on the science. (Dr Ian Ritchie, Technology Entrepreneur, Coppertop)*[66]

Retrospective justification. An important consequence of the uncertainty in scientific research is that its material benefits are often only realised retrospectively.

Sir Peter Williams gave an example from the first spinout form the University of Oxford called Oxford Instruments which he managed for 20 years. In 1982, following Sir Peter Mansfield's Nobel Prize winning magnetic resonance imaging (MRI) technology, which itself was an exploitation of Heike Kamerlingh Onnes's discovery of superconductivity in 1911 (Lakrimi et al., 2011), the company introduced to the Hammersmith Hospital the first scanner magnet, which is still scanning patients to this day:

[64] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 280, Q449)
[65] Mr Nick Dusic, Campaign for Science and Engineering (*Setting Priorities for Publicly Funded Research*, 208, Q333)
[66] Dr Ian Ritchie, Technology Entrepreneur, Coppertop (*Research Council Support for Knowledge Transfer*, Ev 30, Q181)

> *Today they are a five billion dollar worldwide industry and we have also, much more importantly, brought nothing less than a revolution in diagnostic medicine. None of that could have been predicted by Kamerlingh Onnes, and I put it to you that little of it could have been predicted in 1982 when we marched confidently into the Hammersmith hospital. (Sir Peter Williams, Vice-President, the Royal Society)*[67]

This of course points to the downside of 40p-for-a-pound return that Sir Leszek mentioned, as *"to get the return, to get the real value into practice, it actually takes 17 years. This is what people really forget."*[68] Not only is a retrospective analysis needed to justify investments in scientific research, it has to stretch back a very long time which could be at least decades or, in case of the MRI, a century.

Breadth of capabilities. The implication of the uncertainty on how to maintain the health of science and engineering is based, at least in principle, on the need for *"a broad portfolio of research because of that necessary need to have an absorptive capacity"* [69] and *"a strong capability across the whole research base"*.[70] Nonetheless, disagreements can arise where different perspectives on economic reality are taken into account, as demonstrated by the following exchange between Lord Broers and Prof Brian Cox:

> *The US economy is six, seven, eight times larger than ours. I would argue that the US is the only country that any more can pursue all branches of science and technology. [Other smaller successful countries] specialise. They bit the bullet and focused. (Lord Broers)*[71]

> *This is a contentious thing to say, […] let us just look at the research that has been done by the experts: "Since a single piece of basic research may contribute*

[67] Sir Peter Williams, Vice-president, Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 4-5, Q8)
[68] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 163, Q272)
[69] Mr Nick Dusic, Campaign for Science and Engineering (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 8, Q32)
[70] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 289, Q456)
[71] Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 8, Q28)

> *to many different technological and product developments, nations need a portfolio based approach to the public funding of basic research." (Prof Brian Cox, University of Manchester, citing a study by Salter and Martin (2001, p. 529))*[72]

Whether to focus on a limited number of areas or to keep a broad portfolio is very much an issue of "picking winners". Generally the issue can be made relatively tractable by distinguishing mechanisms that are needed to support scientific research funded through the research councils, which would follow Prof Cox's logic, and emerging technologies which fall under the remits of the Technology Strategy Board.[73] However, the contention happens where there is a perception that each may take place at the expense of the other:

> *My point to you is should we not be concentrating more on that side of things in this recession rather than in fact spending more on fundamental science? (Mr Phil Willis, Chair, the House of Commons S&T Select Committee)*[74]

It seems the answer has more to do with ability rather than willingness, as Prof Cox replied, *"The thing is, you need to know how to do that. I agree that if you could do it, then it would be a wonderful thing to do"*.[75] Predicting areas of basic research at the front end to translate into economic growth is *"essentially impossible",*[76] such that *"you are not going to do the medical and biological research well if you try to shrink physics or chemistry".*[77] The breadth of excellence is required for dealing with *"new challenges and new industrial opportunities".*[78] Raising the issue of picking winners, even against

[72] Prof Brian Cox, University of Manchester (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 8, Q30)
[73] Mr Nick Dusic, Campaign for Science and Engineering (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 8, Q32)
[74] Mr Phil Willis, Chair, the House of Commons S&T Select Committee (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 4, Q6)
[75] Prof Brian Cox, University of Manchester (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 4, Q6)
[76] Prof Brian Cox, University of Manchester, citing (2001) (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 4, Q6)
[77] Baroness O'Neill of Bengarve, a Member of the House of Lords, British Academy (*Putting Science and Engineering at the Heart of Government Policy*, Ev 20, Q86)
[78] Mr Nick Dusic, Campaign for Science and Engineering (*Putting Science and Engineering at the Heart of Government Policy*, Ev 29, Q148)

the backdrop of a highly organised application-oriented project, is not taken by the expert witnesses as preventing certain disciplines or certain kinds of research from being funded:

> *Something like Living with Environmental Change[79] sounds a very applied focused project but actually there are huge amounts of fundamental research across a multitude of disciplines that feed into it. (Prof Adrian Smith, Director General for Science and Research, DIUS)[80]*

5.2.2.2 Implications on competitiveness

Attraction and retention of human capital. There are three interconnected bases on which the two-way relationship between the strategic imperative and human capital is discussed. First is the consensus (on the supply side) over the person-embedded nature or exclusivity of scientific knowledge, second is the international mobility of scientific researchers and third is the higher education sector being the focal site of activities.

The person-embedded nature of knowledge, being mutually understood, influenced the witnesses' support for *"policies which ensure that that know-how embodied in individuals is recycled within the United Kingdom",* since *"it is not just about the projects; it is about the people".*[81] In the face of uncertainty and demands for research areas to be prioritised, one of the ways in which to manage within such a condition is to allow individual experts to pursue their lines of inquiry as they see fit. Sir Richard Brook spoke of the principle followed by the Leverhulme Trust:

> *It must be the excellence of the competence of the applicant or of the person doing the research which decides the theme to be addressed. The priority setting*

[79] Living with Environmental Change (LWEC) Partnership comprises 22 public sector organisations that fund, carry out and use environmental research and observations. They include the UK research councils, government departments with environmental responsibilities, devolved administrations and government agencies. The purpose is to ensure that decision makers in government, business and society have the knowledge, foresight and tools to mitigate, adapt to and benefit from environmental change. (http://www.lwec.org.uk/about, accessed 27 January 2015)

[80] Prof Adrian Smith, Director General for Science and Research, DIUS (*Putting Science and Engineering at the Heart of Government Policy*, Ev 31, Q163)

[81] Rt Hon Lord Drayson, Minister for Science and Innovation (*Setting Priorities for Publicly Funded Research*, 330, Q578)

> *is done by picking the right people and then everything else will look after itself. (Sir Richard Brook, Leverhulme Trust)*[82]

People who would be capable of such tasks are internationally in demand and highly mobile, which is a different situation from the conventional labour market, as *"talent for leading academics globally move around the world in many ways more easily than industrial talent does".*[83] It is essential for the UK to be seen *as "a very attractive place to be a scientist, to carry out scientific research"*[84] and to *"develop their careers as science entrepreneurs"*[85] so that *"the really best people want to come from elsewhere, and that is the only basis on which we can sustain a longer-term position".*[86] These comments are especially pertinent considering the threats from other economies whose scales of research activities were growing.[87]

The health of the science base and the allowance for curiosity-driven research are crucial factors for attracting and retaining talent, especially in the higher education sector. The erosion in the level of curiosity-driven research hurts the attractiveness of UK universities:

> *I think it is crucially important to realise that excellent universities will only stay that way if they can attract excellent faculty. They will not attract excellent faculty unless that faculty feels able to get support for responsive mode, curiosity driven research. (Prof Lord Martin Rees, a Member of the House of Lords and the President of the Royal Society)*[88]

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[82] Prof Sir Richard Brook, Leverhulme Trust (*Setting Priorities for Publicly Funded Research*, 275, Q438)
[83] Ms Anne Glover, Amadeus Capital Partners (*Setting Priorities for Publicly Funded Research*, 218, Q356)
[84] Rt Hon Lord Drayson, Minister for Science and Innovation (*Setting Priorities for Publicly Funded Research*, 330, Q578)
[85] Rt Hon Lord Drayson, Minister for Science and Innovation (*Setting Priorities for Publicly Funded Research*, 330, Q578)
[86] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 294, Q465)
[87] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 294, Q465)
[88] Prof Lord Martin Rees, Member of the House of Lords, President of the Royal Society (*Putting Science and Engineering at the Heart of Government Policy*, Ev 10, Q38)

The situation appears to be similar for the case of Diamond Light Source, the UK's national synchrotron science facility:

> *The science that I am involved with in Diamond is totally international. I have been amazed at the unity. I was in Australia visiting the Light Source there and I am familiar with the ones in Brookhaven, and this is one community and everybody knows who is good and which is the good place to be. (Lord Broers)*[89]

Whilst Diamond still remains attractive, perturbing funding seems to be dangerous, primarily because *"these people have an easy road to somewhere else"*.[90] Not following on from success, for example by pausing funding until the economy recovers, could jeopardise a previously successful operation such as the Diamond Light Source. The importance of people as agents of knowledge production also means that the economy would stop learning whilst the growing of the knowledge base continues elsewhere, putting the science base further backwards when the recession is over:

> *You cannot just switch off the R&D and the research in universities for a few years while you come through a recession, because when you come out of that recession you will not have the people educated at the cutting edge who are the engines of innovation. (Prof Brian Cox, University of Manchester)*[91]

The science base and private investment. As another caution against a pause in scientific research funding, a number of expert witnesses see the government's commitment to maintaining the strength of the science base as an essential condition to attract inward private investment. Therefore, funding research is not merely about research, but also *"a magnet for global investment",*[92] as *"overseas companies are making decisions today based on the knowledge of what the investment is"*.[93]

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[89] Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 12, Q54)
[90] Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 12, Q54)
[91] Prof Brian Cox, University of Manchester (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 4, Q5)
[92] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 289, Q456)
[93] Mr Iain Gray, Chief Executive, Technology Strategy Board (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 16, Q69)

Prof Borysiewicz, then the Chief Executive of the Medical Research Council (MRC), stated that industry's investment alongside every one pound of public spending is in the range of 2.50 and 5.19 and *"industry will go where the public money is going".*[94]

> *Over the last 15 to 20 years [the correlation between public and private investment in R&D has] tracked upwards very much in correlation together. [This] means that, basically, the basic research from the public part is feeding through into and stimulating the private investment. (Prof Alan Thorpe, Chair, Research Councils UK)*[95]

The commitment to continued investment provides a *"level of confidence and certainty in the scientific community, and indeed the businesses that work with the scientific community".*[96] Logically, cuts to public investment are likely to trigger cuts in private investment:

> *So the decisions we make about the science base today are not just impacting the research of tomorrow, they are impacting the investment decisions of today. […] I am 100% convinced that a change in our investment strategy in science will impact on those decisions. (Iain Gray, Technology Strategy Board)*[97]

The relationship between public science spending and private investment also coincides with how knowledge transfer initiatives are organised, and the weight that is placed on *"the esteem of the research"*[98] by companies themselves. The very successful Centres of Industrial Collaboration operated by Yorkshire Forward, for example, require a certain academic standard from participants:

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[94] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 163, Q272)
[95] Prof Alan Thorpe, Chair, Research Councils UK (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 23, Q123)
[96] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 12, Q7)
[97] Mr Iain Gray, Chief Executive, Technology Strategy Board (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 16, Q68)
[98] Prof Christopher Snowden, Vice-Chancellor, University of Surrey (*Research Council Support for Knowledge Transfer*, Ev 15, Q84)

> *You have to be grade four or above, which is fine but those are the only metrics that are available. Those are the only metrics that our staff understand. (Prof Diana Green, Vice-Chancellor, Sheffield Hallam University)*[99]

Regarding the perceptions from industry, a consequence of RAE was the polarising effect it had on industrial collaboration and knowledge transfer because many companies would still evaluate universities using such a Mode 1 yardstick:

> *If you talk to most major companies in the States and say, "Which departments would you want to work with in the UK?" they will say in today's terminology, "The fives, the five stars and perhaps some fours." There are no expressions saying, "Some of those ones and twos are really good at knowledge transfer" which they may well be. (Prof Christopher Snowden, Vice-Chancellor, University of Surrey)*[100]

5.2.2.3 Proposition 2

The basis of satisfying a wide range of demands from institutional audiences is contingent on the supply-side strategic imperative and its accompanying legitimacy assumptions. As an imperative, the maintenance of the UK's privileged position in science and engineering provides a foundation on which further arguments can be made in response to any given audience. The assumptions underpinning the strategic imperative lend themselves to justifying the continuous pursuit of Mode 1 quality – in service of the Mode 2 audience.

The aim of preserving "international competitiveness and the sustainability of the top research universities and institutions"[101] mirrors the notion of "sustainability of privileged asset positions" covered in Dierickx and Cool's (1989) influential work on the resource-based view (RBV). The main idea is that critical resources are accumulated rather than acquired, because they are not available in the markets due to their

[99] Prof Diana Green, Vice-Chancellor, Sheffield Hallam University (*Research Council Support for Knowledge Transfer*, Ev 14, Q84)
[100] Prof Christopher Snowden, Vice-Chancellor, University of Surrey (*Research Council Support for Knowledge Transfer*, Ev 14, Q84)
[101] Prof Adrian Smith, Director General, Science and Research, BIS (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 75-76, Q218)

nontradeability. For example, reputation and culture have to be built rather than bought (Barney, 1986a, 1986b). In addition to being untradeable, strategic asset is also inimitable and nonsubstitutable (Barney, 1991; Peteraf, 1993).

To advance the arguments, the strategic imperative is accompanied by the supply side's shared theory of how knowledge and capabilities accumulate. Informants converge on RBV-like explanations to support the assertions that scientific research, with or without immediate and foreseeable applications, should be allowed to remain in the knowledge production system for it to remain competitive. Scientific assessment should be the only necessary (though not always sufficient) criterion to justify scientific research. This idea runs in contrast to the Mode 2 context of application and quality control, which privileges any discernible practical use being identified upfront as an integral part of the research agenda (Gibbons et al., 1994). The supply side, on the other hand, reasons that peer review is the only quality control measure that is reasonably operable at the front end.

The narrative constructed by the witnesses resembled a framework comprising two parts presented in the findings – accumulation of asset stock (5.2.2.1) and sustaining competitiveness (5.2.2.2). In doing so, the basis rests on a number of assumptions – causal ambiguity, limited tradeability and path dependence – believed to characterise knowledge production.

Causal ambiguity. Causal ambiguity is generally spoken of in a competitive context as it contributes to the inimitability of critical resources accumulated (Peteraf, 1993; Reed and DeFillippi, 1990). The witnesses, however, did not make a direct linkage between causal ambiguity and the competitiveness of UK science (e.g. by enacting a barrier to knowledge flow). Instead, they raised the issue of causal ambiguity to suggest the basic specifications needed for the system. That is, a successful knowledge production system must be able to maintain the growth of the knowledge base despite the inherent unpredictability that characterises the core activities.

Arguably the most fundamental assumption, scientific progress is believed to be unruly such that the advances made in the end may have minimal resemblance to what was intended. That science unfolds unexpectedly to the principal investigators demonstrates that the relationship between means and ends is causally ambiguous even when expert knowledge is present. This claim clearly does not apply equally in all individual cases of scientific research but it is generally agreed that "beginning with the end in mind" is not a guarantee for success.

Following from such ideas, the findings suggest that the challenge of foreseeing the ends is the most important justification to continue the quest for Mode 1 quality as judged by peer review. The reason is that it is the only yardstick that is possible to apply systematically at the front end. Also, the infinite number of possible developmental trajectories that is assumed under the condition of causal ambiguity also demands a variety of research approaches, including and especially those of the fundamental kind. The variety, governed by Mode 1 quality control, is expected to provide a condition in which a range of such trajectories can be hosted and, ultimately, both Mode 1 and Mode 2 outcomes can occur.

Limited tradeability of scientific knowledge. Science is not treated as "free goods" in the supply-side narrative (Pavitt, 1991). It is apparent in the witnesses' emphases on human capital that not all individuals are equally capable to utilise, not to mention create, scientific advances. This perception echoes the notion of "natural excludability" of scientific discoveries that is also identified by spinout founders (Zucker, Darby and Armstrong, 2002; Zucker, Darby and Brewer, 1999). The same perception of excludability generates slightly different implications in the two scenarios covered in this study. In Phase I, that knowledge is not fully tradeable makes an important justification for spinout foundation. The limits to off-the-shelf marketability of knowledge meant that the inventing scientists had to stay involved in the development process. In Phase II, the excludability poses limits to free riding (Callon, 1994). Emphases on the role of scientists in growing the science base and putting it to use points to the difficulty of purchasing knowledge from outside, and extracting value from such knowledge if the purchase were possible to begin with. Furthermore, it is generally agreed that it is the people rather than procedures that are better equipped to deal with causal ambiguity.

Sustaining Mode 1 quality is also essential to attracting and retaining personnel from all over the world, as highly capable individuals would only choose to work close to where the frontier is. Not only does this issue affect scientific research *per se*, it also contributes to the competitiveness of the higher education sector. World-class universities can only remain so if they manage to keep the best faculty, whose decisions are typically made using the Mode 1 yardstick. Therefore, Mode 1 quality is not only important for science's sake. It also keeps higher education, increasingly regarded as a business sector, healthy and competitive. That Mode 1 is good for business is something that rarely gets mentioned.

Path dependence. Success breeds success. It is often the case that the larger the pool of existing resources the easier it becomes for increments to be added (Barney, 1991; Dierickx and Cool, 1989; Nelson and Winter, 1982). A competitive undertone is the most prominent, where path dependence features in the discussion. The perception of path dependence connects causal ambiguity (as the property of knowledge accumulation process), limited tradeability (as the property of knowledge itself) and the witnesses' assessment of the UK's standing in terms of scientific research capabilities.

The witnesses generally agree that the UK has been in a good position compared to the international competition that is rapidly catching up, so this position is under threat. This assessment brings two implications – the continuity of commitment and the breadth of capabilities. The call for maintaining investment in scientific research is illustrated by the virtuous cycle of human capital and the science base. Capable scientists are the most important ingredient in the bid to maintain scientific capabilities. At the same time, the most important attraction for said scientists is the strength of the science base itself. Disrupting one component of the cycle that has been working well thus far, according to the witnesses, equals bringing an irreversible decline. The second implication is the need to maintain an absorptive capacity (Cohen and Levinthal, 1990; Zahra and George, 2002) by having a breadth of capabilities present in the system. It is reasoned that it is not possible to appropriate any value from new advances without having corresponding expertise in the science base. Therefore a healthy science and engineering base is regarded as a strategic entity in itself, although its competitive values may be invisible to the Mode 2 audience.

Strategic imperative represents the overall purpose for academic scientists. It is underpinned by shared theories specifying its resource-based characteristics. These shared theories would later serve as "legitimacy assumptions". As a backing for arguments made as to what constitutes appropriate organising principles and performance criteria, legitimacy assumptions provide a governing logic to ensure that the imperative stays intact.

> ***Output proposition 2A:*** *Scientific research, with or without foreseeable applications, is legitimated for its contribution to the system's maintenance of privileged asset position from which both creation and exploitation of knowledge are expected, hence no evident delineation of mode-specific audiences.*

> ***Output proposition 2B:*** *The supply side's shared perception of (i) causal ambiguity, (ii) limited tradeability of knowledge and (iii) path dependence contributes to the legitimacy assumptions justifying scientific research, with or without foreseeable applications, aimed at the system's maintenance of privileged asset position.*

Another emerging theme pertains to the positive effect of public investment on private investment. Since public spending generally goes towards generating Mode 1 outcomes, the positive relationship indicates that a part of the business audience shares the same assumptions as the supply side. Commitment to Mode 1 quality therefore has some relevance to investment decisions, though not for everyone in the audience base. This branch of argument is not central to the supply side's narrative, but it lends support to the assertion that the strategic imperative also has demonstrated benefits for the Mode 2 audience.

5.2.3 Organising knowledge production in means-ends opacity

5.2.3.1 Where do technological advancements come from?

Much of the difficulty in managing knowledge production and justifying public investment is in "*the inherent unpredictability of where the key advances are going to come from*".[102] This creates a situation where valid examples can substantiate arguments in favour of any given type of directionality in scientific advancements. In

[102] Prof Lord John Krebs, Member of the House of Lords, University of Oxford (*Putting Science and Engineering at the Heart of Government Policy*, Ev 11, Q41)

what follows, I present two possible directions where the origins of success cases in science may or may not involve an aim for practical applications:

> *You hear people throw up examples that orient you to one end of the spectrum or the other, such as DNA fingerprinting, which came out through, if you like, unconstrained research that led to something very useful. But, then, if you look at something like NASA, ventures into space, there is lots of truly significant science that has come out of that directed research programme. (Prof John Murphy, Chairman, External Challenge Panel)*[103]

It remains debatable whether the upfront attempt to achieve impact makes a research programme more likely to generate breakthroughs, as demonstrated by two competing views below:

> *If you look at the transistor, Bardeen, Brattain and Shockley at Bell Labs were trying to get rid of having to have a glass bottle out of which they sucked the air so they could have an electron beam in there; they we are trying to make a solid state vacuum valve and they came up with the transistor. (Lord Broers)*[104]

> *Okay. What about the World Wide Web then? Tim Berners-Lee is on record, I have seen the papers that he presented at CERN. His manager wrote "Vague but interesting" on it, threw it back at him, but he didn't say, "You can carry on anyway because this is certain to revolutionise the global information system". (Prof Brian Cox, University of Manchester)*[105]

When it comes to economic implications, on the one hand, it is said that science's generation of spinout business economic activities is serendipitous, as the economic outcome may have little to do with the individual science,[106] such as that the World

[103] Prof John Murphy, Chairman, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 18, Q111)
[104] Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 10, Q46)
[105] Prof Brian Cox, University of Manchester (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 10, Q48)
[106] Dr Ian Ritchie, Technology Entrepreneur, Coppertop (*Research Council Support for Knowledge Transfer*, Ev 27, Q163)

Wide Web had no connection with physics research at CERN. On the other hand, whilst the assertion is not wrong, it represents one of the many possible scenarios which are usually recognised by the expert witnesses:

> *Certainly in the field of defence research, [serendipity] is exactly how it used to be done. When it became very much more focused the volume of exploitation increased enormously. […] Those areas which are more likely to have a transfer are discernible in advance and a considered research programme built around that as an objective is more likely to be successful than simply serendipity.*
>
> *Having said that, brilliant science inventions have a role and I believe there should always be a component of any research programme which is entirely unlimited and purely blue sky for the purpose of civilisation. I think that is entirely legitimate.*
>
> *(Sir John Chisholm, Executive Chairman, QinetiQ Group plc)*[107]

The relationship between science and innovation is indeed a complex business, with the possibilities for both relatively linear, where potential applications are discernible in advance and (unexpectedly) iterative trajectories that are only understandable retrospectively, such as in the case of quantum theory:

> *Sometimes it can be fairly linear, as nuclear magnetic resonance turned to magnetic resonance imaging. On the other hand one of my favourites might be the quantum theory which, as I recall, began as the study of trying to improve light bulbs and then led to the discovery of the quantum theory from this and, in due time, it will probably feed back to quantum computing. So you see the <u>trajectories from applied to basic and back again</u>, and these, surely, are fine instances of complex models of research.*[108] *(Prof Sir Martin Taylor, the Royal Society)*

[107] Sir John Chisholm, Executive Chairman, QinetiQ Group plc (*Research Council Support for Knowledge Transfer*, Ev 30, Q182)
[108] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 291, Q458)

It is said that the system must be able to accommodate this variety of trajectories and respond both to economic reality and the fundamental importance of knowledge creation:

> *From an industrial perspective, it is fatuous to think that this country will excel at everything in the twenty-first century. There will have to be certain areas of technology where we win and others where we accept that we cannot.*
>
> *In terms of science, because of the unpredictability of this pull-through process, […] it would be ill-judged of a science minister and, indeed, of your good selves to try to start picking winners round this table. It is a dangerous game.*
>
> *(Sir Peter Williams, Vice-President, the Royal Society)*[109]

5.2.3.2 In search of balance

With the many possible pathways in which scientific breakthroughs and economic activities can be generated, there is no question that "balance" has to be achieved. Balance can be put simply as the ability to address audiences in both Mode 1 and Mode 2:

> *The first is a healthy science and engineering base. Because if we do not have that – which is that we have to make sure that it is healthy and productive – whatever else we do is lost. And the second – and these are equal – is better exploitation.*[110] *(Prof John O'Reilly, Chief Executive, EPSRC)*

Addressing a diverse range of stakeholders requires a flexible system that is not single-mindedly designed to *"deal in one model with all the requirements placed upon it",* but rather *"a system which will satisfy both of those needs".*[111]

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[109] Sir Peter Williams, Vice-President, Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 8, Q32)
[110] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 36, Q218)
[111] Prof Sir Richard Brook, Leverhulme Trust (*Setting Priorities for Publicly Funded Research*, 280, Q450)

> *Some research confronts a set of identified problems which society has, energy resource, the environment, all of these things, a particular disease, and there you can put a group of researchers together with some confidence in the target which they are going after; but you also want the system to deal with the exploration of unidentified opportunities. You have to let something happen even though you have not seen the target yet. (Sir Richard Brook, Leverhulme Trust)*[112]

The idea of balance is deceptively simple on a conceptual level. Operationally, achieving balance becomes increasingly complex as the witnesses covered two key questions. What notions are being balanced? And how much of each is needed?

A matter of labels: Balance between what? In the context of prioritisation and public spending, I base the discussion of "labels" mainly on directed vs. responsive mode research, as the demarcation reflects two different funding models. Deconstructing what it means by directed and responsive then reveals other traditional language issues that come with such terms as "basic", "applied" and "curiosity-driven" research. Directed mode and responsive mode are defined as follows:

> *Directed research, directed mode, really allows research funders to stimulate activity in certain areas of research. It is defining areas of research and within that applicants, proposers, submit applications for delivering that research.*
>
> *Responsive mode, however, allows researchers to apply for funding right across the spectrum of research areas, so it is open to that breadth.*
>
> *(Prof Alan Thorpe, NERC)*[113]

Much of the conundrum that follows regarding labels is the *"association between economically productive and pure and applied",* which is *"the linkage which people*

[112] Prof Sir Richard Brook, Leverhulme Trust (*Setting Priorities for Publicly Funded Research*, 280, Q450)
[113] Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 167, Q285)

are trying to make the jump to".[114] Since directed mode research supposedly targets specific problems, such as food security and environmental change, it is intuitively associated with problem solving or applied research. Similar logic applies to the coupling of responsive and basic research. These are associations that many witnesses tried to dismiss, albeit sometimes with great difficulty:

> *Chairman: [On the principle of the Living with Environmental Change programme] there is a huge contradiction between a broad base in science and targeted areas of research. The two take us in different directions, do they not?*[115]
>
> *Prof Smith: No. Living with Environmental Change is a targeted challenge to which a broad sweep of disciplines contributes. Entirely compatible.*[116]
>
> *Chairman: Am I missing something here?*
>
> *Prof Edgerton: It has been very difficult to pin down the real meaning of policy statements in the area of science policies, in the plural, for very many decades.*[117]

The above exchange uncovers an important issue – that the labels apply differently across levels. The labels – directed, responsive, pure and applied – are *"terms of art"* which conceptually *"can be quite useful in trying to describe the nature of research but, coming down to project level, these distinctions often are less useful".*[118] By identifying certain areas as strategic or priority areas, they *"automatically become directed"*. For the example of an EPSRC energy programme, *"a large number of applications that come into that are essentially responsive mode calls but they come into that particular*

[114] Rt Hon Lord Drayson, Minister for Science and Innovation (*Putting Science and Engineering at the Heart of Government Policy*, Ev 62, Q379)
[115] Mr Phil Willis, Chair, the House of Commons S&T Select Committee (*Putting Science and Engineering at the Heart of Government Policy*, Ev 30, Q154)
[116] Prof Adrian Smith, Director General for Science and Research, DIUS (*Putting Science and Engineering at the Heart of Government Policy*, Ev 30, Q154)
[117] Prof David Edgerton, Imperial College London (*Putting Science and Engineering at the Heart of Government Policy*, Ev 30, Q155)
[118] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 10, Q2)

pot of money. They all get grouped as directed".[119] In the case of EPSRC (at the time of the session), *"at least a third of what is identified under that directed pot is actually responsive mode".*[120] Moreover, when it comes to an individual piece of research, it is difficult to judge whether it is pure or applied, or is of responsive or directed character, as *"the reality is that it is probably a bit of both".*[121]

The terminology indeed requires some serious considerations *"because of the number of words that are being bandied around with different connotations and emphases".*[122] The language *"gets in the way"* when it comes to application of research, as it is simply stated that *"responsive-mode equals basic science and directive equals applied is, quite clearly, not true".*[123] In terms of quality measured by citations, the two modes are *"virtually identical"* according to citation analyses.[124] With another example from EPSRC, *"the academics who are bidding into the responsive mode pot and those who are bidding into directed mode [are of] 75 per cent commonality".*[125] Researchers are also generally capable of relabelling their funding applications depending on what they think would be funded – basic, applied or interdisciplinary – and such becomes the distinction between basic and applied research. This ability to *"market their research"* further obscures the phenomenon and contributes to resistance to change.[126]

The taxonomy is often put as *"unhelpful"* and *"divisive"* as there is not *"an academic who has put an application that is not curiosity driven whether it is a specific call or into responsive mode".*[127] There is another notable distinction between *"applied"* and *"not-yet-applied"* research which applies better to medical research:

[119] Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 167-168, Q285)
[120] Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 167-168, Q285)
[121] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 11, Q5)
[122] Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 168, Q288)
[123] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 297, Q474)
[124] Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 167, Q285)
[125] Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 167, Q285)
[126] Dr Paul Nightingale, Science Policy Research Unit, citing a study by Jane Calvert (*Setting Priorities for Publicly Funded Research*, 280, Q449)
[127] Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 167-168, Q285)

> *It might not be applied for 50 years, but still most life scientists will be working towards a potential application of the research that they are doing. (Prof Sir Leszek Borysiewicz, MRC)*[128]

How to handle the terminology remains debatable, considering its policy implications. On the one hand, basic vs. applied language is unrealistic but could be convenient *"when talking to policymakers, and when you speak to the public",* as *"a certain amount of simplification of language is possibly in order – as long as you put the right caveats in".*[129] On the other hand, there is a need to ensure that the simplified language, attractive as it is to *"tidy-mined bureaucrats",*[130] is not excessively reinforced, as it has very little to do with the real world:

> *If these terms are given too much weight in the formulation of policy it is easy to lose sight of the fact that they work more at a conceptual level than they do at a practical level. (Dr Graeme Reid, BIS)*[131]

> *I think it is misleadingly over-simple. There is nothing more directed in the world than CERN and is it not about the most fundamental research questions there are? (Prof Adrian Smith, BIS)*[132]

The assumption of optimum point. The term "balance" is inherently associated with the notion of optimum point, if not simply 50/50 on a scale. It is clear that the balance *"has to be got right"*[133] but how to get it right appears elusive:

> *This point about the balance between directed and responsive mode funding is the hot question in research policy and there is no one that has a straightforward answer to it. (Dr Steven Hill, Research Councils UK)*[134]

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[128] Prof Sir Leszek Borysiewicz (*Setting Priorities for Publicly Funded Research*, 169, Q289)
[129] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 291, Q458)
[130] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 11, Q3)
[131] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 10, Q2)
[132] Prof Adrian Smith, BIS (*Setting Priorities for Publicly Funded Research*, 322, Q549)
[133] Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 81, Q246)
[134] Dr Steven Hill, Research Councils UK (*Setting Priorities for Publicly Funded Research*, 169, Q292)

The puzzle may have started from how to know what is right …

> *I find it a very difficult question to answer in terms of balance because it presumes there is an optimum and I do not know whether there is. (Ms Anne Glover, Amadeus Capital Partners)*[135]

… perhaps because the optimum point, if there is one, is a matter of judgement:

> *The number is simply a judgement call. […] I do not think there is an algorithm that would tell you what that proportion is.*[136] *(Prof Alan Thorpe, NERC)*

The optimum point is likely to be dynamic in two ways. First, the criteria informing what constitutes a right or wrong balance may vary depending on what perspective is being used[137] and what outputs are required from the research system.[138] Second, temporally speaking, balances are expected to change over time and they are to be dealt with accordingly by looking at *"leading indicators"* for symptoms to be corrected, as they may not be readily foreseeable:[139]

> *[In] making sure that <u>all disciplines are fully supported</u>, may mean some <u>rebalancing over time</u> and, at different points in time, different sorts of rebalancing in favour of disciplines which have been relatively under-funded at a given point in time. (Prof Dame Janet Finch, Council for Science and Technology)*[140]

Additivity. Regardless of what the optimum point is, there is a logic that governs how it is to be achieved – exploitation and knowledge transfer are to be addressed in addition to, not at the expense of, scientific excellence. The quest is to *"<u>remain</u> world-class in*

[135] Ms Anne Glover, Amadeus Capital Partners (*Setting Priorities for Publicly Funded Research*, 225, Q376)
[136] Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 169, Q291)
[137] Prof Andrew Stirling, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 281, Q450)
[138] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 279, Q448)
[139] Ms Anne Glover, Amadeus Capital Partners (*Setting Priorities for Publicly Funded Research*, 225, Q376)
[140] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 297, Q474)

science and to <u>*become*</u> *world-class in knowledge transfer".*[141] In presence of Mode 2 demands, the fate of Mode 1 quality is under scrutiny:

> *Dr Harris: ... what is the* <u>*evidence*</u> *that what you are doing [research councils' funding for knowledge transfer] is* <u>*not in conflict with creating new knowledge*</u> *because people think that the money that could be spent purely in the pursuit of creating new knowledge empirically will suffer?*[142]

> *Prof O'Nions: [Overall] we are second only to the United States in the impact of our basic research however you look at it and, in value for money terms, it is certainly the best value for money in the world and we are improving trends, particularly in biomedical sciences. Therefore, dealing with excellence of research, there is* <u>*no evidence that any policy over the last decade has detracted from the improving trend in excellence of our research*</u>*.*[143]

There exists some resistance to the change in the overall research direction away from responsive mode. The responsive mode support aligns well with the importance of person-embedded nature of knowledge, as it provides opportunities for individual creativity that may or may not fall into organised projects. This type of allowance matters more in some areas, such as chemistry, than others:

> *So I think we like the balance, but things dipped a little on the responsive-mode, and that worried us a lot. (Prof Sir Martin Taylor, Royal Society)*[144]

The overall picture suggests that *"there have not been very strong trends in changes of the proportion that we spend on responsive mode and directed".*[145] Policy-wise, the

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[141] Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 4, Q22)
[142] Dr Evan Harris, House of Commons S&T Select Committee (*Research Council Support for Knowledge Transfer*, Ev 3, Q12)
[143] Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 3, Q12)
[144] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 297, Q474)
[145] Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 169, Q291)

need to demonstrate commitment to *"maintain our position in pure research but improve the translation of that"*[146] is evident:

> *Is there a shift away from pure towards applied? Absolutely not. What we need to do is make sure we continue being excellent and pure, but we need to get a bit better at the application of applied research. (Rt Hon Lord Drayson, Minister for Science and Innovation)*[147]

There is an example from the MRC where translational research was highlighted upon the release of the Cooksey Report. But the actual policy was that *"there had to be no cutback on the money that was available for basic biomedical research".*[148] The outcomes from translational research came from the extra money *"earmarked towards the translational agenda"* allocated to the council:

> *We were never robbing Peter to pay Paul by having a change of direction. We were doing this as an additional activity which was important as a primary rationale for improving the position of the UK in translation. (Prof Sir Leszek Borysiewicz, MRC)*[149]

5.2.3.3 When can research be exploited?

The concern over *"research councils' lack of strategic vision and approach to knowledge transfer"* generates a pressing demand for *"a coherent and structured approach to knowledge transfer and knowledge creation".*[150] This problem requires some consideration on the manner in which economic value is reasonably expected from scientific research.

Similar to the interview results, exploitation or application of research is anticipated in two ways, given the primacy of maintaining the calibre of the science base. Generally

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[146] Rt Hon Lord Drayson, Minister for Science and Innovation (*Setting Priorities for Publicly Funded Research*, 329, Q574)
[147] Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 85, Q271)
[148] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 170, Q292)
[149] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 170, Q292)
[150] Ms Margaret Moran, S&T Select Committee (Commons) (*Research Council Support for Knowledge Transfer*, Ev 34, Q210)

speaking, application and problem solving are more natural in some sectors than others. Where there is less certainty to make such a case, the dynamic outlook – using conditional and open-ended language – is used to indicate openness to the research being applied at a yet-to-be-specified point in the future.

Sector-dependent embedding. Some academic disciplines operate in an environment that intrinsically involves end users and practitioners who are tasked with applying research outcomes. The expectation is *"clearly more applicable at the applied end of the spectrum",* as it implies less risk of *"imped[ing] blue skies research".*[151] Engineering, for example, is more oriented towards utility:

> *Most of my community does not find this impact agenda an alien one. 40 per cent of the research EPSRC funds is collaborative with an end user. […] This idea of getting the output of research through quickly into product or policy is already part of the thinking of this community. (Prof David Delpy, EPSRC)*[152]

Medical research is an example of knowledge production in an ecosystem that contains various producers, intermediate users and end users of knowledge, which facilitates both knowledge creation and transfer:

> *One of the useful examples to look at is the university hospitals, where I think knowledge transfer takes place relatively automatically. To some extent, the medical sector is in a privileged position to have these, because you have the consultants driving the research, dealing with patients, [and] passing on the knowledge, so that the whole process is closely integrated compared to other sectors. (Prof John Murphy, Chairman, External Challenge Panel)*[153]

Another important factor is whether there is high value in scientific invention closer to the upstream end as is the case in life sciences, meaning *"a lot of investment in invention is much more obviously connected to where the value will eventually be*

[151] Mr Tony McBride, Confederation of British Industry (*Research Council Support for Knowledge Transfer*, Ev 30, Q183)
[152] Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 165, Q277)
[153] Prof John Murphy, Chairman, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 19, Q113)

created from that invention".[154] In physical sciences, on the other hand, *"there is a much larger process to go through, the innovation process that you have to go through before you get to where the ultimate value is. That can take decades and it can go through many, many stages to get there".*[155] In which case, the end results would be less predictable at the outset. The value of invention has some bearing on the demand condition and the prevalence of UILs in certain sectors, such as the pharmaceutical industry:

> *Some sectors of UK industry are better geared for working with universities than others. For example, the pharmaceutical industry in the UK is pre-eminent in working with universities to* <u>bring forward benefits in partnership with research council funded work</u>*; whereas in other sectors, perhaps not naming any, it is less readily forthcoming. (Dr Bob Bushaway, Chairman, AURIL Council)*[156]

Dynamic outlook. Whilst seeing the "pull" end of research is easier in some areas, it is more problematic in others, not least for the scientists themselves, especially the *"purer kinds"*[157] among them. The difficulty with which eventual application can be identified perhaps corresponds to the conventional wisdom that the UK is *"fantastic at the research and then very bad at picking it up, doing stuff to exploit it"*:[158]

> *One case that leaps to my mind is the case of Rutherford who was asked about his nuclear work and he said, "Oh, anyone who talks to you about the possibility of it having a use for energy manufacturers is talking absolute moonshine," and then there was also Faraday who, when asked about the value of his work on electro-magnetism by Gladstone*[159]*, said, "Oh, I don't see any application of it*

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[154] Sir John Chisholm, Executive Chairman, QinetiQ Group plc (*Research Council Support for Knowledge Transfer*, Ev 25, Q153)
[155] Sir John Chisholm, Executive Chairman, QinetiQ Group plc (*Research Council Support for Knowledge Transfer*, Ev 25, Q153)
[156] Dr Bob Bushaway, Chairman, AURIL Council (*Research Council Support for Knowledge Transfer*, Ev 15, Q73)
[157] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)
[158] Prof Adrian Smith, BIS (*Setting Priorities for Publicly Funded Research*, 323, Q552)
[159] William Gladstone, then British Chancellor of the Exchequer (1850)

at the moment, but, when we do find one, you will surely wish to tax it." (Prof Sir Martin Taylor, Royal Society)[160]

The question of where and how research exploitation can take place does not lend itself to generalisation. It is *"typically* sui generis*, [relating] only to that particular circumstance",* operating *"at the nitty-gritty level of understanding"* of the value of the research, the market, the appropriate model of transferring knowledge and how to choose the right kind of funding mechanism.[161] One way in which the supply side can respond to demands from Mode 2 stakeholders is by pointing to the conditional character, that the economic impact can be actively sought after "where appropriate":

> *Dr Iddon: ... do you think the government is putting too much pressure on the research councils to have an economic impact and taking you away from blue skies more and more?*[162]
>
> *Prof Diamond: I do not feel that pressure at all. I personally believe it is an absolute necessity that anyone who wishes to take public money to do research should, where appropriate, use the results of that research to have an impact on the economic development and quality of life of the people of the United Kingdom who funded it, and indeed further afield.*[163]

In this case, "where appropriate" is used to indicate the intention to fulfil Mode 2 requirements and simultaneously provide a significant caveat that points to the primacy of scientific questions. This, again, highlights the underlying idea that economic impact is to be achieved *in addition* to scientific excellence:

> *[The] use of the word "appropriate" is because there are parts of the research base which it would simply be silly for people to rush around trying to maximise*

[160] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)
[161] Sir John Chisholm, Executive Chairman, QinetiQ Group plc (*Research Council Support for Knowledge Transfer*, Ev 26, Q159)
[162] Dr Brian Iddon, Committee member (*Research Council Support for Knowledge Transfer*, Ev 34, Q208)
[163] Prof Ian Diamond, Chief Executive, ESRC and Chair of RCUK Executive Group (*Research Council Support for Knowledge Transfer*, Ev 34, Q208)

> *the economic impact of because it is developing and underpinning theory, for example. (Prof John O'Reilly, Chief Executive, EPSRC)*[164]

As the timeline stretches further into the future, the use of open-ended framing increases applicability to a wide range of situations regardless of academic disciplines or industrial sectors. This idea sees a *"chain right the way from the knowledge creation generation stage, identification stage, through to exploitation".* Most of research council activities would be *"focused more at the front end rather than at the back".*[165] With the remainder of the chain possibly yet to be identified or even unpredictable, thinking of *"how to open up the pathways to enable impact to happen [in] lots of different ways"*[166] seems to be a preferred option among witnesses.

The consideration of *"potential benefits and potential pathways",* contrary to what is understood by many, *"is not about changing the research that they [scientists] are doing".*[167] However, opening up is not the same as being without a plan. Acknowledging the dynamic character of knowledge production, thinking ahead (albeit very broadly) …

> *… opens up possibilities for others to get involved in the research as it goes along. It opens up the possibility of even other funders coming on board to support that research. I think it opens up <u>a range of opportunity that will not be there always</u>. (Prof Alan Thorpe, Chair, Research Councils UK)*[168]

An essential factor contributing to the efficacy of the dynamic outlook is a positive legitimacy judgement that is needed where such "appropriate" conditions are met. This assumption is rarely made explicit by the witnesses, probably because both modes of knowledge production are taken as legitimate in the policy context. However, more work still needs to be done at ground level:

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[164] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 35, Q215)
[165] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 46, Q272)
[166] Prof Alan Thorpe, Chair, RCUK (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 17, Q76)
[167] Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 162, Q262)
[168] Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 164, Q274)

> *What the research councils are about is trying to get mechanisms, a culture, an awareness and a behaviour change so that all along the process we are constantly thinking: if there is an opportunity to exploit, if there is something to exploit, let us make sure that we flag it and if possible we put in place support systems to gather it. (Prof Adrian Smith, BIS)*[169]

5.2.3.4 Suggestions of means for desired ends

Academic freedom. The witnesses' support for academic freedom connects two assumptions discussed earlier, which are a) person-embedded nature of knowledge, and b) the need for allowance to handle causal ambiguity in scientific progress.

There is a strong resistance to the idea of government playing a role in prioritising research areas or "picking winners". Witnesses appear to converge on the notion that, to prepare for the future, *"the key is people rather than topics"*.[170] If there is an inspiration to create Nobel Prize-winning science, government direction is likely to be a wrong strategy because *"the greater the originality of the research the less predictable the outcomes are likely to be"*:[171]

> *I asked him [Sir Timothy Hunt, a Nobel laureate], should the government focus on key areas of priority and he said absolutely not. If you want to foster the kind of innovative research that led to him winning a Nobel Prize you should allow great freedom for scientists to propose research and judge it on excellence. (Prof Lord John Krebs, a Member of the House of Lords, University of Oxford)*[172]

Whilst not all scientists would be on a quest for the Nobel Prize, the question of how to deal with inherent unpredictability remains, as *"the characteristics of the future in terms of the opportunities cannot be predicted right now".* Based on the belief that *"the best*

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[169] Prof Adrian Smith, BIS (*Setting Priorities for Publicly Funded Research*, 323, Q552)
[170] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 289, Q456)
[171] Prof Lord John Krebs, Member of the House of Lords, University of Oxford (*Putting Science and Engineering at the Heart of Government Policy*, Ev 11, Q40)
[172] Prof Lord John Krebs, Member of the House of Lords, University of Oxford (*Putting Science and Engineering at the Heart of Government Policy*, Ev 10-11, Q40)

people will adapt to future opportunities and produce the best research",[173] *"the key themes and the priorities should be presented in a broad way so that the scientists can be innovative within those themes and not be too prescriptive".*[174]

Excessive centralised coordination endangers the diversity of science as *"the greater the contralised control, the less is actually going to be available in (an individual) finite pot",* so *"there is a real risk in getting too close an alignment"*.[175] Therefore, It is important *"not to let the bureaucracy drive the research beyond the healthy limits of what it can do (and) allow the researchers flexibility to pursue their creativity"*:[176]

> *Our intention is to stress the importance of the diversity of science; it is a whole spectrum of different sorts of science – and all of them are valued. We quite like the idea of an "ecosystem of science" – with different parts affecting other parts. If you let one part perish or get ill, that will affect other parts. (Prof Sir Martin Taylor, Royal Society)*[177]

Interdisciplinarity. The witnesses point to interdisciplinary programmes which are an essential part of solving large-scale problems that typically span the boundaries between academic disciplines. Advances in medicine, for example, can be attributed to many contributing fields:

> *There is a wonderful letter by Sir Paul Nurse in The Times. Somebody had said how we need more and more medical research and he pointed out the interdisciplinary nature of many of the major advances in medicine; clinical trials, mathematics and statistics; the understanding of genomics through sequencing algorithms which are computer science, and scanners which are*

[173] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 289, Q456)
[174] Lord John Krebs, Member of the House of Lords, University of Oxford (*Putting Science and Engineering at the Heart of Government Policy*, Ev 11, Q41)
[175] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 160, Q255)
[176] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 11, Q4)
[177] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 293, Q464)

> *physics – and some of that physics has come from infrared astronomy and some of it has come from detectors in CERN. (Prof Adrian Smith, BIS)*[178]

There remains a concern over the *"real problems getting [the] big scientific questions addressed"*,[179] as *"the landscape of research councils does not necessarily favour interdisciplinary research that well"*.[180] The current structure creates some obstacles if a researcher identifies with *"a ground-breaking area of research that does not have a well established peer group"*.[181]

Whilst the peer review system is *"acutely aware"*[182] of the problem, the structural difficulty is not easy to solve. The funding system has been very successful in generating a large number of small, high-calibre projects which are in turn difficult to organise into a coherent solution to a big problem. Some form of *"top-down coordination"* is sometimes necessary to *"make sure that all of these projects talk together"*:[183]

> *[In] coastal vulnerability, if you have a lot of bottom-up projects you can end up with <u>a lot of good projects</u> on sediment dynamics, on biodiversity and on climate change, <u>but they do not actually fit together</u> and allow you to assess how the vulnerability of our coastline will change. (Prof Andrew Watkinson, Living With Environmental Change)*[184]

The *"drivers for the universities are external funding streams, with metrics attached to them"*.[185] The coordination problem above may have resulted from a *"stove pipes"* problem of organisational boundaries and fragmented budgeting.[186] There is a

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[178] Prof Adrian Smith, BIS (*Setting Priorities for Publicly Funded Research*, 316, Q518)
[179] Prof Sir John Bell, Office for Strategic Coordination of Health Research (*Setting Priorities for Publicly Funded Research*, 263, Q425)
[180] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 296, Q473)
[181] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 15, Q21)
[182] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 15, Q21)
[183] Prof Andrew Watkinson, Living With Environmental Change (*Setting Priorities for Publicly Funded Research*, 266, Q432)
[184] Prof Andrew Watkinson, Living With Environmental Change (*Setting Priorities for Publicly Funded Research*, 266, Q432)
[185] Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 209, Q333)
[186] Prof Robert Watson, Department for Environment, Food and Rural Affairs (*Setting Priorities for Publicly Funded Research*, 52, Q96)

recommendation that the role of the *"umbrella RCUK"* should be enhanced with more funds available to better support interdisciplinary research in a timely manner:[187]

> *Concerning the way we fund things, though, I would like to see a greater use of the grand challenge approach to themes of science. I think that will probably be more attractive and productive with scientists. (Prof Sir Martin Taylor, the Royal Society)*[188]

It is worth noting, though, that solving multidisciplinary problems does not necessarily equal abandoning disciplinary research:

> *[Although] of course our mantra is multidisciplinary it has to have the core discipline supported. (Prof Alan Thorpe, NERC)*[189]

Business engagement. Another practice that would improve the value of scientific research, in addition to having interdisciplinary approaches to large-scale challenges, is to strengthen *"the relationship between the academic world and the business world".*[190]

While there is no change to the principle that *"the best science is the criterion for funding from the research councils",*[191] the *"two-way flow of knowledge"*[192] between research communities and businesses brings some benefits to both sides. In terms of the quality of science, *"the best science can sometimes be informed at the earliest stage by interaction with potential stakeholders".*[193] Involving end-users from business also improves efficiency by achieving a better fit between research and practical needs, preventing business from unnecessarily having to *"repeat the research in-house to make it compatible".*[194] Organising knowledge transfer by engaging businesses at the

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[187] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 296, Q473)
[188] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 296, Q473)
[189] Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 169, Q291)
[190] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 15, Q22)
[191] Prof Ian Diamond, Chief Executive, ESRC and Chair of RCUK Executive Group (*Research Council Support for Knowledge Transfer*, Ev 40, Q240)
[192] Prof Keith Mason, Chief Executive, PPARC (*Research Council Support for Knowledge Transfer*, Ev 34, Q209.)
[193] Prof Ian Diamond, Chief Executive, ESRC and Chair of RCUK Executive Group (*Research Council Support for Knowledge Transfer*, Ev 40, Q240)
[194] Prof John Murphy, Chairman, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 19, Q113)

research stage, rather than at the end, *"creates an environment where innovation and new ideas can flourish and that is to the benefit of everybody".*[195]

In good alignment with the person-embodied view of knowledge, the suggestion of business engagement comes with an assumption that *"anything which involves people transfer [is] the best way of getting knowledge transfer done".*[196] The direction goes both ways. Research councils take *"secondments from industry … for them to gain greater understanding of where we are and then send some of our people back into that company to learn the other side".*[197] Similar "academics in residence" programmes can also be initiated from the business side:

> *What happens is these guys come in, […] they interact with our groups where we are kicking ideas around and they realise what our problems are and they go back to academia and if they cannot solve it they know someone who can. (Dr Malcolm Skingle, Director, Academic Liaison, GlaxoSmithKline)*[198]

The challenge going forward is to have enough people who are capable of absorbing, carrying and transferring the latest scientific advances:

> *If you look at the Japanese Light Source, which is perhaps the biggest one in the world, they have eight people full-time working with industry to make sure that their industry is quite up to speed in using these marvellous resources. We do not have that capability. (Lord Broers)*[199]

Strengthening business pull. In addition to efforts required from the supply side, the other side of business engagement is the quality of demands – whether there is an *"appetite of business for engaging in research and associated training in knowledge*

[195] Prof Keith Mason, Chief Executive, PPARC (*Research Council Support for Knowledge Transfer*, Ev 34, Q209)
[196] Dr Malcolm Skingle, Director, Academic Liaison, GlaxoSmithKline (*Research Council Support for Knowledge Transfer*, Ev 26, Q156)
[197] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 41, Q246)
[198] Dr Malcolm Skingle, Director, Academic Liaison, GlaxoSmithKline (*Research Council Support for Knowledge Transfer*, Ev 26, Q156)
[199] Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 6, Q17)

transfer".[200] Since *"the real problems lie at the downstream end",*[201] *"simply shouting more loudly at the universities is not going to increase [the interactions] further".*[202] The problem is particularly more serious for smaller companies:

> *I think a lot of the fault has lain with industry, not necessarily with our university-based science. We have some industrial companies, Rolls Royce and BP, who know very well how to work with universities, perhaps British Aerospace, but across the board we are not particularly good and we are not particularly good at involving SMEs. (Lord Broers)*[203]

The government has a role in addressing *"the weak business pull-through on the research basis".*[204] It is to ensure that *"the world of industry is more receptive to taking up ideas that come out of the science base and taking the risks that go with it"* along with *"cutting-edge ideas, cutting-edge people, best trained PhDs and scientists".*[205]

That the business enterprise R&D is *"D rather than anywhere near R&D"*[206] points to an important observation made by witnesses – *"the lack of clarity in setting policy for government priorities for supporting business development".*[207] In other words, linking back to earlier discussions on "picking winners", government planning and control has a place in downstream industrial development, but planning upstream science is *"not really possible"*:

> *[We] end up with a rather paradoxical situation where ministers are trying to plan science and research, whereas they refuse the opportunity to plan the wider*

[200] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 36, Q217)
[201] Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 200, Q331)
[202] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 36, Q217)
[203] Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 4, Q2)
[204] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 295, Q472)
[205] Sir Peter Williams, Vice-President, Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 7, Q22)
[206] Sir Peter Williams, Vice-President, Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 7, Q22)
[207] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 295, Q472)

> *economy or industry, and I think that is probably exactly the wrong way round. (Prof David Edgerton, Imperial College London)*[208]

Sectoral focus, such as that taken by the National Institute of Health, contributes to driving *"the downstream end of the system to give companies the confidence to invest".*[209] The ways in which government capacity has been used to *"structure the downstream end of the enterprise",* with the examples of Singapore (biotech), Taiwan (communications) and Germany (chemicals and automotives), means that *"external companies – investors – know where to go when they are looking both for the research, and the translational activity that takes that research into utility"*. So *"you do not go to Birmingham any more, you go to Voitsberg"* for an interest in designing electric cars.[210]

The issue brings up some discussion on whether research institutes would deliver strategic value on this matter. With the example of the Fraunhofer in Germany, which pulls from the basic research base created by universities towards application,

> *… industry can see that there are <u>possibilities that they can seize upon readily</u> and invest on a substantial scale without frightening their investors away. I think there is a lot to be learnt, particularly at the downstream end.*[211] *(Prof Geoffrey Boulton, Royal Society of Edinburgh)*

5.2.3.5 Proposition 3

At the heart of how the supply side answers to both regimes of quality control is a deceptively simple matter of balance. It is universally agreed as desirable although it remains impossible to pinpoint what constitutes balance when it comes to how scientific research is funded and organised. Balance is defined according to the *ends* in the means-ends of knowledge production – that there exist two quality control regimes and neither of which can be evaded for the public investment to be justified. However, simply

[208] Prof David Edgerton, Imperial College London (*Putting Science and Engineering at the Heart of Government Policy*, Ev 29, Q147)
[209] Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 207, Q331)
[210] Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 208, Q331)
[211] Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 208, Q331)

knowing who the stakeholders are helps very little with some of the unresolved questions raised by the expert witnesses. What items, categories or concepts are being considered? Is there such a thing as an optimum point, assuming the first question can be answered to begin with?

The apparent intractability of such questions corresponds to the ever-decreasing relevance of the taxonomy of research types that are based on procedural differences, i.e. the *means*. It is made clear by the witnesses that advances and innovation can come from research of any type. Responsive, targeted, basic, applied and fundamental types no longer have one-to-one definitional relationships either amongst themselves or with the nature of outcomes, not to mention any specific audience. Moreover, nothing in the findings indicates the supply side's intention to "change the research" or the combination of different research "types".

The notion of certain means of knowledge production leading to a specific outcome is refuted. Suggestions from witnesses contain attributes from both modes, sometimes in a pair of polar opposites. Elements of academic freedom (normally treated as "disinterestedness") and social accountability are both present. Suggestions in favour of interdisciplinarity are accompanied by a reminder of contributing disciplines. Mode 2 quality may result from direct involvement of other stakeholders (Mode 2) or indirectly through the knowledge developed in the primary interest of science (Mode 1). Equally, different types of research can lead to similar Mode 1 quality measured by citation impact.

The main difference compared to the Mode 1/Mode 2 dichotomy is that a fixed means-ends association and value judgement are not assigned according to the supply side. For example, investigator-led discipline-based research is implicitly associated with the lack of creativity in Mode 2. No such assumption is evident from the findings. Furthermore, another revealing point is that the witnesses suggested that the improvement of practical usefulness does not necessarily require a change in research, but is more likely from the increased sophistication and capabilities on the demand side further downstream.

> ***Output proposition 3A:*** *Both Mode 1 and Mode 2 quality outcomes can be achieved through multiple combinations of otherwise mode-specific attributes.*

The balance of ends – i.e. which audience gets how much and when – is heavily influenced by the legitimacy assumptions. The notion of additivity further demonstrates the primacy of Mode 1 quality control in the pursuit of balance. In other words, the supply side seeks to achieve balance by trying to find opportunities for exploitation whilst staunchly maintaining that Mode 1 quality has to be satisfied as a minimum.

The notion of additivity explains why Mode 2 demand is to be handled in a dynamic, situationally contingent fashion. Although addressing Mode 2 beneficiaries is more natural to some fields than others, demanding visible Mode 2 quality from every individual research programme is technically impossible. Doing so is potentially detrimental to the system's tolerance to causal ambiguity, thereby undermining the long-term health of the science base. Realistic commitment to Mode 2 quality, according to the legitimacy assumptions, has to take into account inherent limitations and simultaneously acknowledge the importance of Mode 2 demand being fulfilled where appropriate. Starting from the minimum condition of scientific soundness, the dynamic outlook – i.e. conditional and open-ended statements – is instrumental in addressing two modes of demand in the context of means-ends opacity.

> ***Output proposition 3B:*** *Based on the strategic imperative and legitimacy assumptions, where* ex ante *incorporation of Mode 2 beneficiaries is problematic, open-ended and conditional statements are used to acknowledge the possibility of economic and social outcomes being realised.*

The organising principle therefore emphasises flexibility and diversity, avoiding the confinement of following a prescribed formula. In the context of an interpretive scheme, the *fuzziness of means* is deliberately advocated as being the most congruent to the legitimacy assumptions of how to achieve the desired ends.

5.2.4 Performance rhetoric

5.2.4.1 Mode-oriented definitions

Impact as Mode 2 performance. The discussion of how *"the UK further encourages innovation and the development of scientific discoveries into new products or services"* and *"the appropriate proportion of effort and funding to devote to research versus encouraging innovation"*[212] that has been the theme throughout the entire chapter reveals an assumption that witnesses thought should be adjusted. Implicit in both questions is the idea that universities should be leading innovation and that *"universities can come up with discoveries and they will be commercialised and therefore lead us to economic growth"*.[213] The assumption may not be the most productive one because it overlooks the notion that universities' indirect contributions to innovation can be much larger than commercialisation. For the overall health of innovation performance, *"skilled people are more important than spinout companies"*.[214]

From the supply-side perspective, this section starts with the idea that impact is *"not just a narrow concept of predicting particular commercialisations"*.[215] Broader, more inclusive measures are to be crafted though commercialisation still remains an important part.[216] Broader perspective takes into account two areas – the stakeholders involved, and how value can be created and delivered to them.

The issue of stakeholders, or what constitutes the Mode 2 audience, is the most salient where receivers (simplistically speaking) have to be identified. There is a concern that conventional knowledge transfer too narrowly focuses on the business community, even though there are opportunities for *"the informing of public policy and a range of other stakeholders as well as just business"*.[217] The business-focused definitions used by knowledge transfer professionals *"only cover a narrow subset of the topic in its entirety and that could lead to some very significant misunderstandings"*.[218] For this reason,

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[212] Lord Broers (Setting Priorities for Publicly Funded Research, 278, Q446)
[213] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 278, Q446)
[214] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 278, Q446)
[215] Prof Alan Thorpe, Chair, RCUK (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 17, Q76)
[216] Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 1, Q1)
[217] Prof Richard Brook, Member, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 18, Q109)
[218] Prof John Murphy, Chairman, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 18, Q108)

"the chase for a simple, one-line common definition is perhaps an academic debate if you wish to have one".[219]

Considering a wide range of stakeholders, a large proportion of whom have contributed to science funding, the research community should be able to *"explain in reasonably clear language what they give back for the money that the taxpayer provides".*[220] This explains the prominence of "economic impact", although there are many ways in which the research base contributes to society. Most significantly, the research base is instrumental in developing highly skilled people, along with creating new businesses and improving the performances of existing ones, informing policy and public services, and, as discussed earlier, attracting business from around the world.[221]

To maximise the potential to make an impact, broadly cast, it is important to recognise that the value of science comes with *"breadth and variability".*[222] Science and engineering can impact on *"the quality of life, on the culture, which is a sign of a civilised society, and on the economic growth of that society".*[223] Accordingly, any *"metricated simplification of the structure into some peer review processes"*[224] is usually criticised for looking *"rather prescriptive".*[225]

A number of witnesses made a special case for the importance of effective science communication to members of the public. Though quantifiable economic value may not be present, better public understanding increases public appreciation for the science they help fund:

> *[The] public do not fully understand the* <u>*public impact of higher education*</u> *in this country, and that is indicated every time you see a reference to higher education in a red-top newspaper and in quotation marks you see the word*

[219] Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 41, Q244)
[220] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 12, Q9)
[221] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 12, Q9)
[222] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)
[223] Sir Peter Williams, Vice-President, Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 9, Q41)
[224] Sir Peter Williams, Vice-President, Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 9, Q41)
[225] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)

> *"boffin". We need to do better. (Rt Hon David Lammy, MP, Minister of State for Higher Education and Intellectual Property, BIS)*[226]

Where effective communication happens, it creates awareness and *"fire[s] the imagination of the nation"*:

> *Just take, for example, the Large Hadron Collider and the Higgs Boson. Those are (to some of us, anyway) rather theoretical concepts in research but that triggered a huge inspiration in the public about science and about the importance of research. (Prof Alan Thorpe, Chair, Research Councils UK)*[227]

Impact as contribution to further Mode 1 quality. In less often heard cases, impact can also be made on the strengthening of the research base, which may not be readily visible to Mode 2 stakeholders. Income generated from scientific research may be reinvested into the research system. For example, where the return on investment from medical research is 40p for one pound of funding, *"only 9p of that 40p is actually due to extension of life or improvement in life. The rest is down to the benefits of the research industry itself".*[228]

Another avenue is through the teaching environment – impactful research makes for high-quality teaching. This argument is especially important when taking a retrospective look at discoveries by the greats, such as the likes of Rutherford and Faraday. Although the eventual economic impact of their work was not clearly discernible at the time, such breakthroughs visibly had tremendous impact on the teaching environments. At the time of Rutherford's gold foil experiment, *"the atmosphere on that campus at that time was quite electric. People knew what was going on but nobody actually knew what would happen when you split the atom, much as people got a bit excited about the Hadron Collider until it broke down".*[229] Therefore, *"it is very important not to divorce a*

[226] Rt Hon David Lammy, MP, Minister of State for Higher Education and Intellectual Property, BIS (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 84, Q268)
[227] Prof Alan Thorpe, Chair, RCUK (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 17, Q76)
[228] Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 163, Q272)
[229] Prof Les Ebdon, Chair, million+ (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 51, Q169)

consideration of the UK research base, much of which is in the universities, from the influence that has on the education".[230]

"Frontier research" as Mode 1 performance. Further to the supply side's dissatisfaction with the taxonomy of research types, it was suggested that labels are not relevant to scientific excellence. The main idea, therefore, is that there should be no distinction between basic and applied research, which is all *"frontier research and all absolutely excellent, world-class research".*[231]

The term "frontier research" blurs the distinction between procedural characters of scientific research and focuses on the merit of the outcomes. Its origin, as recounted by Prof John O'Reilly, is as follows:

> *There was a report*[232] *produced for the European Commission recently from a group chaired by Bill Harris, Director-General of Science Foundation Ireland, where he said that <u>the old divisions that we used to have between pure and applied research are really no longer applicable</u> today. He introduced – or at least he was the first person that I heard introduce – the term "<u>frontier research</u>" and said, "<u>that is what research councils are about</u>". (Prof John O'Reilly, Chief Executive, EPSRC)*[233]

Moving away from the pure-applied dichotomy towards frontier research means that all possible types of research across the spectrum can contribute to the synergy of the enterprise. The outdated equating of "pure" and "better quality" is detrimental to both the scientific community and the wider scene.[234] The *"synergy"* between research and technology transfer are essential for *"knowledge stimulation"* in the research system

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[230] Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 209, Q333)
[231] Prof Ian Diamond, Chief Executive, ESRC and Chair of RCUK Executive Group (*Research Council Support for Knowledge Transfer*, Ev 37, Q223)
[232] Frontier Research: The European Challenge (2005)
[233] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 37, Q223)
[234] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 37, Q223)

and, as a result, *"there is no distinction between pure and applied. You need one to do the other and vice versa"*:[235]

> *We have very demanding scientific requirements for what you might call pure research and studying the ends of the universe – you cannot get more pure than that in some people's minds. Those very strict, very demanding requirements drive technology developments. We need new sensors, we need new equipment in order to push back the frontiers, and so in a sense we are commissioning these things from both the university base and the industry base, high technology, high added value systems, which can then be fed back into wider applications. (Prof Keith Mason, Chief Executive, PPARC)*[236]

The relationship between Mode 1 scientific excellence and impact. The question of whether good science, judged by the peer review community, has any bearing on impact has a number of possible answers depending on what the aim is. In other words, the answer is dependent on the strategic imperative being followed.

In keeping with the main purpose of sustaining the UK's privileged position, it would be *"difficult to imagine how new knowledge, if it is truly new, cannot have some impact"*.[237] If it is accepted that the creation of new knowledge always has an impact, however defined, the most important criterion to look for is originality.[238] In the UK, non-government research funding *"appl[ies] peer review so that all ideas for investment are reviewed by academics"*:

> *The best research gets funded [and] there is a lot of evidence. For example, a very recent report published by Universities UK and the Funding Council for*

[235] Prof Keith Mason, Chief Executive, PPARC (*Research Council Support for Knowledge Transfer*, Ev 38, Q225)
[236] Prof Keith Mason, Chief Executive, PPARC (*Research Council Support for Knowledge Transfer*, Ev 38, Q225)
[237] Prof Michael Arthur, Chair, The Russell Group (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 51, Q166)
[238] Prof Michael Arthur, Chair, The Russell Group (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 51, Q167)

> *England [shows] that the highest quality research base generates the highest quality impact. (Prof Roger Kain, British Academy)*[239]

If the practical usefulness or shorter-term commercialisation outcome is sought after, the answer would be slightly different. Highly impactful research in terms of academic citations is not necessarily the most useful. The exemplary success of biotech spinouts in the US provides a real-world example for this caution. The most successful biotech firms did not come from the *"elite institutions of Stanford and Berkeley, which were the Nobel Prize winners",* instead:

> *More of them came from the University of California, San Francisco, which would be a middle-range university, but that was much more focused on interdisciplinary, problem-based research which was easier to apply than the Nobel Prize winning research. (Dr Paul Nightingale, Science Policy Research Unit)*[240]

Civic engagement and the well-being of the surrounding communities may require a different ethos from the universities mentioned earlier, as there is a much wider set of factors outside of research performance:

> *I do remember many, many years ago when I was at the EPSRC looking at the Times list of universities and a particular university, which I shall not mention, was at the bottom of the list. I went to look at it. The one conclusion to draw was that the community in which that university was placed was infinitely better because it existed. (Sir Richard Brook, Leverhulme Trust)*[241]

[239] Prof Roger Kain, British Academy (*Setting Priorities for Publicly Funded Research*, 206, Q327)
[240] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 279, Q448)
[241] Prof Sir Richard Brook, Leverhulme Trust (*Setting Priorities for Publicly Funded Research*, 280, Q448)

5.2.4.2 Articulation of performance

A broader concept of impact as Mode 2 performance is reflected by more sensitive approaches to measurements and articulation, using qualitative and long-term measures and the combination of *ex ante* and *ex post* articulation.

Qualitative measures. The use of qualitative measures is proposed as an answer to the problem of the *"tick-box mentality"* that brought narrow tables and spreadsheets and *"corrupts and makes the peer review process more difficult".*[242] The breadth that also spans *"impact on public policy"* and *"impact of producing highly educated people"*[243] is not *"readily subjected to quantitative assessments",*[244] so supplementing traditional metrics with qualitative measures may help rectify the problem.

In the absence of variety, quantitative measures targeting commercial outcomes such as university patents and spinouts are *"particularly poor indicators of value to the taxpayer".*[245] Not only do they overlook other potential beneficiaries, the resulting numbers can be misleading even for the very outcome they are designed to measure:

> *I teach an entrepreneurship lecture in which I get on a mobile phone and I start a company in the middle of the lecture. Therefore, in a matter of hours I could produce 50 spinout companies for my university which would go in government figures. <u>Whether or not those spinout companies will ever amount to anything is clearly questionable</u>, to say the least. (Dr Paul Nightingale, Science Policy Research Unit)*[246]

Purely quantitative measures are also not suitable when it comes to assessing qualitative consequences of scientific research. An example of potential limitations of quantitative metrics is, ironically, from the field of pure mathematics and its impact on information

[242] Sir Peter Williams, Vice-President, The Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 10, Q45)
[243] Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 297-298, Q477)
[244] Prof Philip Esler, Chief Executive, AHRC (*Research Council Support for Knowledge Transfer*, Ev 44, Q262)
[245] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 12, Q9)
[246] Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 281, Q451)

security. It is not easy to establish whether there is such thing as a bad impact if the application of research does not go as planned:

> *There are some areas, pure mathematics, for instance, where often the benefits are to the secure exchange of information, and cryptography. If people know about the value of the impact, then it actually has not worked very well as it was not as secure as you had hoped. So again that is another caution about measuring impact. Value impact, yes, but prescriptive measurements of it is a bad idea, we think. (Prof Sir Martin Taylor, Royal Society)*[247]

Long-term measures and articulation of impact. According to what is understood by many, identifying the social and economic impacts of scientific research is a worthy cause but it allegedly requires *"not just a high degree of sensitivity, skill and imagination but an almost supernatural degree of prescience"*.[248] It is rather safe to say that the latter requirement is unattainable, which was also staunchly confirmed by the witnesses:

> *There is a sort of mischievous view which is so nonsensical that, if you pause to reflect, it cannot possibly have been what anybody intended, that one should be able to predict at the beginning of a research project what the outcome will be. If you could, it would not be research. (Prof Adrian Smith, BIS)*[249]

As mentioned in earlier parts of the findings, scientific research can take a long time before its impact becomes visible. Taking into account the long-term nature when measuring and articulating impact reflects the purpose of *"harvesting now the results of research that has been funded over many decades"*:[250]

> *In terms of the timing it can take for things to have impact: in my own rarefied world of pure mathematics, things can take 50 or 100 years to have impact, and*

[247] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)
[248] Lord May of Oxford (*Setting Priorities for Publicly Funded Research*, 161, Q261)
[249] Prof Adrian Smith, BIS (*Setting Priorities for Publicly Funded Research*, 323, Q552)
[250] Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 12, Q10)

> *in the world of the medical science, I think, the MRC and Wellcome say it can take 20/25 years to have impact. (Prof Sir Martin Taylor, Royal Society)*[251]

It also takes time for the beneficiaries on the demand side to fully assess the value of knowledge they receive. Obtaining such data can be difficult, as *"it may take some time, five years or 10 years, until they know whether the knowledge they received has contributed to wealth creation or a contribution to public health"*.[252]

Articulation of impact as Mode 2 performance can be done in two directions – *ex ante* or *ex post*. Due to the long time lag that is often the case, *ex ante* articulation using "leading indicators" is necessary for ongoing assessment and communicating performance where the outcomes are not yet readily apparent. If the *"leading indicators are going in an upward direction, then [there will be] improvements in the outcomes over time"*:[253]

> *Indeed, one of the things we have done to complement the metrics is produce time-line studies which provide examples of this. […] I would encourage you to look at them and think about what that means in terms of the sort of measure you can then get. (Prof John O'Reilly, Chief Executive, EPSRC)*[254]

Short-term, forward measures are thought to be incomplete, because it is *"just the real time tip of the iceberg"*. Retrospective articulation illustrates the impact made *"through the original piece of research, how it was funded, what it led into"*.[255] Historical tracking of impact is useful for retrospective measurement …

> *We have examples of research leading into policy developments, we have lots of statistics on spinouts, on the relationship between business and research councils and individual researchers; we have information on how much inward*

[251] Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)
[252] Prof Sir Richard Brook, Member, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 21, Q130)
[253] Prof Ian Diamond, Chief Executive, ESRC and Chair of RCUK Executive Group (*Research Council Support for Knowledge Transfer*, Ev 45, Q266)
[254] Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 44, Q265)
[255] Prof Adrian Smith, BIS (*Setting Priorities for Publicly Funded Research*, 321, Q 543)

> *investment there is from business because of the excellence of the UK research base; we have got case studies on particular research where, over a 10 to 15 year period, we have invested in the training of research students in academic careers, the prizes being won and the application impact being realised which takes that significant time to be developed. (Prof Alan Thorpe, NERC)*[256]

… and, consequently, justification of investment made for research:

> *We are getting much clearer and much smarter at being able to recognise how successful the UK is at this aspect. So in terms of the retrospective measurement we have a tremendously good story to tell. (Prof Alan Thorpe, NERC)*[257]

Demonstrating that *"at least in the past we have been getting the balance [of funding] right"*[258] *ex post* is important to generate confidence from using lead indicators *ex ante*. If the assumptions that have led to output targets being met in the past still operate, then leading indicators should point generally to a similar direction. Prof Lord Krebs summarised the connection between *ex ante* and *ex post* articulations of impact, which I think should be reproduced here in full:

> *Lord Krebs: Could I follow up on that and check that I have understood your position? The involvement of impact, whether it is assessing retrospectively or prospectively, is not so much about picking winners, I think I understood you to be saying, but it is about both raising awareness of a possible application of research amongst the scientific community but also, retrospectively, making the case to the treasury that past investment, even with a very long time lag – because we know the time lags are in the range of 10 to 25 years – has led to economic benefits.*[259]

[256] Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 163, Q269)
[257] Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 163, Q269)
[258] Dr Steven Hill, RCUK (*Setting Priorities for Publicly Funded Research*, 170, Q292)
[259] Prof Lord John Krebs, Member of the House of Lords, University of Oxford (*Setting Priorities for Publicly Funded Research*, 329, Q575)

Lord Drayson: Yes, that is correct.[260]

Considering what is required to articulate the impact in both directions, tracking and keeping records of impact over time is something that should be carried out systematically, not only because *"many of us would be very interested in seeing the benefit to society and the economy"*[261] in the long term, but it will ultimately help make a case to secure resources and funding in the future:

> *You cannot just evangelise about this; you do need to be able to point to some hard figures where necessary. (Rt Hon Lord Drayson, Minister for Science and Innovation)*[262]

5.2.4.3 Proposition 4

Performance criteria which determine what constitutes appropriate practices and expectations provide an interface between the supply and demand sides. For this purpose, performance rhetoric is the venue in which the witnesses package their considerations for relevant stakeholders from both modes under a common paradigm. Central to the narrative is the refutation of two ideas – (i) the myth of research commercialisation as the main indicator of Mode 2 quality, and (ii) the association of research types and their supposed outcomes.

The rhetoric contains two important parts. The first part requires definitional adjustments proposed to both Mode 1 and Mode 2 constituents. The aims are (i) for the supply side to retain sufficient discretion over the research activities, and (ii) to increase the supply side's own receptiveness to the Mode 2 audience's scientific needs. The second part involves responding to the continuous scrutiny over Mode 2 performance, by using both *ex ante* and *ex post* articulation.

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[260] Rt Hon Lord Drayson, Minister for Science and Innovation (*Setting Priorities for Publicly Funded Research*, 329, Q575)
[261] Prof Diana Green, Vice-Chancellor, Sheffield Hallam University (*Research Council Support for Knowledge Transfer*, Ev 14, Q80)
[262] Rt Hon Lord Drayson, Minister for Science and Innovation (*Setting Priorities for Publicly Funded Research*, 329, Q575)

The first point has to do with what is previously termed "additivity" (5.2.3.2) – finding balance through improving Mode 2 quality whilst maintaining Mode 1 standards. Following from this approach, the question is how to maintain the allowance for uncertainty in scientific research while attending to Mode 2 demands. As earlier discussed for Proposition 2, the knowledge production system's tolerance to unpredictability will likely be undermined if visible economic impact is constantly demanded at the project level. It is therefore necessary to move away from the narrowly cast economic and commercial definitions.

Proposing and legitimating a wider concept of impact relieves the supply side from the constant short-term pressure for economic returns. A wider range of audiences that goes beyond the business community increases the variety of ways in which the return on public investment can be made, especially in non-monetary terms. The breadth and variability should therefore allow researchers to demonstrate their impact more easily and convincingly.

Metaphorically speaking, using a bigger dartboard means more darts can hit the board without changes being made as to how they are thrown.

> ***Output proposition 4A:*** *Based on the strategic imperative and legitimacy assumptions, Mode 1 performance may be maintained by broadening the scope of what constitutes the Mode 2 quality control audience and, consequently, the ways in which impact can be made.*

The denouncing of simplistic taxonomy of research types comes with the message that says the quality of science is not dependent on procedural characteristics. This assertion is especially strong in the context of addressing the scientific needs of the nation. Exploitation and grand challenges are underpinned by various types of research across the spectrum, and the outdated idea equating "pure" to "excellent" does not work in favour of such tasks.

Convincing the peer review community that the funding should be towards frontier research rather than a certain arbitrary type increases the chance of funded research being more diverse and delivering better to the Mode 2 audience.

> ***Output proposition 4B:*** *Based on the strategic imperative and legitimacy assumptions, Mode 2 performance may be enhanced by broadening the content of what constitutes Mode 1 scientific excellence.*

Justifying public investment takes more than demonstrating challenges from causal ambiguity and a long time horizon. The witnesses implied two necessary grounds to be covered. On the one hand, realistic expectations have to be established according to the inherent uncertainty of scientific progress. On the other hand, some results have to be demonstrated so that the demand side is convinced of the validity of the supply side's legitimating assumptions.

The complementarity between *ex post* and *ex ante* articulation is useful to secure the demand side's confidence and continued allowance for the supply side's freedom. Retrospective accounts reinforce the credibility of leading indicators that are used to demonstrate the ongoing progress. Such synergy is important for the justification of ongoing or future projects whose results are not fully discernible in advance.

> ***Output proposition 4C:*** *Based on the strategic imperative and legitimacy assumptions, justifying resource allowance for scientific research involves a combination of* ex post *and* ex ante *articulation of impact towards the Mode 2 audience.*

6 MODE 1/ MODE 2 COEXISTENCE AND THE LEGITIMACY OF SCIENTIFIC KNOWLEDGE PRODUCTION

The findings and propositions developed in Chapters 4 and 5 indicate two key messages:

- Neither Mode 1 nor Mode 2 is stable from the supply side's perspective on the prioritisation and funding of science. This instability allows elements from both modes to coexist.
- The coexistence is supported by a lack of clear procedures prescribing how knowledge is to be produced. This poses limits to our ability to evaluate the supply side's compliance with the legitimacy pressures exerted from the public.

Accordingly, there are two parts to this chapter. The first draws from the output propositions 1-4 to discuss three areas on which Mode 1 still retains its enduring influences, especially where Mode 2 institutional audiences are concerned. Further, I also discuss how this approach helps alleviate an important problem – Mode 1/Mode 2 mutual exclusivity – that has so far impeded our understanding of Mode 2 as a descriptive account of change in scientific knowledge production. The second part stems from the supply side's refusal to commit exclusively to a single mode, regardless of the audience in question. I raise some questions on our current assumptions on legitimacy, especially as to what constitutes compliance and resistance. I also suggest three antecedents that justify the manner in which the supply side responds to diverse institutional demands.

6.1 What happens to Mode 1?

In this study, the fate of Mode 1 is framed through the supply side's perspective on the issues related to funding and prioritisation of scientific research. To secure continuous funding from the public, the supply side relies on the explanations of what scientific progress entails. It is the organised nature of the supply side, its political motives, and the interactions with demand constituents in the institutional field that add to the understanding of the phenomenon of interest.

For their accounts of knowledge production, scientists are regarded collectively as a UK-based sector without specific referrals to universities as their administrative homes. The findings from Phase I suggest that academic scientists do not see universities as the most relevant source of legitimacy, as long as other beneficiaries in the wider societal context can be identified. In essence, they form an epistemic community transcending university boundaries. Phase II builds on this notion, as the expert witnesses representing the supply side also place heavy emphases on individual scientists and funding councils rather than universities, which perhaps reflects the nature of resource allocation for scientific research in the UK.

Regardless, the supply side's coherence and its consensus on the imperative of maintaining the UK's science base further reveal (i) its political motives, and (ii) how responses to institutional demands must be framed accordingly. Amidst the difficult economic climate and pressures for better value for money, the most evident intention of the supply side is for the level of funding to be maintained at least on par with those of competing countries. The notion of science base is instrumental to this task. The public has to be convinced that the assumptions held by the supply side – that scientific research is causally ambiguous and scientific expertise is not tradeable, for example – are valid for subsequent arguments to be credible. When put this way, the utility of the supply side's imperative is in its versatility as the single most important mission that benefits every possible audience across the institutional landscape. Further, as the science base remains the top priority, scientists have afforded a considerable degree of discretion over the course of actions they are undertaking.

6.1.1 Areas of Mode 1 influences in response to Mode 2 demands

There are three ways in which Mode 1 still retains its influences, even when Mode 2 audiences are being addressed. Each of the three statements offered below are drawn from a corresponding group of output propositions listed in Chapter 5. The first proposition outlines which institutional audiences are regarded as relevant. Based on this notion:

- Output Propositions 2A and 2B indicate the primacy of Mode 1 quality control regime (peer review);

- Output Propositions 3A and 3B indicate the necessity of allowance for Mode 1 means of knowledge production; and
- Output Propositions 4A–4C demonstrate how Mode 1's influences are operationalised and communicated to the entire range of audiences.

Mode 1 quality control

Mode 1 quality control regime resides in the supply side's legitimacy assumptions, in service to strategic imperative.

The first indication of Mode 1's presence is in the supply-side expression of the strategic imperative to maintain the privileged position of the science base, along with the assumptions that underpin it. In defence of resource allowance for a broad-spectrum scientific research portfolio, informants converge on what could be described as textbook resource-based view (RBV) principles. The assumptions of knowledge – that it is imperfectly tradeable, and its accumulation causally ambiguous and path dependent – are well aligned with the conventional wisdom (Callon, 1994; Pavitt, 1991). It is these assumptions that are used as a backup for explanations of why Mode 1 quality control is essential for the imperative, and indications as to what is permissible as a response to institutional demands.

This is not to suggest that RBV assumptions are deployed because of their truism, as it is beyond the circumstances in which the data are generated. In fact, the level of truism in itself matters little in this context. It is possible to conclude that the assumptions "ring true" to the intersubjectively agreed characteristics of knowledge amongst scientists, and they can be substantiated by historical evidence. These accounts resemble the "vocabularies of motive" (Mills, 1940) that could be mobilised in favour of the supply side's interest. Causal ambiguity, for example, is heavily leveraged to demonstrate that a Mode 1 peer review judgement is the only quality control regime that is applicable systematically *ex ante*. That knowledge is individually embedded and not fully tradeable also strengthens the need to maintain Mode 1 performance, as it attracts world-class experts who then continue reinforcing the science and engineering base.

The all-encompassing influence of the science base as an imperative highlights a contrast between Mode 2 and the supply-side narrative. There may have been an overarching assumption that informed how Gibbons and colleagues construct the modes as two distinct baskets. Nonetheless, there is no indication as to what said assumption is. It is clear from this study that RBV is a highly unlikely candidate despite the heavy influence found in this study. Commonly accepted characteristics, such as unpredictability, and consequences such as the need for absorptive capacity at the system level, do not seem to have influenced the construction of Mode 2.

Mode 1 means

Mode 1 means of organising knowledge production reside in the dissociation of means and ends.

It can be seen from the findings that no particular privilege is given to any specific form of means-ends association, which is a consequence of the perception of causal ambiguity. Mode 2 means attributes, such as reflexivity, in itself do not have any bearing on how Mode 1 quality is achieved through the peer review process. The same applies to Mode 1 means attributes, such as where a researcher's curiosity does not necessarily preclude application potential. Unsurprisingly, the permeability between the two modes appears to resonate best among the informants.

The preferred state of permeability between the two modes permits Mode 1 means attributes to remain even as the Mode 2 audience is being addressed. It is an organising principle that corresponds to a shared belief in how the science and engineering base develops. The lack of ability to predict where the next advance is coming from is influential to the supply side's insistence on allowing all possible pathways to exist in the knowledge production system. It is therefore essential that the means to both Mode 1 and Mode 2 ends are kept fuzzy to be coherent with the assumptions that underpin the strategic imperative.

The important implication from the fuzziness is that its resolution is to be determined by expert knowledge. It is therefore argued that the supply side should retain sufficient discretion on the operational level of knowledge production. The issue of invoking means fuzziness in response to institutional demands is further discussed for its theoretical implications in section 6.2

Operationalisation

The operationalisation of Mode 1's influence resides in how performance criteria towards the entire range of audiences are defined and articulated.

The role of Mode 1 in the performance rhetoric is contingent on the strategic imperative being pursued. Prioritising for short-term practical results necessarily engenders a set of expectations that is different from a view that favours the accumulation of knowledge and capabilities. In this case, the imperative to maintain the UK's privileged resource position has led to the defence of allowance for both modes to coexist, as previously discussed. Performance definitions therefore have to be crafted in a way that make it possible to defend the broader level interest.

There are two synergistic parts of the proposed adjustment:

- Expand the scope of Mode 2 targets such that the same standard of Mode 1 quality is maintained without being shoehorned into commercialisation.
- Expand the content of Mode 1 excellence accepted by the peer review community so that the increased diversity of research can address (now-expanded) the Mode 2 target more effectively.

What follows is the difference in the immediacy of the results that are discernible to Mode 1 vs. Mode 2 audiences. If the suggestions are successfully implemented, the maintenance of Mode 1 quality can be perceived immediately by the peer review community. The situation is somewhat different for the Mode 2 audience. The expanded definition of Mode 1 quality hopefully helps enhance the benefits to the Mode 2 audience, but the actual results are still characterised by uncertainty and may only be realised in the long run. What this does, though, is to ensure that the strategic imperative remains intact.

Both parts of the performance rhetoric fit with the limited predictability inherent in scientific research and the temporal position of Mode 1 and Mode 2 quality control. We have seen that scientific research is regarded as causally ambiguous, yet the justification of resource allowance is needed upfront. Following the point made earlier in the discussion, Mode 1 is the only quality control regime that is known as systematically applicable *ex ante*. Mode 2 quality is speculative *ex ante*, as its actual outcome is only visible *ex post*. Given the supply side's role being mainly in the upstream part of knowledge production, using Mode 1 as an anchor point in performance definitions seems pragmatic even when pitching directly to the Mode 2 audience. The temporal positions of Mode 1 and Mode 2 quality checkpoints also influence the combination between *ex ante* and *ex post* articulation of performance. The need to demonstrate commitment and maintain long-term credibility is also reflected in various government reports and policy publications on the issue (e.g. Council for Science and Technology, 2010; Royal Society, 2010; Univerities UK, 2010).

The means-ends frame was instrumental in operationalising supply-side assumptions into performance rhetoric. To construct a narrative aimed at the general audience, both Mode 1 and 2 included, using either Mode 2's original bundled form or its five attributes as independent features would be a formidable challenge. Arguments based on the bundled form would be marred by technical and historical inaccuracies and, more importantly, the underlying assumption is not accepted by members of the supply side to begin with. On the other hand, delineating five attributes would be burdensome and difficult to generalise as day-to-day idiosyncrasies of scientific research. Furthermore, the potential risk of incoherence would render the narrative unconvincing (Phillips, Lawrence and Hardy, 2004). Operationalising each mode as means-ends is specific in terms of the audience being addressed and, at the same time, ambiguous enough to allow for discretion to be exercised when the means are spoken of as a collective. In other words, ambiguity promotes "unified diversity" because it fosters "agreement on abstractions without limiting specific interpretations" (Eisenberg, 1984, pp. 230–231). The art, it seems, is to achieve the right amount of such ambiguity.

6.1.2 Visualising coexistence

The three areas of coexistence can be rendered in a single scheme containing attributes from both Modes 1 and 2, as depicted in Figure 6-1 below.

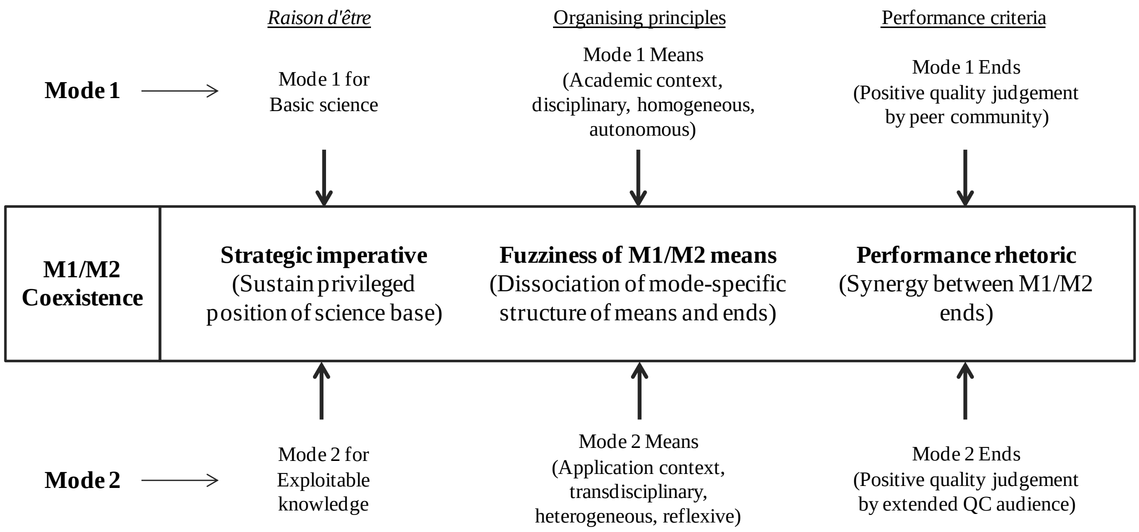

Figure 6-1 Mode 1/Mode 2 coexistence

The coexistence of Mode 1 and Mode 2 hinges on the central importance of the strategic imperative, which is to maintain the UK's privileged science base. This is the central message even when Mode 2 audiences are specifically targeted. Scientists argue that it is not always possible to strictly follow Mode 2 means of knowledge production, as it increases the risk of depleting the fundamental knowledge needed for both the exploitation and further creation of knowledge. Mode 1 means can lead to useful applications, whereas Mode 2 means do not preclude scientific excellence. This means that there can be any number of combinations between Mode 1 and Mode 2 attributes, all of which should be considered legitimate if it adds to the health and diversity of the science base. In other words, if a mode was to exist, it must indeed be fuzzy. It is worth keeping in mind, then, that maintaining the science base is supposed to be for the benefit of everyone, not only scientists. The relationship between the audiences – the peer community and the broadly defined public – is then interwoven in the performance rhetoric that serves to protect the science base regardless of which audience is being addressed.

The term “balance” is often used by both interviewees and expert witnesses to indicate the desired state of mix between fundamental advances and practical usefulness. It is worth noting, however, that “balance” is specified beyond “coexistence” as the latter merely suggests that there are more than one element of interest. Figure 6-1 therefore depicts the coexistence between the two modes without identifying the proportion of each. In comparison, balance seems to be an aspirational term that demonstrates to the audience that this is what academic science strives to achieve. A closer look at the search for balance, however, reveals that although it is universally desired, the optimum proportion remains perpetually unknown.

Key to maintaining coexistence, if not achieving balance, is a break away from the outdated alignment between means and ends of knowledge production. The belief that scientific excellence only comes from academic contexts, or usefulness only comes from application contexts, for example, restricts the opportunities for unexpected outcomes which have, for centuries, been pivotal to scientific advances made.

6.1.3 Empirical basis of Mode 2 as an account of change in scientific knowledge production

The main problem identified in the literature review is the persistent doubt over Mode 2’s accuracy as a descriptive account of change in scientific knowledge production (see 2.2 and 2.3). Our ability to agree or disagree with the diagnosis put forth in 1994 by Gibbons and colleagues is marred by a number of technical difficulties, such as the clarity of individual attributes (e.g. what it means by “transdisciplinarity”), disagreement over Mode 2’s novelty, mutual exclusivity of Mode 1 vs. Mode 2, the generality of the claim, and whether the five attributes are coherent (Hessels and Van Lente, 2008). One of the criticisms is, of course, that the formulation of Mode 2 does not allow it to be tested, examined, or described in a nuanced way (Shinn, 2002), such that it provides “no questions, but lots of answers” (p. 603). It is therefore worth coming back, in the light of this research, to how sense can be made with the help of empirical data, examined through the interpretive schemes consisting of *raison d’être*, means, and ends (Greenwood and Hinings, 1988).

***Raison d’être* as the missing link.** The application of an interpretive scheme (Greenwood and Hinings, 1988) reveals *raison d’être*, empirically identified as strategic imperative, as an additional component bridging Mode 1 and Mode 2. It is important to note that for *raison d'être* to function as a bridge, it must be mode-neutral in character. From the analytical framework (Figure 3-1), this research started by assuming two *raisons d'être* – basic science vs. exploitable knowledge, one specific to each mode. The empirical findings, however, only point to one – the central importance of the science base as the supply-side strategic imperative. Response to the entire range of institutional demands is devised in service of sustaining the privileged position of the science base, which is not reducible a single mode.

Generally speaking, *raison d'être* is a basic element in the institutionally derived connections between the basis of legitimacy, legitimated procedures and expected outcomes. It bears repeating, then, that the way in which Mode 1/Mode 2 coexistence is articulated in this study rests on this assumption that has been put forward since Meyer and Rowan (1977). Table 6-1 provides a summary of comparable terms found in the two frameworks that influence this study, along with those identified from the empirical findings.

Table 6-1 Comparison between theoretical frameworks and findings

Sources	Basis of legitimacy	Legitimated procedures	Expected outcomes
"Formal structure as myth and ceremony" Meyer and Rowan (1977)	Institutional rules as rationalised myths	Means	Ends
"Interpretive schemes" Greenwood and Hinings (1988)	Organisational field/ *Raison d'être*	Organising principles	Performance criteria
M1/M2 coexistence (Findings of this study)	Strategic imperative and legitimacy assumptions	Means fuzziness	Performance rhetoric

The strategic imperative is highly consequential to how Mode 1/Mode 2 coexistence is articulated, as it determines what is permissible as a response to an institutional audience. Resource-based explanations of scientific advances provide legitimacy assumptions that are needed to back the claims justifying Mode 1 in the service of the Mode 2 audience. The perception of causal ambiguity, for example, supports the argument that Mode 1 quality control and means fuzziness are essential. While the institutional audience clearly matters, it is the strategic importance of the science base that provides the anchor and permits certain arguments to be made.

In the absence of strategic imperative and legitimacy assumptions, there is no rationale based on which the coexistence can be articulated and understood. This observation also speaks to Pestre's (2003) critique of Mode 2 being written as technical and naturalistic, giving a false impression of apolitical, interest-free knowledge production. The role of *raison d'être* shows the socially constructed nature of a coexistence narrative, since it varies across different constituents and vested interests.

Empirical evidence and the articulation of Mode 2. The central importance of *raison d'être* to the supply-side argument raises a question regarding the nature of empirical evidence and the role it played in the original formulation of Mode 2. It is stated that:

> It is our contention that there is sufficient empirical evidence to indicate that a distinct set of cognitive and social practices is beginning to emerge and these practices are different from those that govern Mode 1. (Gibbons et al., 1994, p. 3)

As discussed in Chapter 2, the existing critiques of Mode 2's empirical validity suggest that it is not clear what the nature of said evidence is. The use of economic parameters and observations of outward trends could potentially have resulted in a tidy delineation of itemised "modes". In the follow-up volume *Re-Thinking Science*, the issue of responsive vs. directed research is discussed in relation to the "undermining" of the traditional peer-review system:

> In most research council systems the balance of funding has shifted from the responsive mode, based on academic peer review and self-governance, to the directed mode, based on national priorities, thematic research, joint funding, managerial imperatives and a peer review process drawn from a greater range of individuals and groups. (Nowotny et al., 2001, p. 77)

The clear shift, however, has been repeatedly refuted by the academic scientists according to the oral evidence examined in this study, since a large proportion of research projects administratively labelled as directed are in fact responsive (see 5.2.3.2). Nowotny and colleagues did not reveal the source of this claim, but the truthfulness of their statistical interpretation is not the most relevant issue here: instead, it is the vantage point taken. The data generated from different perspectives or levels of analysis can give contrasting impressions. An investigation of "quality control", for instance, from the level of universities and funding agencies (Hemlin and Rasmussen, 2006) can be supportive of Mode 2's claims whereas the opposite is true from the perspective of scientists (Albert et al., 2012). Issues of data aside, the motivation of the authors is also relevant to the question. To influence policy, for example, including socially oriented variables such as *raison d'être* may not be the best idea.

This study shows that the inclusion of motivation and interests provide an opportunity for us to better understand how Mode 2, as a descriptive account of change, unfolds in the struggles of scientific knowledge production. Specifically, the ability to articulate the coexistence alleviates the problem of between-mode mutual exclusivity that previously seemed intractable (Fuller, 2000). As pointed out, however, the approach I have taken comes with the territory. By design, it is contingent on a single interest group sharing the same *raison d'être*. In this case, the fate of Mode 1 is only seen through the perspective of academic scientists who, most importantly, frame the "coexistence" to justify further resource allowances from the public audience.

6.2 Theoretical implications: Legitimacy obscured

Theoretical implications arise from the supply side's use of "means fuzziness", reflecting the shared assumption that the end of satisfying the Mode 2 audience entails a blend of means from both Mode 1 and Mode 2. The lack of consensus over how means and ends connect severely limits the applicability of procedural assumption of legitimacy response underpinned by "rationalised myths" (Meyer and Rowan, 1977). Comprehensibility of myths, such as the link between a quality management system and the actual maintenance of quality standards, means that the adoption of "correct" procedures or structures typically suffices as a signal of compliance. The interaction between scientists and demand constituents presented in this study is significantly different, as the presence of causal ambiguity obscures the connection between means and ends. It is therefore not possible for any specific form of means-ends to be rationalised into accepted procedures without inviting further challenges and refutation.

A situation such as this requires a response that is different from procedural compliance, for the simple reason that the procedure does not exist to be followed. Adding to the challenge is the lack of clear performance definitions. The resulting non-standard response tactic calls into question the assumptions on legitimacy response that have so far appeared to be valid in less opaque fields.

6.2.1 Means fuzziness as a legitimacy response in an opaque institutional field

Responding to Mode 2 demands illustrates the challenge of how to gain and maintain legitimacy in an "opaque institutional field" where "practices, causality, and performance are hard to understand and chart" (Wijen, 2014a, p. 302). A gap between means and ends, as is the case in an opaque field, is usually drawn in parallel to a gap between policy adoption and practice, which is a classic definition of decoupling. The comparison between the two, mapped against an ideal organisation where policies, practices and outcomes are aligned, has been illustrated by Bromley and Powell (2012) and is reproduced here in Figure 6-2.

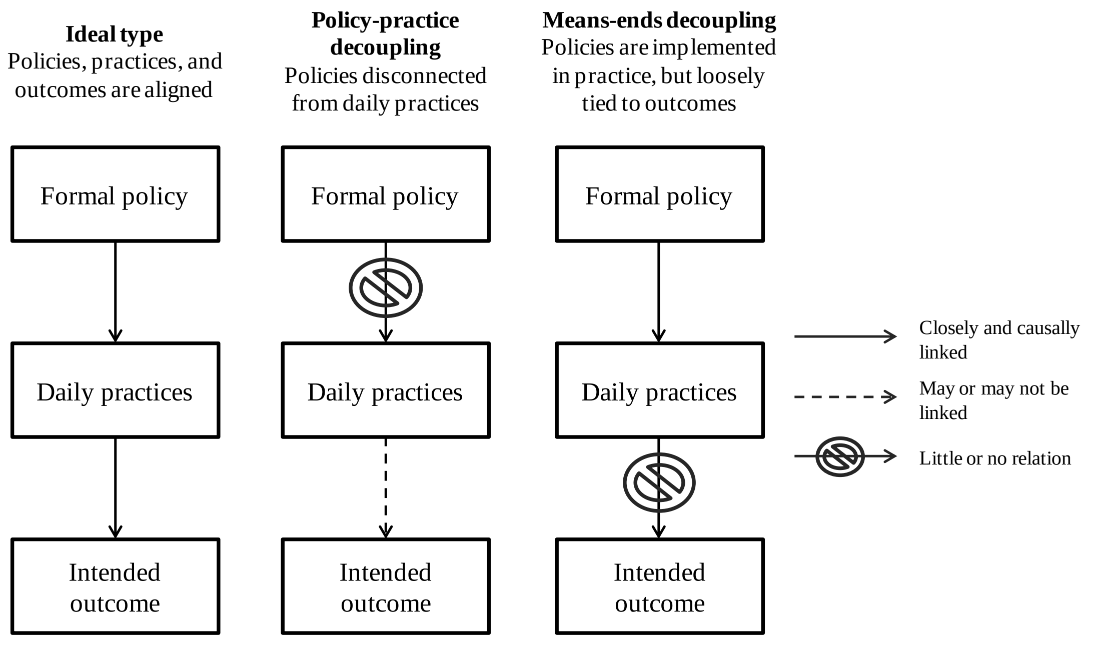

Figure 6-2 Comparison between ideal organisation and two types of decoupling (Source: Bromley and Powell (2012))

In policy-practice decoupling, organisations feign compliance by ceremonially signalling their adoption of legitimated procedures without changing how they operate in the core technical areas (Meyer and Rowan, 1977; Weick, 1976). In other words, the ideal theory prescribed to such organisations does not live up to day-to-day requirements specific to each organisation, especially in the presence of competing demands (Kraatz and Block, 2008). In this case, organisations may continue to maintain satisfactory performance, as they manage to protect internal operations while keeping a façade of compliance (Crilly, Zollo and Hansen, 2012; MacLean and Behnam, 2010; Westphal and Zajac, 1998, 2001).

Substantive adopters experience another kind of gap called means-ends decoupling (Bromley and Powell, 2012). This is the case where following the rules bears little or no relationship to achieving the goal as intended. This kind of gap appears to be increasingly common as a result of audit culture that serves to increase the pressure for compliance that is prominent in areas such as sustainability and corporate social responsibility (CSR) (Bromley and Powell, 2012; Wijen, 2014a). The rigidity of institutions only creates irony as compliant adopters do not achieve their goals. In a recent empirical study, the plausible linkage between introducing part-time work in the police service, the retention of skills of female staff and the improvement of efficiency do not seem to work in practice. Not only do the benefits appear minimal, adverse consequences in operational efficiency have become evident (Dick, 2015). Despite suboptimal outcomes in a technical sense, policies such as this will likely remain in place because they correspond to other demands from stakeholders. To address such challenges, the adoption-performance trade-off has been the main concern in this nascent area of literature (Dick, 2015; Wijen, 2014b, 2014a).

Scientific research also shares an opaque nature with CSR, traffic security, health care and consultancy (Wijen, 2014a) but its intractability is on a different basis from that of the adoption-performance trade-off. To begin with, legitimated procedures have to be agreed upon, formally or informally, for substantive adoption to be verified. Intended performance outcome must also be identified for the actual outcome to be calibrated against the goal. In such instance, it can be said that legitimacy is not likely to be problematic as long as the correct procedure is adopted, only that the intended outcome would then suffer. This study is different on both counts. Both retrospective accounts of spinout formation and strategic priority debates show that a specific procedure does not exist to be followed, and neither does a clear definition of what is expected as performance. Means fuzziness and performance rhetoric demonstrate this point. The continual negotiation between supply and demand sides ensues as a result, even if all constituents appear to share the same goal of "the greater good". Scientists often quote Francis Bacon's statement, "Science discovery should be driven not just by the quest for intellectual enlightenment, but also for the relief of man's estate" (Gruss, 2012, p. 336). How this is achieved has yet to be agreed upon.

Means fuzziness, in particular, denotes the scientists' attempt to retain discretion over their choices of specific approaches to scientific research. The field opacity alone, however, does not warrant the foregoing of means-ends arrangements such as Mode 2, which appears to be coherent and comprehensible. This is where strategic imperative, legitimacy assumptions and performance rhetoric feature, supporting the scientists' bid to protect the discretion. Given the imperative, the use of means fuzziness is backed by an understanding of how scientific advances come about. To this end, experts offer RBV-like explanations that are technically and historically verifiable. The same backing also informs the extent to which promises can be made, what constitutes realistic performance expectations and how to withstand continuous scrutiny even in the absence of immediate results. Performance rhetoric, dealing with these points, is instrumental for an enterprise as fraught with unpredictability as science to secure continued support from the lay public.

6.2.2 Implications on procedural assumptions of legitimacy

The main challenge posed by the use of means fuzziness is that it may not be possible for the public to objectively evaluate the supply side's compliance. By focusing first on how to answer to the audience, this study shows that the procedural assumption of legitimacy – that compliance can be achieved by following the rules (Meyer and Rowan, 1977; Oliver, 1991) – may be less applicable in the context of this study. Oliver's (1991) repertoire of strategic responses to the institutional process, introduced earlier in Chapter 3, has so far been successfully applied where legitimated procedures can be identified (Heugens and Lander, 2009; Marquis and Lounsbury, 2007). Where it is possible for the fuzziness of procedures to be invoked such as in this study, the following assumptions that underpin Oliver's theorising have become somewhat problematic:

- There is a dichotomy between apparent and substantive compliance.
- A response tactic can be placed on the continuum between conformity and resistance.
- Negotiation denotes resistance and dilutes conformity.

Central to the problem is not the opacity or ambiguity *per se*, but the knowledge that is required in formulating responses to institutional demands and evaluating them. The disparity of the specialised knowledge between experts and the lay audience points to the question of whether there is such a thing as real compliance that is unquestionable regardless of the observer. According to Oliver's range of strategic and tactical responses, performance rhetoric involves an element of influencing public opinion that amounts to "manipulation" – the most highly resistant form of strategy. But how much is this so? Who is to say that members of the lay public always know what is best for them, especially in the long run? Equally, who is to say scientists cannot and will not abuse the public trust to advance their professional agenda by doing only what interests them and their peers? The supply-demand knowledge differentials mean that the majority of people who are more technically able to evaluate both of these speculations are on the supply side. The contemporary definition of the Haldane Principle – that specific decisions in science funding and direction belong with scientists instead of government and ministers – also reflects and reinforces this condition (Hughes, 2011).

The meaning of negotiation – what is intended and what it entails – is therefore permanently obscured. As a result, it is nearly impossible to say with confidence whether, or to what extent, the three assumptions mentioned above remain valid. On a broader outlook of the science-society contract, further debates will be necessary on how we understand the democratisation of science (Nowotny, 2003; Weingart, 1997).

6.2.3 Antecedents to means fuzziness

So far we have learned that academic scientists deal with disparate demands for scientific research by attempting to keep the means of knowledge production fuzzy. The main implication is that the fuzziness can only be resolved by using scientific expertise. For this to happen, it is necessary that scientists maintain a sufficient level of discretion over their operational decisions. The findings suggest that this line of argument is possible where certain antecedents exist. In the absence of these enabling conditions, means fuzziness and discretion may not be justifiable as a response to multiple demands regardless of the opacity of a given institutional field.

Discernible and damaging consequences of "getting it wrong". Speaking from the public understanding of science, the attention is on the discoveries rather than how they came to be discovered (Nightingale and Martin, 2004). The public expects breakthroughs to be made in cancer treatment, for example, but it is not equipped to judge whether the current methods of research or how they are being funded will lead to such an outcome. An expert witness's lament over the media's depiction of "boffins", and comments on short-term pressure by interviewees, illustrates this point.

While little of the process is known to the public, the potentially grave consequence of making mistakes is highly visible and not easily reversible. Prudence is therefore fundamentally essential to the application of scientific research. With regard to the complaints over the long period it takes for drug development and testing, for example the thalidomide disaster during the '50s and '60s is a rather extreme case study, though it involved a drug company rather than universities. Thalidomide was developed as a sleeping pill. During the period in which regulations on drug testing were relaxed, it was deemed safe to be administered to pregnant women as relief for morning sickness. Nothing was known of its effect on unborn babies until they were born with malformed limbs (Franks, Macpherson and Figg, 2004; Smithells, 1965). Another example is the false link between the measles-mumps-rubella (MMR) vaccine and autism, originally identified by Wakefield and colleagues (Wakefield et al., 1998). Later research has confirmed that there was no evidence to the claim (Offit and Coffin, 2003), and the original paper was finally retracted from *The Lancet* (The Editors of the Lancet, 2010). Despite the retraction, reversing the public fear over the vaccine's safety would be an uphill battle and require more research expenditure than what it originally cost to produce the refuted results (Offit and Coffin, 2003).

The need for scientific rigour in preventing such disasters places a limit on responding to Mode 2 demands in a more systematic and immediate manner, and highlights the importance of Mode 1 quality control as a basic requirement. As a result of the need for prudence, discretion is afforded by the supply-side experts and stringent requirements on scientific standards remain in place. This does not necessarily lessen any transparency seen from a Mode 1 quality control point of view, but it limits the supply side's responsiveness to Mode 2 demands.

> ***Proposition 5A:*** *In an opaque institutional field, the more damaging the consequences of technical failure, the higher the likelihood of means fuzziness being leveraged as a tactic.*

Clarity of demand definition. The possibility of having a recipe in response to institutional demands is further obscured by the ambiguity of who makes up the demand constituents and, subsequently, demand content. The proposal to broaden the scope of the Mode 2 audience in an attempt to move away from the popular economic focus reflects the currently fluid nature of how demand constituents can be identified.

The broadened range of audiences solves one problem and creates another when it comes to the need for all constituents to be accommodated in a demonstrable way. It allows a greater degree of flexibility and discretion, but simultaneously further obscures the "display" of responses. The first challenge is the sheer variety of stakeholders with disparate interests and expectations, necessitating multiple ways that are required to handle the demands. A less obvious challenge is a consequence from varied perceptions of scientific research found in the audience. Specialised groups of audiences, such as R&D intensive businesses, appear to share the supply-side assumptions, judging from the positive relationship between public research expenditure and private investment. At the same time, there remains a problem of public understanding of science. And finally, academic constituents also have preferences in favour of their own survival, which is typically contingent on Mode 1 quality control regime. These scenarios suggest varying levels of tolerance to means-ends opacity. As a result, adoption of a certain approach is likely to be met with approval from some constituents but not others, thereby calling for further variety. It is worth keeping in mind, however, that the high level of ambiguity has a strategic value as it allows for greater scope for discretion (Goodrick and Salancik, 1996).

More cases of legitimation strategy in the presence of institutional complexity and multiple demands are constantly being added to the literature (Greenwood et al., 2011). More often than not, however, demand constituents within such a plurality are relatively better delineated than those embedded in Mode 2 (Battilana and Dorado, 2010; Pache and Santos, 2013; Raaijmakers et al., 2015).

> ***Proposition 5B:*** *In an opaque institutional field, the less the degree of clarity to which the demand constituents and content can be identified, the higher the likelihood of means fuzziness being leveraged as a tactic.*

Knowledge differentials in demand-supply interdependence. The supply-side narrative in itself suggests that neither the demand nor the supply side has absolute power over the other. The demand side imposes requirements on scientific research but simultaneously relies on the supply side for an assessment as to how realistic such requirements are. Likewise, although the supply side commands a considerable degree of discretion over scientific progress, it is dependent to a great deal on public funding and resources.

On paper, the premise of discussions and debates on "prioritising scientific research" and "value for money for public investment" undoubtedly points to academic science's dependence on public funding. Mode 2 constituents seem to hold the sanctioning power to which the supply side responds. Such is a typical narrative in which organisations seek legitimacy from their environments (Ashforth and Gibbs, 1990; Durand and Jourdan, 2012; Quirke, 2013). Notions such as the democratisation of science (Nowotny, 2003) and the changing social contract between universities and their stakeholders (Elzinga, 1997; Gibbons, 1999) also give a very similar impression. That the many important figures from the supply side have been summoned and questioned on the matter by S&T select committees is testimonial to the dependence on the demand's side approval.

On the other side are the knowledge differentials that grant the supply side a significant discretion over how it "responds" to the demands. If the means-ends chain is already opaque to the scientists themselves, it is even more so for the demand side. Little is known to non-specialists as to how and when scientific needs can be technically fulfilled. From the supply side's legitimacy assumptions, responding to demands will necessarily involve caveats. The opacity does not dissipate because of increased public scrutiny. On the contrary, it may well be more intensely highlighted by the supply side as a result, for it demonstrates that the simplistic means-ends frame will not hold. Some leeway is therefore made possible and can be substantiated by knowledge differentials that are disproportionately commanded by the supply side.

This antecedent raises the question of what constitutes a legitimate source of legitimacy (Deephouse and Suchman, 2008; Deephouse, 1996). It can be said that Mode 2 provides legitimating elements to contemporary academic science (Etzkowitz and Leydesdorff, 2000) but not exclusively. Demand constituents do not necessarily "police their logics with the same insistence … nor are they *able* to" (Greenwood et al., 2011, p. 343 emphasis in original). Realistically speaking, if academic science unquestionably followed policy mandates and conformed to commercialisation targets, would the public see that as a legitimate thing to do for scientists, notwithstanding the immediate economic contributions society gets in return?

> ***Proposition 5C:*** *In an opaque institutional field, the higher the relative command the legitimacy seekers have over the expert knowledge required to fulfil the ends, the higher the likelihood of means fuzziness being leveraged as a tactic.*

7 CONCLUSION

This study has focused on the Mode 1/Mode 2 dichotomy as a concept, which has been a challenge for empirical investigation yet has generated a high normative impact. Building on two lines of literature – one pertaining to critiques on Mode 2's empirical problems, and another on legitimacy that explains Mode 2's popular reception – I have contributed primarily to an improved articulation of how the two modes coexist in a legitimation narrative. Empirical and theoretical propositions made are listed in Table 7-1.

Propositions are made in two domains – empirical and theoretical. Empirical propositions (Propositions 1-4) indicate the ways in which Mode 1 retains influence over scientific knowledge production, especially in the interest of the Mode 2 audience.

- Proposition 1 establishes the reference points, i.e. the quality control audience, to which the legitimation narrative is directed.
- Propositions 2A and 2B reveal the strategic imperative of maintaining the privileged position of the science base, along with resource-based assumptions that underpin the perceived necessity of the Mode 1 quality control regime. The imperative, not being specific to either mode, functions as a backing for the arguments made from the supply side, even where the Mode 2 audience is being addressed.
- Propositions 3A and 3B reject mode-specific associations of means and ends, as they introduce means fuzziness as an organising principle in response to institutional demands. Under this condition, Mode 1 means are permitted. Not only are they essential to the strategic imperative, the dissociation between means and ends indicates that they may yield unexpected results in favour of the Mode 2 audience.
- Propositions 4A-4C show how Mode 1's influence is operationalised in performance definitions and communicated to the quality control audience. Performance rhetoric captures the synergy between the scope of the audience and content of quality judgement in both modes. Furthermore, the combination of *ex ante* and *ex post* articulation of performance justifies continuous public investment, especially in the absence of an immediate outcome.

Theoretical propositions 5A-5C outline the conditions under which means fuzziness can be justified using the form of narrative depicted in Chapter 6. The main implication of means fuzziness is that it has to be resolved by applying expert knowledge, hence the discretion that has to be accorded to scientists. The findings point to three antecedents: first, if the consequences of failure are discernible and particularly damaging; second, if demands are difficult to defined; and third, if there exist significant knowledge differentials in favour of those seeking legitimacy.

Table 7-1 Summary of empirical and theoretical propositions

Propositions	Indications
Empirical domain	
Institutional audiences	
Proposition 1: Research exploitation and scientific research aimed broadly at Mode 2 beneficiaries are legitimated by (i) prosocial narratives directed at the Mode 2 audience, and (ii) defence of scientific integrity communicated to the Mode 1 audience.	Quality control audiences identified similarly to that of the Mode 1/Mode 2 framework
Resources and capabilities	
Proposition 2A: Scientific research, with or without foreseeable applications, is legitimated for its contribution to the system's maintenance of privileged asset position from which both creation and exploitation of knowledge are expected, hence no evident delineation of mode-specific audiences.	Strategic imperative identified along with legitimacy assumptions necessitating Mode 1 quality control measures, and framed in the interests of both Mode 1 and Mode 2 audiences
Proposition 2B: The supply side's shared perception of (i) causal ambiguity, (ii) limited tradeability of knowledge and (iii) path dependence contributes to the legitimacy assumptions justifying scientific research, with or without foreseeable applications, aimed at the system's maintenance of privileged asset position.	

Propositions	Indications
Processing of multiple demands	
Proposition 3A: Both Mode 1 and Mode 2 quality outcomes can be achieved through multiple combinations of otherwise mode-specific attributes. **Proposition 3B:** Based on the strategic imperative and legitimacy assumptions, where *ex ante* incorporation of Mode 2 beneficiaries is problematic, open-ended and conditional statements are used to acknowledge possibility of economic and social outcomes being realised.	Mode 1 means permitted in the organising of knowledge production – dubbed means fuzziness – and framed mainly in the interests of the Mode 2 audience
Performance rhetoric	
Proposition 4A: Based on the strategic imperative and legitimacy assumptions, Mode 1 performance may be maintained by broadening the scope of what constitutes the Mode 2 quality control audience and, consequently, the ways in which an impact can be made. **Proposition 4B:** Based on the strategic imperative and legitimacy assumptions, Mode 2 performance may be enhanced by broadening the content of what constitutes Mode 1 scientific excellence. **Proposition 4C:** Based on the strategic imperative and legitimacy assumptions, justifying resource allowance for scientific research involves a combination of *ex post* and *ex ante* articulation of impact towards the Mode 2 audience.	Mode 1's role operationalised in performance rhetoric aiming to broaden the scope and content of quality control, improve Mode 2 quality outcomes and justify public investment
Theoretical domain	
Antecedents to means fuzziness	
Proposition 5A: In an opaque institutional field, the more damaging the consequences of technical failure, the higher the likelihood of means fuzziness being leveraged as a tactic. **Proposition 5B:** In an opaque institutional field, the less the degree of clarity to which the demand content and constituents can be identified, the higher the likelihood of means fuzziness being leveraged as a tactic. **Proposition 5C:** In an opaque institutional field, the higher the relative command the legitimacy seekers have over the knowledge required to fulfil the ends, the higher the likelihood of means fuzziness being leveraged as a tactic.	Antecedents allowing means fuzziness to be leveraged in response to multiple institutional demands in an opaque field

On the surface, the coexistence involves a great deal of ambiguity. Applying a constructionist view, the articulation of coexistence is contingent on *raison d'être*, which entails a sense of purpose (strategic imperative) and a shared understanding (legitimacy assumptions) governing the narrators' view of the technical world. Along this line, it is essential to note that interpretive schemes are a source of contention as much as consensus. Alternative schemes are to be expected, as they represent diverse interests in the institutional environment (Ranson, Hinings and Greenwood, 1980). Legitimacy "hinges not only on the substance of ideas and claims, but also on where, when, how and why people wield ideas and lodge claims" (Barley, 2008, p. 506). This goes in contrast to the context-free and naturalistic account, dressed as technically objective, of what produces better or more socially desirable knowledge. Along this line, and more cynically so, the coexistence may be articulated in various different ways, depending on whether the narrator makes a living by conducting scientific research or by issuing policy mandates. As a result, it is my view that the omission of sense of purpose and shared understandings in the original formulation has perpetuated Mode 1/Mode 2 mutual exclusivity and so far impeded our ability to understand how elements from the two modes can operate together.

It should also be noted that the coexistence can potentially be expressed and studied in many other ways, subject to a researcher's penchant and the means available. For this study, however, I found that a situation of knowledge producers confronting public scrutiny would make a good starting point in understanding Mode 1/Mode 2 at the science-society interface.

In the rest of the chapter, I review the contributions made as a result of the study and the implications they have for policy and practice. I then proceed to identify the study's limitations, as such knowledge is crucial if the findings are to be generalised or applied elsewhere. Finally, I discuss further research opportunities, most of which are based on limitations of the current study.

7.1 Contributions to knowledge

There are three domains of contributions to knowledge as a result of this study, as summarised in Table 7-2.

Table 7-2 Summary of contributions to knowledge

Domains	Confirmed	Developed	New
Empirical What happens to Mode 1?	Relevance of both QC regimes (Gibbons et al., 1994) Within-mode incoherence (Rip, 2002)	The role of *raison d'être* in bridging Mode 1 and Mode 2	Performance rhetoric as a device operationalising Mode 1/Mode 2 coexistence
Theoretical Fuzzy means in legitimation	Academia as an opaque institutional field (Wijen, 2014a)	N/A	Deliberate use of means fuzziness in response to demands (Oliver, 1991) in an opaque institutional field (Bromley and Powell, 2012; Wijen, 2014a) Antecedents to means fuzziness being leveraged in response to multiple institutional demands in an opaque field
Methodological Analytical framework	N/A	Application of an interpretive scheme (Greenwood and Hinings, 1988) to articulate Mode 1/ Mode 2 coexistence	N/A

7.1.1 Empirical domain

The following empirical contributions resulted from the application of the interpretive scheme (Greenwood and Hinings, 1988) as an analytical framework. Regarding Mode 2's empirical validity, the findings support the relevance of the quality control audience whilst refuting any claim over a mode's internal coherence. The interpretive scheme also points to the role of *raison d'être* as a bridge between the two modes. Finally, performance rhetoric can be identified as a device that operationalises, communicates and justifies the coexistence of Mode 1 and Mode 2.

The findings confirm the empirical relevance of the quality control audience as a reference point in a legitimating context. It should be noted that the study agrees primarily with audience identification, as informants respond to both modes. At this point, reservations are still advised when it comes to other aspects of quality control, such as the weight carried by multiple constituents in both quality control regimes. Considering the findings from this study together with previous research, a question remains over the degree to which other kinds of non-technical expertise count in the process of democratisation that supposedly produces “socially robust knowledge” (Nowotny, 2003; Nowotny, Scott and Gibbons, 2001).

The study refutes any assertion that the five attributes necessarily work together as a mode. It therefore lends support to criticisms over Mode 2’s internal coherence (Hessels and Van Lente, 2008; Rip, 2002). Means fuzziness is indicative of this point, as Mode 1 means attributes are justified, even in service to the Mode 2 audience, by strategic imperative and legitimacy assumptions.

Raison d’être, empirically expressed as strategic imperative underpinned by legitimacy assumptions, has proved to be instrumental to how Mode 1/Mode 2 coexistence can be articulated. It provides a governing logic that both enables and constrains the use of elements from either mode in the same narrative. While this notion was not formulated as an attribute in Mode 2 diagnosis, the idea of purpose for universities or scientific research is not at all new. The intrinsic relationship between the third mission and Mode 2, as introduced at the beginning of this thesis, is a case in point. Stances on how universities should contribute to society have been stated (Starkey and Madan, 2001; Starkey, Hatchuel and Tempest, 2004), as well as a criticism (Grey, 2001; Vavakova, 1998) towards Mode 2 and the third mission. Nonetheless, *raison d’être* has not been used as a bridge between otherwise mutually exclusive modes of knowledge production. The application of an interpretive scheme has highlighted another utility of an already familiar concept in the ongoing debate on the role of universities in a changing world.

Performance rhetoric has been identified as a device that operationalises, communicates and justifies the involvement of Mode 1 towards the Mode 2 audience. The novelty is in how a generic bid for “fuzziness” is operationalised by proposing some adjustments that would create synergy between competing groups of audiences in order to secure an audience’s confidence. On the one hand, adjusting the Mode 2 audience scope helps maintain Mode 1 quality. On the other hand, adjusting the content of Mode 1 quality may help improve Mode 2 performance without undermining the strategic imperative. In addition, *ex ante* and *ex post* articulation of impact justifies resource allowance under continuous scrutiny. As with other components of the narrative, the rhetoric is also supported by the strategic imperative and legitimacy assumptions. It should be noted that this new empirical finding is seen through the analytical framework rather than as a discovery of raw data.

7.1.2 Theoretical domain

Theoretical implications from means fuzziness being leveraged in the legitimation narrative relate to the challenge that is inherent in the field of scientific research. As an opaque institutional field, scientific research is a context in which “practices, causality and performance are hard to understand and chart” such that decoupling between means and ends is likely (Wijen, 2014a, p. 302). The formulation of means-ends decoupling is relatively recent, tracing back to Bromley and Powell’s (2012) article. It is therefore a nascent area of research with promising opportunities to further empirical and conceptual development. One of the implications from opacity is that gaining and maintaining legitimacy in such conditions requires more than procedural compliance. The empirical side has been discussed in the previous domain. The theoretical implication, on the other hand, is that a non-standard response has to be devised due to the lack of recipe as to how knowledge is to be produced for a certain purpose. To this end, it is necessary to revisit Oliver’s (1991) repertoire of strategic responses to institutional processes.

To begin with, this study’s findings agree with Wijen’s (2014a) suggestion that academia fits the definition of an opaque institutional field, based on the supporting evidence for the quality control audience and refutation of within-mode coherence. This means that scientific research and academia in general would be a context in which means-ends decoupling could be studied, although they have received relatively little attention from institutional theorists.

This study covers additional challenges for which procedural compliance does not suffice as a response. A specific procedure does not exist to be followed, and neither does a clear definition of what is expected as performance, hence the means fuzziness being invoked. In previous works (Bromley and Powell, 2012; Dick, 2015; Wijen, 2014a) it is possible to identify an agreed-upon policy and the outcome that is sought after, such that substantive implementation of the former and shortfall of the latter could be verified. Along this line, the practical challenge is to be found in the adoption-performance gap rather than in securing legitimacy. In principle, gaining and maintaining legitimacy in such contexts would not be very problematic since the policy to be adopted is known, regardless of operational outcome (Ashforth and Gibbs, 1990; Westphal and Zajac, 1994, 1998). Better procedures would be beneficial in such a situation (Wijen, 2014b, 2014a), especially to minimise the adoption-performance gap, but very little of that can be said in the context of this study.

Means fuzziness and performance rhetoric call into question the applicability of procedural assumptions of legitimacy that underpin Oliver's (1991) comprehensive repertoire of strategic and tactical responses. Means fuzziness itself is a departure from the adoption of an institutionalised procedure that is more stable and comprehensible. More interestingly, performance rhetoric would be nominally classed as resistant, due to the need to influence public opinion. I raised the issue of the role of expert knowledge in response to institutional demands to question whether negotiation and influencing necessarily mean resistance, and to what extent the concept of "compliance" as we know it applies in this situation.

I have identified three antecedents to the use of means fuzziness – potentially damaging consequences of technical failure, ambiguity of the demand definition and knowledge differentials. An important point to make here is that the context in which all three antecedents are present, together with opacity of means-ends, is likely to be very difficult to come by. Therefore, adopting a functionalist stance, I suggest that there would be little, if any, point in complicating the matter by bringing the notion of fuzziness into more routine cases of legitimation response.

7.1.3 Methodological domain

The articulation and understanding of how Mode 1 and Mode 2 coexist has been improved through the application of the interpretive scheme (Greenwood and Hinings, 1988) as an analytical framework. To this end, two modifications have been made to the original framing of the two modes by Gibbons et al. (1994). First, the framework captures the internal means-ends structure of each mode. Second, it leads to the identification of strategic imperative as a mode-neutral *raison d'être* that eventually bridges the otherwise disconnected modes.

Means-ends restructuring eases the problem of internal coherence (Rip, 2002) that has so far rendered Mode 2 intractable as a subject of empirical research. Previously, Hessels and Van Lente (2008) recommended disbanding Mode 2 to examine each individual attribute on its own. My view is that such an approach is potentially good for technical accuracy but not entirely suitable for a research question pertaining to a wider social context. For the latter purpose, the interpretive scheme has some advantages. It preserves the supposed dichotomy between Mode 1 and Mode 2 that guides the structural perception of the concept. It also acknowledges the overall intent of Mode 2 diagnosis. Perhaps most importantly, as means and ends are now delineated within each mode, no upfront assumption of coherence is necessary, thus allowing for further modifications according to the empirical data.

Explicating the previously implicit *raison d'être* offers a solution for mutual exclusivity between the two modes (Fuller, 2000), although this benefit is emergent rather than by design. Mode-specific *raison d'être* (basic science vs. exploitable knowledge) can be derived from reading *The New Production of Knowledge* (Gibbons et al., 1994). The strategic imperative as a bridge for coexistence, however, is mode-neutral and identifiable only from the empirical data. Considering the theoretical perspective and the resulting built-in constructionist view of the framework, this element may be the ground on which the coexistence narrative differs across the range of interest groups. Thus *raison d'être* warrants particular attention if the same research question is to be examined in other contexts.

7.2 Implications for policy and practice

The results have shown that the broadly defined intent of Mode 2 is highly resonant under current institutional conditions, although its empirical foundation remains questionable. Furthermore, the omission of *raison d'être*, or any other indication of the sense of purpose, highlights a potential problem. It can be said that the naturalistic, objective, apolitical and ostensibly evidence-based formulation of Mode 2 has ironically made the concept difficult to work with. This amounts to giving a simple answer to a complex question. Simplicity in itself is often a useful thing. Without any provision to further absorb single-case and day-to-day complexity, however, it runs the risk of being applicable to nothing despite having been written to apply to everything. This aligns with the general concern over "wicked" problems, for which the quest for "undisputable public good" independent of any perspective would never work as intended (Rittel and Webber, 1973, p. 155). Evidence-based policymaking and audit culture are thus problematic in such contexts, since the principle of instrumental rationality – causality, reductionism, predictability and determinism – is no longer sufficient (Geyer, 2012).

More specifically to the study's phenomenon of interest, the "strategic priorities" of publicly funded science are still a relevant policy struggle and will likely remain so. Some years have passed since the oral evidence sessions were held, but by contemporary indications there is little sign of change in the supply-side perspective. *Research Fortnight* (Hill, 2015) reports an early view of submissions in response to the call for evidence for the Nurse Review of Research Councils (BIS, 2015). A statement below, submitted by the Royal Society of Edinburgh, would fit comfortably with the findings from this study:

> It is right for government to identify the grand challenges facing society […] However, it is critical that investigators retain complete flexibility over how they respond to these questions. It is researchers who develop solutions to challenges, not politicians. Research councils have a key role in protecting this flexibility.

The main focus of implications for policy and practice will be on the issue of legitimacy in academic entrepreneurship, which is closely related to this study's empirical context. Legitimacy is also a relevant concern for business schools (Starkey and Pettigrew, 2016). Applying the lessons learned from STEM to management research, however, requires a lengthy discussion in which careful considerations are necessary to account for empirical divergence between the two contexts. A major reservation is that there is no indication whether the antecedents to means fuzziness also hold for non-STEM subjects. This means that the dynamics of legitimacy in the social contract of business schools may differ from that of academic science and, most importantly, in an unknown way. The scope of this task is therefore beyond the epilogue status of this section.

7.2.1 Legitimation of academic entrepreneurship

The issue of tension between so-called traditional and entrepreneurial values often features in academic entrepreneurship, especially on a micro level (Lam, 2010; Philpott et al., 2011). Academic values and ethical doubts over the un-academic and profit-seeking image of entrepreneurial activities are said to have hampered research commercialisation (Bercovitz and Feldman, 2008; Renault, 2006; Vohora, Wright and Lockett, 2004). On the whole, the academic entrepreneurship literature indicates a serious legitimacy problem for commercial and entrepreneurial activities in research universities. We have learned from this study, along with notable previous research (Lam, 2010; Shinn and Lamy, 2006), that entrepreneurship is unlikely to be categorically illegitimate. Nonetheless, so long as the two ideals are framed as being from a different paradigm, it would be a difficult policy question as to how to improve academics' perception towards research commercialisation and third stream activities in general.

To this end, the orientation of the academic entrepreneurship researchers may have precluded an overarching sense of purpose for science from the conversation. In this area, academic researchers and policymakers operate from a pro-entrepreneurship stance (Bozeman, Fay and Slade, 2013). As a consequence, positive legitimacy is taken for granted since the main aim is to improve entrepreneurial performance. Organisational procedures, intellectual property legislations and policy incentives are extensively researched (Lockett, Wright and Franklin, 2003; Markman et al., 2005b; Rothaermel, Agung and Jiang, 2007), and rightly so. Phase I respondents also agreed that without operational support, spinouts would be virtually impossible. However, little has been asked of the motivation and, expectedly, the strategic imperative as defined by academic scientists. Disagreement with commercialisation is too often attributed to ideology, and agreement to entrepreneurial traits or self-interest – i.e. to increase research funding or capital gains (Bercovitz and Feldman, 2008; D'Este and Perkmann, 2011; Lam, 2011).

Put simply, there is a need to play up science and society and at the same time play down the money when promoting academic entrepreneurship to academics. A more dynamic and situationally contingent perception, as expressed by informants throughout this study, has not received much attention so far. The combination of insistence on scientific excellence and motivation to contribute to society is admittedly more complicated, but it paints a fairer picture for both entrepreneurial and non-entrepreneurial academics. After all, research exploitation only makes sense if there is something to exploit. The dynamic view, based on the shared sense of purpose, should factor into the promotion of academic entrepreneurship. It is more attractive as a narrative because the upholding of scientific excellence is the integral part. Speaking of the place of science in research exploitation, it is worth revisiting the example of the National Graphene Institute (NGI) in Manchester. While one of the inventors, Sir Andre Geim, has emphasised the need for partner companies to help commercialise the technology (Chakrabortty, 2013), he also expressed dismay that out of the £61 million that the institute is worth, £45 million went to "the building, not the science" (Ashton, 2014). Another example comes from one of the respondents from Phase I. His spinout has been mentioned in a *Times Higher Education* article that focuses on the extraordinary amount of money it has made rather than what it does. He left the company soon afterwards, as his interest remained in academic work. While financial numbers help highlight economic contributions to the wider audience, they do not seem to fully resonate with academics – even so-called entrepreneurial ones.

Further to the dynamic view of entrepreneurial decisions, I would also raise a small question over the feasibility of putting the degree of "agreeability" towards commercialisation on a scale. This is an approach used in a number of studies (Ambos et al., 2008; Philpott et al., 2011). Speaking from the perspective of Phase I respondents, it would be difficult for them to categorically assign a number to express their level of agreement. Instead, situational factors appear to be more important for their judgement.

From the researchers' point of view, a score of 5, for example, can be difficult to interpret without knowledge of surrounding circumstances.

7.3 Limitations

Sampling logic and response profile. The approach towards research design has resulted in some limitations that should be addressed here. The most fundamental limitation is in Phase I sampling logic, which targets established major research universities. It is also likely that the academic founders who agreed to participate are among the most confident and productive individuals, especially by Mode 1 standards, considering their academic stature and publication records. The filtering effects of sampling frame (deliberate) and response profile (unintended) may have some influence on findings. Scientists of different demographics, for example, may have a different relationship with the Mode 1 regime, thereby altering the basis of their responses. The same bias carries over to Phase II, which was designed based on Phase I findings. Much like Phase I interviewees, the vast majority of expert witnesses are of unusually high status academically. While it can also be argued that they are tasked with representing academic science, it is more likely that the narratives covered in this study are of a "mainstream" type. This probably masks other types of narratives that operate in different spheres even within academia.

Limited scope of STEM subjects. Considering that some readers are already familiar with discussion of Mode 2 knowledge in the context of management research (Bartunek, 2011; Huff, 2000), I specifically advise against generalising the results in that direction. This study was designed, conducted and analysed based on assumptions that accompany STEM research. Science and management studies differ in a number of meaningful ways, such as their development trajectories, the impact of and on public opinions, variations of how they relate to practice and, most importantly, the level of public investment involved. In addition, the potentially grave consequences of making mistakes on the scientific front favour the adherence to scientific soundness as a matter of necessity rather than vanity.

Institutional context. The study was designed specifically for the UK context, based on relevant literature and background knowledge. It is important to keep in mind that knowledge production operates differently across national contexts, the absence of which in Mode 2 diagnosis has indeed attracted criticism (Shinn, 2002). Science-society interactions, as well as Mode 1/Mode 2 dynamics, are likely to vary according to the consequences of different policy mechanisms being institutionalised (Mowery et al., 2001; Mustar and Wright, 2010; Wright et al., 2007). Most of the findings from this study concern UK-specific issues, such as the strategic imperative to sustain a “privileged” position, interdependence of scientific research and the higher education sector and the presence of the Haldane Principle, which limits government control of scientific research. These variables are likely to be different in other countries.

7.4 Future research

In what follows, I identify four lines of further research opportunities arising from this study. It should be noted that they are all based on the central importance of legitimacy in institutional complexity as a theoretical anchor, although I acknowledge that the same questions may be answered through other lenses such as economics and critical theory. In relation to the content of these four topics, historical research methods may be particularly useful because these phenomena are embedded in the historical context and should be interpreted accordingly.

A small note should be made here on replicating the same research agenda in the context of business schools, which is the intellectual home for this study. Similar to the earlier point I have made on policy implications, the possibility of empirical divergence of business management from STEM subjects will likely entail a separate research programme. The overall intent may be similar but, in my view, the resemblance will be minimal when it comes to research design and operationalisation. In contrast, the avenues listed below are incremental to the findings of this study and, therefore, serve as an extension to the current research.

Paradoxical properties of scientific expertise. So far this study has taken a supply-side perspective in which scientists argue to protect the level of discretion accorded to them. In a wider context it is somewhat more complicated. Scientists, by stressing the importance of scientific rigour, have shunned politics and the public, who might otherwise feel some ownership over the cause and help create visibility that would benefit science (Khan, 2015). Balance will not be easy to achieve. This issue will likely require the addition of paradox theory (Smith and Lewis, 2011) to the concept of institutional complexity (Greenwood et al., 2011) that plays an important role in this study. Although the two conceptually offer complementary insights, they had not been applied together until recently (Jay, 2013). This would be a timely addition to a nascent and growing area of research.

The third mission and academic entrepreneurship in technical universities. Since this research only covers the mainstream, it should be complemented by other perspectives especially from mid-range and technical universities. In this case, applying the interpretive scheme would potentially be less problematic than in the case of management research, but it will likely generate qualitatively different insights. Mid-range universities are different for their capability profiles, research funding, relationships with communities, strategies for competitiveness and survival, indicating different and potentially more complex relationships with Mode 1/Mode 2 regimes (Jong, 2006; Lockett, Wright and Franklin, 2003). When it comes to research design, this topic will likely need different kinds of data located outside of the mainstream. In addition to merely trying to answer this study's question in a new context, the non-mainstream status also raises some interesting questions in its own right. For example, for what technical universities see as challenges and imperatives, is there any mismatch with the wider narrative of academic science that represents them? What are the consequences and how can they be managed?

National contexts and university legitimation strategy. The legitimation narrative in this study is largely contingent on UK-specific factors, most notably the Haldane Principle, according to which the specific decisions in science funding and direction belong with scientists instead of the government and ministers (Hughes, 2011). The nature and internal working of knowledge production systems in general are dependent on national characteristics (Nelson, 1993; Pavitt, 1998; Shinn, 2002). This will likely entail variations in the strategic imperatives and institutional demands, not to mention harder aspects such as specific policies and regulations. Following from the central role of strategic imperative and audience identification, the third mission can have very different implications on a university's legitimacy status. Speaking from personal experience, the third mission can be a major source of clout in a developing country. Academics in such universities are also under the same pressure to publish as a part of epistemic communities worldwide, but the knowledge channelled through the universities is supposedly in service to the public. In the Western context, the third mission is often thought of as universities being “servants of industry” (Lockett, Wright and Wild, 2012, p. 236). This divergence appears side-by-side with the convergence of universities in both contexts – developed or otherwise – to preserve the image of freedom from corporate intervention. Further research can investigate the many ways in which this stance can or cannot be maintained by universities.

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APPENDICES

Appendix A Selection of target universities

A.1 Selected units of assessment from RAE 2008

Table A-1 Selected units of assessment from RAE 2008

Unit of assessment number	Unit of assessment name
1	Cardiovascular medicine
2	Cancer studies
3	Infection and immunology
4	Other hospital based clinical subjects
5	Other laboratory based clinical subjects
6	Epidemiology and public health
9	Psychiatry, neuroscience and clinical psychology
10	Dentistry
13	Pharmacy
14	Biological sciences
15	Pre-clinical and human biological sciences
16	Agriculture, veterinary and food science
17	Earth systems and environmental sciences
18	Chemistry
19	Physics
20	Pure mathematics
21	Applied mathematics
23	Computer science and informatics
24	Electrical and electronic engineering
25	General engineering and mineral & mining engineering
26	Chemical engineering
27	Civil engineering
28	Mechanical, aeronautical and manufacturing engineering
29	Metallurgy and materials

A.2 Selected universities

1. University of Oxford
2. Imperial College London
3. University College London
4. University of Manchester
5. University of Cambridge
6. University of Birmingham
7. University of Bristol

8. University of Leeds
9. University of Sheffield
10. University of Glasgow
11. University of Liverpool
12. King's College London
13. Queen Mary, University of London
14. University of Nottingham
15. Cardiff University
16. University of Newcastle upon Tyne
17. University of Edinburgh
18. University of Southampton
19. University of Bath
20. University of Warwick
21. Heriot-Watt University
22. University of Aberdeen
23. University of Durham
24. Swansea University
25. Institute of Cancer Research

Appendix B Illustrative quotes from Phase I interviews

Table B-1 Representative quotes

First order codes	Second order themes
	Audience identification
Tension recognised at professional level	We do adhere to the rules that we do have set up. ... If you sort of culturally...there is probably belief that if you want to be a doctor, well, you should do it because you are helping patients. And therefore, if you are an academic you, should be primarily focused on doing research for research sake and teaching young people to become good researcher. That's what you do when and if you don't, well, move out. So, you say "okay, well it's that or that" ... I am sure that's everybody's experience. (R07) And the other thing that I find difficult is that if you go down the route of doing translational work, it has a negative aspect in terms of your academic career, like, for example quite often you can't publish, and quite often you have to work to shorter time scales, quite often you take risks with the people that you employ and try to keep the research group together doing this kind of work. (R08) Oh I am sure we will always be experimenting that agenda. I don't think there's any external reference point that tells you where that pointer should be set, what the balance should be between the two, so there'll always be tension. And we'll just have to learn to live with that. (R11)
Policy direction recognised	I think that's been a reasonably positive outcome in the UK. So they're quite, you know, future-oriented in that. There's a lot of government schemes, joint funding schemes, inventors' biomedical catalyst. There are lots of them now. And you can get grants. ... So I think it's … the rules and the ways things are being done have all been changed and evolved to make it encouraging and easier because the country wants to be healthy and wealthy. (R02) The government is always pleased for research to be commercialised. That's what it's wanted. (R03)

Table B-1 Representative quotes (contd)

First order codes	Second order themes
	Audience identification (contd.)
Policy direction recognised (contd.)	Now because policy is following us. What we do sometimes is not necessarily take advantage but we are just fortunate to be in a position where what we wanted to achieve is aligning with what a lot of the policy is directed to. So, not necessarily a conscious plan, not necessarily a tipping point as such, it's just that a lot of people have come around to our way of thinking. (R04)
Tension recognised at organisational level	I think the biggest difficulty I encountered was from I think the academic side of (the University) who thought all of this was too commercial for a university and they would say oh well, it's second-rate funding, because it doesn't come from the Medical Research Council or Wellcome Trust so there was a lot of raising of eyebrows because we wanted to try to do something which had commercial potential and because we were doing something which wouldn't be returned into the RAE. So you know there was a little bit of people looking down their noses at what we were doing. (R01) I remember in 2009, writing these major applications for funding and thinking well, if we're lucky, we're going to get maybe one of these which is going to give us, what, £10-11 million for the next five years. That'll be fine. But we actually won just about everything we applied for during that period which I, I can tell you most certainly that did get my colleagues being interested in what we were doing. ... I think attitudes over the last ten years have changed very much. I think my colleagues in biological sciences now treat me with a level of respect that they wouldn't have. You know, they used to think I was doing applied research which was in some way inferior, second rate research. But I don't think they do now. (R09) I don't think that many of my colleagues are aware of what I do with the companies. I mean occasionally something sort of comes up in public and they say oh wow, that's interesting, I didn't know (the respondent) was involved with that but, you know, that's not all that often. (R14)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Audience identification (contd.)
Uneven responses from different constituencies	I mean there's, thinking about who's involved. There's the people in the company, there's the researchers in this department, there's the administrators who have to manage the output of the research teams and do things like, evaluate the quality of our research for the research evaluation exercise that the government does. And there's the technology transfer department who have an interest in commercialisation, and all of these people have slightly different priorities sometimes, so it can be hard to balance the different things that they all want. (R13) There is a lot more organisation within the universities, designed to try and look for valuable IP to exploit, but it's still my general feeling that it's treated with suspicion by the academics as a whole. ... The engineering faculty (in this university) has a lot of contracts with big multi-national engineering firms. I don't actually know how many patents flow from the university but I'm sure if you went on (their) web pages, they'd be boasting about them. (R18)
	Legitimation: Audience-based rationale **Mode 2**
Impact, usefulness	If it were to make negotiated licensing deals on something we'd invented with customers, they tended to fall through. One thing that having a start up does is it allows you to cut through the paperwork. If the university directly licenses and if the university does contract research, to some degree, there is quite a lot of bureaucracy. (R03) If it were to make negotiated licensing deals on something we'd invented with customers, they tended to fall through. One thing that having a start up does is it allows you to cut through the paperwork. If the university directly licenses and if the university does contract research, to some degree, there is quite a lot of bureaucracy. (R03)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Legitimation: Audience-based rationale
	Mode 2 (contd.)
Impact, usefulness (contd.)	I honestly believe just about everybody, every academic can have something interesting to say to an industrialist. Now, does that mean they make a product based on the academic research? No. But it doesn't have to but it's going to start with engagement. But, if you have got people that aren't able or don't want to go with that engagement, then it is very difficult to progress it. (R04)
	What's important is that people realise that what you need an IP for is not to make money yourself but to provide enough language for a company so that they can make money and the investments that are needed to take the product forward. (R08)
	Well obviously I hope it works and it brings benefit to people with multiple sclerosis, that's why I've done it. I'm not really doing it for commercial benefit. Now I suppose if there is some commercial benefit, I won't say, you know, no, but at the end of the day that wasn't the driving factor in the first place. (R12)
	To some extent it's tidying up loose ends, which sounds a bit trivial. But when you look towards the end of your career, there are some things you say, "Well, I've seen that through, I've said all I want to say on the subject," you know. (R17)
Market demand	It requires ideas which are sufficiently simple in some respects and also short-term in their translation for fund managers and other investors to buy into. Mostly people don't want their money tied up for ten years. And so you need to have the right idea and, to be quite frank, you need to be able to sell that idea. A lot of academics are not very good at selling their ideas because they only talk in terms of the detail of their science. They don't see the big picture associated with the science. (R01)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Legitimation: Audience-based rationale **Mode 2 (contd.)**
Market demand (contd.)	It's a niche market, despite what I said about wide range of products. It's still all in quite a narrow niche. But it's a niche in sort of the energy and oil and gas sector so if you've got a niche in there, that's a big sector to exploit even for a niche application, potentially. So that's why I think there's more market out there than we're addressing at the moment and we do need to expand. (R03) I would say is that in a company provided that you are well resourced as we are, you are basically free to focus on the medically and commercially important aspects of what you do in as a realistic way. (R05) Companies didn't think we could make any money out of multiple sclerosis and now they do, so it's a billion dollar market. (R12) I can't tell the market what it needs, only the market can tell me what it needs. (R16)
ROI for public	Also part of my own personal fears was spending a lot of public money in research. Scientific research in some degree is a selfish activity. You are using somebody else's money to do something that interests you. So, my personal view is that some of us at least have to be able to use this public money with a view to generating social economic benefit. (R04) (Generating returns to tax payers) doesn't necessarily preclude very fundamental research. It simply means you've got to understand how to answer the question. (R16) Yes, but there's a lot of pressure on especially funding councils which get their money from central government to show that there's a benefit to the UK Plc. If you have a company which is set up and employing people, and that's only happened because of a university, then everybody's happy. (R18)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Legitimation: Audience-based rationale
	Mode 2 (contd.)
Regional/economic development	What I am trying to do in collaboration with the university, with support from the Royal Academy of Engineering, support from industry, is to try and set up the single centre for industrial ultrasonics where we can try and make sure that people that want to engage, who don't necessarily have the level of resources of companies like Rolls Royce and Shell and BP, these type of people can get some degree of engagement. (R04) I'm doing them for purposes of making a contribution to economic regeneration in parts of the country that have been deindustrialised ... I wanted to use my science and engineering knowledge to create good, meaningful, socially and environmentally useful jobs for people. (R14)
	Both modes
Constraining effect	So it's been quite successful and we're not really … our expertise was in developing ways to make protein stable, crystallising and solving the structure and then doing rational drug design. It's not in the actual chemistry of drug design nor in the clinical development or in the trials. So that's their expertise so we've basically helped them to get a new philosophy of doing it that allows them to tackle things that were considered to be intractable and people have even given up on. (R02) Sometimes it's more appropriate for them to go and get somebody else to do, who is may be at a higher technology readiness level for very specific requirements. Because we are so closely linked, the company and the research group, reputation is of paramount importance. (R04)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Legitimation: Audience-based rationale **Mode 1**
Legitimate scientific foundation	We thought that would it not be good to develop this as a drug and (also) that over the years we had developed an expertise which was widely recognised as giving quality to what we were doing with (this University). (R07) I would say in network science, and being aware that you are taping this (Laughter), I would say that we had a massive lead, probably a decade's lead. Lots of it now are catching up with where we were in the early 90's. If I look around the UK scene at the moment, in which it's only a small part of the world scene, quite a lot of people who are active are my students. So, I feel that we had a tremendous lead in commercial as well as in academic terms. (R05) (My job is) selling the company from a scientific side and writing scientific papers. I don't know how we've published on this, but it's probably 19 or 20 papers on genetic toxicology tests. (R18)
Tacit knowledge	The know-how that's built up in the group as a result of doing the research might not be published. That is reasonable to exploit and in that way we can because no one's going to be interested in a paper showing the details of (equipment) construction. (R03) The starting point was my scientific understanding of the issues at the time. (R14) We got to the stage where we had five or six patents and we were trying to engage with large chemical companies to get them to take the work on and not having much success. And that's when we decided that probably it was best if we formed a company and got some commercial experts in to bridge that gap between what we were doing in the university and what was going on in the commercial world. (R15)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Legitimation: Audience-based rationale
	Mode 1 (contd.)
Maintaining academic output	If we do work with organisations, they are happy for us to publish the results of what we do provided we don't give specific details of the size of components. Now, that's a solution everybody is happy with. Everything we do we get industry approval for and I think provided that you say to industry "Look! We will listen to what your concerns are. We will work towards a solution where your concerns can be addressed but we can publish". (R04)
	There's been one or two occasions where we've been thinking about formally licencing stuff and I've held back on publication but it's not particularly bothered me because I've got loads of other stuff to publish anyway. (R14)
	I haven't used it to substitute for other activities, if that makes sense. Some other people may take a slightly different pathway. For me it's been an add-on activity to my normal day life. So I kept going at the standard academic activities, kept that all running at the same level it was running at before. (R16)
Increasing academic output (rare)	Actually, I've probably published more since setting up the company, to be honest. And then we have some collaborative things which produce publications and work on other people's tests sometimes. So, no, it hasn't affected my publication rate, it's probably higher. It's just that's my job to be a scientist. (R18)
	Legitimation: Resource-based rationale
	Ex post
Commercialisation income (rare)	There were a lot of people who criticised anything to do with commercialisation. They say this is not our business. But now they've seen the success. They've seen that the income is now three or four times greater than the cost of the lab. (R02)
Research grant	As far as I know the people who give you grants want you to make things that can be commercialised upon. (R03)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Legitimation: Resource-based rationale
	***Ex post* (contd.)**
Research grant (contd.)	If we are able to demonstrate that the kinds of things that we are developing and researching can find their way into use in the real world and what they call now in lots of things like the research excellence framework impact. We have a much stronger case when it comes to writing future research proposals. (R04)
Research input	(On findings from spinout work) We were recently, I think, the first group to experimentally observe (the phase shift), which can actually lead to a lot of confusion when somebody is interpreting the signal. But, it's from a very fundament physics point of view. (R04) And in fact those tools (from a previously folded spinout) came back into the research group because we used those tools in the design of the (chips for the current spinout). In fact, I think we are the only people who used those tools to design real silicon that was manufactured. So in that sense, the company was beneficial to the research group. (R11)
	Ex ante
Development: Sector-dependent research strategy	Where the financial incentives really come in, in translation it's impossible to do it without external finance because it's going to cost too much. If you need to develop prototypes to do clinical trials or something like that, you'll need external financial input to do that. You're very unlikely to get that from, say, a research council or the university or the public sector so you tend to have to fund that with a company. (R08) I would like to probably see compounds to be bought off and then developed by a big pharma, because I think unless we get big pharma to do it, it will just curve very slowly. (R12)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Legitimation: Resources rationale ***Ex ante* (contd.)**
Development: Sector-dependent research strategy (contd.)	They're based on scientific insights and intuitions that are yet, if you like, to be completely proved at full scale. The only way to prove them at full scale is to do them commercially. ... I would draw parallels with other energy industries. I mean the way the oil and gas industry started was much the same. We can model those till we're blue in the face and come up with our best estimates of them, but until you have a fully working process, you'll never know for sure. (R14)
Development: Perceived technology trajectory	So in this lab, when started, nobody did any invention, it was only discovery. And they only invented something if they needed a technique, for example, DNA sequencing or x-ray diffraction. They would be inventing methods that would be used to discover things. So actually everything was to do with discovery. And there were 60 groups discovering things, publishing papers and so on. Now if you look in the lab, there aren't 60 groups doing discovery. About seven or eight of them have stopped. They're not interested in discovering anything. They're only inventing things. (R02) So, those that can't adapt will struggle to survive in certain areas. Certainly I think newer academics are realising the importance of the industrial engagement. (R04)
Development: General capabilities	I think forming the spin-out and to some extent being involved in seeing how they work and the practices, has very much changed a lot of our fundamental way of working in the research lab. (R09) For me, I guess it's been an education, which then makes me think about how we teach about translational neuroscience. (R12) It can also be good for students, too, actually. We've been able to offer internships and placement projects, if you like, for students, which give them a chance to see what it's like, working in industry and doing applied research. So it does have quite a lot of benefits that we didn't really expect when we started it. They're sort of incidental. (R13)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Legitimation: Resources rationale ***Ex ante* (contd.)**
Development: General capabilities (contd.)	Well, you know, that's an interesting challenge and that's where you start putting more intellectual thoughts back in. And so I think there's definitely huge benefits for anybody really in starting up a business like this and seeing how the world works. Personally I found it a very rewarding experience. (R16)
	Foundation of demand processing
Professional roles	I am an academic and my career is based on an academic research and at some points you've got to keep looking at your career as well because it's very difficult to continue within an academic institution if you're so involved with a company that you no longer participate in the academic environment. (R01) I don't think anybody goes into academia or I would have thought very few people go into academia to look for things that could be exploited. I think most of us are just driven by curiosity and by genuine desire to be cutting edge and you chose medicine because you want to do some good to your fellow human beings. (R07) I am an academic and my career is based on an academic research and at some points you've got to keep looking at your career as well because it's very difficult to continue within an academic institution if you're so involved with a company that you no longer participate in the academic environment. (R01) I don't think anybody goes into academia or I would have thought very few people go into academia to look for things that could be exploited. I think most of us are just driven by curiosity and by genuine desire to be cutting edge and you chose medicine because you want to do some good to your fellow human beings. (R07)
Purpose of research	Academic research is about knowledge creation and knowledge transfer, and the question is about how you do that creation and transfer, you've got different ways of doing it. (R12)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Foundation of demand processing (contd.)
Purpose of research (contd.)	I don't necessarily think there should be (a specific purpose) beyond doing good research, doing scientifically sound ... obviously, I'm speaking for engineering and physical sciences here, but doing academically sound research. I think there's certainly a place for industrial research in universities. I also think that it's extremely important that there should be pure research in universities. And you know, you can get the same person doing both things and I don't think there's any problem with that. (R15) Interest driven enquiry. (R18)
	Integration
Perceived connection to application	All you have to do is to be able to see the application of the research that you're doing to the patient population. And that's sort of the bit I think distinguishes the academic who goes on to form a company from other academics, because some academics, first of all, work on things that are so far removed from being translated into medicine that there is nothing there for people to invest in. (R01) It's built around what's coming out of the research group. In our case it's a lot of very applied stuff that's fairly easy to turn into products whereas in other cases, it might be something that's world-beating but requires millions of pounds of investment and massive facilities and years of development. (R03) I think there's a lot of interesting stuff that I can take from what I'm doing at the moment and apply into other fields. And I'm a huge believer in what's called transdisciplinary research. (R15) I wasn't in a pure academic physics department, I was in medical physics. The whole ethos of medical physics is because it's one foot in the universities and one foot in the health service, it's very easy to see that it's outcomes that matter. And you can't just stop once you've satisfied yourself that you understand something. You've got an obligation beyond that point. (R17)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Dynamic outlook
Conditional statements	(Example of work in the research group) They wanted to know what was the mechanism that created antibody diversity. That's why they were doing fusing lymphocytes—antibodies producing B-cells with cancer cells. ... But it turned out, having made the monoclonal cell line, you could produce kilograms of one antibody and if that antibody was useful, you'd make a factory for it. So although they were trying to discover something, they also invented a technique that allowed them to get them a mechanism but also a side effect allowed them to produce large quantities of antibody. (R02) It started off in a purely academic sort of format. I didn't imagine it was anything commercial in what we were doing at all. But towards the end of that time which was around 2000, we got interested in applying this kind of thing in an all practical ways and in fact the first area was defence. (R05) I have this quite applied project and I have a couple of other quite applied projects, I've also got some stuff going on that's pretty… It's interesting but there's no industrial link at the moment (R15) I don't think you could believe anybody who said it was all a perfectly formed plan. (R16) Now, that doesn't mean that we dance to their tune but I means that we have now known what they really want and we can try where appropriate to match up the two sides. (R04) If something comes up...if we discovered something once in the past, I didn't give any more thought to it. I made sure that we published it. Now I stop and think is this something that could be exploited? And more often than not, I come to the conclusion that there is not much that you can do about it so you publish it. It has changed my reflection the way I reflect on things but it hasn't made me into an opportunity seeking animal. So, I am not looking like a mad man "let's exploit this." I am not in that business in that way of thinking. (R07)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Dynamic outlook (contd.)
Conditional statements (contd.)	My research in the university has never been primarily oriented towards the idea that we want a company at the end of it. So it's not been driven by commercial objectives, it's been driven by research objectives but I am just aware that if something emerges from the research that looks like it has strong commercial value then one should consider ways to realise that value to generate the impact from the research, and in several occasions that's turned out to be a spinout. (R11) (What I do gives) me the chance to be starting new projects and testing new ideas in the academic world and having those funded probably by research councils or whatever, and then transferring those to more commercial side, if and when they turn up to work would be useful. I do quite like actually being involved in that process. (R13)
Sector-specific statements	I think anything that can be druggy, anything that's pharmacological. ... You know other areas like engineering, or IT, that's exploitable as well but in the science area, I think it's got to be disease-orientated and it's got to be what we call a druggable target. (R01) It is very difficult for universities to take transfer units to actually work competently right across the research of the university because different industries have very different financial models and cost bases. And, and when I first started talking to the university about spinout activity, they clearly had some big wins in the pharmaceutical area and were trying to treat the whole world as if it was pharmaceuticals. (R11) I worry about impact statements. I mean obviously I find them somewhat easier to write than a lot of people but nonetheless I still find them quite difficult to write, even in such an applied field as mine. And I think that they get filled with hyperbole and people talk about markets that are worth billions of dollars and things like that. ... Don't get me wrong, I'm not suggesting anyone's lying but in certain areas it's probably easier to sound more impressive than others. (R15)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	Dynamic outlook (contd.)
Sector-specific statements (contd.)	Obviously in some of the areas I work in, it's fairly obvious where the value chain is. Or if I'm doing, I don't know, cancer treatment research, it's fairly obvious how to explain the value and the points to the wider world. (R16)
	System-level opacity
Academic freedom	Well academic research is about allowing academics to follow curiosity driven lines of research, not completely in sort of ivory towers but in the context of what are understood as, you know, national priorities and commercial needs and so on. But within that context, university researchers should have as much freedom as possible to pursue interesting lines. (R11)
	In the university, effectively nobody cares what you do provided, a) I can keep the money in and, b) the papers going out, in a sense nobody in the university cares and it is entirely under my control at that point. The downside is, of course, you have to bring all the money in, so you can't go to the Vice Chancellor and say I think this is an interesting area of research, give me £5 million because the Vice Chancellor doesn't have that. (R11)
	There are things that you can't, as far as I can tell, from my experience of either working for other companies or with when we started, that you really don't get a chance to explore, in industry. But I have already come across situations where stuff that either I or other people have been exploring kind of for fun, if you like, in academia, showed now potential to be used in a practical way. I think the freedom to explore questions where it's not clear what they're for to begin with is something that's unique to academia and it is really important because you get surprised by applications later. (R13)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	System-level opacity (contd.)
Academic freedom (contd.)	They don’t want to waste research funds, but on the other hand, you know, if you were the government today and you had Albert Einstein coming up to you saying, well I want to think about light beams, you’d say that’s a waste of money, and then we wouldn’t have general relativity. So it’s impossible to say what’s going to be important or not, all you can say is whether the science is sound. (R15)
Diversity of scientists	(Of Max Perutz) It just so happens that this one case, his original idea did eventually work. But that’s just statistics, I don’t think it indicates anything, any general rule about it. I think it’s just intelligent people making decisions and then what looks like a very seminal insightful idea is probably just a statistical luck you picked it out later. (R02) The thing that does concern me is you don’t want to go too far that way. You do need a core of fundamental research where you can say this has no immediate obvious benefit to anybody. But, I think with pressures with funding, you need to ensure that where you are sending money onto things that don’t have any obvious benefits, those are best quality research being done by the best people. (R04) (On diversity) I think that’s what it is. I think that’s the reason why the two can coexist. And my view is that … those academics that want to do curiosity-driven research, I think they should be encouraged to do that. And that’s what they should do. I don’t think you need to change anything. There’s a funding system that exists for that. The other thing I’d like to do is to try to reform the academic sector so that it becomes more tolerant to people that pursue a translational route rather than the pure academic research one. And then I’ll try and get the rest of us to see the value in having people that do that. So that they are recognised and (there are) rewards and support structures to these people. (R08)

Table B-1 Representative quotes (contd.)

First order codes	Second order themes
	System-level opacity (contd.)
Diversity of scientists (contd.)	I think you need universities, you need them doing every level of research, not necessarily development, that's more spinout. You can never tell in 20 or 30 years' time what the interesting stuff's going to be. So you need people who are just trying everything because if you don't have that, then you grind to a halt. (R15)
Long-term view	I think in some respects the media and other sources of information overhype the potential of some of the discoveries because if you take a chemical discovery in laboratory, then it's going to be, for a standard drug, 15 years before that drug would turn into a medicine on a pharmacy shelf—if it ever makes it. ... the chance of something discovered in a laboratory becoming a drug are probably less than 0.1%. (R01)
	We hold (documents) internally where we know the kinds of challenges industry faces. And we can direct a lot of our fundamental research to try and help us get there. We have worked with industry to develop horizon vision documents looking ahead of 5, 10, 15 and 20 years. What they see is a major challenge, we try to tailor our research through discussion and negotiation to address the challenges. So, they know what they think they want to do. Our job is to try and think of ways that we can do it. You still get the fundamental through to the applied research there. (R04)
	I think one of the things that's least understood both amongst academics, amongst politicians, amongst the general public is quite how long it takes to get from an initial idea through to something that's in the shops. I have some experience of this. (It's 2014 now), and I started my research in this area in 1996, and we're getting reasonably close to having a product that we could sell, but that's, you know, getting on for almost 20 years, and that would be pretty average. If you look at any of the big inventions, the classic example that people give is the laser, there really weren't any products in the shops until the '70s but it had been invented in the late '50s. (R15)

Appendix C List of expert witnesses included in Phase II

Table C-1 Expert witnesses in Phase II

No.	Name	Designation/Affiliation	Year
1	Professor Michael Arthur	Chair, Russell Group	2010
2	Professor John Beddington	Government Chief Scientific Adviser	2009, 2010
3	Professor Janet Beer	Chair, University Alliance	2010
4	Professor Sir John Bell	Office for Strategic Coordination of Health Research	2010
5	Sir Leszek Borysiewicz	Medical Research Council	2009
6	Professor Geoffrey Boulton	Royal Society of Edinburgh	2009
7	Dr Brian Bowsher	National Physical Laboratory	2009
8	Dr Tim Bradshaw	Confederation of British Industry	2009
9	Ms Judy Britton	Government Office for Science	2009
10	Lord Broers	House of Lords member	2010
11	Professor Sir Richard Brook	Member, External Challenge Panel	2006
		Leverhulme Trust	2010
12	Dr Bob Bushaway	Chairman, AURIL Council	2006
13	Professor David Charles	Regional Studies Association	2009
14	Sir John Chisholm	Executive Chairman, QinetiQ Group plc	2006
15	Dr David Clarke	Energy Technologies Institute	2009
16	Mr Jeremy Clayton	Government Office for Science	2009
17	Professor Brian Cox	School of Physics and Astronomy, University of Manchester	2010
18	Professor David Delpy	Engineering and Physical Sciences Research Council	2009
19	Mr Simon Denegri	Association of Medical Research Charities	2009
20	Professor Ian Diamond	Chief Executive, Economic and Social Research Council and Chair of Research Councils UK Executive Group	2006
21	Mrs Barbara Doig	Member, External Challenge Panel	2006
22	Rt Hon Lord Drayson	Minister for Science and Innovation	2009, 2010(x2)
23	Mr Nick Dusic	Director, Campaign for Science and Engineering	2009(x2), 2010
24	Professor Les Ebdon	Chair, million+	2010
25	Professor David Edgerton	Imperial College London	2009
26	Professor Philip Esler	Chief Executive, Arts and Humanities Research Council	2006
27	Professor Dame Janet Finch	Council for Science and Technology	2009, 2010
28	Professor David Fisk	Imperial College London	2009
29	Ms Anne Glover	Amadeus Capital Partners	2009
30	Mr Iain Gray	Chief Executive, Technology Strategy	2009, 2010

No.	Name	Designation/Affiliation	Year
		Board	
31	Professor Diana Green	Vice-Chancellor, Sheffield Hallam University	2006
32	Dr Steven Hill	Research Councils UK	2009
33	Dr Graham Hillier	Centre for Process Innovation	2009
34	Dr Alastair Hunter	President, University and College Union	2010
35	Professor Roger Kain	British Academy	2009
36	Professor Julia King	Aston University	2009
37	Professor Lord John Krebs	House of Lords member and University of Oxford	2009
38	Rt Hon David Lammy	MP, Minister of State for Higher Education and Intellectual Property	2010
39	Sir Alan Langlands	Chief Executive, Higher Education Funding Council for England	2010
40	Professor John Loughhead	Energy Research Partnership	2010
41	Professor Keith Mason	Chief Executive, Particle Physics and Astronomy Research Council	2006
42	Tony McBride	Confederation of British Industry	2006
43	Professor John Murphy	Chairman, External Challenge Panel	2006
44	Dr Paul Nightingale	Science Policy Research Unit	2010
45	Baroness O'Neill of Bengarve	House of Lords member, British Academy	2009
46	Professor Sir Keith O'Nions	Director General of the Research Councils, Office of Science and Technology	2006
47	Professor John O'Reilly	Chief Executive, Engineering and Physical Sciences Research Council	2006
48	Dr Miles Parker	Department for Environment, Food and Rural Affairs	2009
49	Dr Tony Peatfield	Director of Corporate Affairs, Medical Research Council	2010
50	Professor Lord Martin Rees	House of Lords member, President of the Royal Society	2009
51	Dr Graeme Reid	Department for Business, Innovation and Skills	2009
52	Dr Ian Ritchie	Technology Entrepreneur, Coppertop	2006
53	Mr Derrick Ryall	Met Office	2009
54	Dr Malcolm Skingle	Director, Academic Liaison, GlaxoSmithKline	2006
55	Mr Colin Smith	Rolls Royce	2009
56	Professor Adrian Smith	Director General for Science and Research, DIUS	2009
		Director General for Science and Research, BIS	2010(x2)
57	Professor Steve Smith	President, Universities UK	2010
58	Professor Christopher Snowden	Vice-Chancellor, University of Surrey	2006

No.	Name	Designation/Affiliation	Year
59	Mr Paul Stein	Ministry of Defence	2009
60	Professor Michael Sterling	Chair, Science and Technology Facilities Council	2010
61	Professor Andrew Stirling	Science Policy Research Unit	2010
62	Mr David Sweeney	Higher Education Funding Council for England	2009
63	Dr Graeme Sweeney	Energy Research Partnership	2010
64	Professor Sir Martin Taylor	Royal Society	2010
65	Professor Chris Thorns	Veterinary Laboratories Agency	2009
66	Professor Alan Thorpe	Natural Environment Research Council	2009
		Chair, Research Councils UK	2010
67	Professor Andrew Watkinson	Living With Environmental Change	2010
68	Professor Robert Watson	Department for Environment, Food and Rural Affairs	2009
69	Professor Mark Welland	Ministry of Defence	2009
70	Professor Paul Wellings	Chair, 1994 Group	2010
71	Sir Peter Williams	Vice-President, Royal Society	2010
72	Dr James Wilsdon	Royal Society	2010

Appendix D List of oral evidence sessions included in Phase II

Table D-1 Selected oral evidence sessions

Session date	Session word count (Approx.)	Witnesses	Designations/Affiliations	Page
Research Council Support for Knowledge Transfer				
15-Mar-06	8900	Professor Sir Keith O'Nions	Director General of the Research Councils, Office of Science and Technology	Ev 1
15-Mar-06	5800	Professor Christopher Snowden	Vice-Chancellor, University of Surrey	Ev 10
		Professor Diana Green	Vice-Chancellor, Sheffield Hallam University	
		Dr Bob Bushaway	Chairman, AURIL Council	
15-Mar-06	8900	Professor John Murphy	Chairman, External Challenge Panel	Ev 16
		Mrs Barbara Doig	Member, External Challenge Panel	
		Professor Richard Brook OBE	Member, External Challenge Panel	
29-Mar-06	7200	Sir John Chisholm	Executive Chairman, QinetiQ Group plc	Ev 25
		Dr Malcolm Skingle	Director, Academic Liaison, GlaxoSmithKline	
		Tony McBride	CBI (Confederation of British Industry)	
		Dr Ian Ritchie	Technology Entrepreneur, Coppertop	
19-Apr-06	17300	Professor John O'Reilly	Chief Executive, Engineering and Physical Sciences Research Council	Ev 32
		Professor Ian Diamond	Chief Executive, Economic and Social Research Council and Chair of Research Councils UK Executive Group	
		Professor Keith Mason	Chief Executive, Particle Physics and Astronomy Research Council	
		Professor Philip Esler	Chief Executive, Arts and Humanities Research Council	

Session date	Session word count (Approx.)	Witnesses	Designations/Affiliations	Page
Putting Science and Engineering at the Heart of Government Policy				
25-Feb-09	9200	Professor David Fisk	Imperial College London	Ev 10
		Professor Lord John Krebs	A Member of the House of Lords, University of Oxford	
		Professor Julia King	Aston University	
		Professor Lord Martin Rees	A Member of the House of Lords, President of the Royal Society	
25-Feb-09	8900	Dr Tim Bradshaw	Confederation of British Industry	Ev 18
		Professor Dame Janet Finch	Council for Science and Technology	
		Baroness O'Neill of Bengarve	A Member of the House of Lords, British Academy	
		Ms Judy Britton	Government Office for Science	
16-Mar-09	8700	Professor Adrian Smith	Director General for Science and Research, DIUS	Ev 28
		Nick Dusic	Campaign for Science and Engineering	
		Professor David Edgerton	Imperial College London	
		Professor David Charles	Regional Studies Association	
18-May-09	10600	Rt Hon Lord Drayson	A Member of the House of Lords, Minister of State for Science and Innovation, Department for Innovation, Universities and Skills	Ev 55
		Professor John Beddington	Government Chief Scientific Adviser	
The Impact of Spending Cuts on Science and Scientific Research				
03-Feb-10	10600	Lord Broers	A Member of the House of Lords	Ev 3
		Professor Brian Cox	School of Physics and Astronomy, University of Manchester	
		Nick Dusic	Director, Campaign for Science and Engineering	
		Sir Peter Williams	Vice-President, The Royal Society	
03-Feb-10	9100	Iain Gray	Chief Executive, Technology Strategy Board	Ev 15
		Dr Tony Peatfield	Director of Corporate Affairs, Medical Research Council	

Session date	Session word count (Approx.)	Witnesses	Designations/Affiliations	Page
		Professor Michael Sterling	Chair, Science and Technology Facilities Council	
		Professor Alan Thorpe	Chair, Research Councils UK	
10-Feb-10	10000	Professor Michael Arthur	Chair, The Russell Group	Ev 47
		Professor Janet Beer	Chair, University Alliance	
		Professor Les Ebdon	Chair, million+	
		Professor Paul Wellings	Chair, The 1994 Group	
10-Feb-10	7200	Dr Alastair Hunter	President, University and College Union	Ev 73
		Sir Alan Langlands	Chief Executive, Higher Education Funding Council for England	
		Professor Adrian Smith	Director General, Science and Research, Department for Business, Innovation and Skills	
		Professor Steve Smith	President, Universities UK	
24-Feb-10	9500	The Rt Hon Lord Drayson	Minister for Science and Innovation	Ev 81
		The Rt Hon David Lammy	MP, Minister of State for Higher Education and Intellectual Property, Department for Business, Innovation and Skills	

Setting Priorities for Publicly Funded Research

28-Oct-09	7900	Mr Jeremy Clayton	Government Office for Science	10
		Dr Graeme Reid	Department for Business, Innovation and Skills	
05-Nov-09	8100	Professor Mark Welland	Ministry of Defence	46
		Mr Paul Stein	Ministry of Defence	
		Professor Robert Watson	Department for Environment, Food and Rural Affairs	
		Dr Miles Parker	Department for Environment, Food and Rural Affairs	
11-Nov-09	8200	Dr Brian Bowsher	National Physical Laboratory	122
		Professor Chris Thorns	Veterinary Laboratories Agency	
		Mr Derrick Ryall	Met Office	
02-Dec-09	12800	Mr David Sweeney	Higher Education Funding Council for England	158
		Professor Alan Thorpe	Natural Environment Research Council	
		Professor David Delpy	Engineering and Physical Sciences Research Council	

Session date	Session word count (Approx.)	Witnesses	Designations/Affiliations	Page
		Dr Steven Hill	Research Councils UK	
		Sir Leszek Borysiewicz	Medical Research Council	
09-Dec-09	7400	Mr Nick Dusic	Campaign for Science and Engineering	205
		Professor Geoffrey Boulton	Royal Society of Edinburgh	
		Professor Roger Kain	British Academy	
15-Dec-09	8900	Mr Colin Smith	Rolls Royce	217
		Mr Simon Denegri	Association of Medical Research Charities	
		Ms Anne Glover	Amadeus Capital Partners	
15-Dec-09	8900	Mr Iain Gray	Technology Strategy Board	238
		Dr Graham Hillier	Centre for Process Innovation	
		Dr David Clarke	Energy Technologies Institute	
12-Jan-10	9500	Professor Andrew Watkinson	Living With Environmental Change	258
		Professor Sir John Bell	Office for Strategic Coordination of Health Research	
		Dr Graeme Sweeney	Energy Research Partnership	
		Professor John Loughhead	Energy Research Partnership	
12-Jan-10	8500	Dr Paul Nightingale	Science Policy Research Unit	274
		Professor Andrew Stirling	Science Policy Research Unit	
		Sir Richard Brook	Leverhulme Trust	
19-Jan-10	9700	Professor Sir Martin Taylor	Royal Society	289
		Dr James Wilsdon	Royal Society	
		Professor Dame Janet Finch	Council for Science and Technology	
19-Jan-10	9700	Professor John Beddington	Government Chief Scientific Adviser	302
04-Feb-10	7200	Professor Adrian Smith	Department for Business, Innovation and Skills	316
04-Feb-10	8500	Rt Hon Lord Drayson	Department for Business, Innovation and Skills	324

Total number of sessions: 27

Total number of witnesses: 83

Number of unique witnesses: 72

Appendix E Sample of oral evidence transcripts

House of Commons
Science and Technology

The Impact of Spending Cuts on Science and Scientific Research

Sixth Report of Session 2009–10

Volume II

Oral and written evidence

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The Science and Technology Committee

The Science and Technology Committee is appointed by the House of Commons to examine the expenditure, administration and policy of the Government Office for Science. Under arrangements agreed by the House on 25 June 2009 the Science and Technology Committee was established on 1 October 2009 with the same membership and Chairman as the former Innovation, Universities, Science and Skills Committee and its proceedings were deemed to have been in respect of the Science and Technology Committee.

Current membership

Mr Phil Willis *(Liberal Democrat, Harrogate and Knaresborough)(Chair)*
Dr Roberta Blackman-Woods *(Labour, City of Durham)*
Mr Tim Boswell *(Conservative, Daventry)*
Mr Ian Cawsey *(Labour, Brigg & Goole)*
Mrs Nadine Dorries *(Conservative, Mid Bedfordshire)*
Dr Evan Harris *(Liberal Democrat, Oxford West & Abingdon)*
Dr Brian Iddon *(Labour, Bolton South East)*
Mr Gordon Marsden *(Labour, Blackpool South)*
Dr Doug Naysmith *(Labour, Bristol North West)*
Dr Bob Spink *(Independent, Castle Point)*
Ian Stewart *(Labour, Eccles)*
Graham Stringer *(Labour, Manchester, Blackley)*
Dr Desmond Turner *(Labour, Brighton Kemptown)*
Mr Rob Wilson *(Conservative, Reading East)*

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The Committee is one of the departmental Select Committees, the powers of which are set out in House of Commons Standing Orders, principally in SO No.152. These are available on the Internet via www.parliament.uk

Publications

The Reports and evidence of the Committee are published by The Stationery Office by Order of the House. All publications of the Committee (including press notices) are on the Internet at http://www.parliament.uk/science
A list of reports from the Committee in this Parliament is included at the back of this volume.

Committee staff

The current staff of the Committee are: Glenn McKee (Clerk), Richard Ward (Second Clerk), Dr Christopher Tyler (Committee Specialist), Xameerah Malik (Committee Specialist), Andy Boyd (Senior Committee Assistant), Camilla Brace (Committee Assistant), Dilys Tonge (Committee Assistant), Melanie Lee (Committee Assistant), Jim Hudson (Committee Support Assistant) and Becky Jones (Media Officer).

Contacts

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Witnesses

List of written evidence

Professor Cox: The answer, I think, to the question, "Should reductions ever be considered?", is to look at the magnitude of the science budget overall. If you look at it from a Treasury perspective, total R&D investment in the UK next year is around eight billion, of which RCUK, the money into universities, is around three, three and a half billion, if that. If you cut that to zero, it would not make much difference to the bottom line of the UK. That is the first thing to note. The second thing to note is that physics, according to the Institute of Physics' figures which were quoted in the Wakeham Review, contributes 6.4% to UK GDP. That three and a half billion in RCUK is the whole science budget, MRC and everything, but just physics, 6.4% of UK GDP. In my view, it is a rather dangerous and high stakes experiment to consider cutting physics funding, let us say, which is below a billion to RCUK, and see what happens. I do not know why you would take that gamble. The second thing about moving between disciplines, of course, is that you have to constantly reassess the public spend on science. What has happened, what you have to avoid, I think, from a university perspective, is radical and steep step-function changes. That is what has happened with the STFC issue. What we have seen in about two years is a reduction by, let us say, between 40–50% in grant income into universities, this is the projected drop in astronomy and particle physics, nuclear physics astro-particle physics, which are the most populous areas in terms of academics in university physics departments. As a business what are universities to do if you make such radical and abrupt decisions?

Nick Dusic: Can I follow up on a point about the portfolio of investment? The science budget makes up one part of the Government's investment in science and engineering research, a very important part, and the foundation for the rest, but we have seen a decrease in government department R&D around 25% between 2004–07, which is during the 10-year framework period when the science budget was supposed to be increased in line with economic growth.

Q15 Chairman: Can I stop you there, because there is some doubt about those figures. In fact, we are in conversation with the Science Minister at the moment to try to examine that shift, and there is a claim that, in fact, it is a different accounting system rather than a direct cut of 25%.

Nick Dusic: Okay; so this is from the Government stats. There has been a shift of some money between the departmental budgets and the research science budget due to accounting, changes to DIUS, machinery of government, but I do not think that accounts for all of it and I hope the Committee will pursue that line of inquiry with the Science Minister.

Q16 Chairman: We certainly will.

Nick Dusic: Very quickly, the Technology Strategy Board and the Strategic Investment Fund have provided some additional money for these late stage investments, and so that does happen, and, also, there have been two countries, Korea and Finland, who have had to cut public expenditure quite significantly at different periods but increase investment in science innovation because they saw that as a way out for their country.

Q17 Graham Stringer: Lord Broers, there is nothing new here, is there? During your time as a professional engineer this is the fourth recession we have arrived at. What has been the impact of cuts in science and engineering during the previous recessions? What was your experience of that?

Lord Broers: I did not have direct experience in this country; I was in the United States. What used to happen, for example, in IBM research when there was a recession and times became difficult was that the work did become more applied for a while: there were no cuts. I think to cut your science and engineering is very damaging. I think that happened in this country and that is probably what was very damaging. One does have to be realistic at times and change one's priorities slightly. If I look very parochially, declaring my interest as Chairman of the Diamond Light Source Board, we have been cut in the phase of building the actual device, which is a great shame because it means that certain things we could do even if we could change the emphasis a bit we cannot do any more. If you look at the Japanese Light Source, which is perhaps the biggest one in the world, they have eight people full-time working with industry to make sure that their industry is quite up to speed in using these marvellous resources. We do not have that capability. We would like to have it but, of course, it costs money. At the moment we are desperate not to cut our science resource to sustain the user part of our programme, but we are unable to do some of those things that would be hugely beneficial. I think my bottom line on this is, no, of course one should not cut one's science and engineering budget, but one may need to change priorities during very difficult times.

Dr Harris: Can I follow up that Diamond Light Source thing. We had a session with Alan Thorpe, who I think we will be hearing from in a minute, and I asked whether there was a concern that we could meet the Government's side of the funding for Diamond Light Source to keep all the stations running that were planned to run for the time that they could maximally be used. Despite Wellcome having put in all that capital, we were not actually deriving what we could because of funding cuts. What is the position? We were told there was no problem.

Q18 Chairman: Before you answer that, Lord Broers, in addition to that we have had the Chief Executive of STFC make a clear statement in terms of their new proposals that the funding for the Diamond Light Source and ISIS too would be protected.

Lord Broers: They have not been protected to the original five-year plan that we were living on. We have taken a 10% or 11% cut against that five-year plan. Fortunately, unlike some other light sources in the world, Gerhard Materlik and his team run a very, very tight operation, it is very well managed and, by

HOUSE OF LORDS

Science and Technology Committee

3rd Report of Session 2009–10

Setting priorities for publicly funded research

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HL Paper 104–II

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have never known an academic who has put an application in that is not curiosity driven whether it is a specific call or into responsive mode. I think they are very unhelpful distinctions. As Alan said, the key criterion is excellence. We only fund on the basis of peer reviewed excellence. There are however certain areas which we do believe are strategic priorities. We have identified them across council calls and there are one or two in each of the individual councils. Just because we have identified those as priority areas, they then automatically become directed. I have an energy programme. A large number of the applications that come into that are essentially responsive mode calls but they come in to that particular pot of money. They all get grouped as directed. Although I have a ratio of, let us say, 50/50 within EPSRC, I would say that at least a third of what is identified under that directed pot is actually responsive mode. I think it is an unhelpful distinction. The importance is the excellence of the research and we have undertaken an independent review of the outputs of that work, as have NERC, and what it shows is that the citations from what are called responsive mode or what are called directed mode or mission based programmes are virtually identical. In fact, the citations from these research council programmes are higher than the international average anyhow. A recent bit of work from EPSRC showed that programmes which are larger and more ambitious have a statistically higher citation impact than the smaller programmes. The smaller programmes tend to be in responsive mode and the larger, more ambitious programmes tend to be in what we would call directed mode. I would argue it is high quality work. All the evidence is that it has the same international excellence. When we analyse, in terms of EPSRC, the academics who are bidding into the responsive mode pot and those who are bidding into directed mode then it is 75 per cent commonality. It is the same excellent researchers who are doing both.

Q286 ***Lord Broers:*** Do you have a suggestion for better terminology?
Professor Delpy: I would just call it research. What we fund is internationally excellent research. It may be research in the area of energy; it may be research in the area of environmental change or in security.

Q287 ***Lord Broers:*** You could say you are particularly interested in bids in this area?
Professor Delpy: Yes. There are some councils which have almost gone down that route wherever this responsive mode call is issued in an area.

Professor Thorpe: It is essentially what our directed mode is. It is saying that in this area we are soliciting proposals in generally quite broad areas rather than across our whole portfolio.

Q288 ***Lord Broers:*** Why do you not change it?
Professor Thorpe: We are giving serious consideration to the terminology because, as David said, the number of words that are being bandied around with different connotations and emphases, if you like, often are used to say that one mode generates better quality, more excellent research. Again, this is why we did the citation analyses to try and test this. It just does not seem to be the case. We do feel we need to change the terminology and we are giving serious thought to that.

Q289 ***Chairman:*** I think we understand your reservations about the terms, whichever pair you happen to use. If you have statistics that attach to these terms that other people use, as you indicated, they might be very useful to see, if you could send them to us. Secondly, can I just ask whether or not—this is I think one we will be considering—a difference between a strategic priority (I think for example of the MRC, Wellcome and neurodegenerative diseases where you sketch out an area; this is high priority for all sorts of reasons but the excellence of the research is the fundamental thing) as distinct from project driven response mode is helpful.
Sir Leszek Borysiewicz: I think language is language and unfortunately the clarity has to be to the community as well. MRC historically has had a different way of funding to most of the other councils. From 1911 onwards, its priority firstly was the intramural research and 40 per cent of the MRC budget is spent on our own scientists working in our own institutes. The LMB and the National Institute for Health Research are examples. We have 29 such units so we directly employ 4,000 scientists working in these areas. Of the remaining calls, we can again provide you with the data but you will have seen from 2005 onwards 90 per cent was in response mode until last year. What changed last year was the response to the Cooksey Report, where we received additional resource in order to begin to develop the translational components. We had 15 specific calls in those areas where gaps were identified. Now if you look at the ratio, it is 62 to 38 per cent in that resource. The value of that pure response mode coming straight to the boards for pure excellence has not changed. It is 140 million, but the value of the directed calls has gone up because we received a specific budget and the increase in our budget was to address this issue of translational research and the gaps that were occurring there in partnership with NIHR and coordinated by OSCHR. That is the position that the

Appendix F Sample of published reports

House of Commons

Science and Technology Committee

The impact of spending cuts on science and scientific research

Sixth Report of Session 2009–10

Volume I

Report, together with formal minutes, oral and written evidence

Ordered by the House of Commons to be printed 17 March 2010

HC 335-I
Published on 23 March 2010
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Summary

The pressure to be seen to be making cuts across the public sector is threatening to undermine both the Government's good record on investment in science and the economic recovery. Since 2004, the Government has been committed to increasing public expenditure on science and research, in the knowledge that the investment would be recouped in a stronger knowledge-based economy.

There is a growing consensus that increased investment in science is essential to maintain the UK's international standing. That argument is made not only in this report but also in the Royal Society's *The scientific century: securing our future prosperity*, and the Council for Science and Technology's *A Vision for UK Research*, both published earlier this month.

Whilst the contribution of a strong domestic science base is widely acknowledged, methodological problems with quantifying its precise value to the economy mean that it is in danger of losing out in Whitehall negotiations. Despite receiving widespread lip service within Government, the sector is having to make the case anew to even hold on to the money it has at the moment after 2011.

Scientists are under increasing pressure to demonstrate the impact of their work, both retrospectively through the proposed Research Excellence Framework and when they apply for research council grants. Many are happy and able to do so, but there is concern within the academic community that areas without immediate technological applications are being undervalued.

Recent advances in improving translation from basic science to viable businesses are welcome, but can only continue for as long as there is a strong and broad research base to draw upon. The Government faces a strategic choice: invest in areas with the greatest potential to influence and improve other areas of public spending, or make cuts of little significance now, but that will have a devastating effect upon British science and the economy in the years to come.

4 Setting priorities

Picking winners and losers?

40. During our first session, Lord Broers suggested that "the US is the only country that anymore can pursue all branches of science and technology".[78] He argued that, like other smaller countries, "we have got to bite the bullet and focus a bit more than we do. We still think that we can cover the entire base, but I do not think we can".[79] Professor Brian Cox disagreed, contending that "a nation such as Britain, which is a world leading scientific nation, must maintain investment across the whole portfolio in order to take advantage of developments from wherever they come".[80] Sir Peter Williams expressed both views, when he said that "It is fatuous to think that this country will excel at everything in the twenty-first century", but that "it would be ill-judged of a science minister and, indeed, of your good selves to try and start picking winners around this table".[81]

41. In our final session, Lord Drayson revealed that something very much like this kind of prioritisation was being pursued:

> the Government has worked to identify with industry and the academic community those areas where Britain has real clear strengths, where the markets in those areas are growing strongly and where, therefore, if Britain invests in those areas, both on the supply and the demand side, it is most likely that Britain will succeed in generating future economic growth.[82]

42. Such a strategy is designed not only to capitalise upon those areas of technology with the greatest potential for economic growth, but to avoid repeating the mistakes of the past. Lord Broers had previously given the example of semiconductors:

> When I came back from the States we wanted to start a large institute such as they founded in Belgium, where they did specialise, but we could not do it because Southampton wanted it, Edinburgh wanted it, Cambridge wanted it, Manchester wanted it and we took the AlBi programme and divided it five ways and now we have nothing and Belgium has the number one research semiconductor laboratory in the world.[83]

43. It seems to us that Lord Broers and Professor Cox were talking at cross purposes: their two positions being not inconsistent. **Maintaining a broad portfolio of excellent research need not be mutually exclusive with the Government identifying and seeking to capitalise upon areas in which the UK has the potential for world-leading science, provided that it is done in a transparent and accountable way. Where such areas are**

78 Q 28
79 As above
80 Q 31
81 Q 32
82 Q 272
83 Q 30

HOUSE OF LORDS

Science and Technology Committee

3rd Report of Session 2009–10

Setting priorities for publicly funded research

Volume I: Report

Ordered to be printed 23 March 2010 and published 1 April 2010

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SUMMARY

Decisions about how best to allocate public funds to support research, especially in these times of economic stringency, are complex. They are not a matter of applying a simple matrix or formula. Instead, they require careful judgements about the deployment of limited funds between competing priorities so that the pursuit of knowledge and its translation into practical applications meet the needs of society as effectively and efficiently as possible. They involve a web of interacting funding mechanisms that include the research councils, higher education funding councils and Government departments.

At the centre of the debate about research funding priorities are the tensions between the differing objectives of research. For example, the research councils provide funding for the main areas of current scientific inquiry on the basis of the best scientific proposals made to them, whilst Government departments, such as health and defence, fund the research necessary for them to meet their departmental objectives. Meanwhile, there is an additional pull on resources as a result of major regional, national and international societal needs, including the aptly named "grand challenges" of climate and demographic change, and security of food, energy and water resources.

We welcome the fact that public expenditure on scientific research over the past decade has increased significantly (albeit from a lower baseline than that of comparable countries). Given the current economic context, however, it seemed particularly timely and appropriate for the Committee to focus on how the Government should set priorities for publicly funded research. We see the starting point as identifying the objectives of research. The objective of much research, particularly what is described as "curiosity driven research", is to understand more fully the world in which we live. More specifically, research can deliver a range of direct and indirect benefits. These include the creation, attraction and maintenance of scientific and technological skills; economic and social benefits; and providing evidence to underpin Government policy.

In this report, we make a number of recommendations intended to ensure that the Government are best placed to make research funding decisions. Our first recommendation is fundamental: that the Government should make a clear and unambiguous statement setting out their current research funding commitments. The remaining recommendations fall into two main categories: the need for an explicit Government overview of public expenditure on research (at both cross-departmental and departmental levels), and the need to develop improved mechanisms for setting priorities. They include requiring the Government Chief Scientific Adviser to publish annually figures on all public spending to support research, including specific aggregations; the establishment of mechanisms to identify major cross-cutting policy challenges and to co-ordinate and fund appropriate responses to such challenges; and a review of the contribution made by the Council for Science and Technology. Finally, we draw the attention of the House to a number of important issues which we have not been able to explore fully in the time available. These include: the balance between "responsive-mode" and "targeted" research; supporting private-sector research and innovation; concentration of research resources; and the role of "impact" as a criterion for allocating research funding. We anticipate that these are matters to which this Committee may wish to return in due course.

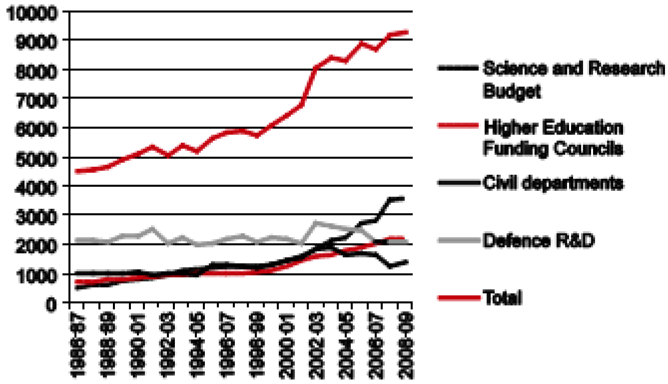
CHAPTER 2: UNITED KINGDOM RESEARCH BASE AND THE ECONOMIC CONTEXT

International comparisons

9. The UK research base ranks highly on many international performance indicators[2] even though the UK allocates a relatively small proportion of resources to research. Over the past 10 years, public research funding in the UK has experienced sustained and significant growth in cash terms (see Figure below), although in international terms it remains relatively small as a percentage of Gross Domestic Product (GDP).[3]

FIGURE

UK Government spending (in cash terms: £ million) on research and development



Note: Figures for 2008–09 are from the 2007 comprehensive spending review plan and are not final.
Source: BIS SET Statistics: Science, Engineering and Technology Indicators (2009)

10. In recent years the UK's position has been increasingly challenged, by two developments in particular. First, other nations, especially in Asia, are catching up rapidly as a result of large investment in research. Secondly, other governments are increasingly prioritising research as part of their policies to support the development of the "knowledge-based economy" in enhancing productivity and growth. In recognition of the importance of such policies, under its 2000 Lisbon Strategy, the European Union has set a target of 3 per cent of GDP—including both private and public investment—to be spent, as an average across all Member States, on research and development by 2010.[4]

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[2] *The Scientific Century: Securing our Future Prosperity*, Royal Society, March 2010, pp 9–10; *International comparative performance of the UK research base*, Evidence, September 2009.

[3] *OECD Science, Technology and Industry Scoreboard* (2009).

[4] *OECD Science, Technology and Industry Outlook* (2008).

Appendix G Selected extended quotes from oral evidence transcripts

Table G-1 Extended quotes from oral evidence transcripts

First order codes	Second order themes
	Mode 2 audience
Public ROI	The first of these can be seen in the document that we produced for the Wellcome Trust and the Academy of Medical Sciences where we systematically used economic and Treasury parameters to explore what the economic value of research in both neurosciences and cardiovascular disease is. There are real problems in biomedicine in doing this because what that analysis showed is a phenomenal return. It basically allows you to say to the Chancellor of the Exchequer, "Chancellor, you do not invest in anything in this country which will give you a return of 40p in the pound by Treasury rules in perpetuity as a result of public investment", because that is what the number is. It is the best value thing that Britain ever does, much more than you would get from a railway or a road. It is an incredibly successful operation. Prof Sir Leszek Borysiewicz, MRC *(Setting Priorities for Publicly Funded Research,* 163, Q272*)*
	Particularly at times like these but actually at any time I think it is important for funding bodies and the research community to be able to explain in reasonably clear language what they give back for the money that the taxpayer provides, and the term "economic impact" has been used as the headline for that description. One of the reasons for introducing that term was to try to get beyond a debate that was couched entirely in terms of pure and applied research and a debate that was couched in terms of how many patents had been filed by university departments, which we thought were particularly poor indicators of value to the taxpayer. Instead, therefore, on advice from an independent review, we opened up the description of the impact of the research base and I like to think of five different routes through which the research base contributes but I recognise that these are five of many. In no particular order, the research base first of all develops highly qualified people who move into many areas of employment throughout the economy and society; the research base creates new businesses and improves the performance of existing ones; the research base makes enormous contributions to public policy and public services in areas such as health and environment but many more; and, finally, I think perhaps the untold story in this is the way that the excellence of the research base attracts businesses from around the world to do research and development in this country. You will notice in that description that I have made no reference to pure and applied or directed and responsive or any of these other terms because the primary driver, as best we can tell, is the excellence of the research base.

First order codes	Second order themes
	Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 12, Q9)
	Mode 2 audience (contd.)
Practical relevance	I think we will cite very early on Bacon's quote that "science should be used for the relief of man's estate." Science, we believe, has all sorts of benefits that are often underestimated: iPods, cash machines, people even accept too easily the benefits of medical health. The understanding of the benefits of science are not really all that fully appreciated by the public and more should be made of that, and that will be in our report (Fruits of Curiosity). Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)
Business	In our view, as an industrial company, we think that publicly-funded research in collaboration with private research has a huge part to play in helping create technology and end products. I will talk about aerospace, but I could talk about the nuclear sector as well. Typically, a new material will take 20 years to go from a sticky black mess in a test tube to something that we can fly around the sky. It is a hugely competitive environment on a global stage and certainly for the first 10 or 15 years of that research you are not sure if there are going to be any benefits. So it is quite hard to convince, in a normal economic cycle, that we should put that level of effort in when it may fail. So when grants are available that we can work with other companies, cross-sectoral if possible with the academics, it is hugely advantageous to us. Mr Colin Smith, Rolls Royce (*Setting Priorities for Publicly Funded Research*, 217, Q347)
	I wrote a paper for the Defence Board in January this year pointing out that some of our most effective military equipment, if you trace it back to where its effect originated, it is actually from long term research that was done 20 years ago. So there is a requirement in my view that we invest in long term research. Can we do that in a construct where we have significantly reduced funding in the context of Dstl as you know it? The answer is almost certainly no, but what we have to do is work more with the university sector and have a much more outward looking face. Dstl has been doing that and needs to do more of that. We need to keep a long term capability in order to deliver the short term effect and that is my strong message that I have been trying to push at the Ministry of Defence. We need to keep that balance but that does not mean that we can have within Dstl highly speculative programmes on cyber or space which are not significantly aligned with current military requirements. We need to work with universities and we have a Centre for Defence Enterprise which is a new structure that allows us to engage with companies— SMEs—that we have not historically worked with, and with universities. That is an innovative structure in that you can put a proposal in to the CDE and we will get a response back, yes or no,

First order codes	Second order themes
	within a few weeks and fund it within a couple of months. That is something that I personally think has been enormously successful over the past year and something which I anticipate expanding. With MoD R&D spend we cannot do a lot of fundamental work—in fact we do very little fundamental work— so it is crucial to us that we engage with UK academia and the innovation that Paul has talked about in SMEs and we need to grow that. Prof Mark Welland, Ministry of Defence (*Setting Priorities for Publicly Funded Research*, 47-48, Q77-79)
	Mode 2 audience (contd.)
Economic development	What we find with industry—and I speak from the small company sector—is that spin-outs and small companies cluster around academic institutions where world-leading research is being done and the interplay of both the flow of talent of the students that come out of those departments into those companies. The actual spin-outs themselves—not necessarily the academics but the ideas—that then develop around research institutions will inevitably follow the nature of the inquiry that that individual group is following. I do not even think that we can choose; it will happen. The market will dictate that leading research institutes will then create around them leading companies and attract leading larger companies to come and work alongside them in research areas that are alike. So the choice of the areas what basic research is done in dictates an awful lot about how the whole economy works. Ms Anne Glover, Amadeus Capital Partners (*Setting Priorities for Publicly Funded Research*, 218, Q356) Just take the Cambridge area, and this is the combined effect of having world-class universities, science parks, many years of different types of investment and venture capital involved. I will just give you the statistics. In the greater Cambridge area, there are 3,500 hi-tech companies employing 150,000 people, and you will know that the population of Cambridge itself is only just about 100,000, with a commercial worth of about £1 billion. These are extraordinary numbers, half of them are biotech and the other half information technology and electronics. There are very impressive numbers for the Oxford area and the Thames Valley. These are developing into clusters I think, which you can start to compare alongside MIT and what is happening in Massachusetts; it is very impressive indeed. Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 4, Q23) The fundamental thinking behind all of this relates not just to scientific research but it relates to the central question of the economic future of Britain and the Government's plan to ensure that Britain has a prosperous and successful future in the context of the difficult economic circumstances in the near term but also very strong global international competition, and that has been pursued through a strategy, described as "industrial activism" by Peter Mandelson, whereby the Government has worked to identify with industry and

First order codes	Second order themes
	the academic community those areas where Britain has real clear strengths, where the markets in those areas are growing strongly and where, therefore, if Britain invests in those areas, both on the supply and the demand side, it is most likely that Britain will succeed in generating future economic growth. You mentioned space. Space is a classic example. It is as if the recession did not happen in the space industry. It has been growing at 9% a year for the last 10 years or so, it is projected to grow at 5% a year globally for the next 20 years, an opportunity for Britain to increase its global market share to 10%, create 100,000 new jobs, but to do that investment has to be made to maintain the fundamental science, first of all—just the sort of things that Professor Brian Cox would be keen on— but at the same time to make sure that that is translated into success in the economy, which means making sure of that translation of that science into projects. Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 86, Q272)
	Mode 1 audience
Scientific soundness and peer review funding	I was on PPARC when that was introduced and it (PPARC's requirement to consider knowledge transfer as part of the standard grant process) seemed like an appropriate thing to do and to ask. My question about that at the time was, is this the right thing to do for the kind of science we are doing? If you have something like gravitational waves, what is the exploitation for that? Maybe we will have weightless machines in 50 years' time or 100 years' time, who knows, but we are not going to have that today. I think it is an appropriate question to ask but I absolutely do not think you should make the scientific decisions on whether there is a realistic answer to that question or not. You should be making the decision dependant solely on the science. Dr Ian Ritchie, Technology Entrepreneur, Coppertop (*Research Council Support for Knowledge Transfer*, Ev 30, Q181) The best example I would give of success in doing this is Surrey Satellites. Out of one of our leading universities, a world lead that we have now in small satellites, Surrey Satellites just having won a major contract for the supply of the Galileo System. 500 million, I think, is the number, half of which will be coming to the UK, so there is a clear policy here. What that means, though, is that both the academic community, industry and government need to work together in the example of space, the innovation and growth team, to come up with a plan and a plan that the academic community supports. Therefore, it is the role of the academic community, through peer review, through the research councils, under the Haldane Principle, having been asked to think by the Government of what these priorities should be, for them to provide that advice. It is not for ministers to tell the scientific community these are the areas, because it is for the scientific community to come up with the conclusions. Rt Hon Lord Drayson, Minister for Science and Innovation (*The*

First order codes	Second order themes
	Impact of Spending Cuts on Science and Scientific Research, Ev 86, Q272)
	Mode 1 audience (contd.)
Academic culture/sanction	The central role for Research Councils is the creation of new knowledge in universities and in research institutes and it is what people do with that knowledge and the way people interact with business that is the knowledge transfer part. Now, in terms of promoting that, part of it is a cultural issue amongst the people who are creating the new knowledge in terms of how they wish to handle it, both individuals, universities and research institutes. Prof Sir Keith O'Nions, Director General of the Research Councils (*Research Council Support for Knowledge Transfer*, Ev 1, Q3) One of the risks in driving knowledge transfer too hard in its own right is that within universities or within organisations knowledge transfer is set up as a separate entity on the side of the university and it is not fully integrated with these very special people who have the ability to create the knowledge. We want these knowledge transfer skills to be added on to the other skills; we do not want separate teams of so-called knowledge transfer specialists. I can see elements of that happening. Prof John Murphy, Chairman, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 20, Q117)
	Resource accumulation
Inherent unpredictability	I think there is a potential danger of trying to allocate research funding towards certain outcomes. It causes researchers to miss the opportunities that randomly come up. Serendipity plays a very important role in research. I can recall a discussion with Professor Weiss who has received huge amounts of research funding from the Medical Research Council and EPSRC and he has come up with lots of wonderful science, but often that science bore very little resemblance to what he originally bid for. There is an important role for serendipity. I think we should encourage people to undertake interesting research and I think that often is very valuable in that it informs teaching. A lot of the links that we have spoken about that create value for the country from research come from this. If you try and over-direct science, you can end up with poor quality science. Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 280, Q449) I think we have quite a strong view that the place not to prioritise is what we, in our submission, called the "upstream" end; in other words, you do not make choices about the sorts of thing you study. The reason for that, of course, is what we geologists call crypto-genesis; that is to say, you never know what the future might hold, you do not know where the important innovations in the future might come from—very often they come from the most unexpected areas. On the other hand, prioritisation is important, and we would argue that you prioritise the downstream end. Our submission very much

First order codes	Second order themes
	directed itself towards the economic agenda, but I could generalise that for you, in a sense, to the whole agenda of research use. Our argument is that there are ways whereby Government, in particular, and the agencies in government, can make choices about economic and technological opportunities; and it should do so and send strong signals out to markets, to potential investors, in the hope that (and I think there are many examples which demonstrate that this is a realistic hope) that will attract investment from companies simply because they realise that there is a long-term potential for benefit in that state because of the long-term commitment to change. Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 205, Q326)
	I guess you can break it down in a number of areas. The research base, so the research councils and the Higher Education Funding Councils, need to be funding the highest quality research. Breaking the research council components down, you have responsive mode and directed programmes. The responsive mode side is extremely important, because many of the areas that science will bring for the future are ones that we have not thought about yet, and that is why the Foresight activities and other activities to try to pick those areas have been quite unsuccessful in seeing where science will lead us in the future. Mr Nick Dusic, Campaign for Science and Engineering (*Setting Priorities for Publicly Funded Research*, 208, Q333)
	Resource accumulation (contd.)
Healthy science and engineering base	There have been three different speeches. We have had Lord Drayson's, John Denham's and the Prime Minister's speech, and each has a different focus on this issue (government planning of research). The Prime Minister has said they will be running increased investment across the board in science, and that was to be welcomed, but Lord Drayson's and John Denham's had an inherent question if we increase research in certain areas and focus on those areas that would be potentially at the expense of others. From the Campaign for Science and Engineering our perspective is that that breadth of excellence that exists within science and engineering within the United Kingdom is one of our core strengths, it gives us a competitive advantage against other countries, and we need to be able to have a strong and excellent research base going forward that is able to deal with new challenges and new industrial opportunities that we should not be getting into a narrowing of the focus of the research base at this time. Mr Nick Dusic, Campaign for Science and Engineering (*Putting Science and Engineering at the Heart of Government Policy*, Ev 29, Q148)
	As I say, what we are committed to is a wide-ranging and open and transparent consultation because ultimately a lot of this is to do with prioritisation. You have to unpick that and it is quite complicated because of the landscape that is out there. We have institutions, world

First order codes	Second order themes
	famous higher education institutions; we have institutes, world famous institutes run by the research councils, like the Laboratory of Molecular Biology in Cambridge; we have facilities—Diamond; we have international activities—CERN; and, of course, underlying all this we produce people through PhDs and post-docs and try to attract the brightest and the best from around the world to come to the UK. There is a very complex landscape of balancing acts among all those things. We want to preserve the international competitiveness of the research aspects. Prof Adrian Smith, Director General, Science and Research, BIS (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 75-76, Q218)
	Resource accumulation (contd.)
Continued investment	It is one of the best investments, yes, along with perhaps education. I think that if you do not invest in your future at difficult times of recession, you will not prosper when the good times come. This is a lesson we have all learned in industry. I sit on a couple of major engineering boards, these remnants of our great past that Alec referred to: GKN, WS Atkins, and so on. We have had to invest during these difficult times so that when we emerge we hit the ground running and will be successful. The nation has to do likewise. Sir Peter Williams, Vice President, The Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 5, Q10) The fundamental thinking behind all of this relates not just to scientific research but it relates to the central question of the economic future of Britain and the Government's plan to ensure that Britain has a prosperous and successful future in the context of the difficult economic circumstances in the near term but also very strong global international competition, and that has been pursued through a strategy, described as "industrial activism" by Peter Mandelson, whereby the Government has worked to identify with industry and the academic community those areas where Britain has real clear strengths, where the markets in those areas are growing strongly and where, therefore, if Britain invests in those areas, both on the supply and the demand side, it is most likely that Britain will succeed in generating future economic growth. You mentioned space. Space is a classic example. It is as if the recession did not happen in the space industry. It has been growing at 9% a year for the last 10 years or so, it is projected to grow at 5% a year globally for the next 20 years, an opportunity for Britain to increase its global market share to 10%, create 100,000 new jobs, but to do that investment has to be made to maintain the fundamental science, first of all—just the sort of things that Professor Brian Cox would be keen on— but at the same time to make sure that that is translated into success in the economy, which means making sure of that translation of that science into projects. Sir Peter Williams, Vice President, The Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 5, Q10) I think your Lordships have, in the very good submission from the

First order codes	Second order themes
	Department for Business, Innovation and Skills, an analysis of the public service agreement metrics and how the UK shapes up, and indicates, broadly, of course, that we are punching well above our weight with a low level of investment in research in comparison with our competitors—1.8 per cent of GDP by comparison with 2.7, or thereabouts, in the US, and so on. The more immediate concern is, of course, that a number of our international research competitors have initiated stimulus packages in the recession; the US, in particular, but, also, Japan, Germany, India and China. Our research funding system is, by its outputs, a very efficient and a very effective one, but, with a lower proportion of funding going in than our competitors, that position must be fragile. If we wish to hold our position of second in the world, and the benefits that that brings in terms of the flows of international students and other research-based activities to the United Kingdom, then I can see a peril over the next two or three years. Prof Roger Kain, British Academy (*Setting Priorities for Publicly Funded Research*, 207, Q330)
	Resource accumulation (contd.)
Breadth of capabilities	My own view is that step one to clarity is that when we talk about science we need to remember that there is a distinction between science in the broad sense (for which DIUS is responsible through a number of delivery organisations) and science in the sense of stem research. It looks as though—but we have to say so far it is a matter of speeches—stem research is being favoured and within stem biological sciences looking to our glorious past and present, so to speak. Whether that is the reality I do not know, but if you want to have successful innovation you actually need to keep the other streams going. I would want to generalise what Lord Rees said when he pointed out that you are not going to do the medical and biological research well if you try to shrink physics or chemistry; I would say that you are not going to do the stem research and stem innovation well if you try to shrink or do without the other sorts of research. Baroness O'Neill of Bengarve, a Member of the House of Lords, British Academy (*Putting Science and Engineering at the Heart of Government Policy*, Ev 20, Q86) It follows logically from the fact that we believe that the breadth of the research base should be preserved and developed in this country on a strong base that the proper role for government and its agents, in making sure that all disciplines are fully supported, may mean some rebalancing over time and, and, at different points in time, different sorts of rebalancing in favour of disciplines which have been relatively under-funded at a given point in time. Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 297, Q474)
	Resource accumulation (contd.)

First order codes	Second order themes
Retrospective justifications	Before I answer that question, can I give you an illustration, which I think goes to the heart of the matter, from purely personal experience. I spent 20 years running a university spin-out from Oxford, it was called Oxford Instruments. In 1911, that is nearly a century ago, a chap called Kamerlingh-Onnes discovered superconnectivity. In 1982, following Peter Mansfield's Nobel Prize winning science for Nottingham University, we wheeled the first scanner magnet into the Hammersmith Hospital. It is still scanning patients today. Today they are a five billion dollar worldwide industry and we have also, much more importantly, brought nothing less than a revolution in diagnostic medicine. None of that could have been predicted by Kamerlingh-Onnes, and I put it to you that little of it could have been predicted in 1982 when we marched confidently into the Hammersmith hospital. The timescales for the process that Alec so accurately described are long, they are indeterminate and they are imponderable, and the idea, Chairman, that science has had a good run in the last decade so it is perhaps time to tighten the belt is a mistaken one, because what science needs, leading to engineering, leading to wealth creation, is continuity and delivery of programmes over very long periods of time. Sir Peter Williams, Vice President, The Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 4-5, Q8)
	Competitiveness
Attractiveness to international human capital	Our recommendations are not about the immediate decisions on next year's funding allocations but about the general direction of travel. We do feel that there is, as Sir Martin has said, a sense of danger, at the moment, about the position of the UK's research standing because of a different sort of much bigger potential global competition coming further down the line. Even the United States is worried about this. The excellent report entitled Rising Above the Gathering Storm, which the Committee will probably be familiar with, produced in 2007 for the US Congress, makes it very clear that the US sees its position as the global research leader, threatened not immediately but over a decade by the emergence of India and China, in particular, as being scientific players, and for the UK the scale of this country's research activities is so much smaller and would only ever be so much smaller on its own by comparison with India, China and the United States. So we think that we need to be positioning ourselves over the next decade to be the place where the really best people want to come from elsewhere, and that that is the only basis on which we can sustain a longer-term position. That plus collaboration with others, and we can perhaps get on to that point a bit later. Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 294, Q465) I think we welcome the commitment towards science by the Government, the acceptance that whatever our economic problems are science is part of the solution and is supported. We are fortunate to have excellent science in the UK. Also we know that we are

First order codes	Second order themes
	especially excellent in some areas. We have some concerns about the way in which this statement has been interpreted because one of the great strengths of the UK is that we are the only country outside the US that has a number of world-class universities. They are a great national asset in a number of ways, not just via direct spin- outs but also via the way they attract talent from around the world and train excellent students. I think it is crucially important to realise that excellent universities will only stay that way if they can attract excellent faculty. They will not attract excellent faculty unless that faculty feels able to get support for responsive mode, curiosity driven research. That is what happens at Harvard and at Stanford and that needs to happen in our universities here. So it is very important that there should not be an erosion in the level of responsive mode support that covers the whole range of science. Prof Lord Martin Rees, a Member of the House of Lords, President of the Royal Society (*Putting Science and Engineering at the Heart of Government Policy*, Ev 10, Q38)
	Competitiveness (contd.)
Science base and private investment	Chairman: If we turned the tap off for a few years while the recession is dealt with and get our finances and our deficit back on track, will it matter? Mr Gray: I think it will make an absolutely huge difference. I say that in two different regards: one is that one of the roles that we have got, and it is in our mission statement, is to be a magnet for investment today, whether it be inward investment—companies looking to invest in the UK—whether it be about retaining companies here in the UK, whether it be about investors investing in small businesses today. They are all saying to us that one of the key reasons for investing in the UK is the strength of the science base. So the decisions we make about the science base today are not just impacting the research of tomorrow, they are impacting the investment decisions of today. So from my perspective that is one really solid reason why it is very important to keep that investment going in science and research today. The second key thing (and it will not be lost on people in this Committee) is we debate now the lost opportunity of topics in the past: plastic electronics, I know, has been a subject that this Committee has spent a lot of time reviewing and debating. What we need to be doing is making sure that we are investing for those technologies, emerging industries of tomorrow, and a gap— whether it be a six, 12, 18-month, two or three year gap—is absolutely crucial. Regenerative medicine is a very, very clear example; if we stop investing in regenerative medicine today then we will lose that industry forever. So the decisions are not about a five-year gap; they are about decisions that actually are discrete points in time that will change the landscape forever. Mr Iain Gray, Chief Executive, Technology Strategy Board (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 16, Q68)
	Attaining balance

First order codes	Second order themes
Issues of labelling	We did indeed express concern about that language and that is only part of the lexicon. There are terms such as "pure" and "applied" research, "blue skies research" and any number of other terms of art. Conceptually these can be quite useful in trying to describe the nature of research but, coming down to project level, these distinctions often are less useful. Looking at an individual piece of research and trying to decide where it is pure and where it is applied can be pretty hard work. If these terms are given too much weight in the formulation of policy it is easy to lose sight of the fact that they work more at a conceptual level than they do at a practical level. It was that that I meant in the note. You will be seeing witnesses from research councils and funding councils later in this inquiry and they may be able to elaborate on that point. I think you will find that they share a similar view. Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 10, Q2) I have the data because obviously I was aware of the concerns. As Alan says, over the last ten years there has been very little difference. EPSRC in general has been roughly 50/50 over a ten year period starting from 51 per cent so-called responsive and 49 directed. I personally however find the whole terminology both unhelpful and in fact divisive. Whether it is basic versus pure or pure versus applied or curiosity driven versus something which is not, I have never known an academic who has put an application in that is not curiosity driven whether it is a specific call or into responsive mode. I think they are very unhelpful distinctions. As Alan said, the key criterion is excellence. We only fund on the basis of peer reviewed excellence. There are however certain areas which we do believe are strategic priorities. We have identified them across council calls and there are one or two in each of the individual councils. Just because we have identified those as priority areas, they then automatically become directed. I have an energy programme. A large number of the applications that come into that are essentially responsive mode calls but they come in to that particular pot of money. They all get grouped as directed. Although I have a ratio of, let us say, 50/50 within EPSRC, I would say that at least a third of what is identified under that directed pot is actually responsive mode. I think it is an unhelpful distinction. The importance is the excellence of the research and we have undertaken an independent review of the outputs of that work, as have NERC, and what it shows is that the citations from what are called responsive mode or what are called directed mode or mission based programmes are virtually identical. In fact, the citations from these research council programmes are higher than the international average anyhow. A recent bit of work from EPSRC showed that programmes which are larger and more ambitious have a statistically higher citation impact than the smaller programmes. The smaller programmes tend to be in responsive mode and the larger, more ambitious programmes tend to be in what we would call directed mode. I would argue it is high quality work. All the evidence is that it has the same international excellence. When we analyse, in terms of

First order codes	Second order themes
	EPSRC, the academics who are bidding into the responsive mode pot and those who are bidding into directed mode then it is 75 per cent commonality. It is the same excellent researchers who are doing both. Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 167-168, Q285) One of the other elements which I think would be very important to stress which has not been stressed so far is the science policy research over the last 10 years has shown very clearly that academics are intelligent people who are able to market their research very effectively towards funders. There was a wonderful piece of research done by Jane Calvert, who is now at the University of Edinburgh, about whether or not research was basic or applied. The distinction between basic and applied research on research funding applications was dependent on what the researchers thought would be funded. If they thought applied research would be funded, it was applied research. If they thought basic research would be funded, they made it that. Also we are finding this to be the case with interdisciplinary research. There is an emphasis on, “Let’s have more interdisciplinary research”, and people now brand themselves as interdisciplinary researchers. It is not an easy system to change. We are dealing with people who are very clever and very good at marketing what they are doing, but I would stress that there is no support in the science policy literature for the idea that the research system can be managed effectively in a five-year plan essentially. Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 280, Q449)
	Attaining balance (contd.)
Assumption re: the optimum point	This point about the balance between directed and responsive mode funding is the hot question in research policy and there is no one that has a straightforward answer to it. To echo Alan’s point, ultimately it comes down to a judgement call. Really, all you can do is look retrospectively and ask the question: are we hitting the output measures that we want on the basis of the balance of funding that we have? The UK looks pretty good when you do that. If you look at the citation impact level or at wider impact measures around economic and social benefit, the UK comes out very highly in that, which tends to suggest that at least in the past we have been getting that balance right. Obviously those are very lagging indicators, but there are no more responsive or more short-term indicators for success. I think the judgement call made by councils, supported by the academic community, seems to be a successful way of achieving this balance. Dr Steven Hill, Research Councils UK (*Setting Priorities for Publicly Funded Research*, 169, Q292) The number is simply a judgement call. I cannot speak for the other councils but I know in my own council it is a really hot topic as to how much to vote to the two major streams. I do not say we have special insight into getting that right. All I can say is that it is analysed and thought about, particularly from the point of view of

First order codes	Second order themes
	making sure that the disciplines that we need are healthy, because although of course our mantra is multidisciplinary it has to have the core discipline supported. I do not think there is an algorithm that would tell you what that proportion is. I think it is a judgement call. If you look back over the last few years, except for some special cases, there have not been very strong trends in changes of the proportion that we spend on responsive mode and directed. Prof Alan Thorpe, NERC (*Setting Priorities for Publicly Funded Research*, 169, Q291)
	The issue directly relates to the overlap between science policy and education policy. The issue for the UK economy is that the high tech sectors which are directly feeding from the science system are quite small compared to the rest of the economy. There are marginal costs if we allocate resources towards particular areas. If we want to focus, as we may want to do, on biotech spin-out firms, then concentration might be a good idea. If we are concerned about the wider economy, then concentration probably is not a good idea. It is what outputs you want from the research system that will determine the answer to that question. Right now, as we have pointed out, it is not clear what the aims of the research system are and it is too broad just to say pro-innovation. There will be opportunity costs if we concentrate research resources in certain institutions. Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 279, Q448)
	Attaining balance (contd.)
Additivity	In fact, in the case of the research councils, the idea of asking for this consideration of impact is to enable the peer review panels in a dead heat, a tie, between decisions, between grants, where the overriding criterion for making that decision is research excellence, and if they have come to the conclusion that those grants are equivalent in terms of excellence that there is a further differentiating factor which can be looked at. Sincerely, I really believe with my 20 years' experience in science as a science entrepreneur that this has value. I really do believe it can be done. You hesitate to characterise a scientist in the company of the Maxwells and Plancks and so forth, but, I think, if we look at it, there have been enough really seriously eminent living scientists who have said, "It is fair enough for us to be asked to do this; it is early days; let's see", to suggest that this is worth doing. I think that there the concern that I have said I recognise is all to do with a general concern: is there a shift away from pure towards applied? Absolutely not. What we need to do is make sure we continue being excellent and pure, but we need to get a bit better at the application of applied research, and so I do not think that this impact agenda should be seen as a part of any kind of intention by the Government to shift allocation of research funding between that pure and applied spectrum, but I do believe it has huge potential benefit and should be followed. Rt Hon Lord Drayson, Minister for Science and Innovation (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 85,

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	Q271)
	The Cooksey Review was a very interesting phenomenon. Everybody recalls Cooksey and talks about translational research. They forget the shortest sentence in the Cooksey Report. I think it is paragraph 28. I stand to be corrected, but it actually says that Britain is excellent at basic, biomedical science and its excellence is driven through that basic, biomedical science. When resource was allocated— and I do recall this because this was at the time when I was taking up my position as chief executive—I was absolutely adamant there had to be no cut back on the money that was available for basic, biomedical research. What came in for the translational budget was the extra money that was widely heralded that was coming to the MRC in the last allocation. That money was earmarked towards the translational agenda and therefore nobody was suffering a penalty. That is why I was trying to point out that, whilst the calls have gone down, the amount of money going through response mode has not changed. That is because we were able to sustain that budget based on the fact that there was no reduction. We were never robbing Peter to pay Paul by having a change of direction. We were doing this as an additional activity which was important as a primary rationale for improving the position of the UK in translation. That was dependent on getting the right coordination through OSCHR and the joint working with the devolved administrations and with NIHR. The system is not that different for the MRC, other than this very large intramural programme that we continue to run. Prof Sir Leszek Borysiewicz, MRC (*Setting Priorities for Publicly Funded Research*, 170, Q292)
	When to exploit research
Sector-dependent	Most of my community does not find this impact agenda an alien one. 40 per cent of the research EPSRC funds is collaborative with an end user, not necessarily always a UK company, but 40 per cent of our grants are already involving a user. This idea of getting the output of research through quickly into product or policy is already part of the thinking of this community. Some 2,300 companies are involved in collaborations with EPSRC-funded grants at the moment. We do not specifically look at whether the users are UK or not UK. We have a strategic partnership arrangement with currently, I think, some 31 partnerships and about 37 companies, most of whom are either UK based in terms of having a large research base there or they are multinationals who are putting a significant amount of research funding into the UK base. Through that strategic partnership we try to encourage the development of the output of the research we fund within the UK base. Prof David Delpy, EPSRC (*Setting Priorities for Publicly Funded Research*, 165, Q277)
	One of the useful examples to look at is the university hospitals, where I think knowledge transfer takes place relatively automatically. To some extent, the medical sector is in a privileged position to have

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	these, because you have the consultants driving the research. They are dealing with patients, they are practitioners, they are driving the research, leading research teams and passing on the knowledge, so that the whole process is closely integrated compared to other sectors. If you look at industry, then there is a big divide. To try to copy that in other sectors, then the answer has to be something to do with people flow and secondments. At the moment I think we are really only scratching the surface on moving people. We need to ramp that up significantly. It is people flow between all of the organisations involved, so that the cultures flow as well as the knowledge flows. One final point is that we cannot consider knowledge transfer without considering the knowledge creation process. Businesses like mine have invested many hundreds of millions into R&D. If you look at our product base, it is enormous. Lots of academics heading off in all sorts of directions, like headless chickens, whether or not their research output will fit into what we have had, is highly debatable, and often we have to repeat the research in-house to make it compatible. Again, it is business engagement at an appropriate stage of the process, but that is at the research stage, not at the end of it, which is knowledge transfer. Prof John Murphy, Chairman, External Challenge Panel (*Research Council Support for Knowledge Transfer*, Ev 19, Q113)
	In our experience, the generation of knowledge works best across the borders between academic disciplines. In other words, horizontal linkages are more important than vertical linkages in many cases to subjects. I would pay tribute to the research councils' efforts to not let borders between their various remits get in the way of recognising that. I think of work, for example, in the last 10 years carried out by the BBSRC, particularly to watch the border with their colleagues in the EPSRC, so that as far as biotechnology and life sciences work in general there was no artificial barrier there that prevented good multidisciplinary work being funded. As far as commercialising, the problem is this one between short term and long term. It often takes much longer to pull through those benefits in some areas than it does in others. Some sectors of UK industry are better geared for working with universities than others. For example, the pharmaceutical industry in the UK is pre-eminent in working with universities to bring forward benefits in partnership with research council funded work; whereas in other sectors, perhaps not naming any, it is less readily forthcoming. Dr Bob Bushaway, Chairman, AURIL Council (*Research Council Support for Knowledge Transfer*, Ev 15, Q73)
	When to exploit research (contd.)
Dynamic outlook (Open-ended and/or conditional)	I think there is a need for a bit of myth busting here. There is a sort of mischievous view which is so nonsensical that, if you pause to reflect, it cannot possibly have been what anybody intended, that one should be able to predict at the beginning of a research project what the outcome will be. If you could, it would not be research. Everybody I work with, the research councils and I totally understand

First order codes	Second order themes
	that. That is not what it is all about. What it is about is asking people to reflect. If they reflect and come to the conclusion that they cannot think of any impact at all, that is fine. The research councils have said it a million times, but there are huge swathes of research where there are right from the beginning quite plausibly routes of impact and things it might impact on. What we have been accused in the past of doing and being is fantastic at the research and then very bad at picking it up, doing stuff to exploit it. What the research councils are about is trying to get mechanisms, a culture, an awareness and a behaviour change so that all along the process we are constantly thinking: if there is an opportunity to exploit, if there is something to exploit, let us make sure that we flag it and if possible we put in place support systems to gather it. That is what it is about. It is not about some nonsensical idea that we can predict the outcomes of the impacts of research right from the very beginning. I think there is a lot of mischievous, either accidental or deliberate, misunderstanding. There is no evidence whatsoever that the research councils' starting point, which is to assess excellence and fund the most excellent research, has been subverted in any way Very interestingly, for those of you who are avid readers of The Times Higher Education Supplement, today there is actually an article where somebody has looked at this. There is no evidence at all that this is affecting decision-making at the level of excellence. As you move down, we all know you have lists of the most excellent and then you get to where the funding gets difficult. All things being equal at certain points in the process, particularly if you are running directed or managed programmes, a better case for impact might shade it. I will be absolutely adamant: the research councils are applying the test of excellence when they are awarding grants, and it is mischievous of people to say they are not. Prof Adrian Smith, BIS (*Setting Priorities for Publicly Funded Research*, 323, Q552) *Case of note: Using "where appropriate" in responses* Dr Iddon: Can I be a bit of a devil and ask the question, do you think the Government is putting too much pressure on the research councils to have an economic impact and taking you away from blue skies more and more? Professor Diamond: Again, if I might speak for my own council, absolutely not. I do not feel that pressure at all. I personally believe it is an absolute necessity that anyone who wishes to take public money to do research should, where appropriate, use the results of that research to have an impact on the economic development and quality of life of the people of the United Kingdom who funded it, and indeed further afield. I think that is entirely appropriate and I think the research councils' role is to act as a conduit where appropriate to identify that and enable it to happen because it will not necessarily happen everywhere. I do not feel any pressure from the Government to do that. Prof Ian Diamond, Chief Executive, ESRC and Chair of RCUK

First order codes	Second order themes
	Executive Group (*Research Council Support for Knowledge Transfer*, Ev 34, Q208)
	Dr Harris: The point about your mission statement, which you have said twice, is that the opposite of what you have said is pointless, is ridiculous, so it is hardly worth saying that your research council should, where appropriate, make sure that economic gain is maximised because that would imply that if you did not do that you would want them, where appropriate, not to maximise economic gain. Professor O'Reilly: No. I am terribly sorry, but the use of the word "appropriate" is because there are parts of the research base which it would simply be silly for people to rush around trying to maximise the economic impact of because it is developing and underpinning theory, for example. Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 35, Q215)
	Dr Harris: Should you not do the same for career development issues, and I know Professor Mason is interested in this, because there is a real problem, particularly with the gender balance, in some of the research councils, including two represented here? Why stop at knowledge transfer and, if you do, it is in Science in Society? Why not look at this again and say, "Right: if we want to change the thinking and put it in grant applications we will do it for all the things that it is necessary for", not just pick on one where you appear to be under more pressure from the Government and industry to do it? Professor Diamond: If you take, for example, ESRC, with our larger centres that we fund, the passage of development and career development are absolutely critical things that we ask our potential centre directors to highlight how they will add to those, so where appropriate—and again I absolutely deliberately use the words "where appropriate"—in our funding schemes we do ask for a portfolio of activities, but the fundamental point that I return to if I may is that the absolute criterion for funding is the brilliance of the science. Prof Ian Diamond, Chief Executive, ESRC and Chair of RCUK Executive Group (*Research Council Support for Knowledge Transfer*, Ev 40-41, Q242)
	Sources of technological advances
Many possible patterns	Can I express a different view from my colleagues? Ian said earlier on that exploitation came from serendipity which as a matter of fact is true but I do not believe it is necessarily true. Certainly in the field of defence research that is exactly how it used to be done. When it became very much more focused the volume of exploitation increased enormously, so I believe that even in funding research you can be more focused upon the areas in which you are investing. Those areas which are more likely to have a transfer are discernible in advance and a considered research programme built around that as

First order codes	Second order themes
	an objective is more likely to be successful than simply serendipity. Having said that, brilliant science inventions have a role and I believe there should always be a component of any research programme which is entirely unlimited and purely blue sky for the purpose of civilisation. I think that is entirely legitimate. I think one should just be very explicit about what one is doing and when one wants to be blue sky, and purely focused on science for its own sake, that is an entirely legitimate thing for a country like the United Kingdom to do but you should be explicit if that is what you are doing. Sir John Chisholm, Executive Chairman, QinetiQ Group plc (*Research Council Support for Knowledge Transfer*, Ev 30, Q182) Chairman: Sir Peter, I know you cannot speak for the Royal Society, but as the Vice President you can come near to it. Which side of the argument do you fall on? Sir Peter Williams: Can I be greedy, Chairman, and say, all of the above. From an industrial perspective, I am with Alec. It is fatuous to think that this country will excel at everything in the twenty-first century. It will not. There will have to be certain areas of technology where we win and others where we accept that we cannot. In terms of science, because of the unpredictability of this pull-through process, as my example illustrated, I am nearer to Professor Cox, in the sense that I think it would be ill-judged of a science minister and, indeed, of your good selves to try to start picking winners round this table. It is a dangerous game. Sir Peter Williams, Vice President, The Royal Society (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 8, Q32)
	Sources of technological advances (contd.)
Starting *with* practical problems vs. Starting *without* practical problems	Dr Harris: Do you have a response, Brian, and then if I may ask Lord Broers to come in? Professor Cox: Briefly, if you applied an impact assessment across government departments, so you said, “What is the impact of scientific advance relative to some other areas of spending of government?” I think it works in those broad terms. All research shows that scientific advance has impact, but I agree entirely—you interpreted my point correctly—that it is next to impossible, I would contend, to draw a series of guidelines for a peer review panel to take into account to make them pick winners more often than they pick losers. I do not see how that judgment can be made by a peer review panel. Lord Broers: I would take a slightly different tack on this. I start from support for very broad ranging curiosity-driven research. However, if you do look at the great advances that came out of Pure Science, you find they came out through people who were very interested in impact. Townes, when he took his understanding of science to create the maser, was trying to solve a problem. He wanted a very high frequency amplifier and did not how to do that with vacuum valves, et cetera. He came out with the maser. Then people thought, “Goodness me, we could do that at light frequencies”, and then came the laser, and from then on there were people trying to use the laser

First order codes	Second order themes
	intensely to see if they could not get it more reliable and at the right frequencies, et cetera, to do the things they wanted to do with it that then exploded completely so that in the end we have applications we could never have dreamt of, but they all came about as a result of people who were trying to get impact out of the science. If you look at the transistor, Bardeen, Brattain and Shockley at Bell Labs were trying to get rid of having to have a glass bottle out of which they sucked the air so they could have an electron beam in there; they we are trying to make a solid state vacuum valve and they came up with the transistor. What were they trying to do? They were trying to get impact out of science, and you find this again, and again, and again. It is not so much that you can judge what that impact will be down the road, but the motivation is very important. Chairman: All scientists, surely, are motivated to do that. Lord Broers: Exactly, all scientists are motivated. There is not a single scientists that I have ever met, if you said, "Mygosh, if we took your ideas we could save half the world", that would not drop everything and start doing that. We should be interested in impact. I do not know why we have got quite so hung about this. Chairman: Because 25% of the REF is going to go on impact. That is why we are hung up. Professor Cox: This is a list of anecdotes, so I can give another list. Lord Broers: Pretty good ones. Professor Cox: Okay. What about the Worldwide Web then? Tim Berners-Lee is on record, I have seen the papers that he presented at CERN. His manager wrote, "Vague but interesting" on it, threw it back at him but he didn't say, "You can carry on anyway because this is certain to revolutionise the global information system." Chairman: I am going to stop you all here, because I do not want you falling out. Nick is going to have a word. Prof Brian Cox, University of Manchester; and Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 10-11, Q46-48)
	Suggested means
Academic freedom and diversity	In order to do that, we believe that we need to maintain a strong capability across the whole research base and here we do need science, technology, social science and creative disciplines as well. We believe that in order to really position ourselves for the future, the key is people rather than topics. Certainly in terms of the research base itself, we do not think that it is the role of government to pick promising topics or areas for the future; we believe that it is much more important to ensure that we have a research base which really, in terms of both home-grown talent and the attraction to the best researchers from elsewhere in the world, attracts, retains and nurtures the best talent because the best people will then be able to produce the best research in the future, and the characteristics of the future in terms of the opportunities cannot be predicted right now. So we believe that the best people will adapt to future opportunities and produce the best research.

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	Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 289, Q456) We quite like the idea of an "ecosystem of science"— with different parts affecting other parts. If you let one part perish or get ill, that will affect other parts. So we take a very holistic view of science, in which all sorts of different things are valued. When it comes to the targeted or more thematic kind of research, I think you will find that we are probably going to be advocating a different stance there, if you were listening to the recommendation about grand challenges. We much prefer the idea of identifying problems, articulating the problems that are there and trying to, as it were, attract scientists into them in a more positive way rather than pushing them by means of funding mechanisms. The notion of grand challenges has played out really rather well in some other countries—there was the Lund conference and we were quite inspired by that. I do not want you to get the idea that this is all about basic research, and if I gave that impression that was wrong. Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 293, Q464)
	Suggested means (contd.)
Public engagement	I think the strategic decision was to say that we needed to have a breadth of expertise within our staff. We can do that partly at the recruitment stage—so recruiting from a spectrum. That was one of the ways in which we were addressing that. The other is to do it through training and experience. In addition, we have had people engaged in secondments as part of our on-going process to develop this rich spectrum of expertise. Indeed, we view it as valuable that this is both ways. You will find that we have taken secondments from industry into the research councils for a short period for them to gain greater understanding of where we are and then send some of our people back into that company to learn the other side. I do think that is really important. This transfer thing sounds too much one-way if we are not careful! It is about a shared understanding of something quite complex that is what we are trying to achieve. Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 41, Q246) I go along with Ian, the best knowledge transfer is definitely through people. GSK co-fund 340 CASE students, approximately 100 with the BBSRC, 100 with EPSRC and 25 with the MRC and then we have some directly with universities, the Dorothy Hodgkin Fellowship Awards for the overseas students. We get great value from these: a real win-win. The student gets access to industry to see whether they want to dip into it; the academic person also often has follow-up grants from those and frankly we get a three month to a one year interview for a person we might wish to recruit and we also keep a watching brief on developing technologies. At the other end of the spectrum we have the secondments of academics into industry, and although we have the Royal Society Fellowships and the industry

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	interchange scheme that BBSRC have just brought in, I do not think we do enough of that. We have just recently started taking on what we call "academics in residence", to fuel certain parts of our science base. What happens is these guys come in with a perception of how we operate and once they are in they interact with our groups where we are kicking ideas around and they realise what our problems are and they go back to academia and if they cannot solve it they know someone who can. Anything which involves people transfer I think is the best way of getting knowledge transfer done. Dr Malcolm Skingle, Director, Academic Liaison, GlaxoSmithKline (*Research Council Support for Knowledge Transfer*, Ev 26, Q156) If I look very parochially, declaring my interest as Chairman of the Diamond Light Source Board, we have been cut in the phase of building the actual device, which is a great shame because it means that certain things we could do even if we could change the emphasis a bit we cannot do any more. If you look at the Japanese Light Source, which is perhaps the biggest one in the world, they have eight people full-time working with industry to make sure that their industry is quite up to speed in using these marvellous resources. We do not have that capability. We would like to have it but, of course, it costs money. At the moment we are desperate not to cut our science resource to sustain the user part of our programme, but we are unable to do some of those things that would be hugely beneficial. I think my bottom line on this is, no, of course one should not cut one's science and engineering budget, but one may need to change priorities during very difficult times. Lord Broers (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 6, Q17)
	Suggested means (contd.)
Joining multiple disciplines	Public health is a big issue. However, public health does not reside in the hospitals that are run by the NHS; it resides in teaching, in training, in education; it resides in how many cycle paths you build; it resides with the environment people; it resides with the energy people; it resides across government. So when government decides to fund an initiative in public health, as it did through the OSCHR process, it says, "Actually, we think it's important and we're going to give you some new money to do it", and it drops it into a department over a three-year timeframe. That is dust, actually, because there is precious little you can do once that has arrived to mould and develop that programme over a period of time. That is not to say my colleagues in health and MRC have wasted any money. That is not true. They have been very effective. However, where they have run into real trouble in the public health arena is that, when they bring the scientific advisers of all those other departments together and say, "This should be a major government priority. What are we going to do about it?" and they say, "Sorry, you guys, we've got other things to do. Bye, bye", there is precious little you can do about it. I think that this is a really serious issue. It relates to energy and to environment, because all those things need buy-in from multiple

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	departments. It seems to me that one of the few ways you can manage that is to say, “How much money are we going to support this big initiative with? We are going to hold that money back and allow it to feed programmes run by different departments who are prepared to play the game. If they don’t want to play the game, no money”. I know that is a different model of government and you are probably not going to like it very much, but I see some real problems getting these big scientific questions addressed with the current structures. Prof Sir John Bell, Office for Strategic Coordination of Health Research (*Setting Priorities for Publicly Funded Research*, 263, Q425) The thing that I have not touched on so far is interdisciplinary research in the United Kingdom, and the fact that the landscape of research councils does not necessarily favour interdisciplinary research that well. To give you a little idea of what I am talking about here, take the case of synthetic biology, which was something on which I have worked for EPSRC a little. This involves, in the first instance, some engineering; actually, also, some computer science and some mathematics and, of course, quite a lot of life science as well. I was able to see that you could only ever go at the speed of the slower of the research councils. It was quite a slow, painful business to get there but there was an awful lot of goodwill, I should say. But the way things are structured at the moment does not really favour interdisciplinary research that much. For instance, the sort of area in which some of our recommendations will go will be probably to enhance the role of that umbrella “RCUK”, with perhaps a little bit more money being held back by them for interdisciplinary research, so that they can act a little bit more quickly. If I could add, also, just parenthetically, my own experience, when I have been abroad speaking with people from the Deutsche Forschungsgemeinschaft in Germany and the Russian Foundation for Basic Science, they were always a little bit perplexed by our research councils’ structure: If there was an RCUK that was a lot more visible as an overarching, unifying structure that would help them greatly. They really are a little bit dismayed by the way things look sometimes. Prof Sir Martin Taylor, the Royal Society (*Setting Priorities for Publicly Funded Research*, 296, Q473)
	Suggested means (contd.)
Strengthening business pull	If we take two parts of this whole process—what I called the “upstream” end, which is basically the research that is done, and the “downstream” end, where it is used—I would take the view (and we are making generalisations at this stage, so I will make some), that at the upstream end we do very well, extremely well, and I do not think we have, frankly, a great deal to learn, except at second order, from many others. It does not mean, of course, that we should sit on our haunches, and if we are going to be able to respond to the investments that have been made elsewhere then we have to think structurally about how we improve an already good research base to make it even better. I think the real problems lie at the downstream

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	end, and I would say there are two principal actors in the two broad areas of demand. One is in public policy and the other one is in, if you like, the economy. The actors are different actors: in public policy, it is largely government; in the economy, it is largely private industry and private business. They have different habits and different ways of behaving, so one has to separate those two, I think. What I will do is just talk a little bit about the economic end and the way others do it. One thing that differentiates us from a number of countries that, I think, are very effective in utilising their science base is that we do not have a business or industrial policy in this country. If you are in the States, the federal Government takes the view that it is not particularly interested in being seen to be a paragon of liberal capitalism, it wants to screw the market in order to bring benefit to the USA, and it does so by, at the Federal level, determining that there are certain sectors which it believes are going to be important in the future and it is going to make sure the research is done and make sure that companies get the signals they need. Other bodies, like the National Institute of Health (the Department of Energy has already been referred to), play a very similar role, and it is very much a process whereby they drive the downstream end of the system to give companies the confidence to invest. In Singapore, they have been systematically investing in biotech, although my sense is they are not doing this as well as they might. In Taiwan, years ago now, they decided that communications was going to be their central activity and they have been immensely successful, for a relatively small country. In Germany it has been chemicals and the automotive industry. So that external companies— investors—know where to go when they are looking both for the research, on the one hand, and the translational activity that takes that research into utility. So if you want to find out how you should be designing electric cars, you do not go to Birmingham any more, you go to Voitsberg. I think that is one of the key things we have got to understand a little more about: the way in which others have used government capacity to be able to structure the downstream end of their enterprise. One of the questions I think we need to ask ourselves is: we divested ourselves of many research institutes through the 1970s, 1980s and 1990s, which played an important strategic role, do we need to reinvent them to create a function which is similar to the function of, let us say, Fraunhofer Institutes in Germany, which in a sense take the raw, basic research that is created within the universities and institutes and ensure that is pulled towards application, where industry can see that there are possibilities that they can seize upon readily and invest on a substantial scale without frightening their investors away. I think there is a lot to be learnt, particularly at the downstream end. Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 200, Q331) I think very good use is being made of the funds that are made available to universities. I think in the UK the universities are very impressive organisations. What we want to do is maximise the value that comes from that work. There is a process that goes from

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	knowledge creation right the way through to economic impact, and there is a part that is very strongly in the domain of the research councils through the universities and then through into business. If again I were to take it to EPSRC; what do I think is the most important thing for EPSRC and where we are channelling our efforts to improve the effectiveness? It is to do what we can to stimulate and increase the appetite of business for engaging in research and associated training and in knowledge transfer. It is that coupling and playing a part in maximising that. And many of the innovations that we have put in place over the last two or three years are very much focused on that. I believe it is the case now that over 40% of EPSRC grants involve collaboration with business directly: substantial in-cash and in-kind contributions. That has been brought about in large measure by us talking with the universities and them responding. We talk with business as well, but I am very clear in my own mind that simply shouting more loudly at the universities is not going to increase that further. What is going to be much more effective is if we can communicate much effectively to business the importance of that and do what we can to increase their appetite. In the case of EPSRC that is achieved largely by empowering the universities and fostering it. Prof John O'Reilly, Chief Executive, EPSRC (*Research Council Support for Knowledge Transfer*, Ev 36, Q217)
	Performance definitions
Impact as Mode 2 performance	Lord Broers: This is along the lines of what I was alluding to before. How might the UK further encourage innovation and the development of scientific discoveries into new products or services? What is an appropriate proportion of effort and funding to devote to research versus encouraging innovation? Dr Nightingale: There is an implicit part of that question which ties into a particular way of thinking about the value of the university system encouraging innovation and the idea that universities can come up with discoveries and they will be commercialised and therefore lead us to economic growth. While that is a very important role for the universities and it is something in which there has been a step change, as we have heard previously, in culture and support for that, the main way in which the university system supports innovation in the UK has been the provision of highly trained people who can solve complex problems. If we are thinking about ways in which the university system can support high tech manufacturing, we need to remember that is only three per cent of GDP and there is another 97 per cent where the universities play a very, very important role in providing skilled people. There has been a fair amount of research on what the interactions are between the university system and how it can support innovation. What they have tended to show is that the indirect forms of support for innovation tend to be much larger than the direct forms of support for innovation. Skilled people are more important than spin-out companies. There are limits to what science policy can do overall, but I think it can be improved. There has been, as we have heard, a big cultural change in the university

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	system over the last 10 years and, forced through by the research councils very successfully, all the universities in the UK are much more receptive to engaging with industry in providing the support. My key issue in arguing for differences between the performance of the UK and, say, countries like the US and the high tech nations of Switzerland, Sweden and Finland is that our research base, while it is high quality, is relatively small compared to the US. It is not necessarily that we need more interactions between the university system and industry, as I pointed out, as a percentage of funding that is received. It is higher in the UK than it is in the US. The links are there. It is just whether or not there is a big enough mass of research. If we want to have a US-style innovation system, I am afraid we are going to have to pay for it and it is very, very expensive. Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 278, Q446)
	We are absolutely not asking researchers to predict what specific impacts their research is going to produce; what we are asking for researchers to do is to think about how to open up the pathways to enable impact to happen. That can be in lots of different ways; it can be in terms of getting the message out about that research, involving public and others in that. Just take, for example, the Large Hadron Collider and the Higgs Boson. Those are (to some of us, anyway) rather theoretical concepts in research but that triggered a huge inspiration in the public about science and about the importance of research. Actually, STFC and colleagues were really great at getting that message out early on when that research was being conceived of. It fired the imagination of the nation. I think that is another example of where we need to think about impact widely; it is not just a narrow concept of predicting particular commercialisations. It is not that, it is a much wider concept. We are not asking them to predict the particular impact but to think about where impact could flow. Prof Alan Thorpe, Chair, Research Councils UK (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 17, Q76)
	Performance definitions (contd.)
Impact as contribution to further Mode 1 quality	My understanding from talking to people who were actually around when Cavendish was doing that experiment was that there was enormous excitement on the campus at the time, that the students knew what was going on, and it was impactful on the teaching environment at that time. Of course much research is impactful on the teaching environment, and if we are going to have high-quality, world-class teaching in this country then it is important that it is done alongside impactful research. I understand that the atmosphere on that campus at that time was quite electric. People knew what was going on but nobody actually knew what would happen when you split the atom, much as people got a bit excited about the Hadron Collider until it broke down. We need to put research in universities in the context of teaching and the impact that research has on teaching. Prof Les Ebdon, Chair, million+ (*The Impact of Spending Cuts on*

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	Science and Scientific Research, Ev 51, Q169) If you ask what are the drivers, in the behaviour of my young colleagues, who are admirable in every respect, the key drivers that are passed down from vice-chancellors and deans and heads of department are actually: “When is your next paper coming out in *Nature*?” There is nothing analogous to that on the teaching side. So I think that it is very important not to divorce a consideration of the UK research base, much of which is in the universities, from the influence that has on the education we give our kids in the universities. I think the research councils try to do far too much, and I also think that in many ways they have an erroneous model of the way in which the world works. If one looks at the sorts of things that they are doing at the moment—they have a concern for interdisciplinary, they think that is important, they are concerned to support what we call blue skies research, but they are also concerned to try to push innovation out from the universities by start-ups and spin-outs and all those things, and my sense is that that is not a particularly efficient way of working. I would far prefer them to be concentrating on really stimulating a strong, powerful and, indeed, ambitious research base and recognise that no one made too much money in the national economy by simply trying to push start-ups or spin-outs from universities. It does not work like that. I think, if you look at the things they are doing in relation to impact, my view is it is based on a quite erroneous premise and it is beginning, I think, to have some quite damaging consequences. Prof Geoffrey Boulton, Royal Society of Edinburgh (*Setting Priorities for Publicly Funded Research*, 209, Q333)
	Performance definitions (contd.)
“Frontier research” as Mode 1 performance	There was a report produced for the European Commission recently from a group chaired by Bill Harris, Director-General of Science Foundation Ireland, where he said that the old divisions that we used to have between pure and applied research are really no longer applicable today. He introduced—or at least he was the first person that I heard introduce—the term "frontier research" and said, "that is what research councils are about". We are about frontier research. But we would do ourselves down, do our communities down and do the country down if we said that that equated therefore only to what in old terms we used to call "pure". It is a spectrum. We are absolutely about funding at the frontier and I do not divide this between whether we should be involved in pure research or something that is the business of business. The fact that over 40% of EPSRC grants have direct business involvement says that business recognises the value of engaging at that early stage in these frontier activities and being part of a channel for it to flow through and get taken up. So I could not tell you what the figure is because in a sense I just question the attribution. If you say, "What fraction of EPSRC funding is pure research?", I would say it would depend what you meant by it. Prof John O’Reilly, Chief Executive, EPSRC (*Research Council*

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	Support for Knowledge Transfer, Ev 37, Q223)
	Performance definitions (contd.)
Relationship between Mode 1 scientific excellence and impact	Mr Boswell: Thank you and congratulations. Can I ask a final question to Michael on impact. In terms of the excellence of research, is impact, in any case, a necessary or sufficient condition for that? Can it still be good even if it has no impact at all? Professor Arthur: It depends on whether you think the creation of new knowledge always has impact and I am slightly in that camp. It is difficult to imagine how new knowledge, if it is truly new, cannot have some impact. Mr Boswell: Even if it does not immediately, without putting words in your mouth? Professor Arthur: Exactly, so I think there is a relationship. One thing that I think is fundamentally important if it is going to be funding the impact assessment is it must be related to original research formed in the institution under question. Graham Stringer: Can I just follow that up. I understand that this is a very difficult area but if you are going to assess projects and put 15 to 25% on the basis of impact, is that not necessarily going to make it more difficult for purely curiosity-driven research to get grants? To put that another way. The work that Rutherford did in Manchester and Cavendish probably had one of the biggest impacts on the 20th century imaginable. How do you think the impact of his research into the structure of the atom would have been assessed? Do you think he would have got through this assessment process for impact? Professor Arthur: I do. I would separate very clearly in my mind the measurement of impact in the REF looking backwards to look forwards and inform QR funding from the types of assessments that the research councils are now asking scientists to put forward. It is my understanding that they are not asking them to predict the impact of their research; they are asking scientists to show that they will engage on what the pathways of engagement are to distribute their research after they have conducted it which it seems to me, considering they are consuming public money, is an entirely reasonable thing to ask people to be prepared to do. I sit on the Council of the MRC and I am also reassured that the research councils are assessing the grants on their excellence but asking for impact to go alongside that. The excellence is informing the grant-funding decision primarily, so I think Rutherford would have been funded. Prof Michael Arthur, Chair, The Russell Group (*The Impact of Spending Cuts on Science and Scientific Research*, Ev 51, Q166-168) It is not necessarily the case that the best science is done in the best universities. It is not necessarily the case that the best science as judged by academic citations is the most useful research for industry. I will give you an empirical example. In the United States they have

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	been extremely successful in producing biotech spin-out firms. If you look at the origins of the most successful biotech firms in California, they did not come from the elite institutions of Stanford and Berkeley, which were the Nobel Prize winners. More of them came from the University of California, San Francisco which would be a middle-range university, but that was much more focused on interdisciplinary, problem-based research which was easier to apply than the Nobel Prize winning research on the basis of cells which was ongoing in Stanford and Berkeley. Concentration assumes that there is a simple research excellence we can focus on and, unfortunately, I do not think the data we have support that. It is a much more complicated question. To be able to answer that, we need a clearer understanding about what the aims of government policy are and also much better data and methods which will inform you about what the correct decision would be. I am sorry, but I cannot give you an evidence-based answer to that. Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 279, Q448)
	Articulation of performance
Qualitative and soft measures	Just repeating what I said earlier, from our perspective, to an extent we are interested in knowledge transfer as the enhancement of social capital. It is not something that is readily subjected to quantitative assessments, so obviously qualitative measures are the things that we are interested in. Sometimes things can be subjected to quantitative assessments. For example, when the National Gallery had its Raphael Exhibition a year or so ago it was extremely popular and a hard economic survey was conducted. We financed the person who did the catalogue so we had a direct impact. The hard-headed economic assessment later on was that the increased value to the UK from the exhibition was £20 million. There are more than two sides to this issue of measuring impact and output. Prof Philip Esler, Chief Executive, AHRC (*Research Council Support for Knowledge Transfer*, Ev 44, Q262) The focus on impact has been a good thing in the past. I think it has been important in a cultural change in the university system which has been very positive. The level of interaction over the last 10 years, in my experience, has changed importantly, but I think it is very clear that diminishing returns have set in. It is very clear now—I speak anecdotally and from subjective, personal experience—that it is easier to fiddle impact measures than it is to do high-impact research. While on the one hand I think the science system very rightly should be responsive to the needs of the Government, should be responsive to the needs of the public, measuring impact is very, very difficult. Perhaps the focus should be less on measures which are so easy to fiddle and more on cultural change which seems to be working effectively. We have heard about how easy it is. An example is that universities were encouraged to form spin-out companies. It is very easy to form a company. I teach an entrepreneurship lecture in which I get on a mobile phone and I start a company in the middle of the

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	lecture. Therefore, in a matter of hours I could produce 50 spin-out companies for my university which would go in government figures. Whether or not those spin-out companies will ever amount to anything is clearly questionable, to say the least. I think there is a need for some form of co-ordination, despite the problems of measuring impact. I think there is a need for some governance, some form of control. This is a very complicated system which needs to be understood and managed effectively. Managing by numbers has been an important part. I think we now need to move on to something else and recognise the severe limitations of it. *Dr Paul Nightingale, Science Policy Research Unit (*Setting Priorities for Publicly Funded Research*, 281, Q451)* In terms of the Fruits of Curiosity and their view of impact, I would want to stress that the breadth and variability. The REF kind of impact, which I think is where Lord May is coming from, looks rather prescriptive to us, and I have tried to stress the different kinds of impact that science has on people's lives. Another caution would be that different subjects have a different kind of half-life in both to when things bear fruit, even to when they are read in journals. So the idea that you put some magic number, 25 per cent or something like that, across the board seems very, very strange. I would also say that there are some areas, pure mathematics, for instance, where often the benefits are to the secure exchange of information, and cryptography. So, if people know about the value of the impact, then it actually has not worked very well as it was not as secure as you had hoped. So again that is another caution about measuring impact. Value impact, yes, but prescriptive measurements of it is a bad idea, we think. Prof Sir Martin Taylor, Royal Society (*Setting Priorities for Publicly Funded Research*, 298, Q478)
	Articulation of performance (contd.)
Long-term measures and articulation of impact	Lord Oxburgh: But, given the reassuring explanation that you have just offered, do you not feel that you need to indicate in some way that it is not really just the short-term results that you are concerned with, the short-term impact? Dr Reid: First of all, I agree entirely that this is not a short-term issue, and in fact our move to that language was an attempt to get away from short-term thinking. I would take every opportunity to reassure this Committee and others that this is a long-term issue. Indeed, I would say that this is about harvesting now the results of research that has been funded over many decades, and indeed the research councils only quite recently have published some timelines that illustrate the benefits that are being reaped now from research that goes back in some cases to the 1930s. Dr Graeme Reid, BIS (*Setting Priorities for Publicly Funded Research*, 12, Q10) Dr Harris: There is a huge tension, is there not, business outcomes generally do not distort bottom-line, profit, market-share, those sorts of things, they are usually consistent and it is hard if you are

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	improving to be doing something wrong, but it is different here. Whatever you measure the principle that you enunciate from quantum theory—which I hope is consistent and not infinitely flexible in this case—is that as soon as you set a metric it will distort activity. There is an argument for not having all that detail in Output 2 because it is going to distort. If you measure inventions then you will distort towards that or patents or whatever it is. How do you solve that problem? Professor Diamond: Surely that is the whole reason for having a variety of metrics and a set of cells under outputs that are not having one output because as you have a variety what you would expect to see at any time is a variety of trajectories and some moving up. As John has rightly said, the time-line here can be so immense that you do need leading indicators as well as outputs. If you accept that all your leading indicators are going in an upward direction then you will see improvements in the outcomes over time. Prof Ian Diamond, Chief Executive, ESRC and Chair of RCUK Executive Group (*Research Council Support for Knowledge Transfer*, Ev 45, Q266) In addition to that, the research councils collectively have a group that looks at knowledge and technology transfer and captures, in a narrative, the impacts, not just the short-term, forward impacts, because that is just the real time tip of the iceberg. The real impacts are when you go back 10, 15 or 20 years and you track through the original piece of research, how it was funded, what it led into. To anybody who has not seen them, I commend to you some wonderful A3 size time charts that the research councils have produced under those three headings of productive economy, healthy society, sustainable world, with an axis of six or eight original research breakthroughs and what they led to in terms of businesses or regulation or laws or policy. It is a fantastic narrative but you have to be willing to take it over 20 years and not two months at a time. Prof Adrian Smith, BIS (*Setting Priorities for Publicly Funded Research*, 321, Q 543) As Lord May described, history teaches us that under tighter financial circumstances people are going to raise questions about whether or not they can trade investment in long-term areas of expenditure, like science and research, for more short-term priorities which may be regarded by some as having greater urgency. We need to be able robustly to prove, in so far as the data enable us to do that, that investment in science delivers fundamentally important strength to this nation. I believe that the fact that, in common with many other countries, we have not been recording that information in a coherent way means that we are not in a position to do that. You cannot just evangelise about this; you do need to be able to point to some hard figures where necessary. I also think culturally we have to ask ourselves what more we can do to encourage the scientific community, when thinking about the research which it is undertaking, so that we are doing everything we can to ensure that

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	science leads to economic growth and jobs here in the United Kingdom. Rt Hon Lord Drayson, Minister for Science and Innovation (*Setting Priorities for Publicly Funded Research*, 329, Q575) The CST report does not specifically address the question that Lord May poses. Some of the other work that we have done is closer to it. I think if I put those things together we would see the impact of research as being quite broad, so we are not just talking about economic impact, we are talking about impact on public policy, for example. We are also talking about the impact of producing highly educated people who transfer knowledge and support various aspects of our society and the economy in different ways. So we think that any assessment of impact needs to take into account that breadth. On your question of whether impact should be assessed prospectively, I have already said that the view of the CST is that there should not be any principle other than excellence in the identification of research projects to be funded on the upstream level. Prof Dame Janet Finch, Council for Science and Technology (*Setting Priorities for Publicly Funded Research*, 297-298, Q477)