



A future in the knowledge economy? Analysing the career strategies of doctoral scientists through the principles of game theory

Sally Hancock¹ 

Published online: 5 November 2018
© The Author(s) 2018

Abstract

In recent decades, increasing participation in science, technology, engineering and mathematics (STEM) has emerged as a globally shared policy objective in higher education. This policy objective is underpinned by a commitment to the economic framework of the knowledge economy and the belief that STEM education, knowledge and innovation are prerequisites for economic growth. This paper is concerned with doctoral scientists, who occupy a position of considerable privilege according to knowledge economy discourse: expertly knowledgeable, highly skilled and sought by elite employers. This paper assesses these policy claims against the experiences of recent doctoral scientists studying in the UK. Data from a 3-year mixed-method study are subjected to a novel, game theory informed analysis of students' values, decision-making behaviour and career ambitions. While all doctoral scientists engage in career-oriented strategizing, the game strategies employed by students are diverse and reveal conflicted understandings of knowledge economy policy. Implications of these findings and the analytical merits of game theory are discussed.

Keywords Doctorate · Graduate careers · Decision-making · Knowledge economy · Game theory · Higher education policy

Introduction: the age of STEM?

In recent decades, a global political consensus has emerged over the importance of science, technology, engineering and mathematics (STEM) education (Freeman et al. 2014). This consensus is underpinned by a commitment to concept of the knowledge economy—an economic framework in which the creation, application and dissemination of knowledge generate prosperity (Bell 1973). In this framework, doctoral students in the STEM disciplines (henceforth, doctoral scientists) represent human capital of the highest value—heralding ‘a

✉ Sally Hancock
sally.hancock@york.ac.uk

¹ Department of Education, University of York, York, UK

new class of entrepreneurial scientists' who are expertly knowledgeable, engage with industry and assimilate commercial sensibilities into their everyday research practice (Lam 2010, p. 308).

The global commitment to the knowledge economy has led both high- and low-income countries to implement policies to increase the number of doctoral students (Smith 2010; Nature 2011), and in the UK, guided the government's decision to introduce loans of up to £25,000 for PhD study:

The OECD has found that knowledge-based capital is a key driver of economic growth in advanced economies and is increasingly the largest form of business investment. The UK is one such economy whose comparative advantage is disproportionately derived from R&D and innovation intensive sectors. In this context, ensuring that there is a sufficient supply of highly skilled researchers is increasingly important and a key component of the government's overall strategy.

Doctoral students make a vital contribution to the UK's world class research base and, through the ideas and skills that they develop, to British industrial performance and to improved economic productivity. The Government fully recognises the importance of PhDs to the country's economic success.

(Department for Education 2017, pp. 3-5).

Within knowledge economy discourse, the individual material benefits of holding a science doctorate are clear. High status, well-paid, interesting and autonomous work is promised (Sauermann and Roach 2012; Agarwal and Ohyama 2013; Walsh et al. 2013; Skovgaard-Pedersen 2014). Increasingly, such employment is found outside the academy (e.g. in Australia [Neumann and Tan 2011], Germany [Enders 2002] and the USA [Council of Graduate Schools 2007]). Admittedly, the framing of doctoral scientists as rational *homo economicus*—undertaking higher education as an economic investment—is not unique. This view of the student has shaped higher education policy for the last 50 years (Marginson 2015). Furthermore, the market value of a science doctorate is known to vary with field of study (Zolas et al. 2015). Nevertheless, relative to other types of higher education qualification, the human capital value ascribed to doctoral scientists—and the promises made regarding their futures—is notably heightened in the knowledge economy context.

Despite this policy attention, there remains little empirical evidence of how doctoral scientists respond to knowledge economy policy and of how these policy claims relate to students' aspirations and decision-making. This paper seeks to further understanding of the consequences of knowledge economy policy by presenting a synthesis of findings from a 3-year mixed-method study with doctoral scientists in the UK. An earlier publication arising from this study noted five distinct orientations to the knowledge economy—ranging from resistance to acceptance (Hancock et al. 2017). This paper offers new insights into how doctoral scientists perceive and plan for their futures. A game theory informed analysis is undertaken to examine how doctoral scientists negotiate values, aspirations, guidance and career 'facts' to formulate a coherent professional strategy.

The paper is structured in five parts. Firstly, the study will be framed with an overview of the shifting epistemological norms and organisational boundaries of knowledge economy science and its implications for the contemporary doctorate. Secondly, the research methods and analytical framework of game theory are detailed. The third section of the paper presents the five game strategies observed within the sample of doctoral scientists as they plan their

future careers. A discussion of these strategies follows, before implications and concluding remarks are offered.

Literature review: the doctorate in the knowledge economy

The life scientific: shifting norms and boundaries

The question of whether the knowledge economy generates a new context for science has been debated extensively in the academic literature (Marginson 2007; Collini 2012; Lauder et al. 2012). Early scholarship considered the organisational changes implied by the knowledge economy (Etzkowitz 1983; Gibbons et al. 1994). Later research focused on the epistemological and commercial values promoted by knowledge economy policy—and judged these to be incompatible to the norms of academic life (Slaughter and Leslie 1997; Slaughter and Rhodes 2004). Typically, such attempts to trace normative shifts encounter both idealism and reductionism, but it is clear that the concept of the ‘entrepreneurial scientist’ departs both from Enlightenment ideals and more recent depictions from the sociology of science.

The persisting stereotype of the scientist—in Steven Pinker’s words, ‘an amoral nerd’ (Shapin 2008, p. xv)—is the product of a number of influential accounts about the specific socio-cultural characteristics of scientific work. First published in 1942, Merton’s description of scientific norms in many ways supported the Enlightenment view of the scientist: belonging to a unified community where legitimacy was premised upon detachment from vested interests—namely those of government and industry (Merton 1973). Subsequent sociological studies served to somewhat undo this representation; instead, portraying scientists as strategic agents engaged in daily negotiations to secure resources, autonomy, and recognition from the leaders of their field (Latour and Woolgar 1986; Knorr-Cetina 1999). In practice, this involved regularly revising the epistemological and cultural boundaries of science (Gieryn 1983)—and often, as Mitroff (1974) concluded from his study of the Apollo Moon scientists—such strategising took place at the expense of Mertonian norms. Far from being universally objective, these studies characterised science as a deeply personal and political pursuit (Mitroff: 590). In these accounts, late twentieth century science emerged as a powerful community, able to dictate the nature of its engagements with government and industry.

Perhaps the most significant implication of the knowledge economy therefore is the expectation that the boundaries between the university, government, and industry will erode (Etzkowitz and Leydesdorff 2001; Lam 2010; Temple 2012). Moreover, the balance of power appears to reside with government and industry. The entrepreneurial scientist is cast as a reactionary figure: expected to endorse the goal of knowledge commercialisation and develop their work accordingly. Since the epistemological and cultural autonomy of science is challenged in the context of the knowledge economy, professional credibility is instead sought by a demonstration of economic value. This process, scholars have argued, has imposed a rewriting of the rules of science and supposes a transformation in the professional identity of academics (Henkel 2000, Henkel 2005; Lam 2010).

The changing doctorate

It might be expected that the proliferation of knowledge economy policy would instigate changes to doctoral pedagogy and practice, aimed to nurture this new wave of entrepreneurial

scientists. In the UK, transferable skills courses are now an established part of most doctoral programmes and seek to ready students for employment in sectors beyond academia (Roberts 2002; Hodge 2010; RCUK 2015). While the need for such provision is largely accepted by government, funders, and universities, the effectiveness of current practice—when measured against the expectation of nurturing commercially sensitive, boundary-shifting scientists—has been questioned (Gilbert 2004; Nature 2014; National Academies 2014; Royal Society 2014; Hancock and Walsh 2016). Successive international studies suggest that academia remains the preferred career for doctoral researchers, but that continued increases in the number of doctoral graduates has intensified competition and led many into non-academic occupations (Sauermann and Roach 2012; Gemme and Gingras 2012; Auriol et al. 2013; Fitzenberger and Schulze 2014; Van der Weijden et al. 2016).

Theorising the doctorate: a community of practice?

In light of these observations, it is perhaps surprising that the notion of the doctorate as an ‘academic apprenticeship’ endures (Park 2005). Given the historic emphasis on the collective nature of science, several scholars have considered the socialisation of doctoral students through the communities of practice (CoP) model (Lave and Wenger 1991; Shacham and Od-Cohen 2009; Lahenius 2012). In this model, learning is conceptualised as a social process, where a novice transitions from the periphery to the centre of the CoP through the accumulation of knowledge, skills and peer recognition.

In the context of knowledge economy science, however, traditional applications of CoP may be unhelpful. Doctoral employment data suggest that most doctoral students’ membership of the academic CoP will be impermanent. Knowledge economy policy implies that even those who remain in the academic CoP will interact closely with government, industry and other external agents—so to say, to move frequently into other CoPs. Additionally, as will become clear, key components of the CoP such as ‘shared repertoire’ and ‘mutual endeavour’ were noticeably absent from the accounts of the doctoral scientists’ participating in this study (Lave and Wenger 1991). Rather, doctoral scientists’ narratives are individualistic and diverse. For this reason, a novel analytical lens—informed by game theory—is employed in this paper to theorise how doctoral scientists navigate the expectations of knowledge economy policy and plan for their futures. A more detailed explanation and justification of this approach is offered shortly.

Research methods

This paper is based on findings from a mixed-method study of doctoral scientists’ attitudes towards the knowledge economy, undertaken between 2009 and 2012. The research design comprised focus groups, an online survey and in-depth interviews. Since this paper is focused on detailed accounts of doctoral career values, ambitions and decision-making behaviour, the findings draw exclusively from the interview component. Nonetheless, an overview of the whole research process is set out below.

The participating institution is an established (pre-1992) science-focused university. As Boliver (2015) notes, pre-1992 universities (so-called since they were established prior to the 1992 Further and Higher Education Act) are characterised by high research activity and income, and high-attaining, socio-economically advantaged student populations. The

institution is home to a large business school and committed to commercialisation of research. It is academically selective and consistently placed in the top ten universities worldwide.

The sample population consisted of UK-domiciled students registered on a STEM PhD programme at the institution. The study received ethical approval from the university ethics committee, and all participants reported in this paper are pseudonymised. Invitations to participate in the study were distributed to all eligible students by the graduate school administrator. Students were informed of the broad study aims and provided opt-in consent. Initially, three focus groups ($n = 24$) were conducted to establish the feasibility of the research. The focus groups facilitated rich discussions, confirming doctoral scientists' interest in the knowledge economy and related issues of scientific practice and identity. It is unlikely that this enthusiasm owed to self-selection bias, since only limited information about the research was shared beforehand.

The online survey included mostly closed questions to ascertain awareness of and attitudes towards the knowledge economy, motivations for undertaking doctoral study and future aspirations. It achieved a response rate of 15% ($n = 165$). Using population data provided by the institution, a bias analysis was undertaken to consider the representation of personal and academic variables, including age, gender and subject. The sample was found to reflect the wider population well. Across the survey sample, five distinct orientations towards the knowledge economy were observed (Table 1). These orientations emerged through several iterations of inductive coding and in response to the knowledge economy literature. The development and characteristics of these positions are discussed in detail elsewhere (Hancock et al. 2017).

Around half of the survey respondents ($n = 68$) consented to a follow-up interview. It is probable that these participants possessed a more developed interest in knowledge economy policy, meaning that a degree of unobserved bias may exist within the interview data. Twenty participants, selected to reflect the range of orientations to the knowledge economy, and pertinent academic and demographic variables (such as subject, year of PhD, prior education and gender) were interviewed.

As can be seen in Table 2, the majority of interviewees entered the PhD before the age of 25, which is typical of the institution's doctoral population. Over two-thirds held a research council studentship, and the rest received institutional funding. Both funding streams are competitive and awarded on academic merit. Only one participant self-funded. Regardless of funding source, all students at the institution are expected to complete a number of professional development courses during their doctoral registration in order to prepare for a wide range of

Table 1 Survey respondents by knowledge economy orientation

Orientation	% (n)	Summary characteristics
Scientific purist	15 (25)	Reject knowledge economy; prioritise basic academic research; aspire to become academic
Social idealist	10 (17)	Reject knowledge economy; prioritise applied socially useful research; aspire to become academic
Weak pragmatist	20 (33)	Ambivalent towards knowledge economy; basic and applied knowledge creation; aspire to become academic
Strong pragmatist	30 (49)	Ambivalent towards knowledge economy; basic and applied knowledge creation; considering non-academic careers
Third-order capitalist	25 (41)	Support knowledge economy; prioritise applied research; aspire to research career in industry
Total	100 (165)	

employment. All students were full-time and expecting to complete their PhD within 4 years. The majority of participants were male, and the vast majority were White British. Again, these observations are typical of the institution's doctoral population. Around two-thirds of the sample completed their first degree at the institution, while a further third previously studied at another pre-1992 institution in the UK. Only one interviewee completed their first degree at a post-1992 university.

The interviews followed a semi-structured design and lasted 1 hour. The interviews further explored orientations towards the knowledge economy, examining how these related to experiences of the doctorate and career aspirations. Interview data were recorded, transcribed and inductively coded, following an open-ended, grounded theory informed approach (Strauss and Corbin 1998). Following the inductive coding of students' career values, ambitions and behaviour, the principles of game theory were adopted to theorise of doctoral scientists' accounts of career planning and decision-making. The selection and application of this particular analytical lens are justified below.

Analytical framework: the lens of game theory

The analysis of the interview data revealed that doctoral scientists' varied orientations towards the knowledge economy correlated with specific career values and ambitions. It is plausible to suggest that knowledge economy policy encourages such heterogeneity, since doctoral scientists are faced with multiple images of science and what might constitute a scientific career. The CoP model—with its emphasis on collective and shared experience—contrasted with doctoral scientists' diverse and strategic narratives. The issue of temporality presented a further theoretical complexity. At the point of the survey, some 75% of doctoral scientists intended to become an academic. By the interviews, approximately half of the participants reported having

Table 2 Interview sample

Name	Main subject	Year	Age	Pre-doctoral work experience	Orientation
Alice	Biology	2	26	–	Scientific purist
Marigold	Medicine	2	24	–	
Sophia	Medicine	3	27	Healthcare	Social idealist
Olivia	Medicine	2	24	–	
Rachel	Environmental science	2	25	–	Weak pragmatist
Charlie	Biology	2	25	–	
Jack	Aeronautics	1	23	Military	
Laurie	Computer Science	3	25	Industry	Strong pragmatist
Rich	Bioengineering	3	26	Industry	
Rose	Biology	2	38	Healthcare	
Daniel	Bioengineering	2	23	–	
Dylan	Engineering	3	27	Industry	
George	Mathematics	2	24	–	
Isabelle	Engineering	2	24	Industry	
Simon	Mathematics	2	24	Industry	
Thomas	Physics	2	24	–	
Graham	Computer Science	2	28	Industry	
Mohammed	Engineering	3	28	Industry	
Toru	Computer Science	1	26	Finance	
Will	Engineering	2	30	Industry	

shifted aspirations. Thus, notions of the ‘future-self’ informed everyday decision-making and behaviour in the present.

The lens of game theory afforded a responsive and detailed examination of doctoral scientists’ values and ambitions, and their individualistic and strategic justifications of decision-making. Specifically, the principles of game theory are applied to analyse the decisions and behaviours undertaken by doctoral scientists as they aim to secure a desired (career) outcome. Originally located in mathematics and developed through the work of John von Neumann and later John Nash, game theory has influenced manifold disciplines, including economics, evolutionary biology and political science—but rarely is it applied to education (Binmore 2007). Game theory—and the younger field of behavioural economics—proceeds from the assumption that individual tolerance for uncertainty is low. Faced with an uncertain prospect—for example, one’s career—decision-making with a view to prioritise or avoid certain outcomes is likely (Lovallo and Kahneman 2000). This observation is particularly interesting in the present context, since earlier research notes that doctoral scientists’ struggle with even the epistemological uncertainty arising from their research (Delamont and Atkinson 2001). For the doctoral scientists in this study, the extent of career planning observed suggested a similarly limited tolerance for ambiguity.

The application of game theory in this study emphasises three significant aspects of the contemporary doctoral experience. First, the analysis exposes the highly individual nature of the doctoral experience, dispelling the notion that doctoral scientists perceive themselves as belonging to an identifiable CoP. Second, the lens of game theory brings to light both the intensely competitive environment that doctoral scientists inhabit and the highly strategic responses that this context provokes. Third, this approach allows for a detailed examination of doctoral scientists’ decisions and behaviour—and their justifications for these. Career strategies are observed to be values-based, but are shaped also by calculations of risk and probability. Interestingly, contingency strategies are seldom offered.

The use of game theory in this analysis is specific and consistent. Crucially, game theory serves as a descriptive device and is not intended to determine or predict behaviour. The analysis is responsive to the assertions of rational self-interest articulated by doctoral scientists and provides an explanation for their reported behaviour. Game theory reveals the PhD as a time of calculated risk-tasking and offers insight into doctoral scientists’ varied attitudes to knowledge creation, academic freedom, the academic profession, non-academic careers and risk. In what follows, the findings section details five game strategies, each aligned to a particular disposition towards the knowledge economy. Concepts and principles of game theory are italicised for emphasis.

Findings

A future in science—the game strategies of doctoral scientists

Scientific purists: academia as a zero-sum game

As critics of knowledge economy policy, scientific purists imagined their future-selves as academics. This ambition predated these students’ enrolment onto their doctoral programme and shaped a game strategy focused on timely completion of the thesis, securing

an academic position and upholding the Mertonian norms of scientific life in the university. For the majority of scientific purists, the doctorate was construed as a *zero-sum* game, in which only one outcome—an academic research career—could be considered a success (Turocy and von Stengel 2001). As Sophia (year three, medicine) explained:

I want a career in research, and it would definitely still be in academia. I always wanted to stay in academic research. I can't personally fathom how people do it – go from a PhD to private research. To me, a PhD is all about preparation for a career in academic research.

Similarly, Marigold (year two, medicine) wished that senior university management and policy-makers would share the purist view of the doctorate.

I hope that they'd say 'we are training the next generation of academic scientists', [and that this] was something important... I've heard people saying that academic research is a pyramid scheme and that the PhD is just cheap labour to get things done. It's not a view that I share.

Such articulations imply an ideological foundation and suggest that purists' game strategies are founded on *imperfect information* (Maschler et al. 2013). Knowledge of doctoral career destinations—which would offer a rather different view of post-PhD employment in the sciences—yielded no apparent influence on purists' aspirations and more general contemplations on the purpose of the PhD. Purists demonstrated little awareness of the 'harsh reality' facing doctoral graduates, conversely asserting the prudence and rationality of consolidating one's position within the academic community. For purists, securing employment in non-academic sectors was framed as a less certain, higher-risk strategy. Put differently, this is an example of *subjective probability*—where players of the same game differ in their assessments of the likelihood of a certain outcome (Maschler et al. 2013, p. 27).

Purists thus concerned themselves with observing and succeeding by the rules of the academic game. The publication of 'basic' research was prioritised (Stokes 1997). Alice (year two, biology) reasoned:

You are being paid to do research, so at the end of the day you are expected to produce publishable scientific work. You are being trained in a particular subject to be a scientist... You are meant to be adding something useful to contribute towards wider research. Lots of people hear the student part without the PhD bit, and they say 'Oh what do you want to do after? Oh god, are you just going to stay in academia?' Where do you think all the scientific research comes from? You're producing something substantial and worthwhile.

Publications were understood not only as proof of 'worthwhile' research, but as an indicator that doctoral students were 'worthy of having a research career' (Sophia). As will become clear, the value attributed to publications was not shared by all doctoral scientists. Purists' definitions of innovation were aligned to the requirements of academic journals; these students were not interested in the commercialisation of research. In this sense, purists' strategies mirrored the traditional practice of scientists, for whom the production of scientific papers is central to professional life (Latour and Woolgar 1986).

Social idealists: science for society and cooperative strategies

Social idealists were concerned to conduct scientific research that would in some way contribute to an equitable and just society. Reminiscent of both J.D. Bernal and Nico Stehr, science here is viewed as a force for change in society—an altruistic activity that ought to improve the lives of the majority in a ‘knowledge society’ (Bernal 1939; Stehr 1994). In order to realise this ambition, social idealists forged careful collaborations within a *cooperative* game strategy. Within such a strategy, coalitions are formed with other actors to bring about a desired outcome (Maschler et al. 2013, p.15).

As with the purists, social idealists aspired to secure an academic position following the completion of their degree. However, idealists’ notions of the university scientist had broadened during doctoral study. Idealists upheld the importance of academic publications; however, the expression of other concerns set this group apart. Idealists sought to work on applied research projects, which promised a straightforward societal benefit (Stokes 1997). Olivia (year two, medicine) recounted how the experience of completing a Master of Research degree crystallised these intentions.

I did an MRes the year before... I did two six months projects. One of them was on cancer and the other was on cell trafficking – and there was barely any clinical relevance to that. It's basic science and obviously it underpins a lot. But the papers were just so mechanistic with no relation to anything that could have real world applications. I found it really dull. Whereas [my doctoral research] helps patients. I'm doing cancer research and I'm contributing to society.

Idealists were not just concerned with the selection of socially responsive research topics. Also prioritised in their strategy was a performance of social responsibility, including public outreach and the development of research impact. Rachel (year two, environmental science) spoke optimistically about the broader applications of her work.

Working as a scientist [is about] investigating different ‘big-picture’ questions that fit into a greater goal. [A PhD] is about contributing to a particular knowledge area – for me, climate change – which has a conservation value and will hopefully be of help to people in a management situation.

Outreach and impact are massive incentives. It's exciting that someone might be learning about what I discover, and not just in my area but also across the disciplines. I'm very ‘pro’ sharing data and information. It is a great thing, openness of knowledge.

Idealists aligned themselves with academics who shared their social values and were the only students engaged in research collaborations with charitable organisations. Forging charitable connections was important to the idealists, as they viewed the university environment as often at odds with their values and objectives. Idealists suggested that science communication and outreach were neglected aspects of the transferable skills agenda. Fellow academic researchers were criticised for their reluctance to share data and engage with interdisciplinary work. Knowledge economy advocates were construed as overly and problematically concerned with the financial potential of scientific research. Should universities become too complicit in this agenda, idealists such as Olivia doubted that their strategy would be compatible with the academic context.

I hope my work will improve society. I think the knowledge economy is an ultimately negative development for the university. Who cares about how the universe works when you can make money instead? It's off-putting. You have to pay for things but not profit.

Weak pragmatists: mixed strategies and the maximin principle

Weak pragmatists occupied a position of uncertainty. Their game strategies both reflect this uncertainty and are compromised by it. These students reported starting the doctorate with the clear aspiration of becoming an academic. By the time of the interviews, however, weak pragmatists' confidence in the realisation of this aspiration had been seriously undermined. For weak pragmatists, academia is a game in which the 'survival of the fittest' principle dominates ruthlessly. In response, these students adopted a *mixed* or *combinatorial* game strategy, which allowed for the exploration of several possible strategies and numerous, albeit less desirable, outcomes (Binmore 2007, p. 68).

Weak pragmatists perceived academia to be an uneven game—a game in which players are differentially positioned and therefore have variable (unequal) odds of winning. Rich (year three, bioengineering), commonly referred to his 'chances' of securing an academic position.

You start a PhD wanting to go on to academia, and then a year or so in you suddenly sit up and realise, 'hang on a minute, there's 30 to 40 people here, scrambling around for one professorship. My odds aren't great'. You can have all the self-confidence in the world, but if you actually sit up and look at the fact of this – that kind of ratio. The number of PhD studentships seems to have increased without a corresponding increase in the number of positions for us to go on to.

In contrast to the zero-sum approach of the purists, mixed strategies are generally lower-risk and more responsive to context. Nevertheless, they can be thwarted by conflicted interests and unresolved decisions. This uncertainty manifests in the *maximin* principle, which, put simply, implies 'hoping for the best' and maximising pay-off in the case of a worst outcome (Binmore 2007, p. 80). Weak pragmatists acknowledged the scarcity of academic positions but concluded that an optimal strategy meant a concerted effort to secure an academic job. Considerably less effort was applied to exploring secondary career options or developing a strategy avoiding worst case outcomes. Rose (year two, biology) related a characteristically passive approach, admitting she had undertaken little research into other career options.

Unlike ten years ago [you can't say] 'focus on something and you'll get that goal at the end'. Now... you think okay I could do this, I could do this, and I could do this. So, it's just sort of spreading the options a bit more. But, the main focus is to become a lecturer.

Similarly, Rich spoke of 'vaguely trying to get an interview with a bank' in his final year, while Laurie (computer science), also in his final year, considered this a possible, if inferior, career option:

I've managed to put off any sort of real life worries... I could set out and go and work for a bank... I don't object to banks [but] it would be really, really dull.

Academic publications were deemed critically important to securing an academic position—according to Laurie, 'once you cross the threshold of publishing in a decent journal it's a more of a level playing field'. Weak pragmatists also noted the importance of institutional

reputation in shaping career outcomes and hoped that their enrolment at a highly regarded institution would work favourably in this uneven game.

Strong pragmatists: mixed strategies and the minimax principle

Consistent to the career strategies already described, strong pragmatists embarked upon the PhD with the intention of becoming an academic. In common with the weak pragmatists, confidence in achieving this outcome reduced significantly during the doctorate. Strong pragmatists similarly conceived of academia as uneven game in which individual players have variable odds of success. These students, however, considered alternative careers more proactively and played a more developed mixed game strategy. Daniel (year two, bioengineering) spoke of his transformed outlook.

Since starting here I've actually changed what I thought my PhD was preparing me for. I used to think the PhD was preparing me for an academic career in science. I don't think that anymore. I think it's preparing me to be a researcher – someone who thinks scientifically and works scientifically. I think it's preparing me to do something much more industry based – having a set problem from a company and knowing I can solve it.

Thomas (year two, physics) described having 're-thought my career path' to focus instead on the development of 'transferable skills'. Several strong pragmatists mentioned being 'unsuited' to academia, and in having little interest in the other roles of an academic, including teaching and administration.

With apparent sincerity, strong pragmatists judged academic and non-academic jobs to be of equal value. Their approach to career planning is arguably highly rational: various courses of action are considered, and the odds of achieving each is weighed up. In game theory, such behaviour is identified as the *minimax* principle, which in its simplest formulation can be described as 'preparing for the worst' (Binmore 2007). These students took seriously the 'worst' case outcome that their original ambition of becoming an academic was unlikely. Strong pragmatists did not abandon the prospect of securing an academic job wholesale, and it is true that for several strong pragmatists, the attractiveness of an academic career had diminished. In contrast to the 'hopeful' passivity of weak pragmatism, strong pragmatists engaged proactively in behaviour that they perceived would bolster their candidacy for non-academic positions. Accordingly, the transferable skills programme offered by the university was viewed positively, and additional work experience in a range of non-academic contexts was sought.

Strong pragmatists appeared empowered by their transformed outlook. George (year two, mathematics) stated that his capacity to 'learn very quickly' had resulted in a 'fearless' attitude towards future employment. In this sense, strong pragmatism seems shrewd and farsighted; responsive to both the realities of the academic labour market and knowledge economy policy, and resolutely rejecting any stigma in leaving the academy. However, this is not to say that the strategy emerged easily. Several students spoke of periods of self-doubt, frustration, anxiety and depression. Furthermore, there was little evidence that those adopting this strategy had clear reason to doubt their individual suitability to academic employment.

Strong pragmatists valued user-inspired, applied knowledge and the opportunity to conduct research in new contexts (Stokes 1997). Publications were important, but so too were collaborations with industry and the possibility of developing patents. Indeed, many students suggested that the tangible applications arising from their research would be of greater

importance to their future careers than the qualification itself. Considering his future plans, Simon (second year, mathematics) stated ‘as far as my career is concerned, it wouldn’t be a complete disaster if I didn’t get the PhD’.

One-third of doctoral students articulated a game strategy consistent to strong pragmatism. Its appeal is evident: informed, malleable—a rebellious response, perhaps, to the pressurised environment of academia and the linear succession of taught study which precedes enrolment onto a research degree. It may of course be a strategy that is best understood as a means of coping with the immediate uncertainty of doctoral study—to be abandoned once more certain future prospects materialise.

Third-order capitalists: rejecting the academic game

Third-order capitalists embraced the expectations of knowledge economy policy and the notion of the ‘entrepreneurial scientist’ entirely. These students embarked on the PhD with no intention of entering academic research and considered careers in industry to be superior. A strategy to realise this aim emerged early in the doctorate. Research topics with ‘an industrial career in mind’ were pursued (Graham, year two, computer science).

Third-order capitalists described their career strategy as well-informed, low-risk, and robust. Academia was criticised in several regards: for job insecurity, poor working conditions, and insular research. These students invested their time in the strategic development of *acts of cooperation*—although contacts and networks were sort within industry, not higher education (Maschler et al. 2013, p.15). The PhD was valued primarily for its role in achieving this outcome. Attachment to the qualification itself, or to the traditional values of the academy, was minimal. Graham referred to his thesis as ‘an administrative overhead... I will be happy to get it out of the way [and] get useful things done’. Toru (year one, computer science) regularly evaluated the labour market value of his doctorate—having decided to undertake a PhD only after becoming unemployed during the financial crisis.

I get constantly bombarded by head hunters asking, ‘Have you done your PhD, have you finished, are you thinking of just going back into employment?’ I always reassess - do I continue, or do I leave?

Third-order capitalists were clear that industry offered a preferable research environment to academia. In contrast, the university was described as a site of dated equipment and facilities, sluggish administrative procedures and bizarre practices—all of which thwarted external collaborations. The pressure to publish—keenly felt by all other doctoral scientists—was singled out for particular criticism. Will (year two, engineering) explained his concerns at length:

[Academics] jump from one publication to the next... they don’t ask hard questions; they just publish what they can. Nobody [in industry] actually cares. There’s only about one person, among twelve PhD students, doing research that I think should ever see the light of day. My [former employer] does invite academics in to tell them what they’re doing. I attended one of these... the academic in question was ten years out of date. He was asking for industry to help him, and they dismissed him because what he’s doing is pointless. You go to an academic conference: nobody really cares about making their work see the light of day. Patents... aren’t the interest.

The pressure to publish is a widely recognised trait of contemporary academic life (Lawrence 2002). The third-order capitalists were therefore comparatively refreshing in their rejection of the sovereignty of publications—a rejection doubtlessly rationalised and facilitated by their strategy to leave academia. Nevertheless, these students offered advice to their counterparts. They encouraged doctoral scientists to engage in a similar strategy: to pitch their work to external actors and focus on conducting commercially valuable, user-inspired research (Stokes 1997). For the third-order capitalists, these endeavours characterised the successful contemporary scientist.

Discussion

The lens of game theory characterises doctoral scientists' responses to the knowledge economy as varied and strategic. The PhD emerges as a time of calculated risk-tasking, when doctoral scientists' hopes for their future employment are negotiated. For half of the sample (purists, idealists, and third-order capitalists), professional intentions remained consistent throughout the doctorate, and single, *pure*, game strategies were played. Pragmatists experienced a shift in their professional outlook and adopted more flexible, *mixed* game strategies to open up their career prospects (Binmore 2007, p. 78). In one sense, all doctoral scientists advanced an instrumental approach to their degree. However, this instrumentalism clearly diverged from the narrow *homo economicus* characterisation of knowledge economy policy. Evident in each of the five strategies was the protection of a specific set of epistemological and professional values, most of which contrasted to knowledge economy policy.

All doctoral scientists responded strategically to the knowledge economy, but their responses were complex and problematic. Scientific purists offered a determined rejection of the knowledge economy. Social idealists voiced similar misgivings. Third-order capitalists stated proud support. Central to each strategy, however, was the (mis)understanding that the university is distinct from the knowledge economy and that knowledge commercialisation takes place beyond the academy. Thus, while doctoral scientists' behaviours conformed to the outcome-focused model of a game theory strategy, they cannot be said to be rational, well-informed, or meaningfully low risk (Lovallo and Kahneman 2000). Doctoral scientists do not obviously consider the knowledge economy as eroding the cultural and organisational boundaries of university, industry and government. Rather, the binary dualism of academic and non-academic work continued to frame their reactions to the knowledge economy.

Doctoral scientists' orientations towards the knowledge economy, and the game strategies advanced, were not randomly distributed (Table 2). While a sample of this size cannot offer generalisations with any certainty, three patterns are notable. First, weak and strong pragmatism attracted a higher proportion of later stage doctoral students. This observation is consistent with these students' explanations of pragmatism as a response to the diminishing likelihood of securing an academic position. Second, an association between the doctoral subject and orientation is evident. Scientific purists tended to pursue basic, non-applied research, while social idealists were located in areas of high societal relevance (medicine and environmental science). Third-order capitalists conducted applied, industry-focused research (computer science and engineering), which has a longer tradition of commercially focused knowledge creation. These observations suggest that knowledge economy orientation and career planning are strongly influenced by the disciplinary or 'epistemic cultures' into which doctoral scientists are socialised (Knorr-Cetina 1999). A more accepting view of non-academic employment is

possible when the disturbance of disciplinary norms is limited. Third, it is apparent that knowledge economy orientations also correlate with professional experience. Those most critical of non-academic employment and knowledge commercialisation—purists and idealists—reported little work experience outside of academia. In contrast, all third-order capitalists had worked elsewhere before beginning a doctorate (hence their relatively older age). Non-academic employment appears to be a less daunting prospect when it complements past professional experience.

It is possible to offer recommendations for pedagogy and practice on the basis of these observations, but the importance of doing so in a way that is sensitive to doctoral scientists' values emerges from this analysis. Clearly, these students are not 'amoral nerds'. Their notions of what constitutes ethical science and a desirable scientific career are values-based. However, departing from research with faculty—which has suggested traditional academic identities persist despite the pressures of entrepreneurialism (Enders 1999; Welsh et al. 2008)—knowledge economy policy clearly prompts challenging questions for doctoral scientists, at critical stage of their career and professional identity formation.

From this study, there is evidence that doctoral scientists could indeed be better informed about knowledge economy policy. The uncertainty experienced by doctoral scientists is considerable, and universities ought to do more to assist with the burden of decision-making. That most doctoral scientists entered the PhD with the intention of becoming an academic suggests that universities could be clearer from the earliest opportunity about the many careers doctoral scientists go on to do, and the reality that most will not secure an academic position. During the doctorate, such conversations may be sustained by supervisors and through professional development training—but these findings suggest that such guidance may be resisted by doctoral students if it is perceived to undermine career values. Doctoral supervisors were held as role models by the scientific purists but criticised extensively by the third-order capitalists—suggesting that support and policies at the institutional level are essential (Campbell 2003; Sinclair et al. 2014). The knowledge economy, and the transformation of academic science it implies, brings both opportunities and challenges, and it would seem that the communication of these to doctoral scientists needs revisiting. The integration of research-related work experience during the doctorate may broaden horizons and reduce the perceived stigma of leaving academia (Hancock and Walsh 2016). Placements in industry and community organisations in particular may counter the view held by all doctoral scientists that academic and non-academic sectors continue to be separated by strict boundaries.

The issue, however, of whether doctoral scientists ought to be more flexibly disposed towards knowledge economy policy is inescapably ideological and impossible to consider without addressing broader debates about the knowledge for economic growth agenda (Robertson 2005). Doctoral supervisors and universities must consider the messages conveyed to prospective and current doctoral students about the value and purpose of a doctorate, and the extent to which these promote or critique the knowledge economy view and wider neoliberal project (Bøgelund 2015; Akerlind and McAlpine 2017). From the basis of this study, it would seem that doctoral scientists will be willing and engaged contributors to this debate.

Conclusion

This paper has assessed the policy claims of the knowledge economy against the experiences of recent doctoral scientists studying in the UK. Doctoral scientists' responses to the

knowledge economy are varied and strategic. An analysis informed by the principles of game theory exposes the PhD as a time of calculated risk-tasking and offers insight into doctoral scientists' varied attitudes to knowledge creation, contribution and future employment. Doctoral scientists play distinct game strategies as they attempt to secure their preferred futures. Responses to the knowledge economy feature in each game strategy, but doctoral scientists advance a narrow and binary understanding of the concept in relation to academic and non-academic work. Suggestions for broadening doctoral scientists' understandings of knowledge economy have been offered, but the policy assumption that PhD graduates ought to be more flexibly disposed to the commercialisation of knowledge is problematic—and prompts an ideological debate beyond the intentions of this paper.

Knowledge economy policies impact doctoral scientists internationally. It is likely that the experiences reported in this paper will have wider resonance, despite the relatively small empirical basis of this study. The precise way in which these findings apply is expected to differ by context—even within the UK, experiences of higher education vary by subject area, institution type and demographic characteristics (Boliver 2017). Within the sample reported here, distinct game strategies were associated with particular academic and demographic characteristics. Future research may further explore the role of these variables, analysing how doctoral strategies play out across higher education institution type or system, mode of study or examining patterns related to gender, ethnicity and various capitals (economic, social and cultural) (Gopaul 2011). Extending the research in this way would verify the broader applicability of the typology. Replicating the research with mid and late career scientists could determine whether knowledge economy policies have shaped researcher identity at more senior levels. It is possible—given the experiences of the pragmatists and the relative youth of this sample—that these individuals are in a process of 'becoming' and that the strategies reported here may shift again (Barnacle 2005). Data collection may therefore also be extended to doctoral graduates in the early stages of their career, to discern whether these game strategies persist into the future.

Acknowledgments This paper developed from the doctoral thesis of Sally Hancock. Elaine Walsh, Dr. Gwyneth Hughes and Dr. Stephen Webster supervised the study, and Professor Steve Fuller and Dr. Felicity Mellor examined the thesis. Two anonymous peer reviewers are thanked for their helpful comments on the original submission.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

- Agarwal, R., & Ohyama, A. (2013). Industry or academia, basic or applied? Career choices and earnings trajectories of scientists. *Management Science*, 59(4), 950–970.
- Akerlind, G., & McAlpine, L. (2017). Supervising doctoral students: Variation in purpose and pedagogy. *Studies in Higher Education*, 42(9), 1686–1698.
- Auriol, L., Misu, M., & Freeman, R. A. (2013). Careers of doctoral holders: Analysis of labour market and mobility indicators. *OECD Science, Technology and Industry Working Papers*, 4, 1–61.
- Barnacle, R. (2005). Research education ontologies: Exploring doctoral becoming. *Higher Education Research and Development*, 24(2), 179–188.

- Bell, D. (1973). *The coming of post-industrial society: A venture in social forecasting*. London: Heinemann Educational.
- Bernal, J. D. (1939). *The social function of science*. London: Faber & Faber.
- Binmore, K. (2007). *Game theory*. Oxford: Oxford University Press.
- Bøgelund, P. (2015). How supervisors perceive PhD supervision – And how they practice it. *International Journal of Doctoral Studies*, 10, 39–55.
- Boliver, V. (2015). Are there distinctive clusters of higher and lower status universities in the UK? *Oxford Review of Education*, 41(5), 608–627.
- Boliver, V. (2017). Misplaced optimism: How higher education reproduces rather than reduces social inequality. *British Journal of Sociology of Education*, 38(3), 423–432.
- Campbell, R. A. (2003). Preparing the next generation of scientists: The social process of managing students. *Social Studies of Science*, 33(6), 897–927.
- Collini, S. (2012). *What are universities for?* London: Penguin.
- Council of Graduate Schools (2007). Data sources: Trends in new PhDs entering academe: 1970 to 2005. CGS communicator newsletter 40, 2–4. March 2007. Washington, DC.
- Delamont, S., & Atkinson, P. (2001). Doctoring uncertainty: Mastering craft knowledge. *Social Studies of Science*, 31(1), 87–107.
- Department for Education. (2017). *Postgraduate Doctoral Loans*. London: Department for Education.
- Enders, J. (1999). Crisis? What crisis? The academic professions in the 'Knowledge' Society. *Higher Education*, 38(1), 71–81.
- Enders, J. (2002). Serving many masters: The PhD on the labour market, the everlasting need of inequality, and the premature death of Humbolt. *Higher Education*, 44(3–4), 493–517.
- Etzkowitz, H. (1983). Entrepreneurial scientists and entrepreneurial universities in American academic science. *Minerva*, 21(2/3), 198–233.
- Etzkowitz, H., & Leydesdorff, L. A. (2001). *Universities and the global knowledge economy: A triple Helix of university-industry-government relations*. London: Pinter.
- Fitzenberger, B., & Schulze, U. (2014). Up or out: Research incentives and career prospects of postdocs in Germany. *German Economic Review*, 15(2), 287–328.
- Freeman, B., Marginson, S., & Tyler, R. (Eds.). (2014). *The age of STEM*. Oxon: Routledge.
- Gemme, B., & Gingras, Y. (2012). Academic careers for graduate students: A strong attractor in a changed environment. *Higher Education*, 63(6), 667–683.
- Gibbons, M., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London: SAGE.
- Gieryn, T. (1983). Boundary work and the demarcation of science from non-science: Strains and interests in the professional ideologies of scientists. *American Sociological Review*, 48(6), 781–795.
- Gilbert, R. (2004). A framework for evaluating the doctoral curriculum. *Assessment & Evaluation in Higher Education*, 29(3), 299–309.
- Gopaul, B. (2011). Distinction in doctoral education: Using Bourdieu's tools to assess the socialization of doctoral students. *Equity & Excellence in Education*, 44(1), 10–21.
- Hancock, S., & Walsh, E. (2016). Beyond knowledge and skills: Rethinking professional development during the STEM doctorate. *Studies in Higher Education*, 41(1), 37–50.
- Hancock, S., Hughes, G., & Walsh, E. (2017). Purist or pragmatist? UK doctoral scientists' moral positions on the knowledge economy. *Studies in Higher Education*, 42(7), 1244–1258.
- Henkel, M. (2000). *Academic identities and policy change in higher education*. London: Jessica Kingsley.
- Henkel, M. (2005). Academic identity and autonomy in a changing policy. *Higher Education*, 49(1–2), 155–176.
- Hodge, A. (2010). *Review of progress in implementing the recommendations of sir Gareth Roberts, regarding employability and career development of PhD students and research staff*. Swindon: Research Councils UK.
- Knorr-Cetina, K. (1999). *Epistemic cultures: How the sciences make knowledge*. Cambridge: Harvard University Press.
- Lahenius, K. (2012). Communities of practice supporting doctoral studies. *The International Journal of Management Education*, 10(1), 29–38.
- Lam, A. (2010). From 'Ivory tower Traditionalists' to 'Entrepreneurial Scientists'? Academic scientists in Fuzzy University—Industry boundaries. *Social Studies of Science*, 40(2), 307–340.
- Latour, B., & Woolgar, S. (1986). *Laboratory life: The social construction of scientific facts*. London: SAGE.
- Lauder, H., Young, M., Daniels, H., Balarin, M., & Lowe, J. (2012). *Educating for the knowledge economy?* Abingdon: Routledge.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Lawrence, P. (2002). Rank Injustice. *Nature*, 415, 835–836.

- Lovall, D., & Kahneman, D. (2000). Living with uncertainty: Attractiveness and resolution timing. *Behavioural Decision Making*, 13(2), 179–190.
- Marginson, S. (2007). *Prospects of higher education*. Rotterdam: Sense.
- Marginson, S. (2015). Rethinking education, work and ‘employability’: Foundational problems of human capital theory. Keynote address to Society for Research in Higher Education conference, 9 December.
- Maschler, M., Solan, E., & Zamir, S. (2013). *Game theory*. Cambridge: Cambridge University Press.
- Merton, R. K. (1973). *The sociology of science: Theoretical and empirical investigations*. Chicago: University of Chicago Press.
- Mitroff, I. (1974). Norms and counter-norms in a select Group of the Apollo Moon Scientists: A case study of the ambivalence of scientists. *American Sociological Review*, 39(4), 579–595.
- National Academies. (2014). *The postdoctoral experience revisited*. Washington, DC: The National Academies Press.
- Nature. (2011). Education: The PhD factory. *Nature*, 472, 276–279.
- Nature. (2014). Editorial: Harsh reality. *Nature*, 516, 7–8.
- Neumann, R., & Tan, K. K. (2011). From PhD to initial employment: The doctorate in a knowledge economy. *Studies in Higher Education*, 36(5), 601–614.
- Park, C. (2005). New variant PhD: The changing nature of the doctorate in the UK. *Journal of Higher Education Policy and Management*, 27(2), 189–207.
- RCUK (2015). Statement of Expectations for Postgraduate Training. <http://www.rcuk.ac.uk/documents/skills/statementofexpectation-pdf/>.
- Roberts, G. (2002). *SET for success: The supply of people with science, technology, engineering and mathematics skills*. London: HM Treasury.
- Robertson, S. L. (2005). Re-imagining and rescripting the future of education: Global knowledge economy discourses and the challenge to education systems. *Comparative Education*, 41(2), 151–170.
- Royal Society. (2014). *Doctoral students career expectations: Principles and responsibilities*. London: Royal Society.
- Sauerma, H., & Roach, M. (2012). Science PhD career preferences: Levels, changes, and advisor encouragement. *PLoS One*, 7(5).
- Shacham, M., & Od-Cohen, Y. (2009). Rethinking PhD learning incorporating communities of practice. *Innovations in Education and Teaching International*, 46(3), 279–292.
- Shapin, S. (2008). *The scientific life*. London: University of Chicago Press.
- Sinclair, J., Barnacle, R., & Cuthbert, D. (2014). How the doctorate contributes to the formation of active researchers: What the research tells us. *Studies in Higher Education*, 39(10), 1972–1986.
- Skovgaard-Pedersen, H. (2014). New doctoral graduates in the knowledge economy: Key trends and issues. *Journal of Higher Education Management and Policy*, 36(6), 632–645.
- Slaughter, S., & Leslie, L. (1997). *Academic Capitalism*. Baltimore: Johns Hopkins University Press.
- Slaughter, S., & Rhodes, G. (2004). *Academic capitalism and the new economy: Markets, state, and higher education*. Baltimore: Johns Hopkins University Press.
- Smith, A. (2010). *One step beyond: Making the most of postgraduate education*. London: Department for Business Innovation and Skills.
- Stehr, N. (1994). *Knowledge societies*. London: SAGE.
- Stokes, D. (1997). *Pasteur’s quadrant: Basic science and technological innovation*. Washington: Brookings Institution Press.
- Strauss, A., & Corbin, J. (1998). *Basics of qualitative research* (2nd ed.). Thousand Oaks: SAGE.
- Temple, P. (Ed.). (2012). *Universities in the knowledge economy*. London: Routledge.
- Turocy, T., & von Stengel, B. (2001). *Game Theory*. CDAM Research Report LSE-CDAM-2001-09.
- Van der Weijden, I., Teelken, C., de Boer, M., & Drost, M. (2016). Career satisfaction of postdoctoral researchers in relation to their expectations for the future. *Higher Education*, 72(1), 25–40.
- Walsh, E., Anders, K., & Hancock, S. (2013). Understanding, attitude and environment: The essentials for developing creativity in STEM researchers. *International Journal for Researcher Development*, 4(1), 19–38.
- Welsh, R., Glenna, L., Lacy, W., & Biscotti, D. (2008). Close enough but not too far: Assessing the effects of university-industry research relationships and the rise of academic capitalism. *Research Policy*, 37(10), 1854–1864.
- Zolas, N., Goldschlag, N., Jarmin, R., Stephan, P., Owen-Smith, J., Rosen, R., McFadden Allen, B., Weinberg, B., & Lane, J. (2015). Wrapping it up in a person: Examining employment and earnings outcomes for PhD recipients. *Science*, 350(6266), 1367–1371.