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Multi-dimensional time and university technology commercialisation as opportunity praxis: A realist synthesis of the accumulated literature

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ABSTRACT

The empirical observation that only a small minority of university patents are translated into commercialised technology, combined with the absence of systematic research on opportunity praxis provided the motivation for our research. Time constitutes a critical dimension in the unfolding of, and therefore it offers a window into, deciphering praxis. In response, we set out to develop a novel temporal framework that could be used to provide insights into the opportunity praxis of university technology commercialisation. This framework builds on the paradigmatic foundations of critical realism and is used to conduct a realist synthesis of the existing literature. Our findings support an extension of the temporal boundaries of commercialisation towards innovation, placing increasing emphasis on user-entrepreneurs and organisations. Moreover, our analysis shows that there is merit in understanding the choices they make, from a kaleidoscope of alternatives visible to them, at specific junctures. This is an important aspect of increasing the translation of university-held patents into commercialised technology.

1. Introduction

It is widely acknowledged in research debates that universities' considerable research capabilities can act as stimuli of innovation and economic growth (Noh and Lee, 2019; Petruzzelli and Murgia, 2020; BrownWood and Sheaf, 2022). University technology commercialisation, defined here as the process of exploiting academic knowledge through the mechanisms of licensing of patents or launching university spin-offs (Perkmann et al., 2013), is widely viewed as the means for realising this potential. This is underpinned by a concerted effort by universities, encouraged by policy actors, to protect research outcomes, resulting in a profound growth in the number of patents granted to the universities (Baldini, 2009; Cho and Kim, 2014; Wu et al., 2015; Bengtsson, 2017). However, only a small part of this protected knowledge – and by implication, the opportunity involved – is translated into commercialised technology: as measured in terms of licensing agreements and income, as well as the performance of university spin-offs (Abrams et al., 2009; Swamidass and Vulasa, 2009; Swamidass, 2013; Valdivia, 2013; Rasmussen, 2018; Battaglia et al., 2021).

Given this apparent empirical problem, the lack of a coherent body of scholarly enquiry focusing on opportunity praxis (Kalantaridis and Küttim, 2021; BrownWood and Sheaf, 2022; Marx and Hsu, 2022) – defined as the identification of a source of demand for the exploitation of knowledge that will be enacted in the present to shape future products and markets (Venkataraman, 1997, 120) – is surprising. This is what Wu et al. (2015) define as marketability, and they consider it an important space for further study to look at 'why some university inventions are taken up by the market but others are not' (ibid., 14). In a more recent study, Molner et al. (2019) suggest that the identification of market spaces for early-stage university-generated technologies is a fundamental but still under-explored activity. Finally, Kalantaridis and Küttim (2021) highlight the importance of further research into how actors discover or create entrepreneurial opportunities in the context of university commercialisation. The absence of a coherent understanding of opportunity praxis is evident despite the rapid growth of research on university technology commercialisation (reviewed recently by Noh and Lee, 2019; Skute, 2019; Hamilton and Philibin, 2020). The disparate nature of the body of research around opportunity praxis may be linked to the absence of a systematic review of the relevant literature. This issue, as well as the ensuing absence of an agenda to shape future research alongside an empirical problem that is important for innovative activity, have provided the motivation for our work.

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Praxis revolves around how scarce resources are to be allocated between present priorities (e.g. improvements regarding current products or customers) and future possibilities (e.g. developments of new products or markets) (Dodgson et al., 2014). In engaging in such activities, academic entrepreneurs, technology transfer officers and user-entrepreneurs must draw upon their experiences, which are themselves shaped by actors' empirical observations of outcomes resulting from past actions. Moreover, the timing of key decisions in the early stages of university technology commercialisation is increasingly recognised as important for success (Thomas et al., 2020). Thus, temporality offers a window into the study of opportunity praxis. However, considerations of time remain under-conceptualised across innovation management research and the study of university technology commercialisation (Dawson, 2020; Ellwood and Horner, 2020; RitalaSchneider and Michailova, 2020). This is also apparent in that recent extensive reviews of the literature (from wide ones like Noh and Lee, 2019, and Hamilton and Philibin, 2020, to narrower ones like Miranda et al., 2018, focusing on spin-offs and Skute, 2019, examining academic entrepreneurship) fail to unveil theory-driven empirical research that considers temporality. Thus, our paper sets out to develop what we believe is a novel temporal framework that could be used to understand the opportunity praxis of university technology commercialisation. Our underlying objective is to map out a research agenda that could increase the translation of protected knowledge into innovation.

The temporal framework developed and used in our paper draws from the paradigmatic ideas of critical realists, particularly Bhaskar. This is for two reasons. First, critical realism acknowledges 'the historicity of the process of change, where this process unfolds over time and where each moment is part of a historically specific point in time and not enveloped within an ahistorical diagram' (Archer, 1995, 154). This is important in understanding a process where temporality is significant and complex; moreover, it helps us articulate our first research question: *how does university technology commercialisation unfold through time?* Second, it advocates for understanding the structures that underpin society so that they can effect change in the future (Hay, 2002). Thus, it accommodates the influence of path dependence (i.e. when past actions are repeated, meaning that protected knowledge remains underutilised) while also allowing scope for alternative potential outcomes (instances when new and alternative courses of action are adopted, leading to commercialisation). This offers a promising outlook for grappling with our second research question: *how does the constraining influence of path dependence afford scope for transformational change that is inherent in opportunity praxis?*

Our paper deploys a realist synthesis approach to a systematic review of the literature on university technology commercialisation. This is a theory-led method that is commonly used for reviewing research evidence with the aim of providing explanations about why and how actions work (or do not work) in particular contexts (Denyer and Tranfield, 2009). The method makes assumptions about how an action is supposed to work by using theoretical frameworks to guide evaluation (Pawson et al., 2005; Pawson, 2006). We systematically review the studies published in Web of Science and Scopus from 1999 until the end of 2021.

We believe that our paper makes a positive contribution to the study of university technology commercialisation in several ways. First, we bring temporality to the fore of the context in which opportunity praxis unfolds. While agency remains the remit of actors in our study (unlike in that of Ellwood and Horner, 2020), we illustrate how their focus moves between a past, present and future that involves chronological, process and lived time (so they can turn from a past process time to a future lived one). Second, our emphasis on opportunity praxis turns the focus of research towards actors who have remained in the shadows of existing research. Users become more visible, providing insights into the realisation of opportunity alongside knowledge creation. Thus, the process explored is extended further towards its innovation end, providing insights into actions taken within user-organisations. Finally, all actors are understood as purposive, making choices from a kaleidoscope of alternatives visible to them in temporal junctures. In our view, the combined effect is a novel perspective on commercialisation that focuses on choices – some enacted and some not – rather than simply on what actors do. This underpins a research agenda that matters because of the significant innovation and economic growth potential involved in the exploitation of the knowledge-generating potential of universities.

The structure of our paper is as follows. The next section considers existing views of time in innovation management, particularly university technology commercialisation, and proceeds to introduce a critical realist view. Then, we discuss the methods used in our study before presenting the results of the bibliometric and content analysis. We proceed to discuss our findings before developing an agenda for future research. Finally, we draw some conclusions.

2. Conceptualisations of time and a critical realist view

2.1. Existing conceptualisations of time

In a recent and well-considered paper, Ellwood and Horner (2020) argue that while the challenge confronting innovation managers is temporal in nature, the study of this dimension of the context within which praxis occurs remains an elusive concern for scholars (Bakken et al., 2013; Hernes et al., 2013; Hernes, 2014; Reinecke and Ansari, 2017). In a more directly relevant contribution to the study of university technology commercialisation, Dawson (2020) contends that the 'increasing recognition of the importance of studying processes of becoming … accommodating flux, non-linearity and temporal flows … the processual nature of business interactions … as well as the process-contextual issues for those wishing to develop a new start-up business highlight the growing centrality of temporal flows' (ibid., 233–234). However, he concludes that 'concerns continue to be raised about the lack of conceptual development in this area' (ibid., 234). Similarly, Barberá-TomásAzagra-Caro and D'Este (2021) emphasise the role that time plays in university technology commercialisation. They advocate for longitudinal research, which is admittedly in short supply, as a means of enhancing our understanding of temporal evolution and change.

Drawing on the ideas of McTaggart (1908), Ellwood and Horner (2020) contend that in the prevailing wisdom of innovation management research, temporality can be viewed in terms of events that are positioned either 'earlier than' or 'later than', and such placements of events never change. Thus, the development of new technology comes after the production of the research outcome and before its launch in the marketplace. This suggests that events occupying fixed temporal positions and time constitute the background upon which actions and events unfold. In the study of opportunity, there is also a view of time as chronological (or a clock; the concepts are used interchangeably here), whereby a given past determines actions taken in the present, which then shape the markets of the future (McKelvie et al., 2020). The implications of the passage of chronological time are often acknowledged as a constraint, moulded by prior knowledge, on entrepreneurial opportunity (Shane, 2000).

In a radically different conceptualisation, temporality is viewed as processes of sense making, whereby individuals construct and reconstruct meanings in their attempts to understand and make sense of what is occurring (Rouleau and Balogun, 2011). According to Weick (1995), this consists of people making sense of events, reflecting back on the past and producing part of the environment they face via enactment. This is not dissimilar to the view advanced by Ellwood and Horner (2020), who consider 'the past, present and future not as fixed and delineated states but as shifting and mobile constituents of the ever-expanding present or duration. According to this view, the past and future are no longer fixed in space along a timeline but are constantly shifting 'seas of meaning' (ibid., 367). Thus, time comes to the foreground, acquiring agency in structuring university technology commercialisation. Similarly, in the literature on entrepreneurial opportunity, McKelvie et al. (2020)

contend that there is a large temporal gap between opportunity belief and action. In these situations, 'entrepreneurs are able to imagine a future situation to be an opportunity before they possess the cognitive or material means to act and/or fully understand their desire to do so' (ibid., 532). There are different views about the relationship between clock (objective) and individual (subjective) types of time. In some works, these types of time are viewed as existing in parallel (McKelvie et al., 2020), raising questions about paradigmatic consistency; in others, they are viewed as alternative conceptualisations (Dawson, 2020; Ellwood and Horner, 2020).

In the literature on innovation management and university technology commercialisation, as shown in detail below, there is an implicit acknowledgement of a temporal dimension in the processes at work. The most obvious example involves stage-gate models, in which activities and events are broken down into clear and discrete stages that are punctuated by critical 'go or kill' decision points (Cooper and Kleinschmidt, 1993). In this setting, temporality is shared between those participating in the process, whereas those outside of it are excluded. This exclusion of those outside reinforces the dominant view of temporality as linear and unidirectional (which is also apparent in clock time), in contrast to a minority view that accommodates cyclicality and movement back and forth.

2.2. A critical realist perspective

We conceptualise the three dimensions of temporality identified in the existing body of literature in the context of the multi-layered ontology of critical realism[1]. In this ontological context, reality is understood as consisting of three overlapping domains – namely, the real, the actual and the empirical (Bhaskar, 1978, 56). The *domain of the real* contains all the causal powers operating within the social world and exists independently of events (actual) or our knowledge of these events (empirical). It comprises objects that 'endure and operate independently of our knowledge, our experience and the conditions which allow us to access them' (ibid., 25). The *domain of the actual* is where the causal powers involved in the real are actualised, irrespective of whether actors have observed them (Martin and Wilson, 2016). Finally, the *domain of the empirical* of actualised causal powers that can be seen and assigned meaning by individual actors.

Chronological time, the first dimension of our critical realist framework (captured in Fig. 1), exists independently of individuals; thus, 2022 will follow 2021 in the same way that June precedes July (and has always done so). Events are dotted along chronological time and are empirically seen by actors. This dimension is what we are the most familiar with in innovation management research: in clock time, historicity emerges, along with specific places in historical flow. Such specific places occur sequentially, and specific events can be mapped out against them and considered by actors (i.e. practicing entrepreneurs) and observers (researchers of university technology commercialisation) in relation to them. Process time constitutes the second temporal dimension and is social in nature. It involves events unfolding around a process, the realisation of an action towards the achievement of an outcome, and it comprises multiple actors. Process time can be mapped

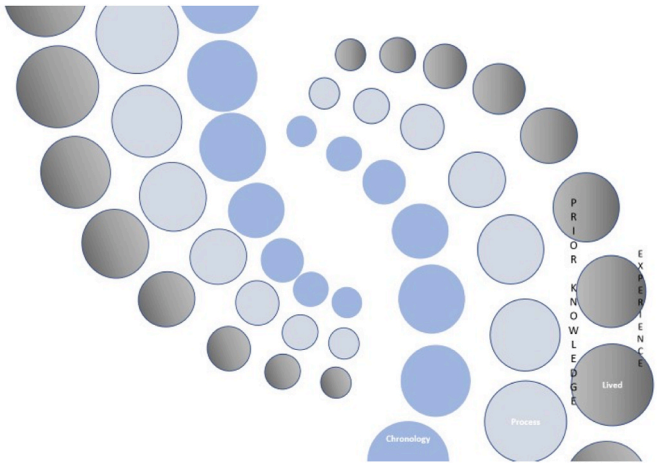

Fig. 1. Critical realist temporal framework for the study of university technology commercialisation.

onto chronological time, but it is also distinct from it. Bhaskar (1978) is cognisant of this dimension, discussing it in the context of the process of science. He states, 'Science is a process-in-motion. It involves three distinct stages that cannot be omitted or collapsed into one another without doing tremendous violence to our understanding of science. But these stages cannot be identified with moments of chronological time; they are phases of science' (ibid., 136). The last dimension of temporality, referred to here as 'lived time', involves time as the life journey of individuals. As such, it is distinct from the other dimensions, and it is shaped by experiences and prior knowledge. Here, experiences are viewed as social products (Bhaskar, 1978) that are the result of our application of a socially influenced conceptual framework to the interpretation of sense data (Elder-Vass, 2007). The relationship between experiences and lived time is twofold. First, accumulated experiences shape this temporal dimension through proximity to (or distance from) the real, actual and empirical. Second, the interpretation of sense data through a socially influenced conceptual framework leads to the formation of new experiences. Another key influence of lived time is prior knowledge (a concept also used by Shane, 2000, in the context of entrepreneurial studies). Indeed, Bhaskar is explicit in stating that a key determinant of our ability to perceive (or not) events is prior knowledge; in this way, he introduces a notion that could be best described as theoretical time. The relationship of prior knowledge and lived time is also twofold, as each element is shaped and influenced by the other. Prior knowledge and experiences influence lived time and individuals' ability to understand not only objective reality as it is but also events that occur in the domain of the actual and their empirical manifestations.

Our conceptualisation allows us a subtler view, than that often prevailing in the literature, of the constraining impact of time. This is because time shapes present actions through path dependence, and by implication, affects future states of affairs. This brings to the fore the issue of whether path dependence affords the scope for multiple and alternative possible future outcomes. Key in this is the concept of fallibilism, that is, that an actor's understanding of the real, actual and empirical cannot be conclusive but only conditional and conjectural in its nature, reflecting the limits to knowing with certainty (Easton, 2010). As Easton (2010) stated,

> The empirical domain is where observations are made and experienced by observers. However, events occur in the actual and may not be observed at all or may be understood quite differently by observers. There is a process of interpretation that intervenes between the two domains. Events occur as a result of mechanisms that operate in the real domain. It is not the case that the real or the actual cannot

[1] There is extensive debate in the literature regarding how the ideas of Bhaskar compare with Gidden's structuration (e.g. Pozzebon, 2004; Jessop, 2005). Researchers espousing a realistic ontology will likely tend toward Bhaskar's account, whereas those ascribing to a nominalist or constructivist ontology should find Gidden's structuration theory more appealing. While the emphasis is placed on the domains of the real, actual and empirical in the case of the former, in the latter, it centres on the duality between structure and agency. This duality means that structure is viewed in isolation from action, implying that a given structure is equally constraining and/or enabling for all actors and all actions. Bhaskar's approach facilitates more diversity underpinned by the use of the concept of fallibilism.

be observed but that it may not always be capable of being observed. (Ibid., 123)

Thus, one day follows another in the same manner that August follows July and precedes September. In most instances, because of the effect of process time linked with the unfolding of specific events, each day will be similar but not identical to the one before. Some processes will result in continuity (either because this is what was intended or because of fallibility), while others may lead to change. This could be conceived as many 'intersecting spirals where linear, irreversible processes fold back upon themselves in multiple feedback cycles' (Adam, 1990, 87). In turn, these spirals may influence lived time – potentially in a differential manner because people have distinct experiences and prior knowledge – while they are also mapped against chronology.

3. Methodology

The methodology employed in our paper is a realist synthesis approach to a systematic review of the existing literature (Ellwood et al., 2017) regarding the role of temporality in studying the opportunity praxis in the context of university technology commercialisation. Systematic reviews of the literature in the wider field of innovation management mainly focus on synthesising theories, methods and contexts to configure the direction of future research (Paul and Criado, 2020). In contrast, realist synthesis – the approach used in our paper – constitutes a theory-led method used for reviewing research evidence with the aim of providing explanations about why and how actions work (or do not work) in particular contexts (Denyer and Tranfield, 2009). The approach makes explicit underlying 'assumptions about how an action is supposed to work – that is, to search out a programme theory or mechanism-of-action – and then to use this theory to guide evaluation' (Pawson et al., 2005, 3). Papers using the realist synthesis approach to a systematic review of the literature have started to emerge in social sciences and innovation management research over the past five years or so (Ellwood et al., 2017; McLainLawry and Ojanen, 2018; Kalantaridis and Küttim, 2021).

Following other recent high-level systematic literature reviews in the area of innovation management (Kirchberger and Pohl, 2016; Miller et al., 2016; Pereira et al., 2021; Vrontis and Christofi, 2021; Vrontis et al., 2021; Christofi et al., 2021), we started the systematic literature review by developing the initial inclusion criteria in the form of search boundaries. These included the following elements: (i) specifying the databases used for searching the literature, (ii) specifying the search time frame and (iii) defining search terms for finding the relevant studies.

Our literature search focused on the Scopus and Web of Science databases, which were selected for their coverage of high-quality research (Mongeon and Paul-Hus, 2016). The search covered the period between 1999 and the end of 2021. The search terms used were 'commercialisation' (also with its US spelling) AND 'university' AND 'opportunity', which were employed to search the title, abstract and keyword fields of the aforementioned electronic databases. Our search strategy was to use all-encompassing search terms to initially review the topic in a holistic manner (Miller et al., 2016). Because we wanted to include a wider range of studies, we did not limit our search to a specific time frame. This generated an original list of 317 papers.

Next, we developed the initial exclusion criteria to decide on the selection of papers for the study (Christofi et al., 2021). These consisted of removing the following: (i) papers for which the full texts were not available; (ii) conference papers, book reviews, book chapters and books (as they do not undergo the scrutiny involved in peer review); (iii) articles published in languages other than English; and (iv) duplicates that appeared in both databases.

To select the relevant studies, a set of inclusion and exclusion criteria were defined and applied across the four steps to select papers addressing the topic of the study and to obtain an unbiased basis to decide which articles to focus the review on (Tranfield et al., 2003; White and Schmidt, 2005; Kirchberger and Pohl, 2016). The steps undertaken in the systematic literature review, as well as the inclusion and exclusion criteria for selecting the papers, are outlined in Appendix 1. Each author performed these steps independently, and any differences were reconciled at the end of all the steps.

As the first step, we read the titles of the 317 papers to confirm that they fell into the general scope of the study, and we excluded those that did not. The abstracts of the remaining 210 papers were read and reread as the second step. We discarded those that did not address the process of transferring university-generated knowledge to the market (e.g. spin-off, licensing). As the third step, the full texts of 67 papers were read and reread. Those addressing entrepreneurial opportunity, commercialisation potential and value, business models and strategies, market ambiguity, market spaces or market scoping as part of the university-industry commercialisation process were included in the study. It was also an important consideration for the papers included in the study to contain a detailed theoretical framework and overview of methods. This left us with 37 papers.

The fourth step in the search process included reviewing the bibliographies of the selected papers (similarly to Christofi et al., 2021) to identify other relevant articles addressing the topic of entrepreneurial opportunity in university technology commercialisation. The 55 new papers (bringing the totality of papers examined to 372) were also subjected to the second and third steps (described above). After this, 11 additional papers remained, bringing the final count of papers included in our review to 48. This number is similar to those reported in other social science studies using realist synthesis (Bendermacher et al., 2017; Ellwood et al., 2017; McLainLawry and Ojanen, 2018; Kalantaridis and Küttim, 2021).

In the extraction, analysis and synthesis phase, we arranged the findings of the 48 papers in analytical tables to identify patterns regarding entrepreneurial opportunity in the commercialisation of university-generated knowledge. The first round of analysis focused on the key thematic areas of bibliometrics (theoretical basis of the paper, methodology), context (i.e. sector and discipline, path dependence – both at the individual and the organisational level, and lead actor experiences and prior knowledge), intervention (description of the process, domain and distance, entrepreneurial actor attributes), mechanism (spin-off and licensing, description of the process) and output (route to commercialisation, innovation introduced) (Miller et al., 2016). The second stage of analysis consisted of developing a variable-by-variable matrix to identify cases, including a specific type of interaction or inter-relationship (Miles et al., 2014); here, columns represented the mechanism (spin-off and licensing), whereas rows signified the lead actor's prior knowledge, experiences and dimensions of time (chronological, process and lived) identified in our critical realist conceptualisation. This underpinned aggregation has been organised analytically (in the Synthesis section of the paper) as the response to the two research questions we presented in the Introduction section.

3.1. Limitations

Despite the transparency strength coming from the adoption of distinct and explicit steps, realist synthesis also has limitations. One of these relates to the sources/datasets used for the selection of articles. In our study, these were defined by the two databases selected. Previous studies have shown that because of the emphasis on high-quality journals, there is less journal coverage in Web of Science and Scopus compared with other databases (e.g. Ulrich's Periodicals Directory) (Airyalat et al., 2019). In addition, books, book chapters and conference papers were excluded. While this is common in literature reviews because journal papers are usually considered to represent more rigorously reviewed research, we are cognisant that this may have resulted in more descriptive works being excluded from our analysis. The third limitation relates to the selection of keywords for conducting the

literature search. The terms 'commercialisation' AND 'university' AND 'opportunity' were used to conduct the search, omitting other narrower concepts related to specific aspects of the entrepreneurial opportunity, such as 'business model', 'business strategy', 'market ambiguity', 'market spaces', 'market scoping' and 'opportunity evaluation'. This is because our intention was to capture as broad a spectrum of published works on the opportunity praxis of university technology commercialisation as possible.

4. Descriptive analysis

The study includes 48 papers published in 29 journals (Table 1), with only three journals (*The Journal of Technology Transfer*, *Technovation* and *Research Policy*) having published more frequently on the issue. This is a highly distributed pattern, suggesting that key themes that could have provided traction were absent.

Publication intensity varied over time (1999–2021), ranging from one paper (e.g. 1999, 2003, 2009) to six papers (2007) per year. The average was two papers per year, which is rather low and indicates a lack of vibrant debates on this topic. However, half of all the papers were published during the last decade or so, suggesting that this is a contemporary topic.

The papers adopted several theoretical lenses, and the lenses used depended on their disciplinary context. Entrepreneurial opportunity was used as the theoretical basis in a limited number of papers (as shown in Table 2). Several studies approached the phenomenon from the perspective of absorptive capacity (including tacit knowledge). The rest of the studies used several different theories, such as dynamic capabilities, signalling theory, network analysis, institutional theory, resource-based view, entrepreneurial ecosystem analysis, sense making, theory of the firm, contextual approaches to entrepreneurship and venture growth.

The methodological approaches used in the selected papers were mostly qualitative case studies, drawing on interview data (Table 3). These proved particularly helpful for our work in that we were able to follow the dimension of temporality through them. There were also several quantitative or mixed-methods studies. A separate strand of research revolved around conceptual studies that further developed the existing literature.

Table 1
Number of papers by journal.

Journal title	No of papers
Journal of Technology Transfer	8
Technovation	6
Research Policy	4
Academy of Management Journal, Industrial and Corporate Change, Technological Forecasting & Social Change, Journal of Management Studies	2
California Law Review, Chemical Engineering Transactions, European Economic Review, European Planning Studies, IEEE Transactions on Engineering Management, International Business Review, International Entrepreneurship and Management Journal, International Journal of Human Resources Development and Management, Journal of Marketing, Journal of Product and Brand Management, Long Range Planning, Management Decision, Management Science, Management Systems in Production Engineering, Oxford Review of Economic Policy, R&D Management, Science and Public Policy, Scientometrics, Technology and Innovation, Uppsala Journal of Medical Sciences, Venture Capital, World Applied Sciences Journal	1

Source: compiled by the authors

Table 2
Theoretical constructs used.

Theoretical underpinning	Studies
Entrepreneurial opportunity	Baglieri and Lorenzoni (2014); Civera et al. (2020); Hindle and Yencken (2004); Kalantaridis and Küttim (2021); Kotha et al. (2013); Molner et al. (2019); Rasmussen et al. (2011); Vohora et al. (2004); Zahra et al. (2005)
Absorptive capacity	Kidwell (2013); Lee (2012); Lim (2009); Miller et al. (2016)
Signalling theory	Gubitta et al. (2016); Kotha et al. (2018)
Other (network analysis, institutional theory, resource-based view, ecosystem analysis, sense-making, theory of the firm, knowledge conversion, venture growth)	Alavi and Hąbek (2016); Battaglia et al. (2021); Cartalos et al. (2018); Cho and Kim (2014); Kalantaridis (2019); Kalantaridis et al. (2017); Logar et al. (2001); Lubik and Garnsey (2016); Nelson (2014); Owen-Smith and Powell (2003); Palo-Oja and Kivijärvi (2015); Prokop (2021); Politis et al. (2012); Siegel and Wright (2007); Thomas et al. (2020); Wu et al. (2015); Zahra et al. (2007); Zhou and Tang (2020)
Atheoretical	Ambos et al. (2008); Berbegal-Mirabent et al. (2012); Braunerhjelm (2007); Colyvas et al. (2002); del Campo et al. (1999); Feller and Feldman (2010); Franzoni (2007); Lenzer and Kulczakowicz (2021); Othman et al. (2014); Siontorou (2014); Thursby et al. (2001); Uranga et al. (2007); Valentin and Jensen (2007); West (2008); Wide (2005)

Source: compiled by the authors

Table 3
Methodological approaches used.

Methodology	Studies
Qualitative	Baglieri and Lorenzoni (2014); Cartalos et al. (2018); Colyvas et al. (2002); del Campo et al. (1999); Feller and Feldman (2010); Franzoni (2007); Kalantaridis et al. (2017); Kalantaridis and Küttim (2021); Kidwell (2013); Lee (2012); Lenzer and Kulczakowicz (2021); Lim (2009); Logar et al. (2001); Lubik and Garnsey (2016); Miller et al. (2016); Molner et al. (2019); Nelson (2014); Palo-Oja and Kivijärvi (2015); Politis et al. (2012); Prokop (2021); Rasmussen et al. (2011); Siontorou (2014); Uranga et al. (2007); Vohora et al. (2004); West (2008); Wide (2005)
Quantitative	Ambos et al. (2008); Battaglia et al. (2021); Berbegal-Mirabent et al. (2012); Braunerhjelm (2007); Civera et al. (2020); Cho and Kim (2014); Gubitta et al. (2016); Kotha et al. (2018); Kotha et al. (2013); Thomas et al. (2020); Thursby et al. (2001); Valentin and Jensen (2007); Wu et al. (2015); Zahra et al. (2005); Zahra et al. (2007); Zhou and Tang (2020)
Mixed methods	Kalantaridis (2019); Owen-Smith and Powell (2003)
Conceptual	Alavi and Hąbek (2016); Hindle and Yencken (2004); Othman et al. (2014); Siegel and Wright (2007)

Source: compiled by the authors

5. Synthesis[2]

5.1. How does university technology commercialisation unfold through time?

University technology commercialisation may occur through one of two mechanisms (unfolding in process time) – namely, spin-offs or licensing. More than half of the papers examined here focus on the launch of a spin-off as the mechanism for university technology commercialisation to emerge as opportunity praxis (Vohora et al., 2004; Zahra et al., 2005; Feller and Feldman, 2010; Kidwell, 2013; Siontorou, 2014; Baglieri and Lorenzoni, 2014; Gubitta et al., 2016; Kalantaridis et al., 2017; Civera et al., 2020; Thomas et al., 2020; Battaglia et al., 2021; Lenzer and Kulczakowicz, 2021; Lubik and Garnsey, 2016; Rasmussen et al., 2011; Prokop, 2021). An example of this, drawing from the experience of Professor John Simpson, is delineated as follows:

> His first entrepreneurial effort can be traced back to 1978 when he founded Advanced Cardiovascular Systems (ACS), in order to manufacture and market his over-the-wire [using a balloon catheter] angioplasty invention. … During his stay in Europe, Simpson observed Dr. Gruntzig performing balloon angioplasty procedures. Back in the United States, Simpson discovered that the catheters, made only in Switzerland, were in short supply. 'When the box arrived, it only had the accessories but there was no balloon. Consequently, I had to buy some tubing and make the instrument'. Therefore, he decided to construct his own catheter … The first big problem they encountered was finding the suitable material from which a balloon could be made. They first experimented with a plastic called polyvinylchloride, which was ineffective, and then tried Teflon tubing which produced unsatisfactory balloons. To solve this problem, they asked Raychem Corporation, one of the largest manufacturers of heat shrinkable materials, for assistance. Thanks to this involvement, they experimented and developed the balloon using a technique called 'free-blowing'. This invention, patented in 1978, led to revolutionary new treatments in coronary disease, using catheters rather than bypass surgery. (Baglieri and Lorenzoni, 2014, 62)

Vohora et al. (2004) stress the importance of the framing and re-framing of the opportunity early in process time; as a result of doing so, 'entrepreneurs thoroughly explore alternative commercial scenarios for a variety of potential applications of their technology … For these entrepreneurs, framing and re-framing the opportunity became an iterative exercise played out over many months and even years' (ibid., 156). Baglieri and Lorenzoni (2014) use the notion of experimentation to capture a similar process. Moreover, Kidwell (2013) focuses on the extrapolation of alternative uses – that is, 'identifying a structural hole and developing a hypothesis on exactly how the … research could address that hole. … They [academic inventors] used these hypotheses to present potential applications to customers' (ibid., 215). Similarly, Wide (2005) contends that this type of knowledge involves a situation where, having found a solution, the potential user is looking for a problem.

Beyond the early stage, past research has identified other elements of process time in the foundation of spin-offs. Probably the most influential analysis is provided by Vohora et al. (2004), who identify five stages and four junctures. The stages of research, opportunity framing and re-framing, pre-organisation, re-orientation and sustainable returns are interspersed with the junctures of opportunity recognition, entrepreneurial recognition, threshold to credibility and threshold to sustainability. It is worth noting here that both stages and junctures unfold in process time. Similar stages are identified by Hindle and Yencken (2004), whereas Palo-Oja and Kivijärvi (2015) focus on early work revolving around planning, selecting and marketing commercialisation ideas.

The alternative mechanism focuses on the licensing of university-generated knowledge by an existing user-organisation (Wide, 2005; Franzoni, 2007; Feller and Feldman, 2010; Lee, 2012; Kalantaridis et al., 2017; Kotha et al., 2018; Kalantaridis, 2019). An illustration of this inter-relationship is provided by Kalantaridis et al. (2017) in the case of Alpha, where an established Finnish venture sought technology that would complement its own (patents pursued simultaneously in both chronological and process time). After searching 'research markets' and using academic networks (the small business being an academic spin-off itself) to establish contact, it approached Tallinn University of Technology with the aim of obtaining licensing rights to a research outcome produced by an academic in the latter organisation. The identification of appropriate use is not a key consideration here because it is the user-organisation that identifies the technology needed to resolve an existing problem (Franzoni, 2007; Nelson, 2014). Nevertheless, licensing should not be viewed as a single event in time; instead, it can be considered as something that could lead to more long-term cooperation and to attracting further research funds (Zhou and Tang, 2020). There has only been one paper exploring stages in licensing: Logar et al. (2001) focus on actions taken within universities (assessment, selection, development, review and appraisal, match making and sale to an established enterprise) to secure licensing.

There are significant but somewhat expected differences in the lead actor and the choice of mechanism. A defining element in this setting is the decision of the academic of whether or not they want to drive the process of commercialisation – and thus occupy the role associated with the terms of academic entrepreneur, scientist-inventor, or scientist-user – or leave the exploitation of the research output in the hands of university Technology Transfer Officers (TTOs). In instances where the academic drives commercialisation, a spin-off is launched (Vohora et al., 2004; Zahra et al., 2005; Siegel and Wright, 2007; West, 2008; Baglieri and Lorenzoni, 2014; Siontorou, 2014; Gubitta et al., 2016; Kalantaridis et al., 2017). Moreover, there is a shared view of how the academic's prior knowledge – both positively in terms of access to the domain of the real of the science involved in the research output and negatively in terms of the academic's distance from the opportunity – shape the process at work (Baglieri and Lorenzoni, 2014). The survival of academic spin-offs is threatened by their high-technological and high-risk business area, whereas the cumulative spin-off experience of academics has been found to increase this survival rate (Civera et al., 2020). Braunerhjelm (2007) and Lee (2012) stress the importance of the network of relationships held by academics (acquired in lived time) as a means of creating a new set of linkages with market-based agents (primarily established firms). The importance of heuristics and the experience (contexts of uncertainty) needed to realise the opportunity is also highlighted in the literature (Valentin and Jensen, 2007). This view is supported by Uranga et al. (2007), who focus on the entrepreneurial know-how of academics regarding market expectations. It is worth providing such an example here:

> Civin began his research on stem cells at JHU's Oncology Center … He … started with the assumption, controversial at the time, that stem cells, the master cells from which all other cells in the blood and immune system develop, have their own unique antigens. … 'In the early 1980s, …he had trouble getting the work funded. "Too many untested assumptions", people said' … Civin drew on earlier and parallel research begun in the early 1980s by Koeffler and Golde,

[2] In this section, we implicitly use an architecture that is common to realist synthesis. Our point of departure comprises the mechanisms that can be used in commercialisation – the creation of a spin-off or the licensing of university generated and protected knowledge. The contextual factors that may influence the processes at work are as follows: (i) the sector; (ii) the scientific discipline; (iii) path dependence, which is inherently temporal; and iv) the lead actor and their experiences and prior knowledge. The envisaged/desired outcome is the introduction of an innovation.

> who, working under a federal grant at the University of California at Los Angeles, had developed the KG-1a cell line. … Making use of KG-1a cell line, Civin discovered the My-10 antibody, one in a series of monoclonal antibodies against the cell line KG-1a,4 which, in turn, led to the discovery of the CD34 antigen (CD for Cluster Designation). In May 1982, Civin received the first of two-three-year NIH grants for further research on the antibody and the stem cell antigens. … The research results, which introduced a new way to isolate large quantities of elusive stem cells, were published in the Journal of Immunology. (Feller and Feldman, 2010, 607)

In a few instances in the literature, an external entrepreneur (i.e. not involved in the production of the research outcome) drives the process of commercialisation (Feller and Feldman, 2010; Politis et al., 2012). Interestingly, these studies show that external entrepreneurs are in a better position to deal with opportunity. An example of such a case revolves around the Programmable Implantable Medication System (PIMS):

> [T]he PIMS resulted from … efforts begun in the 1970s at NASA's Goddard Space Flight Center, located near JHU's Applied Physics Laboratory (APL); In 1969, [Alfred] Mann was approached by JHU scientists … Mann and Robert Fischell, who was on the faculty at APL, founded a new company called Pacesetter Systems to further commercialize the rechargeable pacemaker batteries that they had developed. … In 1979, Mann … was demonstrating a new pacemaker design to clinicians at the University of Alabama when the discussion turned to the severity of heart complications due to diabetes and the difficulties in monitoring insulin levels. This suggested a new business opportunity to Mann. In 1979, he started MiniMed [a subsidiary of Pacesetter Systems] as a firm dedicated to commercializing insulin pumps. The company funded research at the JHU APL to adapt the miniaturized pumps, originally developed under NASA funding, to monitor and deliver an insulin supply to the human body. MiniMed introduced … the MiniMed 502, at the 1983 American Diabetes Association convention. … [T]he 502 was soon followed by the 502A, which represented a major technological advancement in both reduced size and increased programmability … Christopher Saudek, a JHU endocrinology professor[,] implanted the first MiniMed pump in a patient … in November 1986. [MiniMed was … spun off in 1985 when Pacemaker was acquired by Siemens.] Saudek's research on the pump had been funded by grants from the company. Within 4 years, the implantable pump was in wide-scale testing in the United States and France. In 1995 approval to market for the implantable pump throughout Europe was granted, and the pump became the most successful implantation device ever sold in Europe. (Feller and Feldman, 2010, 613)

However, when commercialisation is left to TTOs, the adopted approach is that of discovering organisations that would license university intellectual property to innovate (Owen-Smith and Powell, 2003; Franzoni, 2007; Feller and Feldman, 2010; Kotha et al., 2018; Othman et al., 2014). For the university holding the intellectual property (IP), this revolves around increasing the awareness of this IP so that an organisation may opt to license it (remaining agnostic about how this would be used) (Kalantaridis, 2019). This has significant implications for the means used to increase awareness (as discussed in the next sub-section). In this vein, TTOs' personal contacts with established firms are particularly important (Lee, 2012). This view is supported by 75% of TTOs participating in a survey conducted by Thursby et al. (2001) in the US. Berbegal-Mirabent et al. (2012) also identify a positive and statistically significant relationship between the years of experience in the TTO role and start-up success. Only Ambos et al. (2008) suggest that greater experience does not affect commercialisation. The second dimension, from the point of view of licensing organisations, involves the discovery of the opportunities (in the sense of problem solving) involved in the IP offered.

There is a paucity of work examining the agency of (licensing) user-organisations in university technology commercialisation as opportunity praxis. Existing research stresses the importance of sustained linkages between firms and academics (rather than TTOs) in transmitting information about market needs (Colyvas et al., 2002; Wu et al., 2015). This includes validating the application of the technology and gaining experience in product development (del Campo et al., 1999). Owen--Smith and Powell (2003) also present evidence that emphasises 'the central role that firms play as a source of information that enables effective evaluation of the potential of often ambiguous faculty innovations' (ibid., 1707). They usefully quote a TTO who claims, 'We have very good pipelines into the biotech world, we know who is doing what in cancer, who is working in auto-immune, etc. and we go to these companies and get a quick response. There is nothing equivalent on the physical science side' (ibid., 1705). Instead, as will be discussed below, their characteristics are more profound when it comes to defining path dependence.

How does the constraining influence of path dependence afford scope for transformational change that is inherent in opportunity praxis?

Existing research shows path dependence (i.e. the way that the past influences the present) to be an important and multi-dimensional influence of the choice and shape of commercialisation. The foremost (although not the sole) way that this influence is exercised is through absorptive capacity; this is a dynamic capability regarding the acquisition, assimilation, transformation and exploitation of information access that enhances an organisation's ability to gain and sustain competitive advantage (Zahra and George, 2002). This process revolves around the user's pre-existing absorptive capacity (Lee, 2012; Alavi and Hąbek, 2016). The absorptive capacity is not abstract, but rather, it is understood as proximate to the specific sectoral or disciplinary setting of the commercialised research output. This is articulated in terms of the following: (i) either the inventor-user's ability to achieve the conversion and exploitation of knowledge (Lim, 2009; Baglieri and Lorenzoni, 2014) or (ii) the importance of developing (rather than using already existing) absorptive capacity (Siontorou, 2014). A different way that path dependence influences commercialisation revolves around knowledge bases. Kalantaridis et al. (2017) focus on the proximity (or distance) between the knowledge bases of the participants involved in the exploitation of a research outcome. A variant of this revolves around the different knowledge bases included in the process of introducing innovation: it has been contended that combining more distant knowledge domains is riskier than combining more proximate knowledge domains, but a few of these distant combinations result in fundamental breakthroughs of immense value (Kotha et al., 2013). An altogether different consideration relates to the resource basis of the organisations engaged in the commercialisation process (Vohora et al., 2004; Zahra et al., 2005; Franzoni, 2007). These include the ability to signal the value of research outcomes to potential investors through gap funding (Gubitta et al., 2016), the disciplinary background of the organisation (Vohora et al., 2004; Zahra et al., 2005) and resources internal to the organisation (Franzoni, 2007).

However, path-dependence is not constraining of outcomes as they often involve the introduction of change, though research focusing on the latter is less prominent. Given the different mechanisms involved, different measures of outcome are used. Some papers have focused on outcomes that could be viewed as intermediate ones, including disclosures (Franzoni, 2007), commercialisation plans (Palo-Oja and Kivijärvi, 2015), the creation of teams and action plans to drive commercialisation (Cartalos et al., 2018) or the decision of venture capitalists to invest in the further development of the IP held (Gubitta et al., 2016). Studies focusing on commercialisation through licensing have also used outcome measures, such as the completion of a licensing agreement (Kotha et al., 2013) or the income generated from licensing agreements (Kotha et al., 2018). In the case of commercialisation through spin-offs, measures of success include the introduction of new products, the income generated through these products, profitability, the creation of

new IP and new rounds of venture capitalist investment (Vohora et al., 2004; Zahra et al., 2005; Kidwell, 2013).

One factor that influences the performance of spin-offs appears to be the provision of gap funding (Gubitta et al., 2016), viewed by venture capitalists as a proxy of spin-off quality, thus leading to further investment. Another factor that influences the performance of university spin-offs is their relatively weak conceptualisation and visioning capabilities compared with their external entrepreneur–led counterparts (Zahra et al., 2005). This is linked to differential path dependencies, but it does not prevent the former from focusing on the commercialisation of radically new and disruptive technologies that can create new industries, redefine existing markets and alter the nature and dynamics of competition. In the case of licensing, Kotha et al. (2013) argue that while inventions that recombine elements from the same technological domain are likely to be incremental, and therefore less valuable to a firm seeking commercial benefits compared with inventions that combine relatively more distant domains, increasing science distance creates a concomitant coordination problem.

6. Discussion

In relation to our first research question of how university technology commercialisation unfolds over time, the shift from either the chronology or individual and subjective conceptualisations prevailing in the literature to multi-dimensional time offers an alternative meaning to the concept of *juncture* as it is understood in the literature (Vohora et al., 2004). Working within the logic of stage-gate models, past research views this as part of process time alone – thereby detaching it from chronological and lived time – and imposes linearity and incrementality. In our view, junctures occur within process time, but both juncture and process time are shaped by lived time and open to external influences arriving at the same chronology through different processes (see Fig. 2). Let us focus on the example of Alfred Mann presented in the previous section. To us, as observers, it is apparent that the opportunity for PIMS existed in latent form from the early 1970s because scientific knowledge developed by NASA and knowledge of the problem of how to monitor insulin levels were both present at that time. Chronological time, as external to the processes at work, is important at this level, as it allows us to explore the scientific advances at NASA in parallel with the emergence of the problem of how to monitor insulin levels. Researchers at JHU and the Goddard Space Flight Centre and clinicians at the University of Alabama worked in the process of their collective projects,

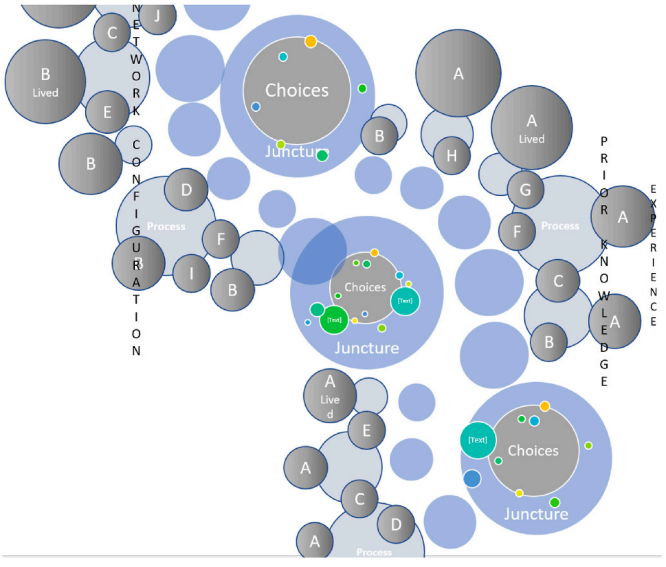

Fig. 2. Revised critical realist temporal framework and agenda for future research on university technology commercialisation.

which did not intersect. Indeed, it was not until Alfred Mann – who worked with JHU – visited the University of Alabama that he was able to bring together and interpret these two elements of knowledge using his individual experiences and prior knowledge acquired in lived time, comprising nearly a decade of running a university spin-off.

Thus, the juncture acquires causal rather than definitional significance. It is not agency in itself (as per Ellwood and Horner, 2020) but instead the result of purposive action by actors that harnesses all three temporal dimensions. While it originates from the past – so that the experiences, prior knowledge and processes may be arrived at – in the sense that the juncture may never be arrived at or that the anticipated future outcomes that it promises may never be realised (for reasons we discuss in more detail below), the juncture is not teleological. What is a necessary condition for the realisation of a juncture is the openness of actors to outcomes coming from processes that they may be able to observe but not directly enact and the openness of process to actors beyond their confines.

This brings us to our second research question, which focuses on the temporal interface between path dependence and transformational change. Lived time is viewed through the lens of experience and prior knowledge, and therefore, it imposes an element of cumulativeness (as shown in Fig. 2) on the actions of actors. In other words, Professor Fischell by virtue of his experiences and prior knowledge could not adopt the same actions as those taken by Alfred Mann. The knowledge bases of actors involved in the exploitation of the entrepreneurial opportunity (Kalantaridis et al., 2017) or the different knowledge bases involved in the process (when cutting across disciplinary boundaries) (Kotha et al., 2013) also constitute constraining influences. In addition, process time results in path dependence at the organisational level: the literature stresses the importance of absorptive capacity (Lee, 2012; Baglieri and Lorenzoni, 2014; Siontorou, 2014; Alavi and Hąbek, 2016), which is specific to the sectoral or disciplinary setting of the opportunity (commercialisation process). Thus, the resource basis of the organisations engaged in commercialisation also shapes choices (Vohora et al., 2004; Zahra et al., 2005; Franzoni, 2007; Gubitta et al., 2016). As a result, lived and process time enable individual and organisational actors to grasp specific opportunities in the domain of the real but prevent them from accessing others.

The importance of fallibility (i.e. outcomes different from those intended) in instigating new processes is apparent in the literature reviewed here. In the case of spin-offs, this is articulated empirically in the case of Professor Simpson, where his failed attempts prompted him to bring in a new partner (Raychem Corporation). Conceptually, this is captured in the work of Vohora et al. (2004). In other instances, such as the cases of Civin and Robert Fischell, fallibility has prompted actors to pursue outcomes from different processes. In the former exemplar, this involves the use of outcomes coming from the work of Koeffler and Golde, while the latter relates to those from the Applied Physics Laboratory. In instances of licensing, an agreement with one user-organisation may lead to very different outcomes than those with another; perversely, this is because of organisation-specific elements of path dependence, as shown in the case of Alpha (Kalantaridis et al., 2017). However, in both licensing and spin-off, this opens up the scope for transformative change. More widely, Braunerhjelm (2007) and Lee (2012) stress networks and the importance of creating new linkages with market-based actors. Thus, the collective nature of process time and the altering of relationships in a network configuration (bringing in new actors or excluding others, as we illustrate in Fig. 2) affords scope for breaking away from path dependence (which is more constraining in the context of lived time). Indeed, we argue that network configuration emerges as a key component of process time in a similar but counterbalancing manner to experience and prior knowledge (in lived time).

Both the transformative implications of fallibility and the constraining influence of path dependence are visible to us as observers retrospectively. However, what is hidden from us is the *kaleidoscope* of alternative processes visible to entrepreneurs – a second causal and

currently concealed influence. TTOs, academic entrepreneurs and users act prospectively. Thus, at any point in time (in all three dimensions), they have alternatives open in front of them. Alfred Mann could have decided to remain involved solely with Pacesetter Systems in 1979 or not to hold onto MiniMed when the parent company was acquired by Siemens. Academics producing knowledge may remain focused on their research and hope that users will license the protected knowledge they created (Lee, 2012; Kalantaridis et al., 2017; Kotha et al., 2018) or they may consider alternative experimentation processes (Feller and Feldman, 2010; Baglieri and Lorenzoni, 2014; Kalantaridis, 2019). When they opt for the latter, they may choose from alternative courses of action, like Professor Simpson did. The alternatives open to them remain at the margins of scholarly research because they focus squarely on what was actualised in a narrow and linear manner rather than what remained latent, in the sense that it was never realised (a present never arrived at). However, this kaleidoscope of alternatives is critically important in shaping the choice of the processes that they drove and were as important as those that were realised.

However, not all alternatives that are open in a latent form are visible to the actors concerned (Kalantaridis and Küttim, 2021). The challenges of monitoring insulin levels in diabetics existed before 1979 but was not visible to Alfred Mann until his meeting with clinicians at the University of Alabama. Similarly Dr Grunzing's procedures were a success at least twelve months before observed by Professor Simpson. Thus, what is relevant in actor choices are the alternatives visible. They have a temporal dimension and may alter from juncture to juncture through -at least in part-new experiences and knowledge acquired by the actors.

7. Implications for future research

Our work has implications for i) the study of the phenomenon and its theorisation, as presented here in three broad themes; (ii) methodology; and (iii) cognate fields. We extend the boundaries of the process temporality of scholarly inquiry towards the exploitation of opportunities within existing (licensing) or emergent (spin-off) organisations (see theme 1 in Table 4). This, in turn, can bring to the fore questions that are present in innovation management research but not in the study of university technology commercialisation, including questions about time (to the market) and timing (of launch). Moreover, we afford a greater scope for research into action that occurs outside universities. As a result, we enhance the importance of research on user-entrepreneurs and organisations that are not academic. While not surprising given the focus adopted by observers/scholars, the relative neglect of these actors means that we know very little about the user perspective. What motivates these user-entrepreneurs and user-organisations in tapping into university-protected knowledge? How do their experiences and prior knowledge shape the processes at work? How may these processes of commercialisation differ from those involving protected knowledge generated internally or by other enterprises? To what extent does experience gained through involvement in the latter facilitate engagement in the former and vice versa?

Table 4
Temporal framework, research findings and directions for future research.

Framework	Findings	Future Research
Multi-dimensional time (chronological, process and lived). Importance of experiences and prior knowledge in lived time.	Juncture as multidimensional, causal influence of change but not teleological.	Theme 1: Focus on the exploitation of opportunities and actions taking place outside universities (in existing and emergent user organisations).
Path dependence and transformational change.	Kaleidoscope of alternative visible actions.	Theme 2: Openness in network configuration and change in actors' temporal focus. Theme 3: Fallibilism as a means of breaking away from path dependence. Methodological 1: Scope for the use of retrospective and prospective methods. Methodological 2: Emphasis on the observer alongside the observed and alternative explanations. Cognate fields: Extension of our temporal framework to innovation management research and entrepreneurial studies.

Our second theme (in Table 4), partly related to the exclusion of users, places emphasis on the importance of openness. Of particular relevance is the flow of knowledge across a wider set of actors involved in a process – an ever-changing network configuration from the original one – suggesting that insights may be gained from the transfer of analytical frameworks from the open innovation literature. More importantly, however, it stresses the merits of heterochronicity, whereby actors turn their attention to different points in time, where the past may replace the present as the focus only to be superseded by a focus on the uncertainties of the future. How does the change in temporal focus influence the decision-making process of actors, particularly in instances where this leads to transformational change? What causes actors to change their temporal focus?

The issue described above is linked with the choice that actors make (the third theme in Table 4). Past research has examined what actors did and not what they chose or (equally importantly) what they did not choose. As a result, it provides no insight into the kaleidoscope of alternative courses of action visible to actors in unfolding junctures. In this sense, we know very little; we are aware of a fraction of what may exist in different domains. We do not know what defines actor choices. However, our study identifies factors that may influence choices that merit investigation – on the one hand, the competing influences of experience and prior knowledge, and on the other, fallibilism and the network configuration. Future research could usefully consider how these factors influence choices, under what junctures they do so and whether this may differ between junctures. In relation to our empirical problem, of particular relevance is the question of how this influence may change and produce a different outcome.

Our work has methodological implications for the study of opportunity praxis from a temporal perspective (Table 4). Prevailing views emphasise longitudinal research as necessary for the study of time (BarberáTomásAzagra-Caro and D'Este, 2021). Instead, we contend – and illustrate – how even a literature review that adopts a retrospective view may provide insights into the unfolding of university technology commercialisation. Moreover, we contend that there is a merit in the deployment of methods (e.g. actor diaries and experiments) that are prospective in nature. Indeed, prospective methods have gained little traction in the study of innovation management and university technology commercialisation research but can be useful in capturing actor choices: we hope that time will provide new momentum for their full exploitation.

Continuing with methodological implications: several times in our paper, we referred to the observers (the researchers including ourselves) of university technology commercialisation. We are cognisant that our paper focuses on the level of action – that is, where actors (academics, TTOs and users) practice the transformation of research outputs into innovation. At the level of observation, as observers, we decipher the practice of actors and operate in three-dimensional time. Indeed, as Bhaskar (1978) states, the advancement of knowledge 'can be shown to have occurred but only from some particular position, some specific vantage point, as it were, in theoretical time' (ibid., 177). The decision to carry out this study was shaped by lived time, under the pervasive

influence of author experiences and prior knowledge; meanwhile, it is positioned in chronological time (e.g. it did not include papers published after 2021), and it occurred in process time. These points undoubtedly influenced our results. Placing greater emphasis on the level of observation may provide new answers to the question of why different conclusions may be coming from studies posing the same research question.

Finally, we argue that the temporal framework we developed could also be used in cognate fields of study. In the introductory section of the paper, we have recorded the widespread view that temporality remains understudied and under-conceptualised across innovation management research. Our critical realist ideas could offer a platform for advancement. Our focus on opportunity praxis, gaining insights from research in entrepreneurial studies, means that we can also contribute to this field. Indeed, scholars involved in the study of entrepreneurial opportunity contend that time remains a lacuna meriting further consideration (Shepherd et al., 2015; Fitzsimmons and Shetty, 2019).

8. Concluding remarks

Our introduction mapped out the empirical problem and gap in literature that motivated our work. Our realist synthesis of the literature on opportunity praxis has allowed us to argue that a fundamental shift of emphasis is required to identify appropriate action to grow university technology commercialisation. Specifically, this will require the extension of the boundaries of research further downstream, placing increased emphasis on users – both as entrepreneurial actors and organisations – of university-generated knowledge. These users merit further consideration, not as agents operating in a closed commercialisation process but as open (alongside academics and TTOs) to interpreting outcomes of temporal processes (which themselves need to be opened to non-participating actors). They are confronted with choices (as through a kaleidoscope) between the alternative visible actions open to them. Each of these alternatives is arrived at from past enacted junctures, which may influence the future in a non-teleological manner. At the same time, past junctures that have not been enacted may not be realised or may remain latent for actors to return to at some point in the future. Also the choices visible to them may alter from juncture to juncture on account of experiences and prior knowledge. Understanding how choices are made is critically important for identifying how best to support those choices aimed at change rather than continuity. We suggest that there is merit in conducting research exploring the ease (or cost) involved in engaging in new and potentially fallible processes and openness in network configuration.

Data availability

No data originating from new primary fieldwork investigation was used for the research described in the article.

Appendix 1. Inclusion and Exclusion Criteria for Papers

	Stage	Criteria	No of studies
	Bibliographic searches	Original 'long list' of papers	317
1	Reading of titles	*Inclusion criteria:* 1) the studies addressed university-industry commercialisation. *Exclusion criteria:* 1) the studies did not address university-industry interactions, focusing on universities' role in society, implications of neoliberalism for public research universities, public policy, research funding, etc.; 2) the studies addressed other forms of knowledge transfer between universities and industry (joint research, joint publications, educational activities, consulting, etc.) than commercialisation.	210
2	Reading of abstracts	*Inclusion criteria:* 1) the studies addressed the process of transferring university-generated knowledge to the market (e.g. spin-off, licensing); 2) the studies explored the stages and characteristics of transfer of university-generated knowledge to the market as a central issue; *Exclusion criteria:* 1) the studies did not focus on the university-industry commercialisation process, but on the identity and motives of academic entrepreneurs in commercialisation, education and training for commercialisation, commercialisation networks, economic impact of commercialised inventions, management of university commercialisation, effectiveness of technology transfer, gender issues in commercialisation, etc.; 2) the studies focused on the technical or historical overview of specific technology development without discussing how it was transferred to the market.	67
3	Reading of full texts	*Inclusion criteria:* 1) entrepreneurial opportunity, commercialisation potential and value, business models and strategies, market ambiguity, market spaces or market scoping were addressed as part of the university-industry commercialisation process; 2) the studies included organisational factors and entrepreneurial actor attributes as influencing factors of university-industry commercialisation process; 3) the studies included a detailed theoretical framework; 4) the studies included a detailed overview of methods. *Exclusion criteria:* 1) the studies did not address the process of opportunity recognition and market scoping; 2) the studies did not focus on the organisational and individual factors; 3) the studies did not include a detailed theoretical framework; 4) the studies did not include a detailed account of methods used.	37
4	Snowballing	Snowballing of bibliographies of selected papers. Repeating stages 2 and 3 with applying the selection criteria outlined earlier in the table.	11
	Final list of papers		48

Source: Compiled by the authors

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