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Markets under the Microscope:

Making Scientific Discoveries Valuable through Choreographed Contestations

ABSTRACT

This paper breaks new ground by revealing and conceptualizing the *marketization of science* as a process that transforms scientific discoveries and markets through a series of choreographed contestations: moments of valuation that occur when different social worlds collide. We follow a scientific discovery, from the moment it entered an incubator, to uncover how valuation practices and market devices enact and contest diverse social values (i.e., what is worth doing) to generate economic value (i.e., what is worth paying for) at the science-market-entrepreneurship nexus. In contrast with commercialization of science studies that focus on institutional arrangements, this study explicates the practices and devices used by multiple market actors to transform a scientific discovery into a marketable object. In so doing, we characterise choreographed contestations and the mechanisms through which they operate to explain how specific valuations are performed to *work out* innovative next steps that unfold the marketization of science.

KEYWORDS: Commercialization, Contestations, Marketization, Market Devices, Valuation Practices, Social Worlds

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INTRODUCTION

The market for cancer treatments is dominated by chemotherapies. Chemotherapies attack every dividing cell they encounter, often resulting in undesirable side effects[i]. Scientists are now seeking antibody-based therapies, which only target cancer cells. Much of this early stage scientific work takes place in university laboratories, but the discoveries must emerge from these non-commercial settings if they are to become both socially and economically valuable. However, we know little of the practices that support the commercialization of such scientific discoveries, or how markets shape this process.

The commercialization of science is understood as the exploitation of a scientific invention to reap financial rewards (Perkmann et al. 2013), making science valuable and marketable. However, scientific discoveries are not always immediately associated with the problem they ultimately address: when patients reported the surprising side effects of Sildenafil Citrate (an angina therapy), Pfizer re-marketed it as Viagra - a treatment for erectile dysfunction (Loe 2004). Discoveries emerging from settings where commercialization and market expertise is lacking have provoked research identifying the institutional arrangements and resources needed to support science commercialization: intellectual property rights protection (Debackere and Veugelers 2005; Lockett et al. 2002; Lockett and Wright 2005), licencing agreements support (Lockett and Wright 2005; Siegel et al. 2003), and setting-up/monitoring spin-outs (Clarysse et al. 2007; Vohora et al. 2004). Yet we still know little of how commercialization forges market connections (Cooke 2001) essential for progression from embryonic science to economically valuable, market object.

The market studies literature conceptualizes markets as socio-economic collectives that contest, calculate and co-ordinate action, organizing multiple social values to generate economic value (Geiger et al. 2014; Stark 2009). Through this co-ordination markets enable compromises on the nature and value of goods produced (Araujo 2007; Callon and Muniesa

2005). This suggests that commercializing any good requires connecting distributed and heterogeneous sets of expertise to work out what is valuable, to whom and why. The process by which this happens is referred to as *marketization* (Araujo and Pels 2015; Çalışkan and Callon 2010). By studying the *marketization of science,* we shift from the commercialisation of science literature's focus on institutional support for academic entrepreneurs, to the collective valuation of scientific discoveries through the engaged and contested practices of multiple market actors.

Adopting this approach, we see markets as being constructed through collective market action (Callon and Muniesa 2005), and seek to uncover the process through which this action transforms both the scientific discovery and the market it seeks to enter. To uncover the tensions that academic-scientists face in this process (Clarysse et al. 2007; Cooke 2001; Vohora et al. 2004), we draw on social worlds theory to explicate the plurality of norms, discourses, symbols and practices (Clarke and Star 2008; Strauss 1978) brought together in market encounters. Fisher, Kotha and Lahiri (2016) recognise this plurality in the way new ventures secure resources from different audiences, arguing that social judgements and valuations reside within socially constructed systems of norms, values, and beliefs. We suggest that the ways in which market encounters are organised and performed is critical to the marketization of science, and particularly the way they produce multiple and sequential moments of valuation at the nexus of multiple social worlds. In this paper we ask: *In the process of marketization, how do contestations between different market actors make scientific discoveries valuable?*

We elaborate theory (Maitlis 2005) through a single, longitudinal case study of *'AntiBod'*, a scientific discovery typical of those incubated at the Stevenage Bioscience Catalyst (SBC), in the UK. This allowed us to generate 'thick descriptions' (Geertz 1973) of how *AntiBod* was made valuable, revealing the complex and pluralistic valuation practices performed in the marketization of science.

We find that there is no predetermined marketization pathway. Rather, a series of choreographed contestations unfolds at the nexus of social worlds, transforming the scientific discovery into a marketable, economically valuable object. Each contestation brings together valuation practices and market devices from multiple social worlds to temporarily frame and fix what is being valued and how. By holding these devices and social worlds in dialogue, new valuations are produced, shaping understandings of what is worth doing next. How marketization is achieved only becomes apparent as each moment of valuation unfolds the next; as the dissonance created through the collision of discourses, symbols and understandings of social worlds is surfaced productively and acted upon, one innovative step at a time.

We extend understanding of the commercialization of science by introducing a conceptual framework of *choreographed contestations* to explain how marketization occurs through the generative interplay of valuation practices and market devices from diverse social worlds. This shifts our attention away from institutional arrangements and towards the practices and devices that perform the collective *working out* of innovative next steps in the marketization process (Callon and Muniesa 2005; Pénet 2015; Pollock and D'Adderio 2012). These insights take us beyond recognition of the challenges and tensions typically experienced by academic-entrepreneurs (Siegel et al. 2003; Siegel and Wright 2015a), by foregrounding the role of collective valuation practices in '*disentangling'* discoveries from extant social worlds and norms in order to make them valuable in markets. Our paper concludes by discussing how our *theories from the lab* have broader implications for management research.

LITERATURE REVIEW

The Commercialization of Science

Much commercialization of science literature focuses on understanding university spin-offs and the institutional environments that shape them, addressing issues such as the impact of equity investment availability (Lockett and Wright 2005), business development capabilities

and royalty regimes of university technology transfer offices (TTOs) (Lockett and Wright 2005; Siegel et al. 2003), and network capabilities progressively developed by spin-offs (Baraldi et al. 2014; Walter et al. 2006). This work foregrounds the significance of creating a credible venture, and the importance of context, particularly the significance of TTOs within universities (Clarysse et al. 2007; Lockett and Wright 2005; Lockett et al. 2003). TTOs stimulate entrepreneurial activity and are responsible for registering patents, organising licencing agreements and establishing spin-outs as independent companies in which intellectual property (IP)-owning universities have a stake (Lockett et al. 2003). As such, they are seen as *'insiders'* with specific skill-sets and expertise (Lockett and Wright 2005, p.1047), organising key evaluative processes before commercialization commences (Vohora et al. 2004). In sum, this institutional approach looks at the organisation and structure of resources and the organisational routines put in place by universities to help academic entrepreneurs commercialize discoveries (Dodgson et al. 2011; Lockett et al. 2002; Perkmann et al. 2013; Roseira et al. 2014).

Perkmann et al. (2013, p.424) see *'the founding of a firm with the objective to commercially exploit a patented invention or in some cases, a body of unpatented expertise'* as a *'preliminary step indicating a disposition on the part of the academic towards some kind of exploitation'*. The context of university spin-outs is distinctive because it involves the development of business opportunities based on unique forms of disruptive technologies coupled with tacit knowledge from academic research (Rasmussen et al. 2011). The academic often continues to work for the university, which retains IP post spin-out (Siegel and Wright 2015a), creating tensions for academics, since they ordinarily adopt traditional scientific norms, standards and values that contrast sharply with conventional entrepreneurial activities (Siegel et al. 2003). Through commercialization, academics step into new and unfamiliar social worlds of management, entrepreneurship and market development that have different social norms and values to their own (cf. Siegel and Wright 2015a). To date, there is little explication of the

impact these multiple 'social worlds' have on scientific discoveries, as the worlds of academia, commerce, business, management and markets collide. Each social world has unique sites of practice, patterned commitments, practices, technologies, and associated ways of organising (Baszanger 1998; Bucher 1962) and so values differently. As Rasmussen, Mosey, and Wright (2011, p.1315) observe, *'academic spin-off ventures therefore require the creation of new development paths that depart from existing practices'*. To gain a deeper understanding of these new paths, through multiple social worlds with multiple practices, we turn to market studies.

From Commercialization to the Marketization of Science: A Conceptual Framework

In the market studies literature, *markets* are conceptualized as categories of goods (e.g., healthcare *diagnostics* or *therapeutics*); often, these categories are multiple, contradictory, and dynamic (Kjellberg et al. 2015). This means that the transformation of markets is never clear-cut. However, actors' conceptualizations of markets are at least partially reconciled through the coordinated, collective actions and devices that constitute them (Azimont and Araujo 2007). This includes the institutionalizing norms and rules, technical devices and infrastructures, images, models, and representations of scientific and market knowledge, and enacted practices and routines that constitute each market category (Çalışkan and Callon 2010; Kjellberg et al. 2015). Markets are the ongoing socio-technical accomplishments that depend on the mobilization of varying bodies of expertise, calculative agencies, devices, and practices (Callon and Muniesa 2005); and the work of *marketing* (i.e., the practice of making and shaping markets) as the distributed and heterogeneous sets of agencies involved in the process of facilitating market exchange and constructing market institutions (Araujo 2007). Callon and Muniesa (2005, p.1229), conceptualizing marketing in terms of valuing*: 'markets are collective devices that allow compromises to be reached, not only on the nature of goods to produce and distribute but also on the value given to them'*, while Doganova and Muniesa (2015, p.120) see the work of bringing these collectives together as a form of 'choreography'. Such

conceptualizations emphasize the distributed nature of expertise and imply that multiple market actors are deliberately brought together to value and make things valuable.

We draw on the commercialization and market studies literatures, together with social worlds theory and our empirical data, to offer a framework for understanding how markets make scientific discoveries valuable (Figure 1). This abductively derived framework brings together concepts from these disparate literatures, representing our contributions: conceptualising choreographed contestations at the nexus of social worlds as the mechanism that unfolds the marketization of science. Our conceptualisation shows the fixing and framing of valuations and the generative dialogue between valuation practices and market devices at this nexus. We introduce our conceptual framework here, before explaining the abductive process of its construction (Methods Section).

INSERT FIGURE 1 ABOUT HERE

Valuation practices: We draw on the market studies literature in our conceptualization of valuation practices. Valuation practices make things socially and economically valuable (Kornberger et al. 2015). They are the routine and recursive practices that collectively determine how new goods are conceptualized, produced and exchanged, as distributed market actors come together to contest and decide what is worth doing, how (by whom) and why (Araujo and Pels 2015; Dussauge et al. 2015; Stark 2000). Both social *and* economic value(s) are implicated in this marketization process. Because the market studies literature focuses on the world of the market, we additionally draw on social worlds theory (Clarke and Star 2008) to understand how market actors value differently (Dussauge et al. 2015; Fisher et al. 2016). Values from different social worlds, when brought together, are likely to create contestations that produce negotiated outcomes through efforts to create economic value. While many social

worlds may be encountered in different contexts, those represented in Figure 1 are most important in this case, as inductively identified through our data.

The study of valuation practices, then, is the study of how things are made commensurate, compared, categorized, and clarified; of how some things are judged to count more than others. It is through valuation practices that the market is ordered, hierarchized, and ultimately valued (Kornberger 2017). This seems particularly pertinent in uncertain marketization settings where the anticipatory nature of scientific and market knowledge requires a pragmatic approach to working out what is plausible and what knowledge should be pursued next (Pénet 2015), using what devices. The devices used in these valuation practices vary, depending on which actors invoke them and why; we consider these next.

Market devices: Valuation practices make use of and generate market devices that value (Kjellberg et al. 2015). Muniesa et al. (2007, p.2) describe market devices as *'the material and discursive assemblages that intervene in the construction of markets'*, offering examples to illustrate the breadth of market devices, including analytical techniques, pricing models, merchandising tools, and trading protocols. Market devices might be technical or epistemic. Cochoy (2009) describes how the introduction of the shopping trolley (a technical market device) facilitated in-store transport of larger volumes of goods, equipping shoppers to make different valuations about what to buy, thus changing market behaviour. In contrast, Pollock and D'Adderio (2012) showed how framing a market using Gartner's Magic Quadrant (an epistemic market device) mediates and constitutes a particular market domain. They argue that material things (including market representations) and markets come to constitute one another. Thus, market devices are often representations of market, scientific or technical knowledge, enabling actors to understand, calculate or work out states of the world. These examples reveal the multiple and adaptable nature of market devices as they are re-presented to different social worlds to work out different forms of value (cf. Fisher et al. 2016).

Choreographed contestation at the nexus of social worlds: The notion of contestation is central to the understanding of markets and their valuation practices. Contestations are understood as the process of disputing or arguing, which often characterises key moments of valuation in which social, economic and political issues are explored and settled (Antal et al. 2015). Stark (2009) views contestation as a form of search where actors struggle with the indeterminate nature of discovery (Dewey 1938), since actors may not know what they are looking for. In the marketization of science, the potential *'therapeutic target'* (e.g., HER2 or breast cancer) for a protein or antibody may remain unknown and unspecified for a considerable length of time (Osta et al. 2004). This is commensurate with observations that many TTOs in universities design processes that incorporate routine contestations whereby ideas can be interrogated, critiqued and explored, so that new searches for information, data and/or resources can be decided on (see Lockett et al. 2002; Lockett and Wright 2005). Stark (2009) argues that the deliberate organising of internal organisational contestations among a variety of actors can be central to success, precisely because contestations allow different values to be identified, explored, and ordered. Doganova and Muniesa (2015, p.120) see the 'choreography' of such contestations as critical in the marketizing process but provide little conceptual guidance. Thus, studying contestations at the nexus of multiple social worlds to understand how they are choreographed and what these choreographies do is likely to reveal deeper understandings of the marketization of scientific discoveries.

METHOD

This research used a qualitative methodology, which is well suited to the study of dynamic processes and the coordinated practices of multiple actors (Denis et al. 2007; Langley 2007). Because this type of qualitative, process research typically follows an object of change (Latour 1987), it is particularly sensitive to context, presenting a valuable means to focus on unfolding practices at the juncture where organisations encounter external market actors.

The aim of this study was *theory elaboration*, drawing on and extending important ideas from extant commercialization of science and market studies research. Theory elaboration is used when pre-existing ideas provide the foundation for a new study, without the need for purely inductive or grounded analysis (Maitlis 2005). This paper draws on an eighteen-month, longitudinal analysis of a single scientific discovery (AntiBod), situated in a bioscience incubator (SBC), and enrolled in a marketization process. We paid particular attention to the incubator context and to AntiBod's multiple, unfolding market encounters and their outcomes in a process of marketization (Langley et al. 2013; Latour 1987; Stark 2009). This design offered a strong foundation for elaborating theory: the initial study of the bioscience incubator setting allowed the meaningful comparison of social processes and practices involved in scientific discovery and bioscience incubation. The subsequent, in-depth analysis of the marketization of a typical scientific discovery allowed us to uncover and examine the practices, devices, and social world interactions that made the discovery valuable (cf. Geertz 1973).

Research Context

Our research question required a context where science commercialization proceeds at the nexus of social worlds (Clarke and Star 2008), which could be considered typical and representative of wider science commercialization settings (Yin 2009). We argue that science incubators and the companies located within them are particularly suited as a research context. Incubators nurture early stage scientific discoveries and the actors involved are often entrepreneurs, but also scientists employed by universities and research organizations (Mian et al. 2016). At the same time, incubators connect scientists to other market actors such as venture capitalists, consultants, and in bioscience, pharmaceutical companies (Bruneel et al. 2012), situating incubators at the centre of many marketization processes. As such, a nexus of social worlds is inherent in the day-to-day practice of science incubation. We conducted our study at

Stevenage Bioscience Catalyst (SBC): a not-for-profit incubator, formed in 2011 by GlaxoSmithKline (GSK), a major pharmaceutical company, the Wellcome Trust and the UK Government. SBC's remit is to support academic-entrepreneurs and incubate scientific discoveries, collaborating with universities in order to do so. Through our engagement with SBC we identified a particular scientific discovery, AntiBod, whose marketization we were able to follow over time.

Case Selection

The specific scientific discovery - AntiBod - was chosen to meet the study's aim: to map out the marketization process of a scientific discovery, to explain how it is made valuable. This discovery is from the largest category of the four at SBC: *therapeutics*. The tenancy of SBC comprised nineteen in therapeutics, four in manufacturing/technology, two in big data, and none in the diagnostics/devices category. Marketization practices for therapeutics therefore represented the most widely engaged in practices at the incubator.

During the initial stages of our study, AntiBod became a tenant at SBC. Studying AntiBod represented an ideal context to elaborate marketization of science theory, for three reasons. First, the marketization of therapeutics was becoming increasingly routine at SBC, typically featuring multiple actors engaged in routine, recursive interconnected, patterned actions recognisable as the early stages of a marketization process (Araujo and Pels, 2015). SBC's need to develop recursive practices that perform marketization, through multiple experimental actions with cases like AntiBod, make AntiBod a typical case. Second, the aim of AntiBod's *discoverer* was to marketize AntiBod. As such, the project did not revolve around the typical challenges associated with implementing a process: instead, the project provided a compressed opportunity to observe the practices associated with marketization, and more specifically in making specific activities and objects valuable and worth investing in (cf. Stark, 2009). Finally, from the outset AntiBod expressed an interest in engaging with multiple external market actors,

particularly other incubator tenants and GSK, suggesting opportunities to observe transformative market encounters at the nexus of social worlds.

Data Collection & Analysis: An Abductive Approach

Through our study of SBC and AntiBod we discovered that valuation practices played a substantial role in the process of marketization and these became the focus of our study. As valuation practices in a commercialization setting are a relatively unexplained phenomenon (Dussauge et al. 2015), we moved abductively between data collection and analysis (Charmaz 2006; Dubois and Gadde 2002), developing our understanding of the case and related literature concurrently, progressing our theoretical framework as we went (Figure 1). All three authors were involved in fieldwork, data collection and data analysis. This contextual immersion allowed us to interrogate the data and discuss the emerging conceptual argument in depth. Our abductive approach (Charmaz 2006; Dubois and Gadde 2002) to this marketization process study (Langley et al. 2013) followed three overlapping stages.

Stage One: The Marketization Context. We spent time observing events and incubation practices, interviewing staff, tenants and visitors at SBC. An important feature of incubation practice identified in this stage was that of bringing together individual academic scientists, pharmaceutical market development managers and bioscience entrepreneurs, each bringing their own devices to question and contest the marketization plans of tenants. We noticed the different ways in which actors understood commonly used terms (e.g. 'markets', 'business models', 'data'). This led us to select social worlds theory as a 'theory/method package' (Clarke and Star 2008, p.113), guiding a systematic analysis of three key social worlds: science, markets and entrepreneurship. We visited and interviewed academic scientists, academic-entrepreneurs, as well as pharmaceutical market development managers at GSK, enabling us to identify the norms, practices, symbols, and where relevant, the technical tools of their everyday work. We

used these observations to sensitize ourselves to the different materials and understandings (Fujimura 1996) actors brought to the marketization process. The description of these social worlds forms the analytical backdrop to AntiBod's marketization process.

Stage Two: Following a Scientific Discovery. Having developed a broad understanding of the incubation context we wanted to understand particular transformative market encounters (Langley 1999). We worked with SBC managers to identify a typical science discovery case (Yin 2009) to follow through the marketization process (Latour 1992). We selected a *'superior antibody'*, referred to here as AntiBod. As with many scientific discoveries entering an incubator, AntiBod was still 'just an idea' and its scientific *'proof of concept'* (SBC1) was only partial when we first encountered it. Drawing on interviews, documents and observational data we followed AntiBod for 18 months. During this time, we never knew what would happen next, so we treated the whole process as an inquiry into an indeterminate situation (Dewey 1938), recording sequential pragmatic steps as they unfolded.

Four key concepts were used to both explain stage one observations and further develop our conceptual framework (Figure 1): the notion of *choreography* (Doganova and Muniesa 2015) was appealing but poorly conceptualised, so we additionally drew on conceptualisations of valuation practices (Helgesson and Muniesa 2013; Kornberger et al. 2015) and market device (Kjellberg et al. 2015) to help us understand what a *choregraphed contestation* was and how it worked in practice. The fourth key concept, social worlds (Clarke and Star 2008), enables us to unpack relations between valuation practices, market devices and actors, revealing how and why these specific forms of contestations were choreographed, the types of valuations they performed and the outcomes they produced (Table II). We noticed how valuations shifted between activities (e.g. information searches), objects (e.g. IP, proof of concept data) and institutions (e.g. AntiBod as a limited liability, IP owning company), to generate powerful associations between different market actors. This happened within and across contestations.

Ultimately, we identified six contestations (C_1-C_6) that produced key moments of valuation in the marketization process of AntiBod (Figure 2).

Stage Three: Conceptualising Choreographed Contestations. Finally, we compared the six contestations, in multiple iterations, to form a conceptual interpretation of the recursive interplay of market devices and valuation practices at the science-market-entrepreneurship nexus. This resulted in the crystallization of our conceptualisation (Figure 1) and the three conceptual observations (Table III).

Summary of Data

The abductive process described above drew on three main sources of data from a range of businesses connected with bioscience, SBC and AntiBod, collected over 34 months (Table I).

INSERT TABLE I HERE

Interviews: We conducted 53 semi-structured interviews (Denzin and Lincoln, 2008) with SBC managers, experts, tenants, and participants from *'big pharma'* and bioscience start-ups at workshops we observed. These interviews evolved as the study progressed, capturing insights into the organizations and their interactions. In stage one we asked participants to describe their activities and their understandings of their work, who they met with, what they took into meetings, what they did as a result of meetings and what they planned to do next. This enabled us to collect data on valuation practices and market devices used, and to draw out the multiple interpretations of events that exposed the importance of social worlds as a conceptual lens. We carried out regular interviews at AntiBod. Interviews were transcribed verbatim.

Observation: By attending key events organized by SBC, we observed the nexus of academic, market and entrepreneurial worlds in action (Latour 1987). Specifically, we observed four events: two *'Open Innovation Summits'* (which included presentations, panel discussions

and workshop sessions), a business model workshop, and a specialized workshop for scientists hosted by the Entrepreneur-in-Residence on the convergence of biosciences and information technology. Two authors attended each of these events and took detailed notes. Open Innovation Summits were video recorded, enabling in-depth analysis.

Documentation: Forty-six documents were made available for analysis. SBC provided strategy documents, board minutes, slide decks, management accounts, and documents describing the firm's business model and the CEO's understanding of markets. Collectively, these documents provided an in-depth understanding of SBC's operations, how it engaged in valuation, and communicated its role. Other documents related specifically to AntiBod, and included various versions of AntiBod-related presentations.

THE MARKETIZATION OF SCIENCE: THE CASE OF ANTIBOD

In this section we present the marketization process for 'AntiBod', a scientific discovery. We first describe the characteristics of three social worlds encountered in this process, then follow the marketization path of AntiBod through a sequence of six choreographed contestations at this nexus of social worlds (Table II).

INSERT TABLE II HERE

Three Social Worlds

The social world of academic science involves juggling teaching, research, grant writing, and administrative roles such as *'running a lab'* (Sci5), or *'co-ordinating the MSc Programme, and courses'* (Sci6). The talk in offices and corridors relates to *'organisms'*, *'antibodies'*, *'molecular and cellular levels…pathogens'*, *'control measures [and] vectors'*. Scientists talk of the *'wet lab'*, the '*microscope'*, and the *'bench'*. Scientific knowledge is circulated at conferences and through publications, which act to validate expertise and provide the legitimacy required to secure future funding streams. The social aspects of performing and

evidencing *'good science'* and *'scientific outputs'* are celebrated and rewarded. But what qualifies as good science is not always straightforward:

> *'[the goal is to publish in] Nature…recognising that it can still be a good story and good work but it is actually probably only of interest to people who work on trypanosomes. …the community was, perhaps, a bit more grounded 30 years ago. Now, I think everybody, because of all the promotional pressures and REF [Research Excellence Framework] pressures and what's the star rating of your journal, everybody's being pushed to go for that highest-ranking journal.'* (Sci5)

The social world of the market is where market development managers (often, heads of R&D with strong scientific backgrounds) engage with their role-specific practices and norms: identifying, describing and representing markets and seeking opportunities for market development and commercialization. To ensure brevity and relevance to our case, we focus on the global pharmaceutical company GlaxoSmithKline (GSK), and more specifically the groups within GSK that work with academics and incubators. These groups are concerned with advancing science for commercial ends, working to present a clear economic understanding of science and its potential markets. At the UK research site, these market development managers work with over 2,500 scientists, and recently, with academic entrepreneurs, to explore drug discovery opportunities.

While many people have PhDs, are actively engaged in scientific activities, and are managed by or managing other groups of scientists, they are defined by the commercial context where scientific talk is accompanied by talk of '*budgets*', '*spreadsheets'*, '*timelines', 'global demand' 'market size'* and *'therapeutics'* (GSK1,7,9). GSK has well developed organisational practices and budgetary processes to manage multiple ongoing R&D projects. The Global Head of Academic Liaison is responsible for some 500 new collaboration agreements every year:

> *'We're not a research council or an altruistic [organization]…we have to make money somewhere down the line. We hopefully do that through doing world leading science with external people who do world leading science…there's something in it for everyone…that's how I honestly see it.'*

This social world has been described by commentators as *'problematic'* with some claiming that *'drug discovery [is] in jeopardy'* (Cuatrecasas 2006, p.2637). Six big pharma companies dominate the market, and struggle with an *'inward-facing culture'* (SBC1). This underpins the rationale for developing better ways of connecting scientists with *'new communities'*, allowing them to understand, interact with, and build *'knowledge-sharing relationships'* (GSK3) with those who inhabit other bioscience worlds:

> *'There's a more explicit recognition within big pharma that you can't afford to do everything yourself internally. Everyone is cutting back, shrinking their organisations, therefore you've got to go and look externally for new science, alternative expertise, etc.'* (Scinovo; GSK7)

While pharmaceutical companies already had some expertise at working with university scientists, SBC aimed to connect more potential academic entrepreneurs with GSK.

The social world of entrepreneurs is reflected in the founding vision and management practices of SBC. The original idea of creating an incubator came from a senior GSK Vice President, after spending time at the Berkeley Innovation Forum[ii]. SBC's purpose is to promote different knowledge sharing practices to support scientific and business development; it opened in 2012 to incubate scientific discoveries through academic entrepreneurship. SBC is *'much more than a landlord selling space to biotech start-ups'* (SBC2), and the language of tenants and managers reflects this with coffee-table discussions and workshop talk referring to *'open innovation', 'partnering'* and *'business models'* (Sci5,7,11); *'funding', 'grants'* and *'Discover-Assist'* initiatives play a role (SBC2,5).

The selection of *'natural collaborators'* as *'anchor tenants'* early in SBC's life is indicative of the oft-heard mantra of *'getting it'*: understanding the value of being part of an academic-entrepreneurial community. This is important when selecting tenants:

> *If their first question is, 'What does it cost?' then I'm not interested. They can go down the road where the rents are lower; that's fine. But if they're excited about being part of the ecosystem, about the connections we can make for them, then they are right for us.* (SBC1)

Regular formal and informal mentoring meetings with the SBC management team provide access to advice. Other activities include monthly tenant lunches, short scientific presentations by tenants, informal *'beer and pizza'* socials, and informal *'cajoling'* by the CEO to engage in the community:

> *It's all about connections. It's all about people at the end of the day, and you need all those different elements working together rather than in isolation to make that happen. ...the event we had yesterday, to have the industry people, the NHS [National Health Service] people, the investors, the clinicians, the students, all in one room together to make those kinds of things happen.* (SBC1)

We now look at how actors connected to these three social worlds worked together to marketize AntiBod. We pay particular attention to how they invoked, assigned meaning to, contested and generated market devices and valuations at the nexus of social worlds.

Following a Scientific Discovery through the Marketization Process

In April 2014, Maria, a scientist (Sci1), worked in her lab in an academic institution. As part of a large, 4-year funded project, she used antibodies to study the genetic pathways associated with Alzheimer's disease. But there was a problem - the antibodies in the test tube were not labelled correctly. Sharing an academic paper by Bordeaux et al. (2010), she explained:

> *'Antibodies are among the most frequently used tools in basic science research and in clinical assays, but there are no universally accepted guidelines or standardised methods for determining the validity of these reagents. For commercially available antibodies, it is clear that what is on the label does not necessarily correspond to what is in the tube. To validate an antibody, it must be shown to be specific, selective, and reproducible in the context for which it is to be used.'*

The problem of *'antibody specificity'* led to a market search that found no solutions: *'I had to invest a lot of money…£20,000, to validate antibodies for the research.'* Maria's work, to develop *'reliable, highly specified antibodies',* (Sci1) resulted in scientific discoveries, in terms of both the antibodies and the process to produce them. As Maria peered through her microscope looking for the specificities of AntiBod, she considered the market. If such highly specified antibodies were so valuable to her, perhaps they would be to other researchers.

So began a process of transformation that would take AntiBod through a sequence of six key contestations (Figure 2), on a path from initial scientific discovery to economically valuable product in the therapeutics market.

INSERT FIGURE 2 HERE

C_1: Contesting the initial market representation (Jan 2015)

Maria encounters the world of entrepreneurship for the first time when she visits life-science incubators. *'I looked at other incubators in the region and then the Stevenage Bioscience Catalyst – I didn't want to move cities… for the time being I will not give up my academic position – until I know that the business … is flying.*'

At SBC Maria meets Martino, SBC's CEO, who will become her mentor. She was asked to bring a two page '*summary'* describing the business idea, the science that needs developing and the markets it will be of value to. *'The size and nature of market opportunity'* are described

as *'the market for diagnostic and research antibodies'* which, it is claimed, *'has an estimated annual turnover of $8bn and $2bn… respectively, is highly competitive and comprises about 300 companies with more than 350k commercial antibodies'* (BM1). Martino asks, *'Why the diagnostics market? … Where did you get these figures from?.... How would your business model fit with this [market]?.... What don't we yet know?... Is there a bigger picture here?'* Martino encourages Maria to *'put it out there'* by speaking to others. Maria takes notes, and draws a diagram in the margin of the summary documents.

There are multiple outcomes to the meeting. Martino challenges the *'facts'* about market scope and scale, sending Maria to search for further market information, suggesting a meeting with the entrepreneur-in-residence, Helen (SBC4). Other outcomes include Maria's adoption of some of Martino's language - the *'summary'* becomes *'the first incarnation of our business model'* (BM1; Sci1); the market now has *'scope and scale'* (Sci1). Martino persuades Maria that there is *'real value'* in AntiBod being incubated at SBC, *'…and actually there are already two other antibody companies …there could be a synergy within SBC for antibody production or validation'*, (SBC1). AntiBod is now a discovery worth investing in and Maria becomes a tenant at SBC, getting access to labs, and management advice from her new mentor: *'…once every two weeks I'm over, keep contact or go to some talks or have meetings… Martino always has the bigger picture in mind….. [He] is a very open and experienced guy'*, (Sci1).

C_2: Contesting how the market is represented in a grant application (Feb 2015)

Maria, Helen (the entrepreneur-in-residence), and someone from a grant funding body (F1), meet. Maria shares a description and images of AntiBod, but wants to explore Martino's comments about the *'scope and scale of the market'* as this will be part of an InnovateUK[iii] *'smart'* grant application to fund AntiBod's development. The grant scheme supports three types of projects *'Proof of Market (up to £25,000 grant), Proof of Concept (up to £100,000 grant); Development of Prototype (up to £250,000 grant)'* (InnovateUK, 2015, p. 2); it is

uncertain which is appropriate because Martino had questioned the scope of the *'diagnostic market'*; the group look at the 'rules': *'[…]academic institutions are not eligible. However, a spin-out that is less than 50% owned by its academic parent may be ….'* (InnovateUK, 2015, p. 3). This raised a more pressing issue – *'so you don't actually own the IP yet'* (SBC4).

A discussion about IP follows. Helen talks through a patent application process and flags this as *'critical'*. Maria pushes back, explaining that the process of producing AntiBod is not always reliable and the antibodies themselves are still somewhat *'uncertain'* (Sci1). Helen asserts that only *if* the process were made reliable, and the antibodies more highly specified, would other scientists buy them. The outcome of this contestation is that understanding and improving the production process for AntiBod is now important, for both scientific development and IP protection; as important as AntiBod itself. This identifies the science that must now be done, and the evidence that must be collected. It shifts Maria's focus to *'the market for the production of other antibodies'* and to new questions: *'who else is producing antibodies? How are they doing it? How is AntiBod's process different?'* (SBC4).

Another outcome is an amended grant application that now says *'more about the business model and who this is likely to be of interest to [the market]'* (F1). The meeting provides Maria with guidance for further market research using the competitor intelligence bioscience data, Medtrack[iv], which details *'all antibody producers in the market'* (SBC4). Finally, there is an instruction to *'secure your intellectual property [IP] ASAP! [As Soon As Possible]'* (SBC4). The contestation reveals that the IP probably belongs to Sci1's employing institution. Both market intelligence and IP associated with AntiBod have been made valuable.

C_3: Contesting the Institution's IP Ownership (Feb 2015)

Maria meets with her Head of Department (HoD) and a Technology Transfer Officer (TTO) from her academic institution. The TTO explains that as Maria has created new materials [AntiBod] which might help in creating *'a therapeutic'*, AntiBod and its production process are

patentable. If the *'expensive work'* (TTO2) of securing a patent was successful, then the next stage for the TTO would be to try to partner with industry, probably *'big pharma',* to do clinical trials. However, the TTO's opinion is that AntiBod is not worth patenting as there is no proof-of-concept data to show that AntiBod can be reliably reproduced. Since further development is needed to stabilise the process, the HoD has no objections to surrendering IP ownership to Maria but tensions emerge about who will be responsible for the costs of this work, in terms of both time and lab resources. The meeting concludes with the agreement that the TTO will pursue this with higher authorities in the institution. This is a protracted contestation because the IP to be *'given away… has to be specified, much as a patent would be'* (TTO2). This contestation extends over eight months before Maria tells us *'I have the letter …I have full ownership of the IP!'* What is significant in this contestation is that the TTO's evaluation that AntiBod was *not* worth patenting is what makes the scientific discovery valuable to Maria, and in so doing holds AntiBod in place in the marketization process. The IP specification enables the calculation of AntiBod's market value.

C_4: Contesting AntiBod's Business Model (April 2015)

SBC organizes a business modelling workshop for its tenants. The workshop instructor uses the Business Model Canvas[v] (Osterwalder and Pigneur 2010), and explains to Maria how this framework asks questions of AntiBod's research programme, which must generate data that evidences the validity and value of AntiBod and its production process. Key activities, resources, partners, value propositions, customer relationships, channels to market, customer segments, and cost structures are used to represent *'the known and the unknown, the real and the imagined'* (SBC3). Maria is pushed to explain how these business elements combine to generate revenue. There are tensions as Maria struggles. Other participants (all SBC tenants) contribute to the discussion, and consider their own business model *'challenges'*. Later, Maria reflects on what she does and doesn't yet know about the *'superior antibodies'*, together with

the more detailed market overview she is working on, to create the *'persuasive case'* for another grant application. An outcome of this contestation is that Maria has a more detailed narrative about how AntiBod will be developed, where the initial resources are likely to come from, and what will be needed, but the idea of *'customers'* is still vague. She now talks about the importance of *'investors'* and how she might use the business model to engage them.

C_5: Contesting the Connection with the Therapeutics Market (June 2015)

Maria presents her new business model (BM2) to the SBC panel, which includes managers from Ely Lily[vi], two industrial consultants, two other bioscience entrepreneurs and Maria's mentor from SBC. BM2 takes the form of a 14-slide presentation titled: *'Developing superior antibodies by a novel integrative screening platform'*. The business model is presented in terms of *'the problem', 'the solution'*, and *'the opportunity'*, incorporating scientific images of antibodies. Richer descriptions of the antibodies and the process by which these *'superior antibodies'* are made *'reliable'* and *'highly specified*', circulate amongst the panel (Figure 3). The antibodies are developing their own identity as important actors.

BM2 reframes the market. The previous description had been *'the market for diagnostic and research antibodies'*. The reframed market is referred to as *'the market for antibodies'* incorporating three distinct market segments: the research antibody market ($2bn with 400 antibody companies worldwide); the diagnostic antibody market ($8bn with 60 diagnostic companies worldwide); and therapeutic antibody market ($70bn). The size of each market is evidenced with citations from peer-reviewed scientific journals. The presentation provokes some excitement about the opportunity to engage with the '*much larger therapeutics market'* and the panel push Maria to answer difficult questions about how this might be done. She doesn't have answers but acknowledges the significance: *'... so it's a much bigger market and much more important investors are interested…'* A panel member explains, '*if you can connect [AntiBod] with the therapeutics market – then bingo!'* (SBC7).

INSERT FIGURE 3 HERE

One panel member suggests meeting the GSK antibody group, to help Maria develop the business model: *'they [GSK] will be able to tell you exactly what you'd need [data] to convince them….'* (P3). The suggestion receives strong support, as panel members recommend questions to put to GSK.

The outcome of this contestation is that the group have imagined a connection between AntiBod and the S70bn therapeutics market. This would significantly raise the value of AntiBod and its production and specification process. The possible connection to GSK could open up an opportunity for partnership or exchange – Maria could sell AntiBod to GSK. Martino (SBC1) makes a call to GSK to fix the meeting. GSK are invoked as the market actor that can establish clear routes to economic value.

C_6: Contesting the Scientific Requirements of the Therapeutics Market (July 2015)

The GSK meeting takes place a month after the expert panel, and Maria makes her presentation. The conversation focuses on *'the [therapeutic] target'*. Maria explains why AntiBod is so significant for the health market by contrasting the impact of an existing drug therapy [chemotherapy] with that of an antibody therapy on a cancer target:

> *'…with chemotherapy it is not the case that there is a specific target. In chemotherapy it turns out that the tumours are more resistant to the toxicity of the chemotherapeutic agent than the healthy tissue - because tumours develop […] multi-drug resistance. So treatment is very complex and very difficult. This is why there has been a paradigm change towards antibody treatment.'* (Sci1)

GSK suggest that the target *'must be a target that people understand'*. The therapeutic target HER2[vii] (breast cancer) is recommended. Maria should identify antibodies against this target:

'…What I take home from this discussion [with GSK] is that for a proof of concept it's best to use a target that is well understood in pharma. […] For example, HER2 EGF receptor – all these receptors where a lot of data is available.' (Sci1)

The discussion raised important concerns about demonstrating AntiBod's potential value:

'…so the data package that I have to get is proof-of-concept experiments, in order to go back to investors and say this is the technology we have, this is the proof-of-concept experiment and this is the data …' (Sci1)

Maria sees the specific forms of data needed to make AntiBod valuable. The activities required to produce such data are now clearly specified and worth engaging in.

'*what would be very important … would be to have data from a tumour mouse model - and what we are doing* per se *is with a set of antibodies, is go through tissue slices from cancer patients, tumour versus controls, to see if there is differential binding of antibodies to patient but not to control tissue.*' (Sci1)

An outcome of this contestation was the third incarnation of the business model (BM3). The market and the science are reframed: the market as *'much bigger'* and the science as *'more tightly characterised and specified.'* (SCi1)

CONCEPTUAL INTERPRETATION AND THEORETICAL IMPLICATIONS

Our conceptual interpretations of the empirical analysis are synthesized into three theoretical observations, which describe: the characteristics of choreographed contestations (O_1), the mechanisms through which they operate (O_2) and how specific valuations are perform (O_3). These observations and their conceptual underpinnings are synthesised in Figure 1, offering a visual representation of our key contributions. Below, we discuss the implications of each observation for existing theory in more detail.

O_1: Scientific objects are transformed into marketable, economically valuable objects by a series of unfolding choreographed contestations at the nexus of social worlds.

Conceptual interpretation: Our findings show how a series of choreographed contestations incrementally transform scientific discoveries into marketable, economically valuable objects. Contestations were not chance events; they were 'choreographed'. Our conceptualisation of 'choreography' is a nuanced yet crucial finding. Contestations at the nexus of social worlds enrol particular actors. Yet, the choreography of contestations does not imply that the sequence of contestations follows a plan that is determined *a priori*. Rather, from each contestation new matters of concern emerge, different forms of knowledge become valuable and worth investigating, and different market devices are created that suggest new valuation practices for later contestations: C_2 was conceived as a grant application discussion, yet the importance of IP ownership and the scientific data needed to secure IP were the significant outcomes, leading to the next significant contestation.

Only when considered collectively (and retrospectively), can the sequence of choreographed contestations be understood as a goal-oriented, programme of action (Latour 1992) for the marketization of science (Figure 2); a process which progressively disentangles the science from its laboratory home and entangles it into the social worlds of markets. While the long-term goal may be to transform science into a marketable object, how this is achieved only becomes apparent as each moment of valuation unfolds the next. Thus, *choreographing* (Doganova and Muniesa 2015) such contestations in an unfolding process of *working out* what is valued, offers a mechanism through which the dissonance created through the collision of discourses, symbols and understandings underpinning different social worlds can be surfaced productively and acted upon, one innovative step at a time.

Theoretical implications: These findings extend existing research on the commercialization of science and market studies. While the commercialisation of science

literature focuses on the structural and resource conditions of science commercialization (Dodgson et al. 2011; Lockett et al. 2002; Roseira et al. 2014), and the need for specific skills and expertise of organizational '*insiders'* (Lockett and Wright 2005, p.1047), research on markets takes an external, interactive view (Araujo 2007; Callon and Muniesa 2005). By drawing on social worlds theory (Clarke and Star 2008) to bridge these perspectives, we develop a nuanced conceptualisation of choreographed contestations as a critical mechanism for the marketization of science (Figure 1). In so doing we show how multiple and varied valuation practices of internal (Stark 2009) and external (Fisher et al. 2016) actors are brought to bear on the marketization of a scientific object through choreographed contestations. This acknowledges the generative interplay of market actors, spanning diverse social worlds, in creating the sequence of goal-directed actions that constitute the marketization of science. By introducing social worlds theory to the conceptualisation of choreographed contestations we emphasise the importance of diversity in the histories, norms and practices of actors that become enrolled in the marketization of science. Thus, we explain how managers can begin to organise productive market connections to generate development pathways through the valuations they peform (cf. Cooke 2001; Fisher et al. 2016; Rasmussen et al. 2011).

O_2: Valuations are framed and fixed by the choreographed contestations and market devices they use.

Conceptual interpretation: The framing of valuations determines who or what is of concern and to be taken into account, while fixing holds those temporarily framed relations, objects, and ideas stable so that they can be collectively contested (Finch and Geiger 2011). We consider first the nature of the choreography that takes place prior to a contestation, and secondly the adoption and production of market devices both before and within a contestation.

First the choreography frames and fixes the form the valuation takes: determining which market actors do the valuing, through which market devices. Thus, choreographed contestation

act as market encounters that value. In some instances, the choreography is tight, identifying very specific actors, practices and value outcomes: C_4 took tenants through a well-structured business modelling process. In other instances, the choreography is much looser, creating more exploratory contestations: C_5 brought together key individuals and social worlds in a loosely controlled exploration of possible next steps, where various experts could ask challenging questions as they calculated what was worth doing and with whom. We also observed tight choreographies, which led to quite different outcomes to those imagined: the grant application contestation, C_2, is an example of this. In each case, the choreography frames and fixes the form the valuation takes: imagining and arranging contestations that bring multiple evaluative norms, principles and devices into play.

Secondly, market devices frame and fix what is to be valued within each contestation; what is socially and economically valuable, and so *worth* doing. Framing and fixing, through the production of visual or discursive representations, enable actors to bring together valuing practices from different social worlds. Valuations are made by contesting these momentarily fixed and shared representations. In C_1, the combined representations of the business, the science, and the market act as the instruments of valuation. Knowing what is being valued (e.g. the market for antibodies) generates an information search judged valuable (i.e. who are AntiBod's competitors?). In each instance, market devices act *through* valuation practices to mutually constitute one another. Valuations frame the next steps worth pursuing, the market actors worth enrolling, and the new knowledge worth searching for. In this way, valuations of knowledge hold the scientific 'asset' in a state of ambiguity so that it can first be made open to multiple ways of redefining, combining and deploying resources for its development, in a process of working out the next innovative steps. These practices are discussed in O_3.

Theoretical implications: The framing and fixing of valuations as a mechanism of marketization has important implications for research on the commercialization of science. We

complement extant research on the institutions of science commercialization such as property rights (Debackere and Veugelers 2005; Lockett et al. 2002; Lockett and Wright 2005), licencing agreements (Lockett and Wright 2005; Siegel et al. 2003) or networks (Baraldi et al. 2014; Walter et al. 2006), with understandings of the materials and practices through which valuations are performed (Callon and Muniesa 2005; Pénet 2015; Pollock and D'Adderio 2012). In so doing, we provide a deeper understanding of the co-ordination and performance of distributed marketization work. Because the expertise required for marketization is distributed across multiple markets, social worlds, devices, and time (in the emergent nature of choreographed contestations), the need to co-ordinate and manage collective efforts of valuation are critical. Framing and fixing valuations enables mini market encounters to collectively experiment and test taken-for-granted market and scientific facts and norms, and opens new opportunities for market action.

The notion of framing and fixing valuations also has implications for how academic spin-offs are valued. Extant research problematizes current spin-off valuation practices, warning that using historical, forecasted or comparable IP development costs to calculate start-up value disconnects them from market value opportunities (Carte 2005; Clarysse et al. 2007). This is problematic because public or 'soft' funds skew development costs (Moray and Clarysse 2005; Wright et al. 2006), inflating early capital valuations, potentially deterring future investment (Clarysse et al. 2007). In contrast, our framework suggests how market-focussed representations, business models in particular can be used to frame and fix what is to be taken into account when valuing the business, in ways that open up connections to multiple market opportunities, enabling multiple market actors to calculate and contest such valuations. Our claim is that business models do more than 'capture value' through their representation of an 'architecture of the revenue' (Chesbrough and Rosenbloom 2002, p.529). Rather, using business models as valuation devices shifts us away from historical development cost analysis,

to focus instead on emergent, future market connections and potential market share as a basis for valuation. This performative view of valuation assumes the co-production of powerful, shared imaginings represented in business models, which shape the unfolding actions of investors and other market actors as academic spin-offs are valued.

O_3: Valuations are generated by holding market devices in dialogue, with each other and with multiple social worlds.

Conceptual interpretation: Our analysis reveals *how* new valuations are generated. The production of new valuations, both for the scientific discovery and for the activities that make the discovery valuable to specific market actors, are a central part of the marketization process. In each choreographed contestation, market actors hold multiple market devices in dialogue: (a) with each other: contesting market and scientific knowledge, raising concerns and generating new directions for their inquiry; and (b) with multiple social worlds: to explore alternative interpretations and framing of problems and challenges. For instance, C_1 holds three market devices in dialogue (the science, the market and the business model), framing the specific concerns associated with three social worlds. This contestation produces new valuations: of potential markets, of competitors, and the importance of identifying new questions as AntiBod begins to disentangle from the small market of diagnostics and research antibodies, and entangle into the larger markets of therapeutics and market investors. In other contestations, the valuing process reveals tensions: in C_3 conflict threatens as our scientist and her institution work out what the AntiBod is worth, who it might be of value to, and the work needed to realise that value. There is no consensus here, but this ambiguity enables Maria to secure the IP.

Thus, contesting one market device, by holding it against other social worlds and market devices, enables actors to collectively produce new valuations that take into account the plurality of valuing principles at play, without requiring consensus. Such contestations can hold

key valuation devices in a state of constructive ambiguity, producing generative tensions that disrupt market categories by reimagining and reassembling resources.

Theoretical implications: While the commercialisation of science literature goes some way to recognising the challenges and tensions typically experienced by academic-entrepreneurs (Perkmann et al. 2013; Siegel et al. 2003; Siegel and Wright 2015a), our research goes a step further. In combining market studies (Callon and Muniesa 2005; Kjellberg et al. 2015) and social worlds theory (Clarke and Star 2008), we foreground the role of market devices in the *'disentangling'* of scientific discoveries from the social world in which they were produced and entangling them in the social world of markets. We have seen how the practices that span social worlds disrupt and change them both, through moves to re-organise market interactions at their nexus. This observation offers a nuanced view of market devices in practice; in the production of valuations. It also explains the process by which the market devices are transformed. In so doing, we extend Grimaldi *et al.'s* (2011) and Perkmann *et al.*'s (2013) understanding of the work of academic-entrepreneurs by showing how they engage collectively, with other market actors, in the substantive work of transforming both science and markets through valuation practices: re-searching and re-presenting market and scientific knowledge in ways that make scientific discoveries valuable to specific groups of market actors. We see how they forge powerful associations not only between the scientific discovery and the concerns of broader social arenas, but also with the concerns of multiple market actors.

CONCLUSIONS: Theories from the Lab to Future Research

Based on the accepted premise that market connections are central to the commercialisation of science (Cooke 2001), we theorize *the marketization of science*. In so doing, we advance extant research on the commercialization of science by recognizing that the valuation of scientific discoveries occurs in market encounters at the nexus of social worlds, through what we call *choreographed contestations*. Choreographed contestations challenge what is collectively

valued - socially and economically, now and in the future – through a process of actors collectively *working out* what needs doing to transform both the scientific discovery and the market in relation to one another, so that exchange can happen. Our analysis reveals the characteristics of choreographed contestations (O_1), the mechanisms through which they operate (O_2) and explains how specific valuations are performed (O_3). By presenting a framework for choreographed contestation and by identifying the associated valuation practices, we hope to stimulate further inquiry into the dynamics of market interactions with scientific discoveries.

A limitation of our study is that data collection began at the point of incubation. We encourage research that analyses commercialization across multiple sites over longer periods, to capture the different institutional regimes that influence the nexus of social worlds. Our approach also neglects non-bioscience settings, where different social worlds, market devices and valuation practices may be implicated in marketization. We encourage future research to adopt a comparative approach, examining multiple discoveries across sectors, to identify context-dependent patterns of choreographed contestations. Despite these limitations we think our *theories from the lab* have broader implications for future research.

The incubator site itself raises interesting questions about the changing form of academic entrepreneurship (Siegel and Wright 2015a). When we looked at the commercialization of science literature, many studies focused on university incubators (Jamil et al. 2015; Kolympiris and Klein 2017). SBC is different. We argue that the practices they adopt to make scientific discoveries valuable have implications for how incubators themselves are made valuable. We agree that extant measures of incubation success are lacking (Siegel and Wright 2015b), and argue that the study of valuation practices stands to make an important contribution to the development of performance management approaches for these new institutional forms of incubation. Only by valuing the management practices needed to choreograph contestations as

innovative and productive market encounters, do we stand a chance of developing accountability practices that perform the kinds of incubation and entrepreneurship we need. We see this as a valuable opportunity for future research.

Our conceptualisation of the marketization of science adopts a performative view, seeing markets as the coordination of distributed agencies, where theoretical and practical knowledge and skills develop in an unending process of designing and managing markets (Çalışkan and Callon 2010). While our focus is on how a scientific discovery is made valuable, our findings also reveal the role of the academic-entrepreneurs and others in making this happen. We argue that the practices they perform are likely to change institutions, but our focus here is a specific institutional form - markets. Exploring how these practices are beginning to change universities and other associated institutions seems worthwhile. Other studies have begun to explore this ground, considering commercialization and other forms of engagement, where individuals play a critical role in change (Perkmann et al. 2013). By conceptualising these actors as institutional entrepreneurs - '…who have an interest in particular institutional arrangements and who leverage resources to create new institutions or to transform existing ones' (Maguire et al. 2004, p.657) - we see opportunities to study how, collectively, actors create new systems of meaning that tie the functioning of disparate sets of institutions together (Garud et al. 2002). While these insights go beyond the scope of this paper, we hope that our *theory from the lab* inspires further research in this field.

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Figures

Figure1. A Conceptual Framework of Choreographed Contestations in the Marketization of Science

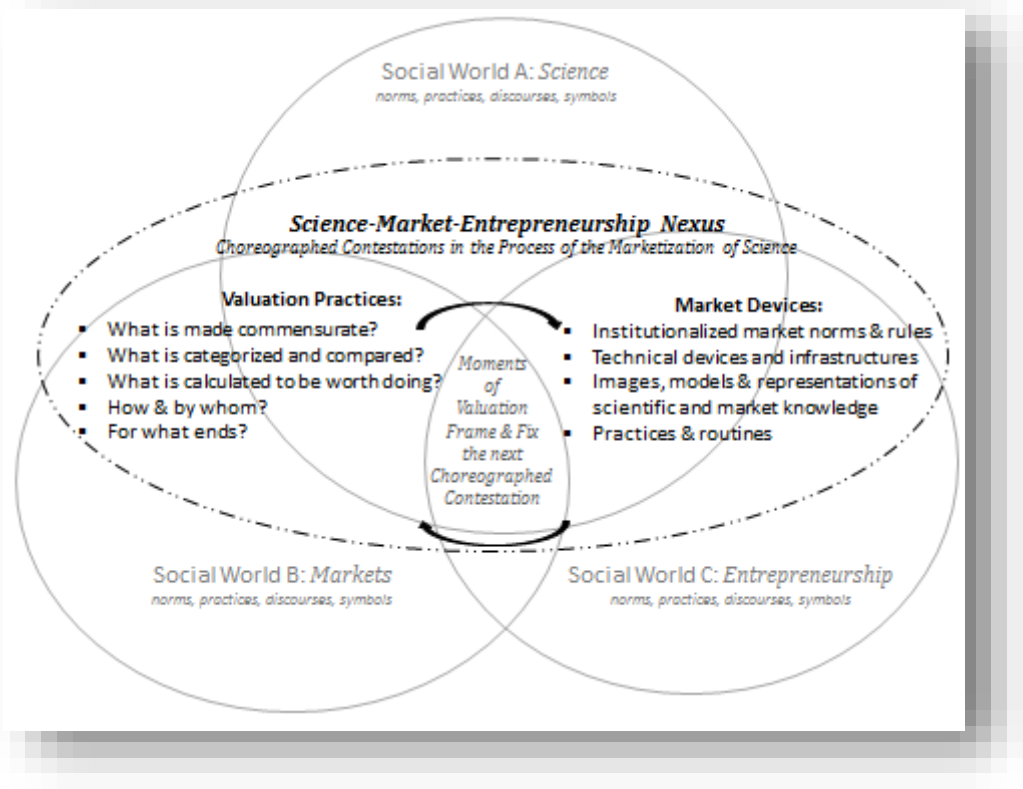
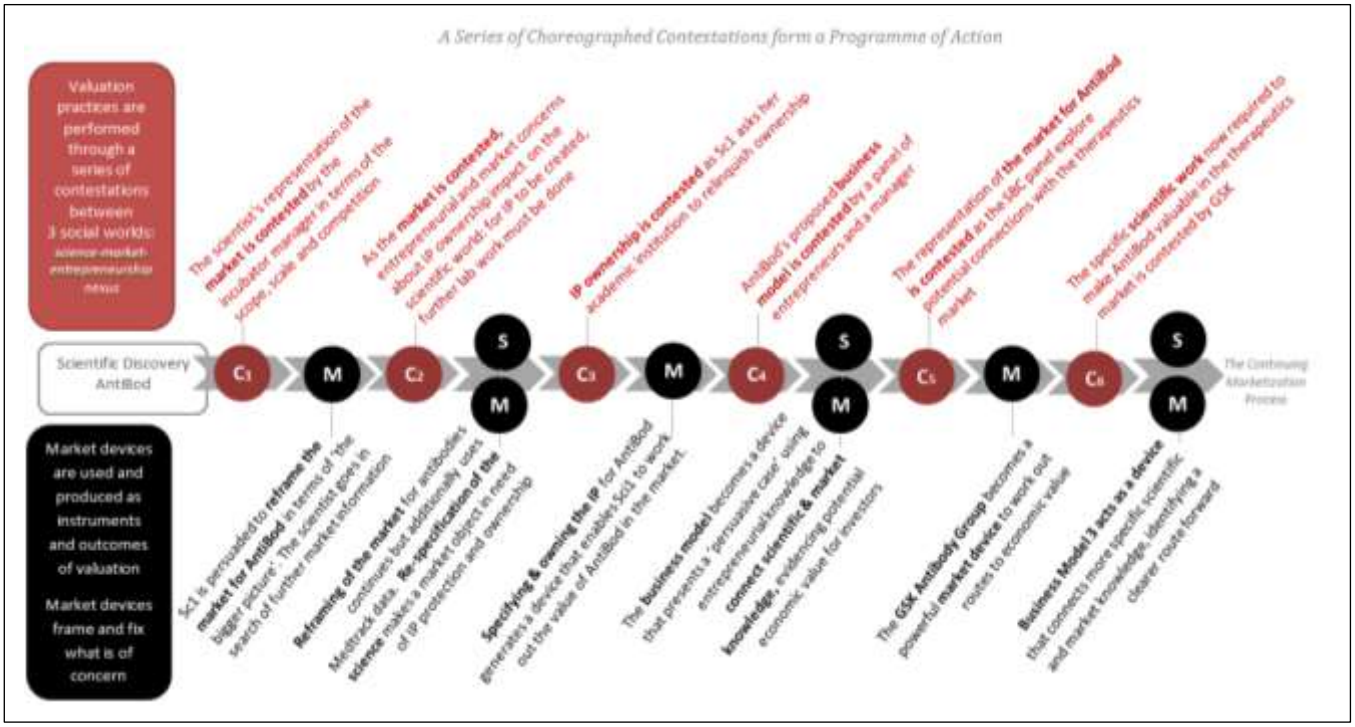


Figure 2: The Marketization Process of AntiBod



Key:

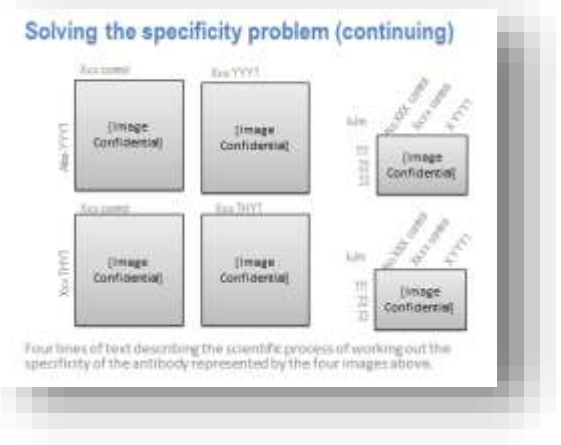
C1 Contestation of Market Device across multiple social worlds

M Transformation in some element of the *market* (as an outcome of the contestation)

S Transformation in some element of the *scientific discovery* (as an outcome of the contestation)

Figure 3: Slides 6 and 7 from Business Model BM2

Note: These slides have been altered to provide the reader with an impression of the information as it was presented but to protect the confidentiality and intellectual property of the scientist.



TABLES

Table I: Summary of Data Collected

Timing	*Interviews**	*Documents & Videos*	*Events attended*
July 2014	5x Interviews with SBC tenants (academic-entrepreneurs and academic scientists)	Tenants' Documents that represent tenants' business models Press Releases, white papers	
	3x Interviews with SBC Managers	SBC documents that represent SBCs understanding of its business model; strategy documents and slide decks of presentation to board	Workshop hosted at SBC on 'The Convergence Agenda'
	2x Follow-up video interviews with SBC tenants (scientists)	Further documents that represent SBC's business model; press release; video footage of open innovation summit	
October 2014	5x Interviews with SBC tenants (scientists)	Press releases, newsletters, press cuttings, official notes produced from workshop	
	3x Interviews with SBC Managers.	Grant Forms	
	4x Interviews with workshop attendees: entrepreneurs in the biotech/bio-pharma area 2x Follow-up video interviews with workshop attendees in the biotech/bio-pharma area	Summary document from 'Convergence Agenda' workshop; White papers from Open Innovation	
January 2015	5x Interviews with SBC tenants (including AntiBod Scientist) 3x Interviews with SBC Managers	Revised business models of Tenants AntiBod Summary document New SBC strategy documents, and pitch for 2nd phase of campus expansion	Open Innovation Summit: hosted by SBC, with 200 key industry players & start-ups in attendance
		Revised business model of SBC	
April 2015	3x Follow-up video interviews: AntiBod, Scinovo, Funder	AntiBod BM1; Grant Forms; SBC Newsletter	Business Model Canvas Workshop
November 2015	3x Interviews with SBC tenants (academic-entrepreneurs and academic scientists including AntiBod)	Activities audit report commissioned by SBC, independent consultant SBC Newsletter; Patent application form	
June & July 2015	3x Follow-up interviews SBC Managers, Scinovo, AntiBod	Slide Decks presented at recent events; AntiBod BM2 AntiBod slide deck; BM seminar slides	BM Seminar
October & December 2015	2x Follow-up interviews with SBC Managers 2x Follow-up interviews with tenants/AntiBod; 7x interviews with academic scientists/TTOs/HoD/Scinovo	Revised business models of tenants AntiBod BM3 SBC Press Releases	Meeting with SBC Execs and Management Scholars
April 2016		Open Innovation Summit videos; White paper, slide decks presented at summit.	Open Innovation Summit: hosted by SBC, with 140 key industry players & start-ups in attendance.

Note: Interview* quotes used in this paper are represented as *T, SBC,* or *GSK* for example, to provide some indication of the role of the interviewee but to provide a degree of anonymity too. Names have been changed to protect the identity of some of the participants. *BM1* refers to the different versions of the business model generated by our scientist *Sci1*.

Table II. Analysis of Choreographed Contestations

Contestation & actors	*Social worlds*	*Market devices used in valuation practices*	*Intersection of social worlds through the performance of valuation practices*	*Valuation outcomes & market devices generated through contestation*
C_1: (Jan 2015) Contesting the initial market representation ▪ Maria (Sci1) ▪ SBC CEO and Mentor (SBC1)	Science Market Entrepreneurship	Scientific representation of 'Superior Antibodies' 'The scope and scale of the market opportunity' Competition within market 'Summary': the business idea, the science that needs developing and the markets that the goods/science will be of value to: referred to by SBC as 'the business model'	▪ Sci1 arrives with a rudimentary knowledge of market and entrepreneurship social worlds, and associated market devices (i.e. how to talk about a market; how to present a business idea). ▪ SBC1 contests multiple aspects of Sci1's market knowledge as represented in her summary document: he queries the claims relating to the market scope and scale, and challenges the scientist to think further about her business model, and how it fits with this market. ▪ SBC1 asserts the value of further interactions across multiple social worlds: With the entrepreneur in residence, other SBC-based antibody scientists, and a wider market search.	▪ The scientist judges the value of SBC incubation, the community of antibody companies there, and in the 'bigger picture' knowledge of SBC1. ▪ The need for a broader knowledge of the market is now deemed valuable to better understand potential futures for AntiBod. *Associated Market Devices:* ▪ Tenancy at SBC is a device that suggests legitimacy as an entrepreneurial scientist, and identifies AntiBod as a discovery undergoing marketization. ▪ Diagram scribbled in the margins by the scientist (informed by the language of markets and entrepreneurship) becomes the '1st incarnation of the Business Model.'
C_2: (Feb 2015) Contesting how the market is represented in a grant application ▪ Maria (Sci1) ▪ Funding Body (F2) ▪ Entrepreneur in Residence (SBC4)	Science Market Entrepreneurship	Scientific representation of the antibody specification and potential for use in clinical testing Smart Grant Competition (with scientific discovery, business model and IP sections) Specification of Routes to Market Intellectual property ('IP') ownership	▪ The initial intention is to identify valuable market-knowledge for success with an Innovate UK grant application. ▪ Through this collective search activity, linked predominantly to market concerns, the importance of establishing IP ownership emerges from the entrepreneurship social world – the scientist must ensure that she, not her employer, captures the value from the science. ▪ These entrepreneurial and market concerns about asset ownership impact on the Scientific world: for IP to be created, further lab work must be done to specify what AntiBod is and how it is produced.	▪ Company formation and IP ownership are established as valuable to Sci1, in relation to investability and asset protection. ▪ Research into other antibodies in the market, and possible routes to market, becomes valuable. *Associated Market Devices:* ▪ New specification of the market object: synthetic antibodies and the process of their production. ▪ New assemblages of market knowledge are to be created, incorporating a comprehensive study of rival antibodies, through Medtrack.

Table II. Analysis of the Choreographed Contestations of Social Worlds Designed to Value, the Market Devices Invoked and Outcomes (cont'd)

Contestation & actors	*Social worlds*	*Market devices used in valuation practices*	*Intersection of social worlds through the performance of valuation practices*	*Valuation outcomes & market devices generated through contestation*
C_3: (Feb 2015) Contesting the academic institution's IP ownership ▪ Maria (Sci1) ▪ Maria's HoD ▪ Tech. Transfer Office (TTO2)	Science	Specification of antibodies Stabilized production process	▪ Patenting AntiBod is presented as a step towards establishing its place in the market for 'big pharma' partnership. However, the IP specification work requires additional scientific activity, at significant cost. ▪ The required investment in this work, whilst being seen as worthwhile and valuable by the increasingly entrepreneurial Sci1, is a barrier to progress for her institution.	▪ AntiBod becomes 'not valuable' to the academic institution, based on their assessment of the costs, risks and rewards of the patenting process. ▪ Non-value to academia is an important source of value to Sci1, whose principal concern now is to own and protect this potentially valuable IP. *Associated Market Devices:* ▪ The Letter confirms willingness to release IP. ▪ The patenting process shifts from being invoked as a barrier by the institution (due to expense), to a key aspect of value protection for Sci1. ▪ Specifying the IP generates a device that enables Sci1 to begin working out AntiBod's potential market value.
C_4: (Apr 2015) Contesting AntiBod's business model in a workshop for academic-entrepreneurs ▪ Maria (Sci1) ▪ Other SBC tenants ▪ Facilitator	Science Entrepreneurship Market	Summarised representations of AntiBod's research development programme Business Model Canvas, which in turn requires multiple inputs including: Analysis of resources potentially available as well as potential markets Well-evidenced descriptions of three markets and their sizes: research antibody market, diagnostic antibody market, and therapeutic antibody market	▪ The practice of business modelling using the Business Model Canvas is a well-established entrepreneurial activity that helps individuals to identify gaps in knowledge, while also seeing how the different elements might integrate. ▪ It is the integrative nature of the BM Canvas workshop that encourages Sci1 to think in a more holistic way, across multiple social worlds, to identify the route through which AntiBod might become revenue generating. ▪ This entrepreneurial activity encourages Sci1 to consider the valuation practices of investors, and to anticipate related future contestations.	▪ Completeness of the business model, with further specification of planned activities and market opportunities, is now seen by Sci1 as a valuable source of understanding, and a communication device. *Associated Market Devices:* ▪ The next incarnation of the business model is being generated through the interactions in this contestation, with further work required. ▪ The 'persuasive case' is being generated, and is significant in that it integrates the scientific, entrepreneurial and market knowledge necessary to evidence potential economic value to investors.

Table II. Analysis of the Choreographed Contestations of Social Worlds Designed to Value, the Market Devices Invoked and Outcomes (cont'd)

Contestation & actors	*Social worlds*	*Market devices used in valuation practices*	*Intersection of social worlds through the performance of valuation practices*	*Valuation outcomes & market devices generated through contestation*
C_5: (Jun 2015) Contesting the connections between AntiBod and the therapeutics market. ▪ Maria (Sci1) ▪ SBC ▪ Ely Lily ▪ Entrepreneurs ▪ Industry Consultant	Science	Rich descriptions of synthetic antibodies Rich descriptions of the process of production of synthetic antibodies	▪ The BM slide deck is an important entrepreneurial device, constituted of multiple elements of scientific and market knowledge, woven together to evidence the value of AntiBod, the legitimacy of Sci1, and the routes through which value might be realized (i.e. 'much larger therapeutics market'). ▪ The discussions span the social worlds of science (what science still needs to be done) and markets it is of interest to. ▪ The combination of expertise from across these social worlds allows judgements to be made about which markets to pursue, and which next steps are valuable.	▪ The value of doing therapeutic target search work is established, based on the reframing of the potential market. ▪ AntiBod is now seen as having sufficient potential value to put it in front of GSK. Simultaneously the value of GSK's antibody expertise to the scientific work is identified. *Associated Market Devices:* ▪ The specific data required to evidence AntiBod's value becomes an important device that needs to be generated through interaction with GSK. ▪ GSK Antibody Group becomes a powerful science and market shaping device, as a known source of expertise and a potential route to the realisation of economic value from AntiBod.
	Market	Well-evidenced descriptions of three markets and their sizes: research antibody market, diagnostic antibody market, and therapeutic antibody market.		
	Entrepreneurship	Comprehensive BM slide deck aimed at evidencing the authenticity of AntiBod as an investable market object		
C_6: ((Jul 2015) Contesting the scientific requirements of the therapeutics market ▪ Maria (Sci1) ▪ GSK ▪ SBC1	Science	Contrast between alternative therapeutic approaches and the 'paradigm change' towards antibodies	▪ The GSK scientists offer Sci1 a more tightly defined understanding of the scientific work that needs to be carried out, and why. ▪ The connection between potential market value and very specific forms of scientific work is now made explicit.	▪ Value of proof-of-concept requires comparability to existing and FDA approved antibodies. ▪ Economic value of AntiBod and the IP is now specifically linked to its medical value as a potential cancer treatment. *Associated Market Devices:* ▪ Business Model 3 connects presentations of more specific scientific & market knowledge to create a clearer route for advancement.

Table III Summary of Theoretical Contributions

Observations	*Interpretation of findings*	*Theoretical contribution*
O_1: Scientific objects are transformed into marketable, economically valuable objects by a series of unfolding choreographed contestations at the nexus of social worlds.	▪ Choreographed contestations are the purposeful bringing together of multiple actors at the nexus of social worlds – they are not chance events. ▪ The sequence of contestations cannot be pre-determined as each one reveals valuable next steps. ▪ Collectively and retrospectively a sequence of choreographed contestations can be understood as a programme of action for the marketization of science.	▪ Social worlds theory (Clarke and Star, 2008) provides a bridge between commercialization of science and market studies literatures, yielding new insights into the marketization of science. ▪ The generative interplay of actors at the nexus of social worlds gives insight into the role of different actors' norms, histories and practices in choreographed contestations (cf. Doganova and Muniesa, 2015), which collectively form a sequence of goal-directed actions. ▪ Choreographed contestations rely on the multiple and varied valuation practices of internal (Stark 2009) and external (Fisher et al., 2016) actors to organise productive market connections and development pathways.
O_2: Valuations are framed and fixed by the choreographed contestations and market devices they use.	▪ Framing reveals who or what is of concern and to be taken into account, while fixing holds ideas, objects and relations stable. ▪ Choreography frames and fixes the form the valuation will take as actors determine what will be valued, by whom, and through which devices. ▪ Market devices frame and fix what is to be valued, as their representation enable actors to bring together diverse valuing practices from different social worlds.	▪ Framing and fixing offers a new perspective on the mechanisms through which commercialization proceeds. ▪ Framing and fixing through the choreography of contestations enables the co-ordination of distributed expertise, enabling critical moments of collective valuation to take place. ▪ This understanding of the materials and practices through which valuations are performed complements extant research concerned with the institutional conditions of science commercialization (Baraldi et al., 2014; Debackere and Veugelers, 2005; Lockett et al., 2002; Lockett and Wright, 2005; Walter et al., 2006)
O_3: Valuations are generated by holding market devices in dialogue, with each other and with multiple social worlds	▪ We reveal *how* new valuations are generated in the process of science marketization. ▪ Actors hold market devices in dialogue with each other during contestations to generate new directions for inquiry. ▪ These valuations draw on devices and practices from multiple social worlds, allowing alternative interpretations and problem framings to be explored.	▪ The role of market devices in '*disentangling*' scientific discoveries from the lab, and entangling them into the world of markets, extends understandings of the challenges faced by academic entrepreneurs (Siegel and Wright, 2015; Siegel et al., 2003; Perkmann et al. 2013). ▪ We show the role played by market devices in valuation practices, highlighting the importance of interactions at the nexus of social worlds to extend our extant understanding of the work performed by academic entrepreneurs (Grimaldi et al. 2011, Perkmann et al.2013) as they engage collectively, with other market actors, in the transformation of science and markets.

ENDNOTES

[i] https://www.cancer.org/treatment/treatments-and-side-effects/treatment-types/immunotherapy/monoclonal-antibodies.html

[ii] The Berkeley Innovation Forum is a membership organization hosted by Dr. Henry Chesbrough, Faculty Director of the Garwood Center for Corporate Innovation. Professor Chesbrough has become a world renowned authority on the topic of open innovation.

[iii] Innovate UK is UK's innovation agency: an executive non-departmental public body, sponsored by the Department for Business Energy & Industrial Strategy.

[iv] Medtrack follows all the companies and people that touch Healthcare: financing, drug discovery, manufacturing, contract manufacturing and development. Coverage spans discovery through patent expiry and loss of market exclusivity and generic entry. See: https://pharmaintelligence.informa.com/products-and-services/data-and-analysis/medtrack

[v] To see 'the business model Canvas in 2 minutes' visit http://www.businessmodelgeneration.com/canvas/bmc

[vi] Eli Lilly and Company is a global pharmaceutical company headquartered in Indianapolis, Indiana, with offices in 18 countries. Its products are sold in approximately 125 countries. The company was founded in 1876.

[vii] Human epidermal growth factor receptor 2 is a member of the human epidermal growth factor receptor (HER/EGFR/ERBB) family. Amplification or over-expression of this onco gene has been shown to play an important role in the development and progression of certain aggressive types of breast cancer. In recent years the protein has become an important biomarker and target of therapy for approximately 30% of breast cancer patients.