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Moving from non-interventionism to industrial strategy: The roles of tentative and definitive governance in support of the UK biotech sector

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ABSTRACT

This paper develops a framework for characterising tentative and definitive governance modes. Using investor financing of UK-based therapeutic biotech firms as a context, the paper traces how policy makers have blended tentative and definitive elements in the design and implementation of six different kinds of policies to spur investor support for these firms. We find that tentative and definitive governance are used together to balance the need for certainty with necessary responsiveness to the dynamic circumstances that surround technological emergence. Moreover we show that the relative use of tentative and definitive modes is shaped as much by higher landscape-level influences as by technology or sector-level factors. Challenges are also identified, for instance, how to maintain synergistic rather than either/or relationships between state and non-state actors when both hesitate to engage with markets at different times.

1. Introduction

This paper explores state governance of emerging technologies that are expected to exert a considerable socio-economic impact (Rotolo et al., 2015: 1830). Whilst these fields may exhibit a degree of coherence in 'the composition of actors, institutions and [their] patterns of interactions', their prospects are essentially 'uncertain and ambiguous' (Rotolo et al., 2015). The paper deals with the challenge faced by the state in constructing policy designed to draw in private investment to unproven fields where uncertainty makes it difficult for actors to provide the required resources or place the right 'bets' to deliver promising solutions to societal needs (Wong, 2011, Nuffield, 2013).

Private investors in emerging technologies are expected to make long term, illiquid investments under high uncertainty while being subject to information asymmetries, moral hazards, and potential tax issues (Westhead and Storey, 1997; Hall, 2002; Revest and Sapio, 2008; BVCA-NESTA, 2009). Under these conditions investors rarely provide the levels of investment sought by firms and expected by governments (Bell, 2017; Hughes, 2013). As a result, in the USA, Europe, and Asia policy makers have chosen to make repeated interventions to address market failure with respect to investments in emerging technologies, such as biotechnology, often with limited success (Hopkins et al., 2007; Orsenigo, 2016; Wong, 2011).

Policy makers can attempt to improve their performance through governance responses that are explorative, experimental, reflexive, flexible, adaptive, open and dynamic when dealing with uncertainty (Kuhlmann et al., 2019). When governance practices respond to, and are shaped by, emerging inter-dependencies and contingencies in a flexible and preliminary manner they can be characterised as tentative, and contrasted with definitive governance, which is more prescriptive and persistent (Kuhlmann et al., 2019). Definitive governance is observed when policies move along decisive paths to accomplish specific objectives, while tentative governance is observed when policies have less specific outcomes (Kuhlmann et al., 2019).

This paper fosters a deeper understanding of the utility of these two different modes of governance; in particular we explore how tentative and definitive modes of policy making operate to assist the formation, financing and sharing of knowledge among firms supporting emerging technologies in the UK therapeutic biotech sector. In this context, we observe that the relationship between tentative and definitive modes of governance is mediated not just by uncertainty, but also by a desire to learn and create better policy instruments, and also to forge agreements between stakeholders with differing perspectives.

The first research question is how to unpack what is meant by definitive versus tentative governance? This is addressed by identifying seven relevant policy dimensions that span the descriptive "where, when, what and who" aspects of a given policy instrument. Our analysis will suggest that whilst these dimensions are conceptually clear and

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coherent - in practice a policy could be tentative along one dimension but definitive along another. For example, a policy by the state with very clear goals to support a specific group of firms for a given period of time could be classified as definitive in its targeting, but tentative because of the small amount of money allocated and/or the shortness of the intervention's duration.

This leads to our core second research question, how are policies for an emergent technology actually formulated and implemented? Is there a coherent pattern across the governance dimensions. For instance, are policies with a definitive purpose typically executed in a definitive manner; or is it common that the different dimensions are differently executed, as hinted above?. And if there is dissonance, is it clear why this is the case?

This leads to our third research question: How are definitive and tentative governance modes used over time to support an emerging technology? Do policies in the early stages of a sector's development start with governance having many tentative elements while actors learn, before a shift to more definitive policies (as one would expect with a simple adaptive bottom-up learning approach). Or is the governance of policy the result of broad attitudes of the prevailing government of the day (as one would expect with a top-down intentionality of political philosophy)? Or are wider landscape-level forces influential?

To explore how policy makers use tentative and definitive governance in the context of emerging technologies, we use a longitudinal approach, covering the history of the UK therapeutic biotech industrial sector from 1980 to the present day. We explore changes to the prevailing modes of governance for policy instruments that have (1) set up new firms (2) supplied tax incentives to investors (3) supported collaborative R&D initiatives (4) set up hybrid funding schemes that join state monies with those of private investors (5) set up directed technology development initiatives and (6) formulated coordinated industrial strategies.

Studying these six policy initiatives in the UK biotech sector over this long history provides a rich context for theorizing about definitive and tentative modes of governance for emerging technologies and allows us to draw out a number of lessons. These are discussed in detail at the end of the paper, but can be broadly summarized as follows: tentative and definitive governance should not be treated as being in opposition. Instead tentative governance appears to have broad utility in policy, and there appears to be an overlap in usage and a dynamic interaction between tentative and definitive modes. Looking at how policies unfold over time, we argue that technological development and political will do not have a strong influence on the choice of mode. Rather governance mode appears to be the outcome of a complex interplay between actors in government (at the department level), with firms, investors and the economic context playing a particularly strong role in the final outcomes.

The rest of the paper proceeds as follows: Section 2 synthesizes conceptual material to generate a framework for identifying and classifying governance actions, so that trends can be revealed and analysed. Section 3 outlines the main sources and methods used for of the empirical analysis. Section 4 provides the empirical study of four decades of changes in governance. Section 5 discusses how and when tentative and definitive governance modes are applied, and draws implications.

2. A framework for exploring tentative and definitive governance

To explore the dynamic interaction between tentative governance and definitive governance, some initial steps must be taken. First, we need to identify relevant actors and understand their role in relation to a specific governance issue. Secondly, we need to characterise their actions with regard to the different dimensions of tentative/definitive governance. Together these two steps provide the basis for tracking the interplay between the two forms of governance over time, allowing insights into their perceived utility and a basis from which to reflect on their consequences.

2.1. Relevant actors in governance and their roles

Drawing on the traditional economic distinction between markets and hierarchies, evidence suggests that, in recent decades, globalisation has led to a shift in the balance of power away from government hierarchies to wider policy making networks with more actors involved (Braithwaite, 2009). Yet at the same time the state has grown, rather than shrunk, driving interest in 'regulatory capitalism' (Levi-Faur, 2005, 2006, Braithwaite, 2009). The unique capabilities of the state are relevant to consider in relation to this growth. The state can create laws and regulations, relocate resources and risks across the economy and through time; and it can investigate, call to account and punish those not in compliance with legislation (Braithwaite, 2009; Moss, 2002). The state can also spread risks by creating 'social contracts' that bind future generations, act as a trusted third party, reducing uncertainty and structuring public expectations about regulatory regimes, risk levels and future technological outcomes (Moss, 2002; Hopkins and Nightingale, 2006; The Royal Society, 1992). The state's capabilities are particularly prescient in relation to emerging technologies and the shaping of markets associated with them (McLeish and Nightingale, 2009; Lyall et al., 2009; Nuffield Council on Bioethics, 2013; Mazzucato, 2013).

Where an innovation supports key state functions, governments can work with firms to sponsor development or even develop new technologies themselves (e.g. in defence). State involvement may be high during innovations' early stages, when uncertainties are high (Pavitt, 1999; Wong, 2011) and with systemic technologies whose costs, risks and complexity are beyond the resources of firms to manage (e.g. nuclear power) (Scranton, 2006). However, government interventions can be problematic: they may reflect technology-push from lobbies, focus on big technology jumps with limited market assessment, or lead to commitments that are difficult to abandon (Pavitt, 1999). States have often failed when they have attempted to 'pick winners' with emerging technologies (e.g. in UK programmes for supersonic transport or nuclear reactors), although elsewhere successful interventions such as Airbus, suggest some heterogeneity in results (Owen, 1999). Interventions can also attract a lot of damaging criticism of the state for ineffectiveness and 'meddling' where large investments do not seem to have paid off (Mazzucato, 2013).

While the state can be expected to take policy action to support its key functions, firms can be expected to seek profits by addressing emerging demands (and even anticipating them). This could include performing governance functions that are either delegated or necessitated by state inaction (van Zwanenberg et al., 2011; Braithwaite, 2009; Francis, 1993). However, firms have different interests and capabilities to the state. Their actions are guided by market opportunities for profit and this leads to underinvestment in areas where profits are not expected or where spillover and free rider effects will reduce rewards from investing (Lacasa et al., 2004; Lazonick, 1993; Salter and Martin, 2001). This is not to say that firms cannot invest for the long term - quite substantial R&D investments can be made where they expect good commercial returns (Eads and Nelson, 1971; Jewkes et al., 1969); they even invest in basic research (Rosenberg, 1990). However firms typically only make such commitments after key technical and market uncertainties are reduced as a result of state interventions (Wong, 2011; Mazzucato, 2013). Firms can also retreat from previously profitable markets when economic conditions change, leaving the state to step in once again, e.g. in the market for debt during economic recessions (Reinhart et al., 2011).

In summary, the state plays a key role fostering private activity in support of emerging technologies – that may include delegating some important technological development functions to the private sector. But there are also limits to this substitution and the need for flexibility, as at some moments the private sector may fail to be effective, and at

other moments it is the state that can be lacking. For example, if the state leaves provision of a function to private actors (e.g. during times of fiscal constraints) it might have to move back in to fulfil that function if firms subsequently retreat and market failure occurs.

2.2. Identifying and following relevant governance actions

Before we delve into the details of policy actions, we need to locate the initiatives that we have to analyse. In this respect, it is important to note that determining the boundary of a governance regime for analytical purposes is challenging (Rogge and Reichardt, 2016). Not all actions by relevant (that is influential) government actors will be directed at the emerging technology studied, and not all relevant actions may be immediately apparent to the functioning of a system (indeed these influences may be international or cross-sectoral - Hekkert et al., 2007; Hopkins et al., 2013). Governance interventions may be targeted at a particular domain – be it sectoral or technological – in which case these may be referred to as 'focused or vertical' policies (Lacasa et al., 2004). Alternatively, interventions may be intended to address a particular challenge across all the sectors within a geography - so called 'general or horizontal' policies (*ibid*). So in our review of governance mechanisms we need to take account of both the vertical (focused) as well as the horizontal (general) policies, even though the influence of any given policy on a system may be difficult to discern (Rogge and Reichardt, 2016).

We must also recognise that whilst the ultimate aim of the state may be to encourage firms to invest in the design and development of new technologies, there are many routes by which this may be achieved. The mapping of state actions onto particular functions in a technology's innovation system is an important approach to chart the dynamics of these systems (Hekkert and Negro, 2009). In Section 4, this paper examines a broad range of government policies that stretch from direct investment and ownership of firms, to assisting financing of firms, to helping build a knowledge sharing eco-system for the industry. These different situations can be characterised as different *governance functions* or *niches*. Our characterization of these *governance niches,* as opportunities for policy interventions to act as levers on technological emergence, draws on the literature on innovation systems. This literature suggests that a relatively small number of functions are required to support technological emergence (Edquist, 2005; Hekkert et al., 2007). These include (i) entrepreneurial activities (ii) knowledge development (iii) knowledge diffusion (iv) guidance of search (v) market formation (vi) resource mobilisation and (vii) support from advocacy coalitions (Hekker et al. 2007).

In our empirical work, we will classify our policy initiatives along the above two dimensions to locate their context, and our sample deliberately selects a wide range of policies as seen from these two dimensions.

2.3. Characterisation of tentative and definitive governance modes

Governance can be considered as 'tentative' in mode when 'it is designed (practiced, exercised or evolves) as a dynamic process to manage interdependencies and contingencies in a non-finalizing way; rather prudent (e.g. trial and error, or learning processes in general) and preliminary (e.g. temporally limited) than assertive and persistent' (Kuhlmann et al., 2019). Definitive governance can be thought of as the opposite mode, practiced in a more assertive manner, seeking to steer a deliberate, predictable course. While these two poles are intuitively distinct, we suggest that in practice classifying a policy along these lines must consider the different dimensions of the policy. Thus any given policy action can be characterised as tentative or definitive in different dimensions independently.

Table 1 provides a set of possible dimensions upon which policy actions can be plotted. The dimensions chosen reflect standard descriptive situational variables: where, how, when, what, and who (the why – is a common/ constant in this study: each policy is aimed at improving the environment for firms seeking finance to support their R &D activities). Dimensions are further informed by Kuhlmann et al. (2019) - with the notable additions of a dimension that focuses on the breadth /narrowness of the policy target and a dimension to reflect the scope of the intervention across Hekkert et al.'s TIS functions. The former is a helpful and necessary addition as it distinguishes broad (horizontal) versus narrowly focused (vertical) governance measures, as discussed above, while the latter positions governance interventions within in the innovation system.

Table 1 demonstrates that there are many different dimensions for characterizing policy actions as relatively more or less tentative. An obvious analytical implication of our framing is that to understand the frequency and incidence of tentative governance a detailed analysis has to consider multiple perspectives. In the following sections the governance of entrepreneurial finance for emerging UK therapeutics firms is explored drawing on the above framework, in order to understand exactly what is happening.

3. Research method

This explorative paper traces how the state has acted to shape the UK's market for entrepreneurial finance to support the commercialization of a specific emerging technology – namely biotechnology. It adopts a longitudinal approach to explore a time period of around 40 years, allowing for observation of governance from the emergence of the first UK biotech firms up to the present.

3.1. Empirical focus

Entrepreneurial firms play a key role in the commercialization of emerging technologies (Freeman and Soete, 1997). The enduring emphasis on the financing of such firms in policy discourse confirms their crucial importance as a governance focus in relation to commercialisation of novel technologies in the life sciences (ACARD, 1980; Bioscience, Innovation and Growth Team (BIGT, 2003, 2009, Office for Life Sciences 2017). It is possible for biotechnology-based businesses to take many forms but those that seek to develop novel therapeutics are at the extreme end of equity finance-hungry firms in the sector (Hopkins, 2012). Sector-specific policy has often focused more intensively on these firms rather than other forms of biotechnology (for example see recent criticism of the UK sector's industrial strategy in a report by the House of Lords Science and Technology Committee, 2018). By following prominent governance actions, this paper also follows this same focus to the exclusion of areas of technological application beyond medicinal drugs. The term 'therapeutic biotech firm' is used here to refer to commercial organisations established after the emergence of novel biotechnologies in the 1970s, seeking to bring medicines to market (in keeping with prior work – see Hopkins et al., 2013). The maintenance of the prior-established pharmaceutical industry is also an important concern for UK policy makers given its high contribution to the economy, in terms of jobs, exports and gross value-added (PWC, 2017). The role of 'big pharma' in the commercialization of emerging technologies is beyond the scope of this paper as the focus is on emerging firms. Big pharma firms are mentioned only where they have been influential in the shaping of governance relating to the financing of their smaller contemporaries.

3.2. Historical process study

This paper follows the development, implementation and adaptation of policy instruments affecting firm development, including important policies that influence the equity financing market for UK therapeutic biotech firms. It draws on contemporaneous materials wherever possible as these are superior to retrospective interviews (Soderqvist, 1997). Archival sources used include company annual

Table 1
Seven dimensions of tentative and definitive governance modes.
Source: Authors elaboration drawing on Hekkert et al. (2007), Kuhlmann et al. (2019), and Lacassa et al. (2004).

	Examples of more tentative governance	Examples of more definitive governance
What is being targeted? (governance niches following Hekkert *et al.*'s TIS functions)	Unfettered knowledge creation	Providing money directly for investment
Where is the target for governance?	Horizontal (or general): Avoids singling out a narrowly defined group, sector or activity to be governed.	Vertical (or focussed): Specific measures deployed for governance of a clearly defined group, or activity.
How do governance processes operate?	Emergent and evolving based on experiment, and evaluation of experience	Pre-determined or fixed processes that can be relied upon not to change
How much resource is committed?	Commitment is minor due to uncertainties or pending developments	Commitment is extensive in recognition of established needs
When is support available?	Time limited/ reversible	Persistent/ permanent
What are the goals to be achieved?	Goals are changing/ and goal selection is flexible	Goals are fixed and unchanging
Who are the stakeholders involved in governance formulation?	Open/ potentially extensive involvement of stakeholders at a high level.	Closed/ potentially narrow consultation with little room for input

reports and accounts, government policy documents, reports by professional service firms, press releases and articles from the financial press and specialist trade journals. Extensive use is also made of detailed prior studies by scholars of the UK biotechnology sector, and entrepreneurial finance (as cited).

Wider context is provided from prior research, based on methods discussed by Hopkins et al. (2013) and Owen and Hopkins (2016). Hopkins et al. (2013) provides quantitative analysis of key financial trends. Owen and Hopkins (2016) identify key institutional and firm-level events that have been influential on the evolution of the sector. Findings from these studies are synthesised in Fig. 1.

3.3. Characterisation of policy instruments

In order to explore the dynamic interplay of tentative and definitive governance modes during technological emergence, we have selected six examples that span four governance niches associated with the four technology innovation system functions that form a virtuous cycle driving one 'motor' for the resourcing of technological change. These functions are: (i) *allocation of resources,* (ii) *knowledge creation,* (iii) *entrepreneurial activities,* and (iv) *legitimise/lobby* (Hekkert et al., 2007). Within these governance niches examples of specific policy instruments, such as incentives for investors, direct subsidies, forming new firms, encouraging knowledge sharing, have been purposely selected to demonstrate governance practices covering the full period studied, with the aim of illustrating a narrative – developed elsewhere – that the use of industrial policy for this sector was neglected in the UK for much of the 1980s and 1990s but has been making a return in more recent years (Owen and Hopkins, 2016).

The characteristics of governance activities are described in Tables 2 and 3, which further expands on the dimensions introduced in Table 1 (and a more detailed picture of the actual characterisation of six policy initiatives using this scheme is shown in the discussion section). As indicated in Table 3, the governance mode of each instrument is assessed over seven dimensions, with each being graded as either: (i) tentative, (ii) more tentative than definitive, (iii) more definitive than tentative or (iv) definitive. Given the inherent subjectivity of such characterisation decisions, at least two authors have considered each grading decision for each dimension of each instrument characterised. To add further consistency grades are not assigned in an absolute sense, but rather in direct comparison to the five other instruments studied here. Thus an instrument assigned the grade of 'tentative' in one dimension of Table 1 is more tentative than most other instruments we discuss, but could conceivably have been graded as 'more tentative than definitive' against examples that were more tentative still, had these been studied also.

4. Empirical findings

Section 4.1. provides context by showing the rise and fall of investor support for the UK therapeutic biotech sector over the period studied. Section 4.2 uses three policy instrument exemplars to demonstrate how the UK government disengaged from interventionist policies in favour of more tentatively targeted approaches. Using a further three policy instruments, Section 4.3 demonstrates how the government returned to interventionist policies in order to provide support after a sustained period of lower-than-expected support in the sector by private investors.

4.1. Section 4.1

The growth of the UK biotech sector is illustrated by Fig. 1 which shows annual firm foundation rates based on an industry database developed by Hopkins et al. (2013) and combined with key milestones in institutional change taken from a detailed history of the national sector (Owen and Hopkins, 2016). The Figure shows the rate of firm entry gathering momentum in the 1980s before strengthening in the 1990s. The trend line showing the number of firms receiving their first Venture Capital (VC) funding round per annum closely tracks the trend for foundations (most firms attracted VC investment with many receiving this in their early years). Both lines appear to fall sharply in the final years of coverage - an artefact due to lag effects in databases. However the trend-line on stock market IPOs is not subject to this lag effect (the more established nature of firms undergoing IPOs ensures faster detection). This trend-line indicates that by the mid-1990s more firms were being founded than VC funds or IPOs would support. Furthermore, IPOs for therapeutic biotech firms were becoming scarce in the mid-2000s, fell to zero during the global financial crisis and remained at zero in the UK for some years in its aftermath (also visible in Fig. 4 which covers later years as well).

Fall in investor support for UK biotech firms needs to be seen against generally improving institutional conditions for entrepreneurial financing in the UK. When the UK biotech sector gradually emerged in the 1980s, there was little venture capital (VC) in the country and the only accessible trading platform for shares in such firms was the Unlisted Securities Market (USM) - a lightly regulated junior stock market. This situation changed as the development of an institutional framework for entrepreneurial equity financing was strongly encouraged by government.

In the early 1990s, as the US biotech sector boomed, the London Stock Exchange's (LSE) strict regulations were amended to allow shares in loss-making UK biotech firms to be publically traded, matching the practices of the rival American NASDAQ exchange (Owen and Hopkins, 2016). Further stock markets opened in the mid-1990s including London's Alternative Investment Market (AIM) and the Brussels-based EASDAQ, providing additional sources of equity for high risk

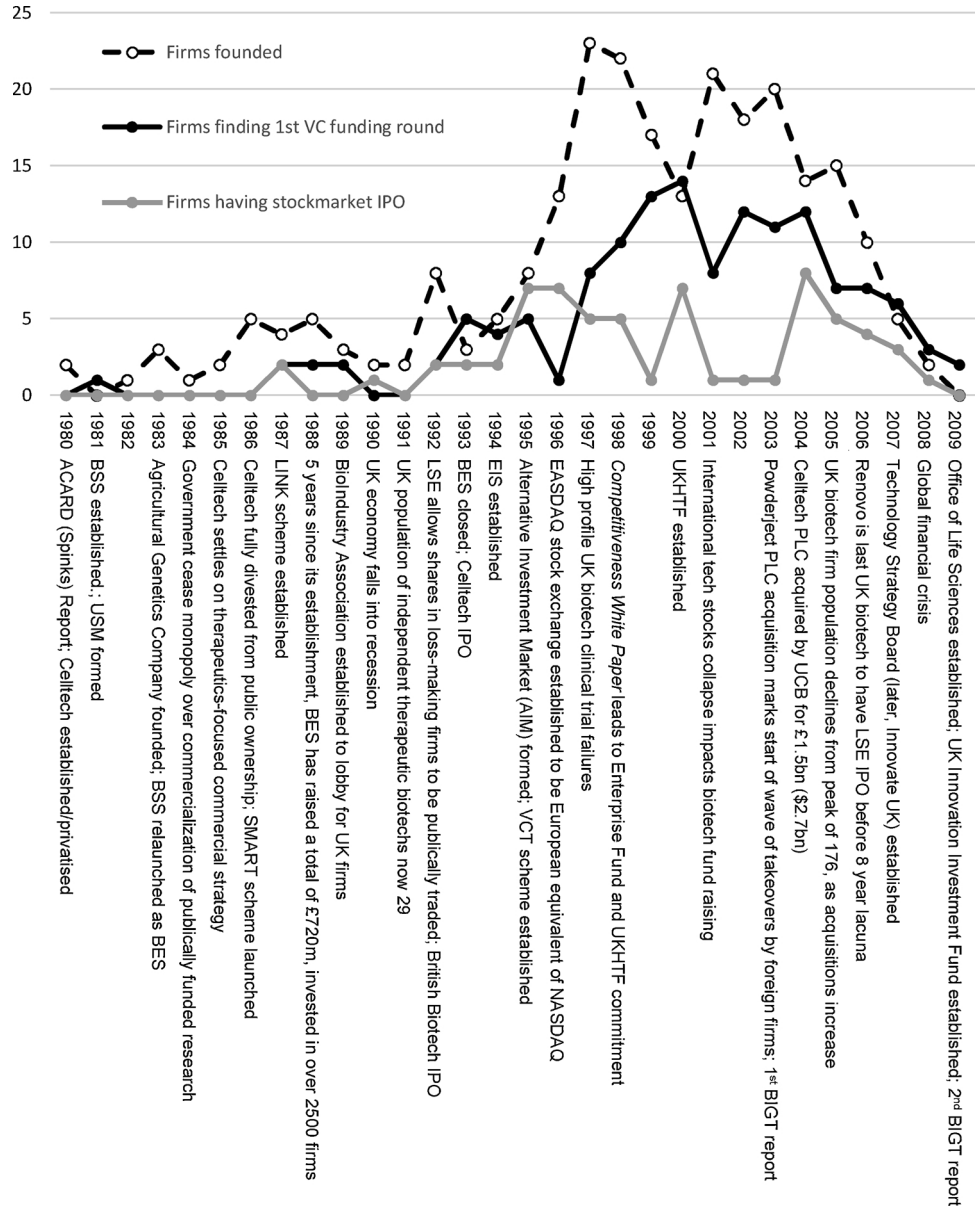

Fig. 1. Annual tally of foundations, initial VC funding rounds and stock market IPOs for UK Therapeutic Biotech firms and contextual events (1980–2009). Source: Authors' elaboration on figure from Hopkins et al. (2013) with milestone events identified in Owen and Hopkins (2016).

investments including emerging biotech firms. The potential to exit their biotech investments via the LSE positively influenced VC funds' commitment to the sector (E&Y, 1997). Similarly, stock market investors were more likely to support VC-backed biotech firms, suggesting a certification effect (Hopkins et al., 2013).

After a honeymoon period, stock market confidence was shaken by product failures during clinical development at several high profile biotech companies in the late 1990s. During this period, IPOs fell short of targeted values reflecting an investor "feeding frenzy followed by a slump" (Davidson, 1998).

As non-specialist stock market investors lost confidence in the sector, a few specialist VC funds remained committed, and even increased their funding in individual biotech firms. The difference in support provided by VC and stock market investors is reflected in Figs. 2 and 3. The VCs undertook more numerous and larger deals over time while stock markets facilitated more numerous but lower-value deals. After the 2008 financial crisis, VCs had to make larger investments to maintain the required funding in investee firms that stock markets would not support. The lack of stock market interest in supporting new biotech IPOs meant VC funds were forced to accept lower returns and higher risk as they had to support their existing portfolio companies for longer than they might otherwise have done, while biotech firms suffered from more 'drip feeding' of cash (E&Y, 2003, 2004; E&Y, 2005, 2007; E&Y, 2008, 2009). With stock markets not supplying profitable exits for VCs, trade sales of investee firms to more established drug developers became more common (E&Y, 1999). This trend continued in the 2000s (Hopkins et al., 2013). Foundations per year declined and activity in the sector began to contract (see Fig. 1). Investor interest in UK biotech investing was further curtailed by the global financial crisis in 2008 – a landscape-level event with origins entirely unconnected to the sector. Stock-market interest in the UK sector strongly recovered in 2014 but by then the state was already moving to support the sector in much more interventionist ways (Owen and Hopkins, 2016).

When one compares the UK situation with that of the USA, the extent of the disadvantage that UK firms face becomes very apparent and stark – see Fig. 4. To be precise, US biotech companies had market capitalisations with a median in excess of $200 million most years

Table 2
Framework for analysis of tentative and definitive governance modes.

Instrument	What aspect of governance (governance niche) is being targeted?	Where is the target of governance?	How do governance processes operate?	How much resource is committed?	When is support available?	What are the goals?	Who are the stakeholders involved in governance formulation?
Policy X	Tentative? If fewer niches are addressed	Tentative? If vertical, narrowly targeted	Tentative? If flexible following learning	Tentative? If modestly resourced	Tentative? If support is time limited	Tentative? If goals change	Tentative? If wide actor involvement, and deliberative
	Definitive? If more governance niches are addressed	Definitive? If horizontal, broadly applicable	Definitive? If unchanging	Definitive? If highly resourced	Definitive? If support is longer term and open ended	Definitive If goals are fixed	Definitive? If narrowly based, top down

between 2004 and 2013, whereas the comparative valuation for UK companies was $74 million in 2004, with a subsequent and rapid decline (note that Fig. 4 focuses on IPO valuations – while Fig. 3 focuses on money raised in IPO and follow-on placing, explaining the discrepancy in activity levels between the two figures).

The following sections illustrate how firms seeking equity financing, and biotech firms specifically, had long been of policy interest. As the financing predicament faced by these UK firms became more concerning, policy commitments grew.

4.2. Governance in the 1980s: good-bye to definitive industrial policy

This section discusses three policy instruments with roots in the 1980s: state-funded Dedicated Biotech Firms (DBFs), tax incentives for Venture Capital investors and grants for public-private R&D collaboration. The first targeted firm-specific intervention, but subsequent instruments in the 1980s and 1990s were less focused on narrow sectoral targets (while still related to UK equity finance).

4.2.1. State-funded DBFs

This first policy instrument was deployed at the start of the 1980s with the creation of Celltech, the UK's first DBF, founded in 1980. A second state-backed DBF, the Agricultural Genetics Company was founded in 1983 (Owen and Hopkins, 2016). The former became a flagship for the UK biotech sector, the latter was less successful.[1] Here we explore how a definitive governance intervention was rapidly turned into a more tentative commitment following a change in political environment.

Biotechnology became an emerging technology of substantial interest to policy makers and investors around the world in the late 1970s (Orsenigo, 1989). The UK state's first move was the commissioning of a report on the prospects of commercial exploitation of biotechnology in the late 1970s, by the Advisory Council on Applied Research and Development (ACARD), authored by Alfred Spinks, Director of Research at Imperial Chemical Industries, a large established chemical company. Even though the Conservative government ignored almost all of ACARD's recommendations, one that was favoured was the recommendation to found a state-backed biotech firm to commercialise public sector research – on the basis that the UK private sector was not yet thought to be taking an adequate interest in the sector (Sharp, 1989).

Even before government approval, planning for founding Celltech was undertaken within the National Enterprise Board (NEB), the state agency responsible for nationalised firms and meeting some industry financing needs (Sharp, 1989; Fairtlough, 1989). Founding such firms was a tried and tested NEB formula in the UK under the Labour government, which had a record of creating national champions in strategically important sectors (Owen, 1999). In contrast, Thatcher's incoming Conservative government favoured free market economics with no role for the state in promoting emerging technologies, other than funding the basic science and creating the right conditions to allow private investors to do the rest (Sharp, 1989). Thatcher's new government now sought to brake from previous patterns of support.[2]

The highly targeted action of creating a particular firm to exploit new technology is definitive in nature, but exploration of events around Celltech's founding suggest tentative governance was used too. There

[1] Agricultural biotechnology was less commercially successful in the UK and perhaps as an indication of the government's willingness to be tentative, AGC seems to have been allowed to wither away.

[2] This is illustrated by the treatment of Inmos, the Labour Government backed semi-conductor firm, which received £25m from the National Enterprise Board (NEB) in 1978. The new Conservative government begrudgingly met an outstanding NEB commitment for further funding but then rapidly sold the company off to an industry incumbent (Owen, 1999).

Table 3
Dimensional analysis of tentative and definitive governance modes used in six policy instruments (with shading indicating more definitive governance).

Instrument	What governance niches are targeted?	Where is target of governance?	How do governance processes operate?	How much resource is committed?	When is support available?	What are the goals?	Who are the stake-holders involved in governance?
State funding for new DBFs (Celltech and AGC) (Early 1980s)	More tentative than definitive: Two niches targeted allocation of resources entrepreneurial activities	Definitive: A bespoke, highly targeted intervention at the level of individual firms although commercial focus was not pre-determined	Tentative: Plans were highly negotiated and changed. - State involvement and control was diluted. Full privatisation followed a hybrid public/ private phase	Tentative: Celltech promised £2m of state funding per year for first 5 year, but private investment reduced the scale of state investment needed.	Tentative: State ownership changed to full state withdrawal within six years	Tentative: The aim to exploit biotechnology commercially was vague and allowed exploration of different applications. Private investors steered final focus	More tentative than definitive: NEB initiated planning but involved several government departments/ agencies and a small group of private investors also became involved
Tax incentive schemes to induce private investment in SMEs. (BES, EIS, VCT) (Early 1980s to present)	Tentative: One niche targeted allocation of resources	Tentative: A horizontal policy aimed at stimulating investment in SMEs across the economy. Ongoing attempts to target to knowledge intensive firms	Tentative: Schemes were monitored, evaluated and redesigned frequently (or sometimes closed)	Definitive: Starting small but rapidly escalating, these schemes now provide >£1Bn in tax relief to investors annually	Definitive: Despite changes in form, this instrument has been use for more than 40 years, with commitment for at least the next decade	More tentative than definitive: The focus of the tax relief has changed over time to cater for more investor types, but the principle of the instrument has remained the same	Tentative: HM Treasury run schemes with high transparency and broad, regular consultation (but with entrenchment of interests apparent too)
Collaborative R&D schemes (Collaborative clubs, LINK, SMART) (Late 1980s to present)	More tentative than definitive: Two niches targeted knowledge Creation entrepreneurial activities	More definitive than tentative: Frequent involvement of silo'ed research councils, although programs were specific in technological focus, these were generally not application specific	More tentative than definitive: Policy learning led to adaptation/ modification. Competitive process for awards based on peer review. Close programme management. Cancellation of schemes that do not work	More definitive than tentative: Academic-industry collaboration where industry/government pay 50/50. Few programmes at any one time. Awards are individually small (~£1M or less). £50m over 15 years in biotech. However growth to >1000 collaborative R&D awards made overall each year across sectors.	More definitive than tentative: LINK has been in available since 1988, and used by research councils even after Innovate UK established as main hub for government funded collaborative research (replacing DTI).	More tentative than definitive: DTI and the Research Councils shared LINK steering. Its focus has moved over time (e.g. from applied to pre-competitive research) Individual programmes had their own goals.	More tentative than definitive: Run by DTI and research councils but generally applied to sets of technologies of interest to industry as determined by committee or foresight process (not open)
Technology-focused hybrid funds (2000- to present)	Tentative: One niche targeted allocation of resources	Definitive: UKHTF targeted at early stage technology firms; UKIIF adds a focus on specific sectors including Life Sciences	More tentative than definitive: Hybrid fund design has evolved; More hands off control in the latest iteration run by an arms-length management company	More definitive than tentative: Fund size and investment size are increasing in this scheme although overall size is small (£150m) in comparison to portfolio of government funded schemes	More tentative than definitive: Only two rounds have been established since 2000 and it is unclear when the next round will be	Definitive: Goals for this scheme are set at the outset and the funds distributed	Tentative: Established by but devolved from DTI/BIS. Hybrid funding schemes including this one have attracted high levels of evaluation and consultation. Other hybrid fund designs have been cancelled following poor performance and criticism
Establishment of Catapult Centres (under Innovate UK) (2010- to present)	More tentative than definitive: Two niches targeted knowledge creation entrepreneurial activities	Definitive: Focus is on a relatively small number of specific technologies within "strategic" sectors	More definitive than tentative: Centrally defined process for all catapults, with some centre level flexibility. Oversight process is evolving and informed by regular evaluations	More definitive than tentative: Centres have access to £50m per catapult for 5 years, with programme potentially ramping up to 30 centres and £400m spend per annum	More tentative than definitive: Centres' continuity is not guaranteed but subject to evaluation and attracting most of its funding competitively	More definitive than tentative: Goal of the programme is set centrally, but there is some flexibility in how centres service their clients.	More tentative than definitive: Run centrally by Innovate UK and BEIS. Many stakeholders involved in the set-up of the programme and in evaluations of performance
Life Sciences Strategy and Sector Deal (2017- to present)	Definitive: Four niches targeted knowledge creation entrepreneurial activities legitimise and lobby allocation of resources	Definitive: Targeted set of measures specifically to improve the UK environment for Life sciences companies and facilitate better healthcare through use of new technologies	More tentative than tentative: Processes based around competition and evaluation are already evident but much remains to be done	Definitive: More than £400m has been committed to new commercial R&D projects and infrastructure specifically for emerging technologies in the life sciences with mention off further commitments for the future – as well as more generic support for knowledge intensive firms	More tentative than definitive: Too early to say if commitment will be maintained but already milestones are in the 5-10 year range rather than longer term	Definitive: A long list of precise targets have been set out in the strategy and a board appointed to track progress against these	More tentative than definitive: Led by an academic, the strategy was shaped by the Office of Life Sciences guided by a series of consultations. The sector deal was a negotiation between many organisations that brought money to the table.

were protracted discussions and disputes involving several government departments and agencies over two years during which time the plans evolved (Dodgson, 1991). The state initially expected to fund Celltech with £2 M per year for five years (at 1980s prices), which the government had been advised would be sufficient to test whether further investment was warranted and whether this should be private or public. However, several commercial investors were then persuaded to invest as well, reducing the State's share of the investment and ownership (down to 44%), so that Celltech rapidly became a jointly held public-private company firmly under private control (Fairtlough, 1989; Dodgson, 1991). Furthermore, Government pressured NEB to fully disinvest as soon as was practical, selling all its shares by 1986

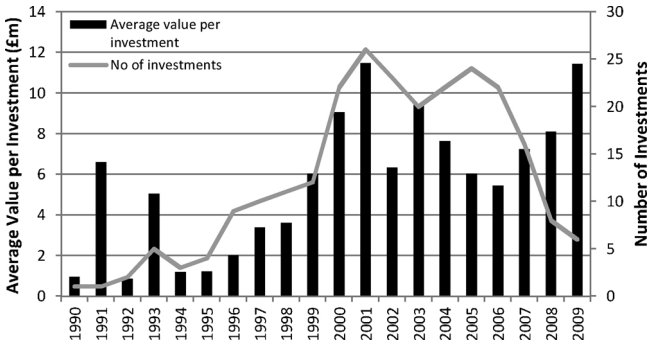

Fig. 2. The Dynamics of VC investment in UK therapeutics 1990-2009.
Source: Authors' elaboration of data from Thompson one banker

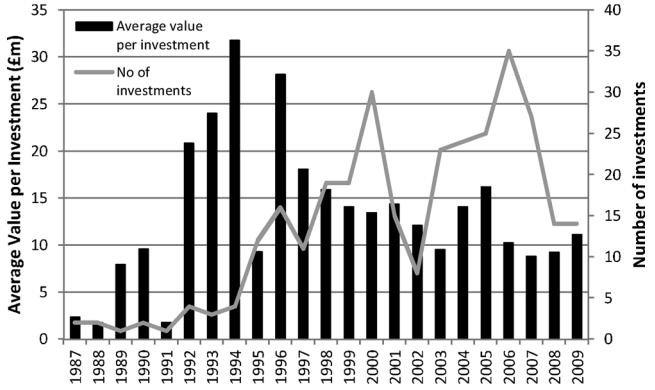

Fig. 3. Dynamics of stock market investments (>£1 m) in UK small therapeutics firms 1987-2009.
Source: Authors' elaboration based on data gathered from company reports

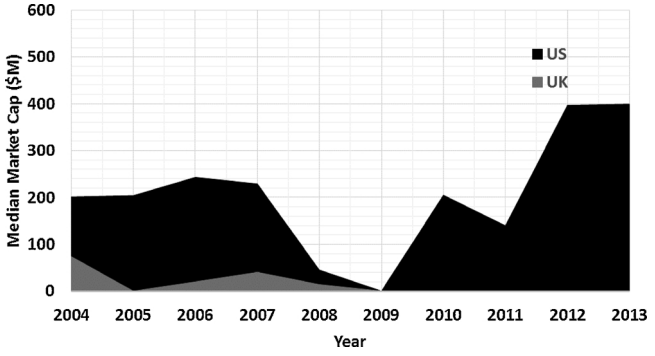

Fig. 4. Market Capitalisation of US and UK biotech firms at Initial Public Offering.
Source: Authors analysis based on data published annually in 'Public Biotech: the numbers' - *Nature Biotechnology*.

(Dodgson, 1991).

A further illustration of the tentative nature of Celltech's state support is that it was drip-fed funding to ensure greater control for the private investors over the direction of the company (Dodgson, 1991). Celltech's research programme can also be described as tentative rather than definitive, with observers suggesting unfocused organization meant it had more in common with a university than a corporate R&D lab in its early years. For example, it did not finally settle on a therapeutics-focused commercial strategy until 1985 (Dodgson, 1991). Indeed the choice of therapeutic R&D over other possibilities was not immediately obvious. Other early small UK firms founded to exploit biotechnology were not initially focused on therapeutics either - exploring applications in diagnostics was more common (Sharp, 1985).

The case of Celltech shows how a narrowly targeted intervention making a potentially open-ended commitment to an emerging technology was given more tentative characteristics. The state had intervened firstly to allocate resources to a new emerging technology, and also in effect, been poised to enter directly into entrepreneurial activity albeit only underwriting the enterprise until commercial investors were brought on board. Thus support for Celltech illustrates state governance action across of two of Hekkert et al.'s seven functional niches (allocation of resources and entrepreneurial activity). Despite some difficult early years, Celltech gained the confidence of investors and remained the largest UK biotech firm for nearly a quarter of a century. It eventually brought a series of medicines to market – although its greatest commercial successes came following its takeover by Union Chimique Belge (UCB) (Owen and Hopkins, 2016).

4.2.2. *Tax incentives for venture capital investors*[3]

Tax incentives for UK investors were introduced by the UK Treasury in the early 1980s. These instruments are intended to encourage the allocation of resources by private investors in favour of knowledge intensive firms. This policy can be seen as tentative because government did not focus on particular sectors or particular firms. Equally the increasingly large financial commitment made through these instruments and the Treasury's long term commitment to them illustrates more definitive elements in their governance.

In the early 1980s the VC sector was underdeveloped. By contrast the US sector was well established and able to quickly support emerging technologies such as biotechnology (Owen and Hopkins, 2016). One long lived and much adapted line of policy instruments designed to boost the availability of capital for entrepreneurial finance (including VC funds) was established in 1981: the Business Start-up Scheme (BSS). BSS had the goal of encouraging individuals to invest in starting their own businesses by providing them with tax relief on sums invested of up to £20,000 per annum (this rapidly jumped to £40,000, £100,000 and later £1 m in subsequent schemes). BSS was highly novel but attracted little investor interest and its design was flawed (Siepel, 2009). It was redesigned and relaunched in 1983 as the Business Expansion Scheme (BES) with the goal of incentivizing external investors to support high risk ventures, again in return for tax relief. Under close government scrutiny, rules were soon changed in 1984 to avoid it becoming a tax shelter for consumers investing in low risk businesses such as property investments. Yet restrictions to the scheme that could have focused investment in high-technology firms were reversed due to competing political goals and lobbying by the financial services industry – a pattern that was repeated as the scheme further evolved (Siepel, 2009).

By 1988 £720 m had been invested in over 2500 firms through BES. The VC sector was suggested by the Chancellor to now be meeting demand for capital from entrepreneurial firms. Yet BES was soon once again being mainly used to support property investments. It was closed in 1993 and replaced afterwards by the Enterprise Investment Scheme (EIS), launched in 1994, and Venture Capital Trusts (VCT), launched in 1995. The former's goal was to stimulate business angel investment in start-ups, the latter's was to support investment in more established firms. EIS rules were less appealing to those without a high risk appetite and there was low initial use of the scheme (only £25 m of investment capital was raised in its first two years) but this grew to over £600 m by 2000 (Siepel, 2009). Although fund management companies were slow to adapt to the new VCT scheme at first, VCTs are now a firmly established vehicle for investment in small firms attracting >£350 m each year in the period 2010–2014, while EIS raised >£1Bn annually over the same period (British Business Bank, 2015).

Like BES before them, VCTs were soon found to be supporting low risk investments (while still providing investors with tax relief) rather

[3] This section draws extensively on a comprehensive study of UK policy in this area by Siepel (2009)

than aiding high risk technology firms (Bank of England, 2001), but mooted changes to the scheme were slow to emerge (Siepel, 2009). In 2015 EIS and VCT were reformed to provide greater incentives for investors willing to invest in 'knowledge intensive' firms and a 2018 consultation by HM Treasury was established to explore further targeting with the aim of expanding capital raised to £20Bn for these firms over the next decade (HM Treasury, 2018).

Throughout their long existence, this line of policy instruments has been closely monitored by members of Parliament and the Government, including the Chancellors of the day, the civil service, the financial services industry and other business interest groups. There have been regular stakeholder consultations and evaluations. Modifications have been made to processes often. Failing schemes have been modified or closed. In these respects EIS and VCT and their predecessors have been tentatively governed. They have always been horizontally applied i.e. these are sector and technology agnostic instruments– also a tentative characteristic. Goals have also been changed in response to the economic situation – a further tentative characteristic. However the growing financial commitment of the state to these instruments (in terms of tax revenues forgone) seems to have become more definitive over time, even when they are reported to be a relatively expensive way to create jobs (Siepel, 2009). In part this reflects the entrenched interests of the financial services industry that has grown to depend on these schemes.

Returning to the issue of biotech firms seeking VC, the impact of these horizontal instruments was clear in that the investment environment was transformed (Sharp, 1989). Indeed by 1989, one firm, British Biotechnology Ltd. had raised more than £30 m in VC (Large, 1989; Kleinwort Benson Securities, 1992). Wider availability of VC brought many UK biotech firms up to the levels of capitalization and credibility needed to be considered by stock market investors, a development that strongly supported the growth of the sector in the 1990s (discussed previously in Section 4.1).

4.2.3. Grants for public-private R&D collaboration

The provision of grants for collaborative R&D discussed here act to connect two important functions of innovation systems - knowledge creation and entrepreneurial activities (Hekkert et al., 2007). This provision can be seen as tentative governance in the sense that grants to firms are individually small and the processes for offering these awards have developed incrementally over time. Yet definitive elements are observed too – including sustained support for the instrument over time, relatively closed governance of awards and a considerable financial commitment to collaborative R&D by the UK state over several decades.

The focal policy instrument in this governance niche is the LINK scheme, established at the end of the 1980s, and used across different arms of the state (in the Department for Trade and Industry and by the research councils – these run joint and separate LINK competitions). LINK provides grant finance for R&D projects involving public and private researchers, co-funded (50/50) by industry and the state. A sister scheme (SMART) was also established to support industry-only projects (BERR, 2008). LINK scheme funding supports a range of sectors and was the most financially significant mode of targeted state-support for UK biotech firms in the 1990s. During one 15 year period, LINK distributed £50 m to collaborative biotechnology research projects (BERR, 2008:49). LINK was organised as a series of themed programmes each funding a number of projects. Several programmes focused on biotechnology. For example the applied genetics programme, launched in 2000, funded 21 projects by distributing £28 m over 8 years.[4] Choice of topics for programmes was strongly influenced by industry directly or (during the mid-1990s) via the UK's technology foresight process (Georghiou et al., 2010).[5]

Over the decades, generations of LINK and SMART programmes were run as an institutionalised policy experiment with the many successive programmes providing an opportunity for policy learning. Key to LINK's perceived success was that it addressed a market failure by helping industrial partners to overcome their reluctance to invest in early stage technologies where uncertainties are high (BERR, 2008). Individual grants were small, but projects are commercially lead rather than being steered by government or academics. LINK grants also bestowed a beneficial investor signalling effect on their commercial partners (Siepel, 2009). In 2004 the government established the Technology Strategy Board (TSB) - later renamed Innovate UK and this took over from DTI (and LINK) as the main means to incentivize of business-led R&D, running similar schemes including the sector targeted Biomedical Catalyst Fund (Owen and Hopkins, 2016).

LINK's iteratively changing processes and commercially led grant design can be regarded as indicative of tentative governance. It is not clear that LINK has had much high-level political attention, but it has been subject to departmental evaluation (BERR, 2008). DTI programmes that did not meet expectations were redesigned or scrapped (as happened to SMART) demonstrating that commitment to these instruments is to some extent tentative. However, the technology-focused nature of most programmes limits their breadth, and their frequent sponsorship by research councils with narrow remit (e.g. medicine, or biotechnology) also suggests these are definitively governed in as many aspects as they are tentatively governed. The long existence of LINK and growth in funding of collaborative R&D grants under Innovate UK, rising to >1000 awards totalling >£200 m per year by the late 2000s, does suggest definitive commitment.[6]

4.3. Post-millennial interventions: the rise of industrial strategy

In the early 2000s with a generally benign economic context, horizontal policies supporting public-private R&D links proliferated while vertically targeted (sector-specific) or application-specific interventions by the state were rare and modest in terms of financial commitments (BERR, 2008). However, in the wake of the 2008 global financial crisis this began to change, with more interventionist, definitive governance being used to provide continuity of funding for entrepreneurial firms in technological fields identified to be of strategic importance for the economy. The (Conservative) Government's Minister for Universities and Science at the time explicitly identified 'Eight Great Technologies' and set out to support them with a new "Industrial Strategy 101", despite his (and Thatcher's) political party's previous anti-industrial strategy positon. He justified this change as follows:

> *"After the failure of the economic interventionism of the 1970s and the triumph of the liberal revolution in economic policy of the 1980s we are wary of Government trying to pick winners. … Until recently we have tended to favour so- called 'horizontal' measures rather than 'vertical' ones which focus on particular sectors… Strong science and flexible markets is a good combination of policies. But, like patriotism, it is not enough. It misses out crucial stuff in the middle – real decisions on backing key technologies on their journey from the lab to the marketplace. It is the missing third pillar to any successful high tech strategy. It is R&D and technology and engineering as distinct from pure science. It is our historic failure to back this which lies behind the familiar problems of the so-called 'valley of death' between scientific discoveries and commercial applications." (David Willetts, 24th January 2013).* [7]

[4] https://www.parliament.uk/documents/lords-committees/science-technology/stgmresearchcounciluksuppevi.pdf (accessed May 2018)

[5] http://webarchive.nationalarchives.gov.uk/20000824181734/http://www.dti.gov.uk:80/comp/competitive/pdfs/wh_pdf7.pdf (accessed May 2018)

[6] Full details of awards made after TSB (Innovate UK) was established are available: https://www.gov.uk/government/publications/innovate-uk-funded-projects (accessed May 2018)

[7] https://publications.parliament.uk/pa/cm201011/cmselect/cmsctech/

The gradual return of substantial government commitment to industrial strategy is successively more apparent in each of the following three examples.

4.3.1. Technology-focused hybrid Capital funds[8]

The focus of this section is a new policy instrument, the High Technology Fund of Funds (UKHTF) and its successor, the UK Innovation Investment Fund (UKIIF). Intervening to directly boost a market through providing capital for equity investment is a definitive move in the key 'allocation of resources' governance niche (Hekkert et al., 2007). After disappointing results in such direct interventions (e.g. regional VC funds), "High Technology" focused equity finance by government was delivered with some tentative measures to temper definitive intensions.

In the late 1990s a series of reports (by the Bank of England, the Confederation of British Industry (CBI),the House of Lords Science and Technology Committee, and the government commissioned Williams Report concluded that small UK technology firms still could not raise capital sufficiently easily (Siepel, 2009). When the New Labour Government took power in 1997 there was further emphasise of the importance of SMEs to the knowledge economy in the Government's *Competitiveness* White *Paper* (1998). A broad array of new policy initiatives followed, including the commitment of £150 m to a new Enterprise Fund to be managed by the DTI, including the commitment to fund UKHTF, which received £20 m.

In common with several of the DTI's other policy instruments the UKHTF committed state funds alongside private capital in a manner in which the public capital served as a risk-reduction or profit enhancement measure for private investors thereby encouraging them to join a market that would otherwise be underserved. These 'hybrid funds' combined public funds with private funds invested by commercial fund managers. These efforts could be seen as a response to dissatisfaction with state-managed VC funds, where the state invested directly in investee firms - often with poor results. This poor performance has been attributed to the state's failure to make commercial investment decisions; a dissatisfaction that was experienced not just by the UK but by a wide group of other countries that formed similar state managed VC schemes (OECD, 2004). A number of features make hybrid funds an attractive instrument for states. In particular, government can use hybrid funds to direct capital into the market for equity finance as deemed necessary; they can change the fund design to moderate commercial investor risk exposure as needed; they can choose whether to manage investments actively or passively; they can choose which fund managers to use, to direct where funds are invested (e.g. by geography or sector). Early UK hybrid fund designs had a number of problems that limited their effectiveness e.g. small fund size (with disproportionately high management costs) or funds that competed with existing pools of investors such as business angels rather than drawing capital into remaining 'equity gaps' - however there was substantial policy learning following their sustained use (BVCA-NESTA, 2009).

UKHTF was set up in 2000, specifically to draw VCs into the equity finance market for high tech firms and to demonstrate to the VC fund managers that commercial returns could be made from UK high tech firms. The £20 m of public money committed to UKHTF attracted a further £106 m in private investment. The UKHTF was allowed to invest up to £2 m of state funding into each investee firm (a cap set to comply with EU state aid rules). By 2006 the UKHTF had committed all of its funding to investee firms and was soon found to be one of the more successful of several hybrid fund models, despite being smaller than comparative European funds (NAO, 2009, BVCA-NESTA, 2009; SQW Consulting, 2009; BIS, 2011). Yet no additional state funding was committed to this instrument until the global financial crisis.

In 2009 the UK Innovation Investment Fund (UKIIF), a new scheme with £150 m budget, took on a very similar design as part of a more of definitive governance intervention in the equity finance market. This attracted £180 m in co-invested private capital (the lower ratio of public to private capital compared to UKHTF reflecting the very difficult market for investment at the time). Funds were managed by an expert commercial fund management company which could distribute money to further VC funds, with investments made on equal terms to those funds' investors. In a departure from the design of prior instruments, pre-determined targets were set for UKIIF funds to be invested in key sectors, including £25 m for the life sciences (BIS, 2012) – although the Bioindustry Association, a lobby group for biotech SMEs, and life sciences VC veteran Chris Evans lobbied unsuccessfully for a government fund of up to £1Bn focused on life sciences in the wake of the financial crisis.[9] The UKIIF was well received by stakeholders for addressing a perceived equity gap in the investment market for high tech firms at the £2m-£5 m level. Yet it was also criticised for its rushed implementation following pressure for action in the wake of the global financial crisis (BIS, 2012).

To put UKHTF and UKIIF into perspective in the years 1999–2011, over £1.1bn of UK government funding was pledged to hybrid funds in order to attract £1.1bn in private funding together with an additional £0.5bn from the European Regional Development Fund. These monies were invested through more than 150 different individual funds in support of a range of DTI policy instruments (Capital for Enterprise, 2012). Yet focusing just on UKHTF and UKIIF, these hybrid schemes seem to have become more definitive.

Firstly, while UKHTF was not *a priori* targeted at specific sectors, UKIIF was – with the purpose of supporting "key" sectors at a time of crisis. The scale of support has also become more definitive, with much larger sums invested in the 2009 round than in the 2000 round. Moreover, the goals seem to have become more focused over time and once money was awarded it was up to the fund managers to manage investments. However hybrid funds management processes have tentative characteristics: they have evolved considerably through learning over time, driven in part by the high attention these schemes have attracted from stakeholders (e.g. the British Venture Capital Association), as well as the numerous studies of the evidence base for these interventions, and routine early and late-stage evaluations of their performance. State management has become more 'hands off' with the UKIIF funds-of-funds now overseen by a specially established state company, Capital for Enterprise Ltd., rather than directly via a government department. Commitment has also been tentative in the sense that funding was not committed in a continuous manner. The UKHTF scheme was not re-funded immediately after its initial funding was allocated in 2006 nor was the UKIIF refunded after the conclusion of its most recent round.

4.3.2. Technology innovation 'Catapult' centres

In the wake of the 2008 global financial crisis, the government invested to further reinforce the link between knowledge creation and entrepreneurial activities through the establishment of a network of government funded specialist centres of technical and commercial expertise. The growing commitment to these centres and their top-down management are definitive, but tentative governance is observed as the

(*footnote continued*)
619/619vw20.htm (Accessed August 14th 2017)

[8] This section draws on material gathered from a comprehensive review of UK entrepreneurial finance by Siepel (2009).

[9] http://www.fiercebiotech.com/story/crisis-uk-bailout-biotech-industry/2008-10-08 (Accessed July 20th, 2017) Evans was later successful in his efforts to persuade the Welsh Government to support biotech firms with a £50m Venture fund, which he became a manager of and used to invest in at least one of his prior established companies. http://www.bbc.co.uk/news/uk-wales-politics-35654527 (accessed August 12th 2017).

market plays a role too in determining the direction of investment.

High-tech entrepreneur Hermann Hauser led a government commissioned review on the potential role of Technology Innovation Centres (TICs) in which he criticized the UK for having no national strategy for the commercialization of its research, as well as generally sub-critical levels of investment (Hauser, 2010:3). The report called for the UK 'to make choices and focus' its investments in a network of TICs to boost innovation in relation to emerging technologies where the UK had strong capabilities and a sizable market opportunity to exploit (Hauser, 2010:3). The TICs or Catapult Centres, as these became known, can be thought of as a definitive intervention with sector-level targeting and a substantial scale of investment. The initiative started with a £200 m investment in four centres with proponents aiming for this to rise to 30 centres costing a combined £400 m per year by 2030 (Hauser, 2014). Governance is definitive in the sense that the TICs' mission and focus (on translational activities related to emerging technologies) is fixed – modelled on the German Fraunhofer research organisations.[1] The network is overseen centrally by Innovate UK using a common evaluation process (E&Y, 2017).

Selected sectors benefit from substantial government investments (£50 m per 5 year term for each centre), sums that government intends to be leveraged by commercial contracts. Within the network, centre management teams are accountable to Innovate UK and the Department for Business, Energy and Industrial Strategy. At present 10 centres are in operation, including two biotech-focused centres (Cell and Gene Therapy – opened in 2012, was just the 2nd in the network to open; Medicines Discovery has been open less than a year at the time of writing).

The definitive governance elements of the Catapults initiative are tempered with tentative elements: Continued government support for centres depends on regular evaluations of their progress e.g. Hauser (2014); E&Y (2017). Each intervention is experimental in the sense that there seems to be a real prospect of restructuring or closure (e.g. the Precision Medicines Catapult was moved and merged with Medicines Discovery Catapult at an early stage). The process to establish the catapults drew on broad stakeholder consultation and evaluation involves interviews with a wide range of stakeholders too. Moreover, while catapults are supported by some core funding from the state, they are expected to raise two-thirds of their budgets through competitive bids and commercial tendering to ensure that they are focused and market-led (E&Y, 2017).

4.3.3. Sector specific industrial strategy and sector deals

In recent years, definitive governance in support of biotech SMEs has become a prominent, leading example of a new wave of UK state interventionism in support of emerging technologies. This strategy supports knowledge creation, allocates resources to support entrepreneurial activities and also seeks to legitimise/ lobby for the sector creating a definitive policy support package for the sector. Yet tentative elements still permit some flexibilities, notably through stakeholder engagement and co-funding.

In the early 2000s, the BioIndustry Association, joined with Government's Department of Health and DTI in an initiative called the Biosciences Innovation and Growth Team (BIGT) to deliver a report (with foreword by Prime Minister Tony Blair) lobbying for resources in support of the biotech sector. Bioscience, Innovation and Growth Team (BIGT, 2003 led to a series of impacts over the next decade, mainly implemented as horizontal policies by government. When the global financial crisis weakened the UK's entrepreneurial finance market, BIGT wrote a second report in 2009 emphasising that biotech equity investment had 'virtually ceased' while suggesting that the sector was a 'key part of our knowledge based economy at risk' (Bioscience, Innovation and Growth Team (BIGT, 2009:2). Lobbying efforts led to the establishment of targeted state investments (including part of UKHTF – discussed above).

The BIGT's warnings led to the establishment of a cross-departmental Office of Life Sciences (OLS), with a mission to co-ordinate government policy support efforts for the sector (BIS, 2010). The OLS was soon inherited by the new coalition Liberal-Conservative government in 2010 (replacing New Labour). The next year, when Pfizer (a large pharmaceutical firm) brought a damaging blow to UK life sciences by threatening closure of a major R&D site in 2011, OLS lead a rapid government response – a Life Sciences Strategy, launched by Prime Minister, David Cameron.

The multi-faceted strategy included vertical funding instruments such as the Biomedical Catalyst fund (administered by Innovate UK), launched in 2011 with a budget of £180 m – subsequently refunded with another £110 m in 2016.[10] The political importance of the sector was further underlined in 2014 by the appointment of a dedicated government Minister for Life Sciences, George Freeman, to oversee the work of the OLS – Freeman was a former VC with experience the sector (Owen and Hopkins, 2016).

Meanwhile at the national level, there was continued poor productivity growth in the economy. The government commissioned a review to explore further policy interventions. The review, *No stone unturned*, led by Lord Heseltine, produced many recommendations (which were mostly accepted), including the proposed development of a national industrial strategy with commitment to co-create industrial strategies with 11 sectors to boost economic performance (Heseltine, 2013; Her Majesty's Treasury and Department for Business, 2013). However, the industrial strategy was not published until after another landscape-level shock to the economy – the result of the UK's 2016 referendum on leaving the EU.

In the face of considerable Brexit-related economic uncertainty, Prime Minister Theresa May suggested that the new UK industrial strategy 'epitomises my belief in a strong and strategic state that intervenes decisively where ever it can make a difference' (HM Government, 2017a:4). Sector champions were nominated to work with industry to develop actions, including to 'make the UK the best place in the world to invest in life sciences' (HM Government, 2017a:102). Thus, a second Life Sciences Industrial Strategy was commissioned by government, again largely co-ordinated by the OLS but this time led by an Oxford academic with industry experience, Professor Sir John Bell. Published in Autumn 2017, its relationship to the 2011 Life Sciences Industrial Strategy is unclear. The 2017 strategy set out a number of goals including some very specific expected outcomes – such as to stimulate the emergence of new industries and to build four businesses with a market cap of £20Bn in the next decade (Bell, 2017). The government moved quickly to resource Bell's strategy with the publication of a Life Sciences Sector Deal, in late 2017. The Life Sciences Sector Deal (2017b) includes state commitments worth over £400 m. This includes a series of new specialist research centres and grant competitions to develop capabilities and projects related to new methods for manufacturing medicines (£162 m) and early diagnostics and precision medicine (£210 m). These investments are promised alongside industry commitments worth >£250 m to build new facilities for R&D and manufacturing in the UK in a carefully coordinated series of announcements, managed to gain maximum media attention.

The Life Sciences Strategy (2011), The Industrial Strategy (Her Majesty's Government, 2017a), Life Sciences Industrial Strategy (Bell, 2017) and Industrial Strategy Life Sciences Sector Deal (HM Government, 2017b) provide targeted, sizable and sustained financial commitments making these definitive governance interventions in several respects. The goals (as set out in the sector's 2017 Industrial Strategy) are precise, explicit and extensive – and so also potentially quite definitive. It remains to be seen whether these will stay unchanged in the future though. Indeed the planning and implementation (including time scale/ milestones) for both the 2011 and 2017 Life

[10] https://www.bioindustry.org/uploads/assets/uploaded/3b1adf21-0a72-4594-b2680f04846f2989.pdf

Science industrial strategies has been characterised as insufficient (House of Lords S&T Committee 2018).

Although the 2017 strategy sets out some timescales suggesting objectives are mainly to be met in 5–10 years (Bell, 2017: 3) – this is not a particularly long period of support given the ambitions set out in the strategy. Although it is rather early to classify the evolving processes of governance around the industrial strategy, we note that details (particularly on leadership, evaluation and some other aspects including more funding in the future) are still emerging. Furthermore, stern criticism has already been made of the strategy indicating that current processes are seen as 'wholly inadequate' (House of Lords 2018:3). With both processes and timescales underdeveloped and emerging, it seems these are perhaps more tentative than definitive. Finally, stakeholder engagement has been extensive but fast paced and also somewhat secretive. Furthermore, because the sector deal has emphasised the need for industry co-creation and co-funding, there is a tendency for larger firms to be given more prominence, and so the policy targeting is open to incumbents' influence. The potential for governance capture here is concerning, particularly in light of prior policies introduced after industry lobbying, such as the Cancer Drugs Fund (established in 2010) which was criticized for paying £1.3Bn to established pharmaceutical firms for certain expensive drugs of limited effectiveness (Aggarwall et al., 2017).[11]

5. Discussion and conclusions

By exploring the governance of six prominent policy instruments shaping the UK's entrepreneurial capital market for therapeutic biotech firms, we demonstrate how tentative and definitive governance modes can be analysed and show how they are used to support the growth of an industry characterized by an emerging technology. In this section we discuss the three main contributions of the paper which address our research questions, followed by some observations that are apparent from the context studied. Finally some limitations of our approach are noted.

Our first contribution has been to address the question of how to unpack tentative and definitive governance to facilitate application of these concepts at the level of the policy instrument. To achieve this we use a simple expository framework to delineate relevant governance actions in the domain of interest, and to indicate how actions can be characterised along a spectrum from tentative to definitive in a series of seven dimensions. These dimensions are: the choice of governance niches, the targeting of beneficiaries, changes in implementation processes, scale of resource committed to the intervention, the temporal duration of commitment, changes to the goals of the intervention, and the range and position of stakeholders involved in formulation of the governance action.

The analysis of Section 4, concerning six policy initiatives affecting the financing of R&D in the biotech sector is summarised in Table 3 and clearly shows that our framework can be operationalised. Table 3 summarizes the key aspects of the six selected policy instruments to support analysis.

First, Table 3 highlights that our selected governance interventions range from the comprehensive, addressing many parts of an innovation system (more definitive), as the Life Sciences Industrial Strategy shows, to those that are limited to a single governance niche (more tentative). Second, it shows that our selected governance interventions include horizontal (non-specific) policies that cover many sectors – not just those of emerging technologies as well as vertical (sector specific) ones, the latter policies being perhaps more easy to miss by those undertaking sector specific studies. Third, we show that the governance processes are mainly managed in a way that allows learning and redesign, rather than unchanging processes formed definitively at the outset. The fourth and fifth dimensions of the table summarise the details of the scale and duration of commitment to policies, which may be large and unwavering in definitive governance (in the case of EIS and VCT) or experimental, preliminary and contingent, for tentative governance (as in the case of technology-focused hybrid capital funds). Sixthly, the table summarises our analysis of the goals and whether they are adaptable or immutable, and whether progress against these goals is monitored, for example by use of key performance indicators for Catapult Centres – or perhaps more loosely followed. The Seventh dimension of Table 3 shows how, in tentative cases, stakeholder engagement can be transparent, long term and extensive (as has been the case around investment oriented tax incentive schemes) or more closed but still negotiated. Finally, the structural position of those in the state involved in governance actions is noted. Our analysis detailed that departments, such as HM Treasury, were often ambivalent about the fate of particular sectors or emerging technologies, and may tend towards tentative actions (for example, recall in UK there has been a fear of civil servants and politicians making a poor job of 'picking winners'). However some arms of the state are more sector-focused, such as OLS, and may be more inclined to support definitive actions in aid of those within their domain.

Our second contribution has been to examine how coherently tentative and definitive governance modes are used in practice, and to show that tentative and definitive governance modes are often blended. Table 3 assigns one of four grades to each dimension of each policy instrument: (i) tentative, (ii) more tentative than definitive (iii) more definitive than tentative and (iv) definitive. From this grading (and associated shading in Table 3 it is immediately apparent that definitive and tentative governance elements are discernible throughout the time period studied and occur in combination in all the instruments studied. It seems that UK policy makers in this field have rarely been minded to be wholly tentative or definitive when developing policy instruments – perhaps in the tradition of Lindblom (1959).

Our analysis shows how definitive policies that might at first appear too rigid to critics were often made more flexible and responsive to uncertain circumstances. For example in the case of Celltech, an intervention that was at first substantially at odds with a new government's ideology, was reshaped through the introduction for more tentative elements until what seemed at first to be a definitive action became a short period of government ownership during a start-up phase, pending privatization. This example also shows that seemingly definitive support measures may be reversed by the determined policy maker (assuming they are willing to see sunk investments at risk). In other cases, such as the BSS (later EIS) tax break for investors or the collaborative R&D LINK scheme, experimentalism has become routinized as support actions are launched, refined, and relaunched amid policy learning processes – allowing long term support to be maintained for policy interventions that can be justified by their effectiveness. Most recently with the Life Sciences Industrial Strategy and Life Sciences Sector Deal, the state seems to have placed greater emphasis on definitive rather than tentative governance commitments in order to create certainty when deemed necessary, to reassert a positive narrative for the sector during a time of uncertainty. Yet at the same time tentative elements have been used in some dimensions of policy planning and design, often those associated with consultation and learning.

Kuhlmann et al. (2019) note that the concept of tentative governance has great value because it is neutral, without any single purpose or expected outcome. And that the concept of tentativeness comes from, but is distinct from other previously defined concepts that emphasize notions such as reflexiveness (shaping innovation), anticipatory (forward looking along a particular path); adaptive (related to learning), distributed (multilateral); experimental, and explorative. Our analysis in Section 4 and its summary in Table 3, supports Kuhlmann et al.'s assertion that seeing definitive governance in a neutral manner is more valuable that trying to allocate actions to one of the many possible boxes, at least when considering its role in these policies reviewed here.

[11] http://www.bbc.co.uk/news/health-39711137 (accessed July 20th, 2017).

For example, we see cases where the tentative dimensions of governance were related to the desire to learn (experimental or adaptive) – as with UK tax incentives, but also sometimes they were related to pacifying actors with different attitudes to the policy intervention as in the case of Celltech. And whilst some kinds of tentative were clearly desirous for shaping innovations and were very directional (such as with LINK or Catapults), others were simply tentative in a more pragmatic manner to get some kind of movement, not necessarily in any particular direction (as with the tax incentive schemes for investors). In short, we suggest that "tentativeness" is not just an umbrella concept that includes others, but in the context of UK biotech, it is also useful in characterising what is going on.

A third contribution relates to the use of tentative and definitive governance over time – with particular attention to the emergence of an industry associated with a new technology. Our findings suggest that tentative and definitive governance practices can be found throughout the process of technology and market emergence. Taking all dimensions from all instruments together, Tables 2 and 3 shows a shift back towards more definitive governance interventions (favoured in the1970s in the UK but not in the 1980s) – but this is largely because these instruments have been selected as examples to illustrate this trend, which is described elsewhere (Owen and Hopkins, 2016). That same trend is further evidenced by the statements of Hauser, Willetts and May exhibited in Section 4. However these statements illustrate a shift in the broader economy and not in governance of the biotech sector *per se*. This evidence should not be used to support a model whereby tentative or definitive governance is associated with particular stages of technological emergence, and if there were such an effect it likely is subordinate to landscape influences. Instead we note that at the macroeconomic level, a period of low productivity growth in the wake of the 2008 global financial crisis led to interventionist government responses in a range of industrial sectors selected by the state for special support. State support was delivered through redoubled efforts using established polices (e.g. hybrid funding schemes) as well as new sector-level coordinated action (e.g. sector deals). This was a turning of the tide in political culture, as before then, there had been a broad shift (internationally) away from certain types of industrial policy interventions tried in the past and now expected to have less success in highly uncertain emerging technologies such as biotechnology as compared to, for example, electronics (Wong, 2011).

We therefore conclude that tentative and definitive governance are both used by the state irrespective of the political ideology of the party in power with respect to market interventionism - echoing Birch's argument that neoliberalism may be difficult to adhere to in practice (Birch, 2015). Furthermore, some of the cases show that governance is influenced by lobbies that can create a sense of urgency around action, and also that the overall economic outlook can spur definitive policy action. Our findings therefore suggest that theorising around tentative and definitive governance should take these factors into account. Finally, we demonstrate that tentative governance appears to have broad relevance, being frequently used in the context studied as a pragmatic response to the need to act definitively while taking specific stakeholder concerns or uncertainties into account.

Following from the above contributions, some further observations can be made on governance practices in relation to emerging technologies. First, something that can hamper governance is the tendency of one group of actors to be disengaged in a niche even as another is engaged (an either/or relationship). At such times, capabilities for governance (through investment and learning effects) can move out of sync with one another, reducing or delaying potentially fruitful co-ordination. For example this happened in the UK when stock market investors disengaged from biotech investing and the state chose to increase its interventions to support the sector. We also note that at any one time, different parts of government can have differing stances – for example definitive governance modes may be used by one arm, while tentative approaches are used by others. Under favourable conditions, the state may appear to have a choice between being active or more passive in its governance role. However, if conditions deteriorate, the state's unique capabilities to shape markets, and consequently the social distribution of other actors' risks and rewards (Moss, 2002), make it politically difficult to resist intervening.

Secondly, to encourage investors to engage with an emerging sector, co-investment has been repeatedly deployed (e.g. in the cases of Celltech, LINK grants, hybrid VC funds, and the Life Sciences Sector Deal). In these cases private investment is secured for particular sectors, or application areas, with the state moderating commercial risk by investing along-side private investors as well as providing other incentives. The state has tried to establish a commercially-led market with minimal state involvement whenever possible, consistent with (the contextually predominant) free market thinking. However, market failure has been a recurrent challenge. In the early 1980s small amounts of funding were needed to establish the UK's first dedicated biotech firms. The moves to support markets for entrepreneurial finance through horizontal tax incentives was a tentative scheme that simply led to investors sheltering their money in lower-risk assets in return for their tax break. High risk, long duration investments with unproven returns have proven to be less than tempting to private investors – except during relatively short periods of techno-hype. Hence the need for more direct incentives to encourage investment which, although we do not evaluate their effectiviness here, have been noted to be difficult to deploy successfully (Lerner, 2009).

Finally, this account offers insight into the effects of tentative governance on co-ordination efforts which are an important influence in national systems of innovation (Biopolis, 2007; Kooiman, 1993; Lyall and Tait, 2005). On the one hand opening-up policy processes to tentative governance can be beneficial, but on the other hand, openness to stakeholder input in policy design can also allow incumbents to further entrench their positions and for path dependency to dominate. Examples quoted here show incumbent influence on policy in financial services and for life sciences, particularly with regard to the large pharmaceutical firms. This is a trend that has tracked the emergence of the sector and the establishment of sizeable markets for equity finance in the UK. As the sector became more important to VC, pharmaceutical firms and to the government's economic ambitions, lobbying for more definitive governance measures appears to have become more effective. This lobbying has also, unsurprisingly, coincided with growing economic stress for the sectors involved. Incumbent actors may act in ways that lead to lock-in (Arthur, 1989), such as closing down options that do not favour them, potentially leading to socially suboptimal outcomes (Ramjerdi and Fearnley, 2014). In extremis, regulatory capture may occur with governance actions favouring sectional interests over the public interest (Dal Bó, 2006).

We find that tentative governance can be employed in a wide range of circumstances as a way of managing the uncertainties (including but certainly not limited to technological emergence) but it may be difficult to maintain in the face of organized lobbies for established interests and exogenous shocks such as deteriorating economic conditions.

Limitations of this research

Long term studies of changes in governance have limitations that are reflected in this work. Firstly,

in the study of tentative governance, the longer the time period studied, the more likely it is that flexibility or reversals may observed (and so governance may retrospectively appear to be more tentative in the long run than it appeared a short while after the events took place). Secondly, understanding whether tentative or definitive governance is successful in achieving its objectives depends on knowing *ex-ante* goals, baselines, outcomes and whether those outcomes were achieved and if so the extent to which the policy design was influential in this. In some cases interventions are fully evaluated *ex-post* (such as BSS, BES, EIS, VCT, LINK) in an open and transparent manner. However, while it has

been possible to demonstrated various ways in which policy actions can be made more tentative or more definitive, we have not provided an evaluation of impacts that stem from the choice of governance mode. Nor have we been able to fully determine whether outcomes were more or less effective as a result of these practices or whether any positive outcomes were intentional or incidental to the policy design. It is apparent though that despite the interventions described here, recent a policy report suggest that the UK market for entrepreneurial finance remains a work in progress (HM Treasury, 2017).

Another key limitation is that this account focuses on state governance actions and ignores non-state actors. This is partly to do with space but also because it is more difficult to access detailed data on non-state interventions. Our empirical evidence also does not cover important activities undertaken by established pharmaceutical firms, many of whom were actively exploring biotechnology in the period covered by the analysis. Similarly, the actions of medical research charities and other third sector actors are not explored even though some, like the Wellcome Trust, are of high significance in the UK context.

Finally, while a focus on a single sector within a single national context over a long period of time is informative about the relationships between tentative and definitive modes of governance, other aspects and dimensions beyond those studied here may be found to be analytically informative in other countries or sectors and at other times. The exploratory account provided here leaves much room for room for further research on the effectiveness of governance modes that include a wider range of countries, sectors, and actors.

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