# Strategic Choice in Universities: Managerial Agency and Effective Technology Transfer

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**Abstract**

Current theorising about the contingencies underpinning the effectiveness of university technology transfer has emphasised the importance of organisational support, namely the scale of Technology Transfer Office (TTO) support and the provision of incentives. Empirical results pertaining to the effects of these organisational supports are mixed. More recently, academic research and policy reviews have highlighted the potential significance of the strategic choices made by university managers in contributing to the effectiveness of technology transfer activity. Our research attempts to reconcile these two streams of technology transfer research by drawing on Child’s strategic choice theory as an integrating framework. Through operationalising a strategic choice framework and drawing upon data from 115 UK universities (collected through multiple waves of the HE-BCI Survey), this research shows that supporting organisational infrastructure is necessary but not sufficient to account for improved technology transfer effectiveness. Specifically, it highlights the key mediating role of strategic choice, suggesting that it is the *alignment* between strategic choices made by university managers and the supporting organisational infrastructure that accounts for variations in technology transfer effectiveness. Furthermore, we find the mediation relationship between strategic alignment and technology transfer effectiveness is moderated by the breadth of strategic planning efforts, with those universities that engage a wider number of faculty in strategic planning efforts benefiting most from the alignment between strategic choices and supporting organisational infrastructure.

**Keywords**: Strategic Choice, Technology Transfer, Contingency Theory, Commercialization, University-Industry

## Introduction

Recent calls for the reconceptualization of academic entrepreneurship have drawn attention to the fact that institutional heterogeneity is largely overlooked in existing research on technology transfer (Grimaldi et al., 2011; Sánchez-Barrioluengo, 2014; Siegel and Wright, 2015a, 2015b). Specifically, it has been suggested that the ‘one- size-fits-all’ model of teaching, research and technology transfer is not realistic, nor appropriate, given the organisational heterogeneity that characterises universities (Sánchez-Barrioluengo, 2014; Wright et al., 2008). In light of this critique it is argued that universities need to be ‘strategic’ in their technology transfer activities, suggesting the importance of managerial choices and strategic planning.

In the UK context, which is the focus of this paper, the importance of managerial agency in the technology transfer activities of universities has also been suggested by recent policy developments. For example, the UK’s Higher Education Funding Council for England (HEFCE), review on university knowledge exchange concludes that “university leadership plays a vital part in successful technology transfer, yet this role is not well understood in policy reviews and needs to be highlighted further” (HEFCE, 2016, p. 16). This report highlights that one of the important decisions university leaders must make is the extent to which technology transfer is strategically significant to the institution. In the US, a 2015 statement from the Association of American Universities (Association of American Universities, 2015) encouraged its 62 member institutions to “develop and state a clear mission and vision for university management of intellectual property” in accordance with a recommendation by the U.S National Research Council (NRC). The NRC suggested that “the leadership of each institution- the president, provost, and board of trustees should articulate a clear mission for the unit responsible for intellectual property.” (Merrill and Mazza, 2010, p. 66). This recommendation highlighted that the technology transfer mission should be situated within the broader university strategy. Collectively, these policy reports serve to highlight the significance of the strategic choices made by university leadership, in multiple policy contexts.

Whilst previous research and policy reviews have drawn attention to strategic choice as potentially significant for technology transfer activity of universities (HEFCE, 2016; Sánchez-Barrioluengo, 2014; Siegel and Wright, 2015a), the specific role that strategic choices play in impacting the effectiveness of technology transfer activity remains unclear. Here we contribute to existing debates pertaining to technology transfer effectiveness by elaborating the roles that strategic choice and strategic planning play in contributing to the effectiveness of university technology transfer.

Research into the effectiveness of university technology transfer has highlighted several organisational antecedents or ‘agent characteristics’ (Bozeman et al., 2015). The role that technology transfer offices (TTOs) play in promoting technology transfer activity has been subject to extensive empirical analysis (Caldera and Debande, 2010a; Heisey and Adelman, 2011; Rothaermel et al., 2007; Sengupta and Ray, 2017a; Siegel et al., 2003; Siegel and Wright, 2015b; Van Looy et al., 2011). Another key organisational antecedent highlighted is the provision of incentives for staff to engage in commercialisation activity (Arqué-Castells et al., 2016; Caldera and Debande, 2010a; Friedman and Silberman, 2003; Lach and Schankerman, 2004, 2008; Lam, 2011; Link and Siegel, 2005). Interestingly, results from this existing research are ambiguous with regards to the effect of these organisational configurations on technology transfer effectiveness, with some demonstrating positive associations between TTO support, incentives and technology transfer effectiveness and others demonstrating inverse relationships.

This research builds on the logic of Child’s (1997, 1972) strategic choice theory to explain inconsistencies in these results. Specifically, following Child’s proposal that it is the alignment between strategic choices and organisational configurations that determine operational effectiveness, we suggest that university strategic choices play a critical mediating role in determining the effectiveness of technology transfer activity. Therefore, our primary research question is “What role do strategic choices play in determining the effectiveness of university technology transfer activity?”. Recognising the significance of strategic planning in the role of strategy realisation, we also ask “What impact does strategic planning have on the effectiveness of technology transfer activity?”.

We draw upon data from 115 UK universities to answer these questions. The context is significant since there is a large body of literature suggesting that UK universities have increasingly adopted managerial structures from the private sector over the past 30 years (Burnes et al., 2014; Waring, 2017). In sum, our paper offers the following contributions: First, we show that it is the alignment between strategic choice and the scale of TTO support that determines technology transfer effectiveness. Second, we show that the relationship between incentives and technology transfer effectiveness is partially contingent on the alignment between incentives and organisational strategic priorities (see Arqué-Castells et al., 2016). In combination, these two contributions broadly demonstrate that investment in technology transfer infrastructure is *necessary but not sufficient* to enhance the effectiveness of university technology transfer activity. Effectiveness is determined by the degree of *alignment* between technology transfer resources and university strategic priorities. Third, by integrating insights from the strategic planning literature, we show that the impact of strategic alignment is accentuated when strategic plans are developed with input *across* the university. If no strategic planning is conducted or is conducted with limited engagement across faculties then the impact that strategic alignment has on technology transfer effectiveness is attenuated. This is the first study, to the best of our knowledge, that explicitly examines the relationship between strategic planning and technology transfer effectiveness. By highlighting the significance of strategic choice and strategic planning in technology transfer, we suggest that this paper will form the basis for future research that integrates constructs from broader strategy research with the technology transfer literature.

## 2.0 Theory Development

### 2.1 Technology Transfer Effectiveness, Incentives and Organisational Support Structures

The Contingent Effectiveness Model of Technology Transfer (CEMTT) (Bozeman, 2000; Bozeman et al., 2015) provides a cohesive theoretical framework that identifies the key contingencies on which technology transfer effectiveness depends. Specifically, this framework draws attention to the characteristics of the transfer agent; the receiver; the transfer channel; and the transfer object. As well as defining the contingencies that underpin technology transfer effectiveness, Bozeman et al (2015) offer several ‘effectiveness’ principles. Specifically, they propose ‘out-the-door’, ‘market impact’, ‘scientific and human capital’, ‘political’ and ‘public value’ as key technology transfer effectiveness criteria. Most published research pertaining to the effectiveness of university technology transfer operationalises the ‘out-the-door’ effectiveness criterion (Ambos et al., 2008; Anderson et al., 2007; Bozeman et al., 2015; Caldera and Debande, 2010a; Chapple et al., 2005; Debackere and Veugelers, 2005; Lach and Schankerman, 2008; Link and Siegel, 2005; Perkmann et al., 2013; Powers, 2003; Sengupta and Ray, 2017a; Siegel and Wright, 2015b; Van Looy et al., 2011). ‘Out-the-door’ effectiveness refers to the capability of universities to transfer technology to external partners through formal or informal mechanisms. However, this measure essentially reflects levels of activity rather than downstream outcomes of technology transfer (eg economic impact~~).~~

One variant that has been adopted is termed the *out-the-door with agent impacts* effectiveness criterion (Bozeman et al., 2015). For example, when a university transfers technology to an external party in exchange for a licence fee, then the revenue received constitutes an impact to the transfer agent. Following previous research that has adopted monetary value of technology transfer as an indicator of technology transfer success, we adopt the ‘out-the-door with agent impacts’ criterion of effectiveness (Arqué-Castells et al., 2016; Caldera and Debande, 2010a; Chapple et al., 2005; Heisey and Adelman, 2011; Lach and Schankerman, 2008; Link and Siegel, 2005; Powers, 2003; Sengupta and Ray, 2017a; Siegel et al., 2003; Van Looy et al., 2011). This effectiveness criterion is adopted over alternative effectiveness criteria for both empirical practicality and theoretical coherence.

Alternative conceptualisations of technology transfer effectiveness including market impact; political reward; opportunity cost; development of scientific and technical human capital; and public value; are all extremely challenging to operationalise empirically (Bozeman et al., 2015). For example, it is very difficult to systematically examine political rewards as outcomes of technology transfer activity. Likewise, it is very difficult to work on the basis of counterfactual reasoning to ascertain the value of technology transfer in relation to opportunity costs. The public value criterion, which considers technology transfer as effective only when it enhances ‘the collective good’ and contributes to socially shared values, is even less amenable to systematic evaluation, given the difficulties in objectively evaluating ‘social value’. Thus, whilst the ‘out-the-door; criterion is limited as it does not adequately capture the downstream effects of technology transfer, it remains the most commonly employed conceptualisation of effectiveness within university technology transfer research (Bozeman et al, 2015).

The primary concern of this research lies in understanding the relationship between certain agent characteristics and effectiveness. Since our focus is on the role of managerial agency in technology transfer effectiveness, it would be inappropriate to adopt effectiveness criteria that are concerned with the downstream impact, since university managers’ locus of influence is largely constrained by their organisational boundaries. In other words, it would be unreasonable to adopt the ‘market impact’ effectiveness criterion to explore the influence of managerial choices on university technology transfer effectiveness, since there are factors that influence market impact (e.g. strategy and capabilities of the partnering firm) that are beyond the control of university managers. However, university managers do have the capacity to reconfigure internal organisational arrangements that impact on the effectiveness of technology transfer (as highlighted below). The CEMTT model suggests that ‘organisational design’ and ‘technical human capital’ are important agent characteristics that influence the effectiveness of technology transfer (Bozeman et al, 2015). Consistent with this model, research in the context of university technology transfer has established that supporting organisational infrastructure, namely technology transfer offices (technical human capital) (Caldera and Debande, 2010a; Heisey and Adelman, 2011; Rothaermel et al., 2007; Sengupta and Ray, 2017a; Siegel et al., 2003; Siegel and Wright, 2015b; Van Looy et al., 2011) and incentive structures (organisational design) (Arqué-Castells et al., 2016; Caldera and Debande, 2010a; Debackere and Veugelers, 2005; Lach and Schankerman, 2008; Markman et al., 2004; Wu, 2010) are important influences on technology transfer activity.

Despite extensive empirical analysis, the results regarding the capacity for incentives to influence technology transfer effectiveness remain ambiguous. Some have shown that the provision of pecuniary incentives for staff, such as royalty sharing and equity sharing policies results in higher revenue from licenses (Caldera and Debande, 2010a; Friedman and Silberman, 2003; Lach and Schankerman, 2004, 2008; Link and Siegel, 2005). Belenzon and Schankerman, (2009) draw on panel data from 86 US universities to show that adopting incentive pay is associated with a 30-40% increase in the average income per licence. Similarly, Caldera & Debrande (2010) draw on data from 52 Spanish universities to show that an increase in 10% of the inventor’s royalty share could yield up to an 80% increase in licence revenue. Lach and Schankerman (2008) also provide evidence confirming that pecuniary incentives, in the form of royalty shares, strongly affect licensing outcomes when controlling for university characteristics including size, R&D income, local demand environment and scientific composition.

Conversely, others highlight the limited impact that incentives have on technology transfer activity (Arqué-Castells et al., 2016; D’Este and Perkmann, 2011; Göktepe-Hulten and Mahagaonkar, 2010; Lam, 2011; Markman et al., 2004). In an early study, Markman et al (2004) examined the impact that pay policies have on the number of licences granted by universities, drawing on qualitative and quantitative evidence from 128 US institutions. Their regression models show that monetary incentives provided to inventors of licenced technologies have a significant negative relationship. Markman et al (2004) suggest that this negative association indicates a potential misalignment between technology transfer objectives and incentive structures. This potential misalignment is also highlighted by Lam (2011) who explores the motivations of UK scientists to engage in commercialisation activities. Based on a survey of 735 UK scientists, Lam (2011) shows that those academics most likely to be involved in commercial activity are motivated more by an intrinsic desire to provide solutions to real world challenges rather than potential monetary gain. Thus, she concludes that universities seeking to encourage commercialisation should build incentives based on reputational and intrinsic motivations rather than financial motivations. Other studies that adopt the individual academic as the unit of analysis have also demonstrated the relative insignificance of monetary incentives in stimulating commercialisation efforts when compared to reputational motivations (D’Este and Perkmann, 2011; Göktepe-Hulten and Mahagaonkar, 2010).

From the literature discussed above, it is clear that studies adopting *the university* as the unit of analysis are consistent in demonstrating a relationship between pecuniary incentives and licencing activity and those adopting individuals as the unit of analysis are consistent in demonstrating the insignificance of pecuniary incentives as drivers of commercialisation activity. However, Arqué-Castells et al (2016) have recently questioned the link between pecuniary incentives and licensing revenue at the university level. Drawing on data from 15 Portuguese and 39 Spanish universities, they show that the provision of higher royalty shares to staff fail to translate into higher licensing revenues for universities. They echo Markman et al (2004) by suggesting the lack of a relationship between incentives and outcomes is a consequence of the misalignment between TTO objectives and university incentive structures. In concluding their analysis, Arque-Castells et al (2016) draw attention to the important mediation role that TTOs play in the technology transfer process.

This highlights the second form of internal arrangement that university managers can influence, the establishment of specific organisational structures to support technology transfer, namely TTOs. The impact of different TTO arrangements on technology transfer productivity have been the subject of extensive empirical analyses (Ambos et al., 2008; Chapple et al., 2005; Sengupta and Ray, 2017b; Siegel and Wright, 2015b; Van Looy et al., 2011). Specifically, several papers explore linkages between the scale of technology transfer support and relative technology transfer performance (Anderson et al., 2007; Chapple et al., 2005; Heisey and Adelman, 2011; Lach and Schankerman, 2008; Link and Siegel, 2005; Macho-Stadler et al., 2007; Siegel et al., 2003; Thursby and Kemp, 2002; Van Looy et al., 2011). One of the most comprehensive studies of TTO productivity, Siegel et al (2003) demonstrated that larger TTOs experienced greater revenue generation (up to a point) and exponentially increased returns in terms of number of licence agreements. Similarly, Thursby and Kemp (2002) confirmed that larger technology transfer offices are more likely to have higher numbers of licencing agreements. More recently, Heisey and Adelman (2011), in their analysis of panel data from the US covering the period 1981-2003, showed that the number of full-time equivalent staff within TTOs significantly increases licensing revenues accrued by a university. Specifically, they estimate that increasing the number of FTE staff by one in TTOs established post-Bayh-Dole Act could increase median licence revenues by $900k. Although evidence on the scale effect of TTO support broadly points to a positive relationship, some argue that this is not always the case. Notably, Chapple et al (2005) provide parametric and non-parametric analysis on the productivity of 50 UK TTOs concluding that they experience decreasing returns to scale in terms of licensing agreements and revenues. More recently, Berbegal-Mirabent et al (2015) examine the relationship between the number of specialised support staff and productivity in terms of contract research. Based on a sample of 52 Spanish universities they show that the number of support staff has no influence on either the number of research contracts or the income generated by research contracts. Taking the ambiguous relationships between incentive structures, scale of support organisational support and technology transfer effectiveness outlined above into consideration, some have suggested the potential significance of a critical mediation variable, namely that of strategic choice (Siegel and Wright, 2015b).

### 2.2 Strategic Choice and Technology Transfer Effectiveness

Siegel and Wright (2015a, p. 586) in their revaluation of academic entrepreneurship suggest that “many universities are starting to adopt a strategic approach to technology transfer activity” and argue that the strategic choices of universities will vary according to their particular resource endowments and knowledge bases. They specifically emphasise the need for universities to make appropriate choices about strategic priorities with regards to the type of technology transfer and the specific scientific fields (Siegel and Wright, 2015a). This follows earlier reviews of commercialisation research suggesting that universities need to “adopt a strategic approach to commercialisation of IP” and that “they must consider a set of key formulation issues involving choices related to institutional goals and priorities and consequent resource allocations” (Siegel et al., 2007, p. 655). Existing research pertaining to the role of strategic choice in technology transfer effectiveness has characterised strategy as a function of prevailing institutional or environmental characteristics. For example, Hewitt-Dundas (2012) suggests that strategic choices about technology transfer should be based on the research intensity of the institution; those universities characterised by high research intensity should place a greater emphasis on research commercialisation. Similarly, Sengupta and Ray, (2017a, p. 894) adopt an ambidexterity framework in their analysis of the relationship between the ‘research pillar’ and ‘technology transfer pillar’ of UK universities. They find that “the marginal impact of research on both commercialisation and academic engagement channels depends on the university’s scale and reputation, which is dampened for universities that are larger in size and/or particularly reputed in the sector”. Consequently, Sengupta and Ray, (2017a) suggest that university technology transfer strategic choices should relate principally to the research profile, age and reputation of the university. Earlier research by Wright et al (2008) highlighted that ‘mid-range’ UK institutions face distinct challenges in the establishment of effective technology transfer activities due to their relative lack of critical mass of internationally recognised research. They suggest that these universities need to make “careful strategic decisions to build up those areas where they have scope to make an international impact but also to differentiate investment in those areas where they can make a regional contribution” (Wright et al., 2008, p. 1222). Others argue that strategic choices about technology transfer should be consistent with the size of the university (Chapple et al., 2005) and the scientific base of the university (Perkmann et al., 2011).

These existing conceptualisations of strategy are based on two assumptions that will be clarified in this research. First, all existing approaches imply that the strategic choices of university managers have a significant impact on the effectiveness of technology transfer activities. However, there is a paucity of empirical evidence that demonstrates a relationship between university strategic choices and technology transfer effectiveness. Second, strategic choices are viewed as contingent upon the prevailing institutional or organisational characteristics rather than as a consequence of managerial actions (De Rond and Thietart, 2007). For example, strategy is perceived to be a function of university characteristics (research profile; research intensity; size; scientific knowledge base) or environmental conditions (regional characteristics) (Perkmann et al., 2011; Siegel and Wright, 2015a; Wright et al., 2008). Whilst these are important factors, reducing strategy to situational contingencies overlooks the significance of managerial choices (Child, 1972). We consider this problematic, particularly in the UK context, where senior university administrators have increasing discretion regarding university priorities and resource allocation (Burnes et al., 2014; Waring, 2017). Consequently, this paper will focus on managerial choice by exploring the relationship between university strategic priorities, internal organisational configurations that can be manipulated by university managers and technology transfer effectiveness. In order to facilitate this analysis we drawn upon insights offered by Strategic Choice Theory (Child, 1997, 1972).

### 2.3 Strategic Choice Theory: Priorities, Choices, Planning and Effectiveness

Strategic Choice Theory was initially advocated as a corrective to Contingency Theory, which attributed variations in inter-organisational performance to environmental and organisational contingencies (Child, 1997; Donaldson and Luo, 2014). According to Child (1972), variations in inter-organisational performance are a consequence of strategic choices made by senior managers. Child (1972; 1997) outlines a process of strategic choice whereby senior managers first evaluate the organisation’s competitive position related to internal resource configurations and external market demands. Following this evaluation, managers make choices about the strategic priorities for the organisation[[1]](#footnote-1). Then they make specific choices about the actions that are to be undertaken to realise the strategic priorities which involves the commitment of managerial attention and resources. The logic of strategic choice theory suggests that organisational effectiveness is determined by the congruence between internal organisational configurations and the strategic priorities determined by organisational managers.

The focus of this research is on the capacity for university managers to make *appropriate strategic choices* about the significance of technology transfer in light of existing organisational configurations. To clarify, we do not focus on the *specific* *strategic actions* that are undertaken in light of the determined strategic priorities, rather it is assumed that once strategic priorities are established, managerial attention and resources are committed to their realisation. Therefore, we suggest that university managers will first make an evaluation about the strategic significance of technology transfer for their university, based on existing organisational configurations. Following this evaluation about the strategic significance of technology transfer, managerial attention and resources will be committed to technology transfer activity. The commitment of managerial attention and resources will contribute to a closer fit between the specific strategic actions concerning technology transfer and the perceived organisational strengths that contributed to the prioritisation of technology transfer. Therefore, it is the ability of university mangers to make appropriate strategic choices that plays a critical role in determining the effectiveness of university technology transfer activity.

Section 2.1 highlights the organisational configurations that have been identified within the existing literature that both impact on technology transfer activity *and* fall under the domain of senior university managers’ control. Following the logic of Child’s Strategic Choice model outlined above, we suggest that existing internal configurations including the scale of TTO support and commitment of resources to incentives will inform senior managers’ evaluation of the organisation’s competitive position, which will in turn inform their choice about the strategic significance of technology transfer for the university. This is consistent with existing research which suggests that organisational conditions inform choices about technology transfer (Wright et al, 2008; Hewitt-Dundas, 2012; Sengupta and Ray, 2017a). Thus, it is argued that TTO support and incentive mechanisms are *necessary but not sufficient* to account for variations in technology transfer effectiveness, specifically we propose:

***H1:***  The choice to make technology transfer a strategic priority mediates the relationship between the scale of TTO support and the effectiveness of technology transfer activity

***H2:***  The choice to make technology transfer a strategic priority mediates the relationship between the provision of incentives for technology transfer and the effectiveness of technology transfer activity

Child (1997; 1972) notes that strategic priorities are typically articulated through a *formalised strategic planning process*. Therefore, it is important to consider the characteristics of strategic planning when evaluating the role of strategic choice in organisational effectiveness (Arend et al., 2017; Brews and Hunt, 1999; Mintzberg, 1994; Wolf and Floyd, 2017). Specifically, it is argued that one of the key contingencies that affects the realisation of strategic priorities is the breadth of formalised strategic planning (Brews and Hunt, 1999; Wolf and Floyd, 2017). Within this broader literature, strategic plans are conceptualised as “tools that are used by actors to manifest and communicate strategy as well as to control its implementation” (Mintzberg, 1994; Wolf and Floyd, 2017, p. 1772). A recent review of the strategic planning literature suggests a generally positive relationship between breadth of planning and performance (Arend et al., 2017; Wolf and Floyd, 2017). It is highlighted that strategic planning influences organisational performance by fostering the development of shared understandings of organisational strategy which enhances organisational commitment and contributes towards realisation of strategic ambitions (Wolf and Floyd, 2017). Although the value of formal planning has been questioned extensively over the past 20 years, strategic planning has recently been re-conceptualised as a mechanism for integrating levels of management, facilitating the co-ordination of centralised and peripheral sources of strategy (Wolf and Floyd, 2017, p. 1766).

This conception of planning is particularly significant in the UK university context where, over the past 30 years, decision-making has shifted from a participative ‘collegiate’ model towards a hierarchical ‘managerialist’ model (Burnes et al., 2014). This managerialist model is reflective of classical rationalist approaches to strategic planning (Brews and Hunt, 1999), whereby decision-making authority is concentrated in a small group of senior university managers who set strategic priorities for their respective institutions (Dearlove, 1995; Waring, 2017). Mirroring the critiques of classical rationalism within the strategy literature, this mode of planning has been questioned as strategic decisions taken by senior university administrators are short-term, transactional, inconsistent and bureaucratic in nature (Burnes et al., 2014; Pounder, 2001; Smith et al., 2007; Waring, 2017). Burnes et al (2014) advocate an alternative approach to strategy that they term ‘new collegiality’, which attempts to reconcile the need for centralised strategic planning, with local, departmental input (Bryman, 2007; Waring, 2017). Furthermore, they suggest that if universities are to be ‘entrepreneurial’ (Etzkowitz, 2003) then preoccupation with ‘hard’ managerialism focused on centralised decision-making needs to give way to a more participative, collegiate mode of planning. Based on these disparate strands of literature, it is argued that *strategic planning* can play an important role in the relationship between university strategic choices and technology transfer effectiveness. Specifically, it can be argued that approaches to strategic planning that facilitate the integration of centralised decision making with peripheral adaption may be more impactful than classical rationalist strategic planning (Wolf and Floyd, 2017). Therefore, we suggest that the breadth of strategic planning, that is the degree to which strategic plans are developed *across* the institution with input from departments outside of centralised strategic planning, plays an important role in moderating the relationship between strategic choices, organisational configurations and technology transfer effectiveness. Thus, we propose:

***H3a:*** The breadth of strategic planning will moderate the indirect effect of the scale of TTO support on technology transfer effectiveness (via alignment with university strategic priorities). Specifically, the indirect effect will be stronger when the breadth of strategic planning is high rather than when it is low.

***H3b:*** The breadth of strategic planning will moderate the indirect effect of the provision of incentives for technology transfer and technology transfer effectiveness (via alignment with strategic priorities). Specifically, the indirect effect will be stronger when the breadth of strategic planning is high rather than when it is low.

Before outlining how we operationalise our theoretical framework (Fig 1.0), it is important to address the theoretical and empirical rationale for concentrating on the UK. Theoretically, we suggest that the transposition of Strategic Choice Theory, which has developed in the context of private commercial enterprises, to a university setting is unproblematic in the context of UK Higher Education. This is mainly because there is a strong evidence that supports the notion that UK universities have moved from traditional ‘collegiate’ modes of governance towards more ‘managerialist’ models developed within private commercial enterprises. Hence, UK universities are characterised by the adoption of more centralised leadership based on resource allocation, formal planning procedures, implementation of key performance indicators and the development of robust monitoring and evaluation systems (Burnes et al., 2014; Jarratt, 1985; Waring, 2017). Thus, there are reasonable grounds to assume that, over a 30-year period, modes of operation transposed from the private commercial domain have become embedded with UK universities and, therefore, conventional organisational theory is appropriate to analyse *public sector* organisations (such as UK universities).

The second theoretical justification for our focus on the UK context relates to the institutionalisation of technology transfer practices. Specifically, Lockett et al (2015) demonstrate that organisational practices associated with technology transfer have diffused rapidly amongst UK universities; in particular, the proliferation of TTOs. The relative homogeneity in organisational support for technology transfer is evident in our dataset (detailed below) which shows that all 115 institutions have technology transfer personnel and most provide some degree of incentives for staff (only 9 institutions indicate they do not). Therefore, the UK provides an ideal context to study the potential significance of strategy in relation to technology transfer, since the impact of strategic choices on organisational effectiveness may be more discernible in a context characterised by a relatively high degree of institutional homogeneity. This relative institutional homogeneity refers not only to the fact that technology transfer practices are institutionalised in the UK but also that most UK universities are public organisations subject to the same institutional pressures.

The third reason we focus on the UK case is the availability of data. Although much of the work related to technology transfer activity is based on US data, drawing on AUTM survey, it has recently been suggested that data collected in the UK by the Higher Education Statistics Agency (HESA) provides the most comprehensive survey of technology transfer activity globally (Lockett et al, 2015). The particulars of this dataset are discussed in the next section.

## 3.0 Research Methods

### 3.1 Data Sources

We draw primarily upon data collected by HESA in the UK via their Higher Education- Business Community Interaction Survey (HE-BCI). The HE-BCI survey is increasingly adopted in research pertinent to university technology transfer activity (Hewitt-Dundas, 2012; Hewitt-Dundas and Roper, 2018; Lockett et al., 2015; Rossi and Rosli, 2014; Sengupta and Ray, 2017b, 2017a). The survey consists of two main sections. The first asks respondents questions about technology transfer strategy; technology transfer infrastructure; university intellectual property arrangements; approach to social, cultural and community engagement; and university arrangements for continuing professional development. In the second section, respondents outline outputs generated by their institution, in terms of volume and pound (£) values, with regards to: collaborative research; contract research; facility and service provision; intellectual property (patents, licences, sale of shares in spin-off firms); and CPD provision and cultural, social and community engagements.

One of the key strengths is that all UK HEIs are included in the HE-BCI survey. However, it is not appropriate for us to consider all HEIs in our analysis, since some of institutions are not ‘universities’ *per se* but colleges and specialist higher education providers (e.g the Royal Northern School of Music). Therefore, to ensure comparability across our sample, we selected those institutions for which a completed return was submitted that was recognised as a ranked university by according the Times Higher Education Rankings in 2014. Thus, the final analysis was based on data from 115 ranked UK universities

### 3.2 Measures

Technology transfer effectiveness, our dependent variable, is measured by three performance indicators: (1) total IP revenue; (2) value from the sales of spin-off shares; and (3) total value of research contracts. These measures were taken from 2013/14 annual returns giving a three-year time lag between the mediator variable, ‘University Strategic Priority’ (taken from 2010/11 returns) and the outcome variable and a five year time lag between the exogenous variables, Technology Transfer Support and Incentives (taken from 2008/09 returns)[[2]](#footnote-2). Construct validity was established through exploratory factor analysis (EFA), indicating that those three items formed a single factor, eigenvalue = 2.615 with 65.37% of variance explained. Factor loadings were 0.958, 0.937 and 0.849 respectively for the three measures.

We used two exogenous variables related to the commitment that each university makes in terms of realising their strategic aims in relation to technology transfer. The first of these variables is referred to as TT Support and is measured through the number of commercial engagement staff employed by the TTO. Second, in the 2009 questionnaire, HEIs rate the level of incentives for staff to engage with external partners, assessing themselves against a five-point scale where ‘1’ represents barriers outweighing incentives and ‘5’ suggests strong incentives in place. Incentivising is therefore a measure of the perceived level of commitment demonstrated through the offering of incentives for staff; higher scores indicate stronger commitment.

The main mediation explanatory variable of interest is Technology Transfer Priority (TT Priority). In the HE-BCI survey, all respondents were asked to rate, on a dichotomous scale, three strategic priority areas from a list of thirteen, which the respective university regards as important for their competitive position in the market. TT strategic priority in this study was defined as an array of prioritised areas that facilitate the effective transfer of technology in HEIs course of action. In this respect, strategies to attract and retain students; supporting community development including meeting regional and national skill levels; and attracting investments were not included within the boundary of Technology Transfer in this study. Furthermore, ‘support SMEs’ was excluded from the scope of technology transfer because this relates principally to training and CPD rather than IP-based exchanges. This left us with three indicators from the 2011/12 survey to consider: ‘technology transfer’; ‘research collaboration with industry’; and ‘establish spin-offs’; all are dichotomous measures where 1= is a strategy priority; 0= not a priority. A fourth dichotomous variable was created using the item ‘importance of commercial partners’; this has a four-scale measure where 1= highest priority and 4= lowest priority. For unidimensionality, after EFA, the item ‘research collaboration with industry’ was dropped leaving three items with factor loadings 0.875, 0771 and 0.699 explaining 51.6% variance to represent TT strategy latent variable in CFA and SEM analysis.

Our operationalisation of Breadth of Strategic Planning is a measure of the extent to which a business support strategy is embedded in respective HEIs, ranging from limited (no strategic plan) to full implementation (“Strategic plan developed as a result of an inclusive process across the whole HEI”). To create the moderation variable, the five-point Likert scale ‘strategic development of business support’ measure, taken from the 2011/12 HE-BCI survey, was rated dichotomously (1 = “high level of planning”; and 0 = “low level of planning”).

In addition, we measured three variables that previous studies have shown as significant drivers of a university’s level and capacity to invest in technology transfer activities with single-item scales. The log of university size measured by student numbers was a measure of capacity. The log transformed measure of age refers to the age of the TTO. ‘Research quality’ is also included, to control for the possibility that having high calibre research active staff is associated with higher revenues through technology transfer activities. Although industry dummies were included in a linear model (found not to be significant); these were not included in the SEM analysis to reduce complexity. Analyses of the two latent variables confirmed unidimensionality, reliability, and measurement invariance of the loadings across all control variables.

### 3.3Analytical Strategy

To test the hypothesised relationships between TT Support; TT Incentives; University Strategic Priorities; Breadth of strategic planning; and TT Effectiveness, we adopted a structural equation modelling approach. First, exploratory factor analysis (EFA) followed by confirmatory factor analyses (CFA) implemented in AMOS 24 were used to establish the measurement scales for the structural equation models (SEM), tested using the Maximum Likelihood method[[3]](#footnote-3). SEM permits a simultaneous examination of an array of hypothesised equations involving multiple endogenous variables alongside measurement errors, thus providing an accurate measure of the variance explained by exogenous variables (Kline, 2016). SEM is a particularly attractive choice when testing mediating variables in a structural model.

Several goodness-of-fit indices were used to evaluate the model fit in both CFA and SEM: chi-square; normed chi-square (χ2/df ratio - desirable if < 2); root-mean-square error of approximation (RMSEA, good if < 0.06); Tucker-Lewis index (TLI, best if > 0.95); incremental fit index (IFI, best if >0.95); and comparative fit index (CFI, best if > 0.95) ( Hu & Bentler, 1999). When undertaking CFA, measurement reliability was analysed using Cronbach’s coefficient and composite reliability. The convergent validation was evaluated using Average Variance Extraction (AVE), and discriminant validation by comparing the square root of AVE values and correlation coefficients. Prior to the analysis, we checked the data for violations of normality assumptions, for missing data and used the natural logarithm to transform the skewed data and mean substitution to eliminate missing data (Kline, 2016).

The missing value substitution procedure did not cause any statistically significant bias in the data; no statistically significant differences between the original and the missing value mean substituted data series were observed. Nested modelling was performed in both CFA and SEM to ensure the best fitting model is chosen for the final analysis. With SEM, the indirect effects were accounted for using the bias-corrected 95% confidence interval with 2000 bootstrapping samples (Selig and Preacher, 2008). Bootstrapping was performed using nested modelling to confirm full or partial mediation. In instances where zero lay within the lower and upper bound, the results associated with the indirect effect were accepted, rejecting the null hypothesis with a p-value less than 0.05.This method was more powerful than the Baron and Kenny (1986) approach to test mediation effects as it calculates effect sizes for an estimate where the underlying distribution is unknown, which is the case with small sample sizes as used in this research. Moderated mediation using estimand plug-in MyModMed in AMOS 24 was used to test for moderation of the two mediated relationships. Here, composite measures were created to represent the mediator and the outcome variable in the SEM model.[[4]](#footnote-4) The hypothesised moderated mediation model with latent variables was further tested using the PROCESS macro developed for SPSS (Hayes, 2013) and these data were used to provide graphical images of the moderation role.

## 4.0 Data Analysis

### 4.1 Confirmatory Factor Analysis (CFA)

Using EFA results, we compared a series of nested CFA models to select the best fitting model (see Appendix 1 for results and selection process). A chi-square difference test showed that the two factor model consisting of the mediator variable and the output variable exhibited a significantly better fit than any other alternative model (χ2= 19.468; *df* =8; CFI = 0.955). This best fitting model was then used to examine construct validity and reliability using CFA Maximum Likelihood estimation method. Regarding the measurement model, we assessed individual item reliability (see Table A in Appendix 1). Loadings are generally above the accepted threshold of 0.6 (Nunally, 1978). In addition, both constructs and dimensions achieve convergent validity as indicated by the average variance extracted (AVE) rates of over 0.5 (Bagozzi and Yi, 2012) and discriminant validity by the significant chi-square differences between the constrained and unconstrained models (Δχ2(12) = 4.53, *p* < 0.05) (Anderson and Gerbing, 1988)[[5]](#footnote-5).

Table 1 presents the descriptive statistics, zero-order correlations for latent variables, the two exogenous variables and control variables. As shown in the Table, moderate positive or negative correlations were evident among the variables. We also studied the bi-variate correlations for regional dummies but as none of them significantly associated with the mediator and outcome variables these were not included in the Table or in the SEM model for parsimony. The correlations between the key variables suggest that the coefficients are largely in the expected direction and are statistically significant.

Table 1: Descriptive statistics and the correlation matrix.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Mean | S.D.  | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TT Effectiveness (ln) | 6.07 | 1.98 | 1 |  |  |  |  |  |  |
| TTO Support  | 2.96 | 1.07 | .467\*\*\* | 1 |  |  |  |  |  |
| Provision of incentives  | 3.79 | 0.87 | .231\* | .265\*\* | 1 |  |  |  |  |
| TT strategy  | 0.47 | 0.35 | .658\*\*\* | .310\*\*\* | .239\*\* | 1 |  |  |  |
| Strategic planning  | 4.31 | 0.76 | .113 | .173 | .185\* | ..098 | 1 |  |  |
| University Size (ln) | 9.63 | 0.57 | .643\*\*\* | .610\*\*\* | .190\* | .368\*\*\* | .166 | 1 |  |
| Age of the TTO (ln) | 2.71 | 0.74 | .340\*\*\* | .267\* | .238\* | .263\*\* | .016 | .340\*\*\* | 1 |
| Impact (%) | 34.3 | 12.03 | .737\*\*\* | .283\*\* | .183\* | .511\*\*\* | .084 | .539\*\*\* | .341\*\*\* |

\*p<0.05; \*\*p<0.01; \*\*\*p<0.000

### 4.2 Hypotheses Testing: SEM modelling

Following the previous CFA analysis, a SEM analysis using technology transfer priority as a latent variable with three indicators; technology transfer effectiveness as a latent variable with three indicators; and TTO support and provision of incentives as single item observed variables, was performed. As the two exogenous variables represent conceptually related processes, we allowed TTO support and provision of incentives to co-vary and controlled for the effects of institutional size, age and the impact of research activity on all endogenous variables.

Mediation was analysed with the help of structural regression models in AMOS 24 and performed bootstrapping as recommended by Preacher and Hayes (2008, 2004). In this study, we model Technology Transfer Strategic Priority as a mediating variable. Mediation (TT Strategic Priority) tests specify the presence of a significant intervening mechanism between antecedent variables (TTO Support and Provision of Incentives) and the outcome variable (TT Effectiveness). For a strong mediation, the mediator variable (TT Strategic Priority) should account for a significant proportion of the relationship between the intervening and the outcome variables. Mediation can be full or partial. While in full mediation the presence of the mediator variable is necessary for a significant outcome between the independent variable and the dependent variable (e.g. prioritisation of technology transfer is necessary for a TTO to reap the benefits from technology transfer activities) the partial mediation explains both a direct and an indirect relationship. This means that the mediator alone does not influence the relationship between the independent and the dependent variables, although it is an important criterion (e.g. technology transfer priority alone does not facilitate the provision of incentives to produce financial returns from the technology transfer activities, although the presence of a strategy is a significant enabler). Figure 1 provides a schematic representation of the mediated (and the moderated) model.

Figure 1: Schematic Overview of Mediated and Moderated-Mediation Models



Before testing the hypothesised relationships, we estimated a series of competing nested models against the baseline model using sequential chi-square tests. This provides successive fit assessments (Steiger et al., 1985) of models that differ in the number of hypothesised paths. We compared four models: a null model (Model 1), a direct model (Model 2), a partial mediation model (Model 3) and the full mediation model (Model 4)- see appendix 2 for further explanation and data tables.

When comparing mediated versus the null and the direct models, evidence of mediation can be established when a fully or partially mediated model provides a significant improvement over other models (Kelloway, 1995). Since the partial mediation alternative is nested within the full mediation model, the model comparison is based on the chi-square difference tests that builds on the goodness-of-fit indexes (Kline, 2016). The goodness-of-fit statistics and the Chi-square difference test results are presented in Table B (see Appendix 2). Both the full and partial mediation models (Models 3 and 4) were found to have a good model fit with all fit indices meeting the criteria supporting the hypothesised mediated relationship between the two technology transfer enablers (TTO support and provision of incentives) and TT effectiveness, our output variable.

In the partial mediation model (Model 3), the two direct relationships between the independent and dependent variables were not statistically significant. To further examine whether technology transfer priority fully or partially mediated the relationship between the two exogenous variables and the outcome variable, we tested two alternative models that excluded direct paths one at a time from the independent variable to the outcome variables.[[6]](#footnote-6) In Model 5, the conditions for full mediation for H1 and partial mediation for H2 are assumed by constraining the direct path between TTO support and TT effectiveness to zero. In Model 6, the conditions for partial mediation for H1 and full mediation for H2 are assumed whereby the path from provision of incentives to TT effectiveness was forced to take the value of zero. In both Models 5 and 6, an increase in Chi-square was observed, which suggests that the direct paths were not an important driver of TT effectiveness in the absence of a Technology Transfer Strategic Priority (mediator). The mediation proposed in Model 5 provided a good fit to the data (χ2=35.28, χ2/df=1.176, CFI=0.976; IFI =0.978, TLI=0.965, RMSEA=0.038). The Chi-square difference test for Model 5 is also significant at 5% significance level, indicating a full mediation between TTO support and TT effectiveness. The full mediation for both H1 and H2 proposed in Model 4 also provided a good fit to the data (χ2=36.37, χ2/df=1.173, CFI=0.977; IFI =0.978, TLI=0.965, RMSEA=0.038). As the model fit statistics are very similar in both Models 4 and 5 we compared estimates from both models in our hypothesis testing.

Table 2: Coefficients and Bootstrap CIs

|  |  |  |  |
| --- | --- | --- | --- |
|  | Standardised Coefficient  | Bootstrap confidence intervals  | Sig.  |
|  |  | Lower Bound | Upper Bound |  |
| Model M4: H1 –Full mediation; H2 – Full mediation |  |  |  |  |
| *Direct Effects*  |  |  |  |  |
| TTO support TT strategic priority  | 0.412\*\* | 0.218 | 0.622 | 0.002 |
| TTO support TT effectiveness  | - |  |  |  |
| Incentivising TT strategic priority | 0.289^ | -0.038 | 0.527 | 0.069 |
| Incentivising TT effectiveness | - |  |  |  |
| TT strategic priority TT effectiveness  | 0.693\*\* | 0.381 | 1.372 | 0.002 |
| *Indirect Effects*  |  |  |  |  |
|  TT office TT effectiveness | 0.372\*\*\* | 0.144 | 1.065 | 0.000 |
| Incentivising TT effectiveness  | 0.209\* | 0.012 | 0.592 | 0.046 |
| Model M5: H1 –Full mediation; H2 – Partial mediation  |  |  |  |  |
| *Direct Effects*  |  |  |  |  |
| TTO support TT strategic priority  | 0.408\*\* | 0.196 | 0.600 | 0.003 |
| TTO support TT effectiveness  | - |  |  |  |
| Incentivising TT strategic priority  | 0.282^ | -0.039 | 0.527 | 0.071 |
| Incentivising TT effectiveness | -0.127 | -0.391 | 0.119 | 0.334 |
| TT strategic priority TT effectiveness  | 0.658\*\* | 0.351 | 0.947 | 0.003 |
| *Indirect Effects*  |  |  |  |  |
|  TTO Support TT effectiveness | 0.334\*\*\* | 0.167 | 0.481 | 0.001 |
| Incentivising TT effectiveness  | 0.217\* | -0.016 | 0.471 | 0.050 |
| Model 3 – Partial Mediation Model a |  |  |  |  |
| TTO Support TT effectiveness | -0.069 | -0.698 | 0.227 | 0.724 |
|  |  |  |  |  |

a estimates from this model were only used to show the negative non-significant direct path between TT officers and TT effectiveness; ^p<0.10; \*p<0.05; \*\*p<0.01; \*\*\*p<0.000

Table 2 provides results of the standardised parameter estimates of the structural Models 4 and 5. Following the recommendations of Preacher and Hayes (2008, 2004), we conducted additional mediation analyses with a bootstrap method,[[7]](#footnote-7) In H1, we suggest that technology transfer priority mediates the relationship between TTO support and TT effectiveness. The results from both models show that TT support is positively associated with TT strategy (model 5: *β* = 0.435; *p* < .01); the relationship between TT strategy and TT effectiveness is significant at 99% level (Model 5: *β* = 0.700; *p* < .001); and the positive relationship found between TTO support and TT effectiveness (Model 3: *β* = -0.073; *p* = 0.711) is negligible in the presence of the TT strategy mediator. As shown in the Table, 95% CI of the indirect effects of TT support and TT effectiveness did not include zero, showing that this indirect effect was statistically significant, providing further support for a fully mediated relationship in H1. Regarding H2, while the results show that the relationship between TT strategy and TT effectiveness is significant at 99% level (Model 5: *β* = 0.700; *p* < .001) and the positive relationships found between incentives and TT effectiveness relation is not significant in the presence of the mediator (Model 5: *β* = -0.120; *p* =0.323); incentivising is not positively associated at the conventional level of significance with TT strategy (model 5: *β* = 0.279; *p* =0.076). Upon a closer look at the bootstrapping results, we also found that the 95% CI of the indirect effects of the incentivising and TT effectiveness did not include zero, confirming partial mediation in H2.

To test H3, that the indirect effect of the enablers of technology transfer (TTO support and the provision of incentives) on TT effectiveness through strategy is conditioned by the breadth of strategic planning, we conducted a moderated mediation analysis with strategic planning as a moderator of the two mediated relationships found above. Moderated mediation occurs when the mediating process that links an independent variable to an outcome variable varies because the moderating variable accentuates or attenuates the relationship between independent variables and the mediator (Edwards and Lambert, 2007; Muller et al., 2005). We used multi-group SEM analysis[[8]](#footnote-8) that entails dividing the sample into groups according to the moderator variable and performing multi-group comparisons. The moderating variable was divided into the high-breadth planning and the low-breadth planning using the median split. The two models for the two levels of the moderator were tested simultaneously, after imposing constraints on the mediation paths in each structural model for the two levels of the moderator[[9]](#footnote-9)

Table 3 presents the estimates and bootstrap CIs for the conditional indirect effects of strategy across low and high levels of planning. It shows a strong moderated mediation is proposed for the mediation relationships between TT offices/support and TT effectiveness (*β* = 0.44; *p* < .01). The indirect effect of TTO support via strategy on TT effectiveness differs significantly when strategic planning breadth is high versus low (*β* = 0.23; *p* < .01). The indirect effects of provision of incentives via strategy do not differ significantly when planning breadth is high versus low values (*β* = -0.106; *p* =0.681). To determine whether the above conditional and indirect relationships were influenced by our control variables, the analyses were repeated with all control variables. Although the indirect and conditional relationships were somewhat attenuated, the findings provided support for unconditional indirect effects for all these variables.

Table 3: Moderated mediation

|  |  |  |  |
| --- | --- | --- | --- |
| Strategic Planning – moderator  |  | Bootstrap confidence intervals  | Model  |
|  | Β (sig)  | Upper  | Lower |  b/dTT effectivenessTT strategic priorityIncentives TTO support  a/c |
| *TTO support TT effectiveness*  |  |  |  |
| (A X B) – ( C X D) | 0.44\*\*(.006) | 0.771 | 0.168 |
| At a High level of Strategic Planning  | 0.23\*\*(.007) | 0.128 | 0.329 |
| At a Low level of Strategic Planning  | -0.02 (0.718) | -0.154 | 0.096 |
| *Incentivising TT effectiveness*  |  |  |  |  f/hTT effectivenessTT strategic priority e/gIncentives TTO support  |
| (E X F) – ( G X H) | -0.106 (.681) | -0.493 | 0.301 |
| At a High level of Strategic Planning  | 0.03 (0.589) | -0.073 | 0.128 |
| At a Low level of Strategic Planning  | 0.114 (0.21) | -0.044 | 0.236 |
|  |  |  |  |

\*\*p<0.01

We also used graphical methods to clarify the moderation effect as suggested by data in table 3. The interaction shown in Figure 2, suggests that, for institutions where planning involves greater engagement with the entire university, TTO support more positively relates to TT effectiveness than for institutions where planning efforts are limited[[10]](#footnote-10). This along with the results from table 3, offer full support for Hypothesis 3a. Such a moderation was not visible for the mediation effect of strategy on provision of incentives and TT effectiveness Thus, Hypothesis 3b is not supported.

Figure 2: Moderated Mediation on Technology Transfer Effectiveness

## 5.0 Discussion

Although there are “surprisingly few academic studies examining data pertaining to technology transfer success” (Bozeman et al., 2015, p. 37), existing research has successfully illuminated several factors impacting the effectiveness of academic institutions in transferring technology. The Contingency Effectiveness Model draws attention to organisational characteristics and structures that contribute to variations in university technology transfer effectiveness, under the label of ‘agent characteristics’. The most commonly identified agent characteristics for universities are TTO support and the provision of incentives (Arqué-Castells et al., 2016; Caldera and Debande, 2010a; Debackere and Veugelers, 2005; Heisey and Adelman, 2011; Lach and Schankerman, 2008; Markman et al., 2004; Rothaermel et al., 2007; Siegel et al., 2003; Van Looy et al., 2011). Although previous research has drawn attention to the significance of these two organisational factors, results concerning their impact on technology transfer effectiveness are ambiguous. Concurrently, recent research and policy reviews have identified the potential significance of university-level strategic choices in the effectiveness of technology transfer activity (Association of American Universities, 2015; HEFCE, 2016; Hewitt-Dundas, 2012; Sánchez-Barrioluengo, 2014; Sengupta and Ray, 2017a), drawing attention to the fact that universities can, and should, adopt different strategic priorities. Here, we build on these emerging insights to offer a novel contribution to the CEMTT perspective. Specifically, we integrate insights from studies of technology transfer effectiveness with strategic choice theory to suggest that it the *alignment* between university-level strategic choices and enabling organisational characteristics that determine technology transfer effectiveness. Thus, we highlight strategic choice as the key underlying variable that accounts for performance variation amongst universities in terms of technology transfer activity, accounting for the mixed results regarding the role of TTO support and staff incentives.

The scale of TTO operations has been identified as a key determinant of technology transfer effectiveness (Caldera and Debande, 2010a; Rothaermel et al., 2007; Siegel and Wright, 2015b; Van Looy et al., 2011). Following the logic of strategic choice theory, we hypothesise that TTO support is necessary but not sufficient for effective technology transfer. Instead, we suggested that the relationship between TTO support and technology transfer effectiveness is mediated by the strategic choices made by senior university managers to prioritise technology transfer. The results of our structural modelling provides strong support for this postulation, which is significant because existing research examining the relationship between the scale of TTO support and the effectiveness of technology transfer broadly indicates a positive relationship between scale and effectiveness (Heisey and Adelman, 2011; Lach and Schankerman, 2008; Siegel et al., 2003).

However, some studies, notably Chapple et al (2005) and Berbegal-Mirabent et al (2015) have identified a negative relationship between the scale of TTO support and technology transfer effectiveness. Based on our findings, we demonstrate that these inverse relationships can be explained by misalignment between TTO support and university strategic priorities. This may be particularly useful in clarifying the negative relationship found by Chapple et al (2005) in their analysis of UK universities. Lockett et al (2015) show that during the late 1990s and early 2000s technology transfer became more institutionalised within UK universities, with isomorphic and regulatory pressures driving the formation and resourcing of TTOs. Following Chapple et al (2005) and in light of our results, it may be concluded that UK TTO’s exhibit decreasing returns to scale due to misalignment between the strategic priorities of UK universities and the level of technology transfer support resulting from these institutional pressures.

Consequently, it is the strategic commitment to technology transfer which is the key underlying determinant of technology transfer effectiveness rather than the scale of TTO. In a practical sense, support for H1 suggests that universities should not increase the scale of their TTO infrastructure, if technology transfer is not a primary strategic objective of the institution. This follows the recent analysis of university knowledge transfer organisations by Sengupta and Ray (2017b), who suggest that TTO structure should be concordant with university strategic priorities. Specifically, Sengupta and Ray (2017b) highlight that most UK universities perform poorly in terms of research commercialisation and have therefore moved to outsource commercialisation functions of their TTOs. Importantly, they draw attention to the significance of strategic responses by UK universities as a key influence on the structure of TTOs. Our analysis, combined with the insights of Sengupta & Ray (2017b) suggests that only those universities that prioritise technology transfer should retain commercialisation functions in-house. Conversely, those institutions that do not place strategic emphasis on technology transfer would be advised to move towards outsourcing models in order to improve the overall efficiency of their knowledge transfer operations.

In H2, we suggested that the provision of incentives for staff to engage in technology transfer activity is necessary but not sufficient to explain variation in technology transfer effectiveness. Most studies demonstrate a positive relationship between incentives (usually in the form of royalty shares) and technology transfer revenue (Belenzon and Schankerman, 2009; Caldera and Debande, 2010b; Friedman and Silberman, 2003; Link and Siegel, 2005). However, some suggest that the provision of incentives to staff has no effect on the level of technology transfer (Arqué-Castells et al., 2016) or even a negative effect (Markman et al, 2004). The results of our structural modelling show that the provision of staff incentives results in greater technology transfer activity when there is alignment with university strategic priorities. This finding echoes research by Arqué-Castells et al (2016), who found that the influence of incentives (or lack thereof) on technology transfer effectiveness in Spanish and Portuguese universities was potentially a consequence of incongruence between incentive structures and TTO objectives.

The fact that our model shows only partial mediation indicates that the degree to which incentives are aligned with university strategic priorities does not fully account for variations in technology transfer effectiveness. One reason could be that engagement in technology transfer activity is also an individualised phenomenon (D’Este and Perkmann, 2011; Lam, 2011; Perkmann et al., 2013). Therefore, while alignment between organisational strategic priorities and incentive systems influence the level of technology transfer activity, the overall impact depends on the nature of organisational support designed to influence individual-level motivational factors. Broadly, our results indicate that incentives have a greater impact on the effectiveness of technology transfer when they are aligned to the organisation’s strategic priorities. This is line with previous work that indicates a one-to-one relationship between incentives and technology transfer effectiveness (Belenzon and Schankerman, 2009; Caldera and Debande, 2010a). On a practical level, our results related to H2 suggest that the provision of incentives for staff are not sufficient to develop greater levels of technology transfer effectiveness as previous studies examining this relationship have indicated (Arqué-Castells et al., 2016; Markman et al., 2004). Rather, we argue that to enhance organisational effectiveness in technology transfer, it is critical that incentive structures are aligned with the university’s strategic priorities to yield greater technology transfer effectiveness.

In proposing H3a and H3b, we suggested that the strategic choices made by senior university managers impact the relationship between TTO support and technology transfer effectiveness. Although the impact of managerial strategic choices in determining technology transfer effectiveness is accentuated by the degree to which these strategic choices are operationalised. Simply, it is not enough for strategic choices to prioritise technology transfer, they must be implemented at department level. This argument is supported by recent research that highlights the limitations of centralised decision making without wider departmental considerations in the context of university strategy (Bryman, 2007; Burnes et al., 2014; Waring, 2017). In finding support for H3a, we show that the alignment between university strategic choices and the scale of TTO support influences the effectiveness of technology transfer activity. However, the impact of university strategic choices on technology transfer effectiveness is enhanced when plans are comprehensively implemented at department level. Conversely, our results for H3a suggests that if universities make technology transfer a strategic priority and establish appropriate TTO support, the effectiveness of their technology transfer efforts may be limited if they fail to adequately operationalise strategic priorities at department level. This finding lends evidence to arguments that advocate a move away from hierarchical decision making within universities towards a more ‘collegiate’ mode of governance whereby strategic priorities are established through engagement with departments (Bryman, 2007; Burnes et al., 2014; Waring, 2017).

Surprisingly, we find no support for H3b, which suggests that the mediation effect of strategic choice on the relationship between incentives and technology transfer effectiveness will be accentuated by the operationalisation of strategic priorities at department level. However, when we consider this result in light of our results for H2, which shows that university strategic choices only partially mediate the relationship between incentives and technology transfer effectiveness, the implication of this result becomes clearer. As highlighted above, engagement in technology transfer activity is an individual as well as an organisational phenomenon, decisions to commercialise research findings are largely individually driven (D’Este and Perkmann, 2011; Lam, 2011). Therefore, arguably the role of incentives in enhancing technology transfer effectiveness is less sensitive to organisational influences such as university strategic priorities (as highlighted in H2) and their operationalisation (as highlighted by the lack of support for H3b). In other words, the role of incentives in promoting technology transfer effectiveness will be more sensitive to individual-level motivational factors than other forms of organisational supports for technology transfer, such as the scale of TTO support, over which university management have more control.

## 6.0 Limitations and Directions for Future Research

Despite its theoretical and methodological strengths this research has limitations that highlight opportunities for meaningful future research. First, the validity of structural modelling depends on theoretical sophistication, measurement accuracy, data distributions, variable selection and the size of the database (Shook et al., 2004). Specific to this study is the size of the database and the use of some single item observed variables (instead of latent variables) which limits our understanding of the enabling conditions for effective technology transfer. Further research should explore the relevance of other constructs in the assessment of these relationships using more fine-grained multi-item measures not only to look at the extent, sequencing, and effectiveness of technology transfer strategy but also to study the relationships at a more exploratory level. For example, process-oriented research could build on our insights by exploring how departmental managers operationalise university level strategic choices and how these operationalisations impact technology transfer effectiveness. Alternatively, further research could focus more explicitly on the role that university top-management teams (TMTs) as key strategy participants play in technology transfer effectiveness, by examining how TMT composition impacts the performance of technology transfer, perhaps drawing upon Upper Echelons Theory and the Attention-Based View (Hambrick, 2007; Ocasio, 2011)

Second while we confirm that strategic choices influence effectiveness (not vice versa), the cross-sectional research design set limitations in terms of making strong inference of causality. However, in this study we used data from various waves to ensure temporal ordering of variables in our model to make causal attribution of relationships possible. Furthermore, the measurement limitations resulted from the observed exogenous variables has to a certain extent overcome by studying various measurement models using nested modelling. Although the small sample size set limitations in relation to the number of control variables included in the model and the number of causal relationships assumed, the data from a population-based study of all UK universities gave it a unique advantage. Future research could add greater rigor to our results by adopting a longitudinal approach, making use of the panel data in the study of the relationships.

Third, we conducted the study within the single context of the United Kingdom. While there are good theoretical reasons to believe that universities in other countries may experience similar dynamics, namely the widespread adoption of mangerialst modes of organisation in Higher Education Institutions (Marginson, 2007; Teelken, 2012), the focus on a single country context may limit the generalizability of the results to some degree. Thus, a useful extension would be to extract data from other developed nations and conduct a multi-level analysis using universities nested within a country to learn the conditions set by the objective environment and its institutional context.

## 7.0 Conclusion and Policy Considerations

In summary, our results offer several new academic and policy insights relating to technology transfer effectiveness (Bozeman et al., 2015). First, we highlight the significance of strategic choice as a key underlying determinant of technology transfer effectiveness. Specifically, we show that it is not enough for universities to invest in TTO support and provide incentives for engagement in technology transfer if they are aiming to enhance the effectiveness of their technology transfer activity. Previous research, grounded within the CEMTT framework has highlighted these agent (university) characteristics as key determinates of technology transfer effectiveness, yet the role of managerial strategic choice is often overlooked in analysis (Siegel and Wright, 2015a; Wright et al., 2008). Drawing on insights from strategic choice theory (Child, 1997, 1972), we argue that these ‘internal variations’ are not the only determinates of organisational effectiveness but it is their alignment with strategic choices that actually impacts technology transfer effectiveness. Second, we show that the alignment of strategic choice and supporting organisational infrastructure is not sufficient to ensure greater technology transfer effectiveness by highlighting the degree to which this alignment is moderated by the operationalisation of strategic priorities throughout the university. This is the first study, to our knowledge, that has explicitly investigated the relationship between university strategy implementation and technology transfer effectiveness. Our results suggest that for strategic priorities to be realised and for organisational supports to be effective in enhancing performance, senior university managers should ensure that strategic plans are operationalised through engaging middle management in strategic planning. Clearly, this finding has implications for the need to broaden the influence on strategic planning beyond senior university managers, suggesting that a move towards more ‘collegiate’ modes of governance might enhance the effectiveness of strategic decision making in universities. Third, our findings show that there are limits to the impact of managerial strategic choices on technology transfer effectiveness. It is clear that the relationship between strategic choices and incentives as an organisational support for technology transfer has a weaker influence on technology transfer effectiveness than the relationship between strategic choices and TTO support. We suggest that this relatively weaker relationship is due to the fact the impact of incentives on technology transfer effectiveness will always be subject to individual-level motivational factors that are beyond the control of university managers.

With regards to policy, our findings provide evidence to support recent policy reviews that have highlighted the potential significance of senior university managers in the effectiveness of technology transfer (HEFCE, 2016). Our findings also indicate that there needs to be careful consideration of the metrics and evaluation frameworks for technology transfer effectiveness. Current frameworks precipitate institutional pressures to adopt certain organisational configurations (Lockett et al., 2015) by focusing on binary input/output measures. Instead, our findings highlight that these organisational inputs are not sufficient to stimulate technology transfer effectiveness. Therefore, frameworks for policy evaluation should be more attentive to the alignment between organisational strategy and supporting organisational infrastructure. In other words, it is important to avoid the current “one-size-fits-all” approach to encouraging technology transfer. Evaluating this ‘alignment’ rather than simple inputs and outputs would encourage universities to clearly define strategic priorities regarding technology transfer. It would also encourage universities to focus on establishing a bespoke suite of strategic organisational support and incentives, more closely aligned to specific university contexts and research specialisms in order to reduce some of the current inefficiencies and encourage greater technology transfer effectiveness.

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Appendix 1: Confirmatory Factor Analysis - nested modelling

Model 1 included all measurement items as one latent variable. This one factor model did not fit the data. We then tested a two-factor model (M2), and a three-factor (M3) model consists of mediator variable, output variable and the two attributes of technology transfer enablers (TTO support and provision of incentives) as a single factor to find out whether the two latter exogenous variables are part of a latent factor or are two correlated observed variables.

Table A: Confirmatory factor analysis: nested modelling

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model  | χ2 (*df*) | χ2/ *df* | *p* | CFI | IFI | TLI | GFI  | RMSEA |
| M1: one factor model (all items as one latent) | 45.14(20) | 2.257 | 0.001 | 0.895 | 0.899 | 0.853 | 0.915 | 0.102 |
| M2: two factor model(Mediator & Outcome as latent factors) | 14.23(8) | 1.779 | 0.076 | 0.969 | 0.970 | 0.942 | 0.964 | 0.071 |
| M3: three factor model (Mediator, Output & exogenous as 3 latent variables)  | 40.27(17) | 2.369 | 0.001 | 0.903 | 0.907 | 0.840 | 0.929 | 0.107 |
| M2: Factor 1(Technology Transfer Strategic Priority - Mediator): 3 items, Cronbach α = 0.62; composite reliability = 0.692; AVE = 0.49Factor 2 (Technology Transfer Effectiveness – Outcome): 3 items, Cronbach α = 0.83; composite reliability = 0.91; AVE = 7.1  |

Common method variance – as all items in the SEM model were not collected from the same source, common method variance is not a major problem in this study. However, we used the nested modelling to test any potential common method variance following Malhotra et al’s recommendations. Here all items in the SEM model are recoded to allow similar scaling across measures and used a single latent variable model as the base model in our nested modelling (model 1). The fit indexes indicated that the model consisting of a single latent variable has a very poor fit.

Appendix 2: Structural Equation Model: nested models

 In the null model (Model 1)no relationships are posited; in the direct model (Model 2) the direct effects of the two exogenous variables and the direct effect of the mediator on the output variable are tested; the partial mediation model (Model 3) includes both direct and mediated effects of the TTO support and the provision of incentives; the hypothesised full mediation model (Model 4) includes indirect effects of the TTO support on TT effectiveness (H1) and the indirect effects of the provision of incentives and TT effectiveness (H2).

Table B: Structural Equation model: nested modelling

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model  | χ2 (*df*) | χ2/ *df* | *p* | CFI | IFI | TLI | GFI | RMSEA |
| M1: Null model | 109.09(37) | 2.948 | 0.000 | .678 | .689 | .608 | .830 | 0.127 |
| M2: Direct model | 60.57(32) | 1.893 | 0.002 | .872 | .879 | .820 | .914 | 0.086 |
| M3: Partial mediation  | 35.06(29) | 1.209 | 0.203 | .973 | .975 | .958 | .948 | 0.042 |
| M4: Full mediation | 36.37(31) | 1.173 | 0.233 | .976 | .977 | .965 | .946 | 0.038 |
| M5: H1- full & H2: partial mediation  | 35.28(30) | 1.176 | 0.233 | .976 | .978 | .965 | .948 | 0.038 |
| M6: H1- partial & H2: full mediation  | 36.29(30) | 1.210 | 0.198 | .972 | .974 | .958 | .946 | 0.042 |

1. Child uses the term objectives whereas we refer to priorities. [↑](#footnote-ref-1)
2. In this study the measurements were collected at four time points, giving a reasonable time lag between exogenous variables, mediator, moderator and the outcome variables. This was done to overcome the potential measurement errors due to simultaneity bias often associated with cross sectional estimates. [↑](#footnote-ref-2)
3. Accepting the fact that overfitting could produce unreliable results (Babyak, 2004) and that performing EFA and CFA on the same data set often results in model overfitting (Fokkema and Greiff, 2017), as a robustness test, we split the sample into two groups on a random basis and performed EFA on one set and CFA on the other. We repeated the same analysis by switching the samples. Although the factor loadings did not show an exact match, the items loaded on to each factor remained same in the two instances. Model fit statistics and validity and reliability criteria (using factor loadings, factor covariances and associated standard errors) followed as part of the CFA were also found to be very close in values in the two models tested. Furthermore, prior to formulating the hypotheses, we were unsure of what items to be loaded together as both strategic choice and the TT effectiveness items were selected from a range of items included in the questionnaire, some of which are theoretically related while others are not so but hold valid given the broader definitions to technology transfer used in the literature. As suggested by Fokkema and Greiff, (2017), “an exploratory approach is appropriate when the number of factors and the allocation of items to factors are unknown”. Taken together, we are confident that utilising EFA and CFA on the same sample has in fact not inflated our results. [↑](#footnote-ref-3)
4. the latent variable approach where a group of individual measures represent each latent variable (as is the case with our mediation models) was not appropriate for testing moderated mediation when estimand plug-in in AMOS 24 is used due to the set restrictions in degrees of freedom and the sample size . The relatively small sample size in relation to the number of study variables in our models required that weighted composites of the measured indicators to be used as observed variables rather than individual measurements representing latent constructs in the moderated mediation SEM analysis using the estimand plug-in in AMOS 24. The estimand plug-in in AMOS is recommended as the most reliable technique to test moderated mediation even though it sets limits to the data structure when using smaller samples in SEM analysis.

 [↑](#footnote-ref-4)
5. Additionally, for discriminant validity, we followed Voorhees et al's (2016) recommendations and employed the AVE-shared variance comparison (Fornell and Larcker, 1981), and found that, on average, each construct relates more strongly to its own measures than to others. [↑](#footnote-ref-5)
6. To exclude a potential reverse causality argument on the basis of a competing argument that the prioritisation of technology transfer may cause universities to build their technology transfer capabilities, including provision of more human resource in the technology transfer office and provision of more incentives to drive technology transfer performance. To counter this contention, we modelled technology transfer prioritisation as an antecedent variable impacting on TTO support and provision of incentives, and with strategy directly linked to technology transfer effectiveness. The overall fit indices show that this alternative model is significantly worse than our proposed conceptual model. [↑](#footnote-ref-6)
7. Bootstrapping follows a non-parametric resampling procedure that does not impose the assumption of normality on the sampling distribution. We used 95% confidence intervals for the indirect effects, drawing 2,000 random samples with replacement from the full sample (Stine, 1989). [↑](#footnote-ref-7)
8. To determine the values of the moderator at which the conditional indirect effect was significant, multiple group SEM analysis using MyModMed estimand plug-in in AMOS 24 was used. This method provides effect sizes and bias-corrected 95% confidence interval with 2000 bootstrapping samples (Selig and Preacher, 2008) [↑](#footnote-ref-8)
9. A reduction in the estimated path coefficients between sub- samples evidenced by the CI in bootstrapping tests would verify a significant difference between two models: high breadth planning versus low breadth planning. [↑](#footnote-ref-9)
10. The start and end points of the two lines represent the lowest and the highest scores for technology transfer effectiveness measure in logarithmic scale. [↑](#footnote-ref-10)