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Entrepreneurial universities: Modelling the link between innovation producers and innovation users shows that team structures in the tech transfer function improves performance.

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ABSTRACT

To investigate successful technology transfer, the potential path of innovations from the university research bench to the knowledge recipient is modelled. Universities exist in highly regulated environments and the initial path of decision-making is a hierarchical model and where decisions flow upward from manager to manager until a small number of candidate innovations for commercialization remain. These are then routed for further processing to the link connecting to the knowledge recipient, the Technology Transfer Office (TTO). In the TTO, a hierarchical decision-making model can be acceptable in terms of outcomes, but ambidextrous co-operative team structures are much superior in cases where staff have good insight and decision-making abilities. This report represents the first Structured Equation Model investigation of the management architecture of a TTO.

KEYWORDS

Entrepreneurship; decision making; technology transfer; university innovations

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1. Introduction

Nobel laureate Paul Romer (Nobelprize.org, 2018) focussed attention on technological innovation, suggesting that market economies alone tend not to generate sufficient new ideas and that '*well-designed government actions*' are needed to stimulate more innovation. But how do innovations progress from the university laboratory to the market economy? To address this, Etzkowitz (1983) first introduced the concept called "the entrepreneurial university", building partly on the case of Stanford University and "Silicone Valley" (see e.g. Adams, 2003). From this arises a concept known as the triple helix model (Etzkowitz and Ranga, 2010). This model describes the relationship between universities, industries and government bodies, roughly representing a corkscrew motion of the three sectors around each other, progressing with time, this is the classical triple helix, and beyond to a fourth helix, as described by Leydesdorff and Etzkowitz (2002). In the original model, the relationship between these three sectors (university, industry and government), is interdependent, although this view has undoubtedly become much more complicated (see e.g. Germain et al, 2023). It is not the remit of this paper to review these hypotheses and models, and the reader is instead pointed to recent overviews by Carayannis and Campbell (2010) and by Germain et al (2023).

Purely functionally, the process (an 'innovation pipeline') involves an ambidextrous approach linking research, management, innovation and entrepreneurship (Audretsch and Guerrero 2023) when transferring innovation from the proposed innovation source, (metaphorically the lab bench or any kind of research performed at a university) to an external recipient. The progress towards commercialization must first be judged by the university hierarchy to be worthy of an initial investment. Investment includes transaction costs like staff time, patenting costs etc and a go/no-go decision to be made at high level. As Will et al (2019) point out, the costs incurred by a failed innovation are greater than the benefit derived from adopting a successful innovation. Thus, a classical or non-entrepreneurial university would be expected to exhibit risk-adverse behaviour including, for example, simply waiving any rights and allowing their employees, the inventors/researchers, to attempt to progress their innovation privately and independently of the university. This type of behaviour from a less entrepreneurial university can indeed be broadly successful for organizations that exist in highly regulated environments (Will et al, 2017). To reduce this option to a user perspective, Hegde and Tumlinson (2020) built a probabilistic model as a nonlinear Bayesian optimization problem showing that, in universities, academics' credentials are high but entrepreneurial intent and experience tend to be poor. Therefore, research employees transitioning to entrepreneurship may struggle to bring their innovations to the market in the new environment.

On the other hand, the "entrepreneurial" university may choose to invest in the innovation(s) and the necessary surrounding infrastructure, including decision-making, keeping contact with sources of investment, the cost of maintaining a Technology Transfer Office – TTO etc where the returns are expected to exceed these outlays (a brief overview is given by Harmon et al, 1997). This scenario emphasises the importance of the TTO as an essential link between the knowledge source and the knowledge recipient, an aspect emphasised by Parmentola and Panetti (2020). In this context Tracey and Williamson (2023) also recently highlighted this link reporting that '*Just over half (53%) of respondents had involvement from their TTO when deciding between a spin-out and other commercialisation routes, compared to a third (34%) who did not*'. Once the new innovation has left the university and is embedded in an incorporated entity, either spun out of the university or as a completely separate organization as described by e.g. Gunsel (2015), whereupon that entity may find its place in the high-tech entrepreneurship ecosystem e.g. a Science and Technology Park (see, for example Germain et al, 2023 as well as Mondal et al, 2023).

This paper explores the most efficient practice in transitioning from pure research into a high technology entrepreneurship ecosystem.

The effect of management architecture on corporate performance was first postulated by Nobel laureate Joseph Stiglitz (originally in Sah and Stiglitz, 1986), and such analyses have been applied to the high-tech entrepreneurship ecosystem by Al-Kfairy and co-workers (Al-Kfairy et al 2020, 2019a and 2019b). The research question is; how does the innovation pipeline work best in the space between the innovation leaving the research lab bench and becoming incorporated into the recipient(s)?

In the following we simulate the decision-making process in large and small universities, and we model the outcomes of various ambidextrous (or otherwise) management architectures in the essential link department, the TTO.

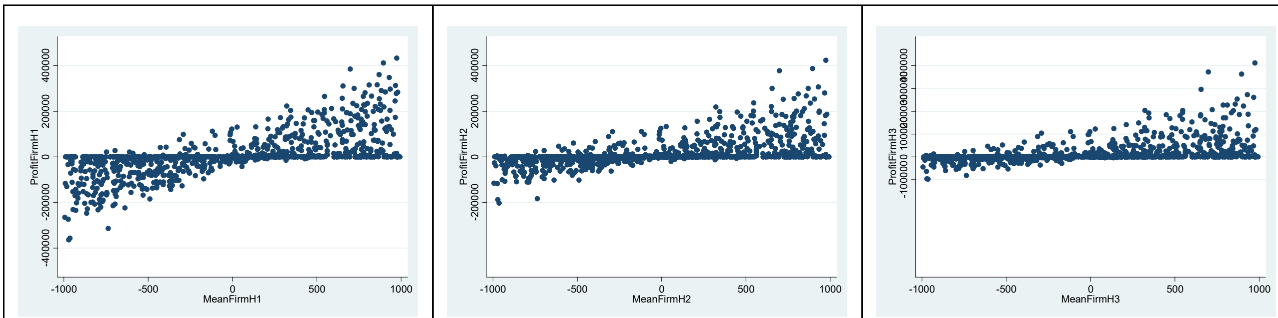
Routine robustness checks and sensitivity analyses were as in Al-Kfairy et al (2020).

2. University decision-making, the effect of size

In this analysis, irrespective of the size and productivity (in terms of innovations) of the university, it is assumed that the inventor or otherwise source of the innovation possesses highly specialized knowledge and deep technical insight. The first decision about if the innovation is to be progressed is made by a line manager (head of department or school, dean etc) who has less specialized insight and who, after making a positive decision, progresses the issue to their line manager, who has even less specialized insight. In simple terms this can be represented by:

$$b = \sum_{i=1}^{n} \begin{cases} b_i, & if\ \rho_i = yes | b_i > 0\ with\ \pi\ or\ if\ b_i < 0\ with\ (1-\pi) \\ 0, & if\ \rho_i = no \end{cases} \qquad \text{equation 1}$$

Where the equation describes the quality of the manager's decision: with a probability of π when a correct decision is made, i.e. accepting good innovations and rejecting poor ones. Thus, the probability to make a wrong decision is (1-π). The mangers' decision is taken as π~unif(0,5;1). Therefore, the quality differs between π=0.5 (managers make decisions as they would flip a coin) and π=1 (managers have perfect knowledge regarding the quality of the innovation). The outcomes with 1-3 levels of hierarchical decision-making are shown in Figure 1 below:



1 level of hierarchical coin-flipping decision-making	2 levels of hierarchical coin-flipping decision-making	3 levels of hierarchical coin-flipping decision-making

Figure 1. Comparison of number of levels of hierarchical control for monetary efficiency

During the decision-making process, innovations are semi-randomly rejected by the hierarchy, which raises the overall performance outcomes due to removing expensive mistakes. Better decision-making skills merely improve model outcomes, but not overall trends. Clearly in the case of a small university, the number of innovations produced may be many fewer than for a large university. Nonetheless, in each case the ratio will be similar; 1 hierarchy halves the number of innovations, having 2 hierarchies' quarters the number, while 3 hierarchies reduce the number of innovations to one-eighth, and so on.

To model the benefit accrued, equation (2) can be used. Equation (2) calculates the total benefits gained using the gross benefit minus the costs of each connection and where the net benefit for organization j, will be B1,j – C1,j, where j ≠ 1.

$$\pi = \sum_{j=2}^{N} (B_{1,j} - C_{1,j}),$$
equation 2

Using equation 2 the benefit in Monetary Units (MUs) can be seen for the number of innovations in any time scale. The number of innovations explored was between 0 and 500 (for a large university), where the vertical line represents 50 (a university smaller by a factor 10).

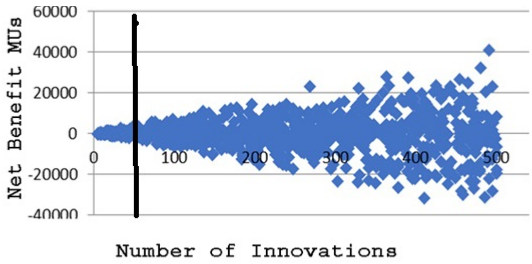


Figure 2. Effect of monetary outcomes (in Monetary Units, Mus) with number of innovations showing that with fewer innovations the potential harm is smaller than with larger numbers of innovations, simply because there are fewer opportunities for incurring a damaging loss.

Figure 1 shows paradoxically that employing managers with poor decision-making ability is much better than having no hierarchy at all and, in addition, every additional level of poor management reduces further risks. For achieving good quality results, the managerial decision-making quality must be just higher than flipping a coin. This should be contrasted to the risk-minimization approach where the university would waive its rights completely and allow their employees, the inventors, to attempt to progress their innovation privately and independently of the university.

Figure 2 shows that with increasing size, and thus number of innovations, potential risk and potential benefits also increase. Figure 2 contrasts the situation where, after a certain time, we assume a large university produces 500 innovations and a small university only 50. From Figure 2 at vertical line 50, it can be seen:

1. Small universities, colleges etc have fewer potential gains from technology transfer.
2. Conversely, projected losses are also small.
3. Reduced transaction costs may contribute to the minimization of losses.
4. Thus, the projected low gains may reenforce the argument against small universities employing a large TTO, with its associated high overheads.

Conversely, for large universities, the gains of avoiding poor innovations must prevail, otherwise, as Figure 2 shows, losses will outweigh gains in the long run. With the innovation pipeline in a large university the TTO will incur significant transaction costs. Under these conditions the hierarchical decision-making structure shown in Figure 1 may not be appropriate, and therefore other structures are explored in the next section.

3. The TTO; different management structures

The innovations surviving the university decision making process will be fewer than at the starting point, but the ratio of ‘good’ to ‘poor’ may not have changed. To improve the decision-making situation, an ambidextrous type of management architecture in the TTO can be considered: Thus, to compare the sustainability of organization forms for ambidextrous business behaviour in the TTO, three types of management structure (hierarchical, cooperative and hybrid) were contrasted.

The first model is of a hierarchical department (the TTO) where employees on the lower hierarchical level need the approval ρi of the departmental head and the parameter π describes the quality of the decision made. This results in the same function as equation 1. Because the TTO is a much smaller entity than the university, further hierarchies are unlikely and thus not modelled.

In the second model (equation 3) the quality of decision made by co-operating peers is symbolized by π. Thus, staff believe the innovation is good, they have to convince more people as compared to the situation where evaluations are made by the head of department (cf. equation (1)) and as a consequence, the total transaction costs for implementation increase.

$$b = \sum_{i=1}^{n} \begin{cases} b_i - \frac{ct}{\pi}, & if\ b_i > 0\ and\ \ b_i - \frac{ct}{\pi} > 0\ and\ \frac{c}{\pi} < Size\ of\ the\ Organization \\ b_i - \frac{ct}{1-\pi}, & if\ b_i < 0\ and\ |b_i| - \frac{ct}{1-\pi} > 0\ and\ \frac{c}{1-\pi} < Size\ of\ the\ Organization \\ 0, & otherwise \end{cases}$$

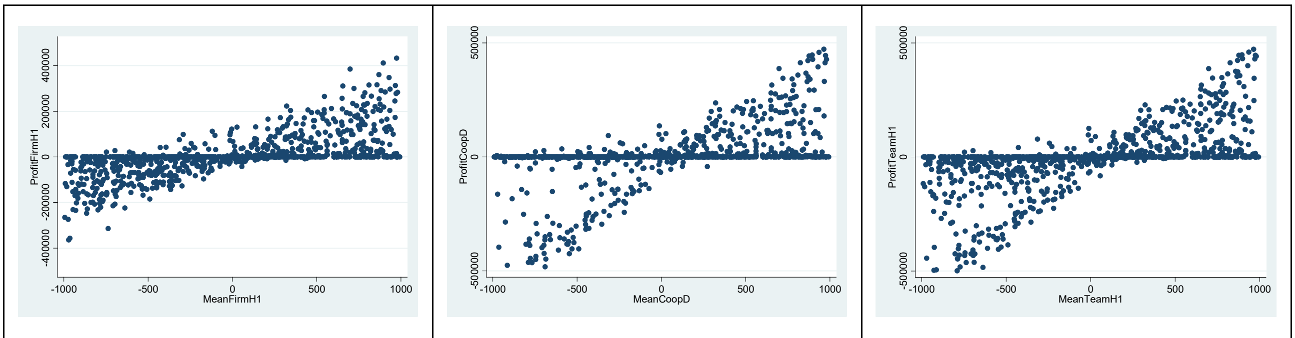
Equation 3

The hybrid model: In equation (4), the terms *E(hier.)*>E(team) and *E(hier.)*<E(team), respectively, describe how staff compare the effects of hierarchy (equation (1)) with the impact of their networks (equation (3)). Thus, staff use hierarchical structures in the case that their superiors approve and that the absolute value through the hierarchy is higher than the effect of using their networks would be. For a firm with team structures and one level of hierarchy, we get:

$$b = \sum_{i=1}^{n} \begin{cases} b_i - ct, & if\ \rho_i = yes\ and\ E(hier.) > \mathrm{E(team)} |\ b_i - ct > 0\ and\ b_i > 0\ with\ \pi \\ b_i - ct, & if\ \rho_i = yes\ and\ E(hier.) > \mathrm{E(team)} |\ |b_i| - ct > 0\ and\ b_i < 0\ \ with\ (1-\pi) \\ b_i - \frac{ct}{\pi}, & if\ E(hier.) < \mathrm{E(team)}\ |\ b_i > 0\ and\ \ b_i - \frac{ct}{\pi} > 0\ and\ \frac{c}{\pi} < Size\ Org. \\ b_i - \frac{ct}{1-\pi}, & \mathrm{if}\ E(hier.) < \mathrm{E(team)}\ |\ b_i < 0\ and\ |b_i| - \frac{ct}{1-\pi} > 0\ and\ \frac{c}{1-\pi} < Size\ Org. \\ 0, & otherwise \end{cases}$$

Equation 4

The results of the comparisons are shown below in Figure 3 below.



(a) Hierarchical model | (b) Cooperative model | (c) Hybrid model

Figure 3. A comparison of potential profits made by (a) hierarchical, (b) cooperative and (c) hybrid (mix of hierarchical and cooperative) models.

Figure 3 shows that if the decision-making ability of staff is high, then both the co-operative and hybrid ways of working are superior (scatters to the top right-hand corner). Conversely if the staff members decide that a poor innovation is good and should be promoted (thus incurring transaction costs) when it actually is poor, then these two models can inflict the most harm (scatters to the bottom left-hand corner). It the latter situation, then retaining a hierarchy, even where the manager decides by flipping a coin, inflicts the least harm, although gains are also lower.

In this simulation the assumption has been that the university hierarchy is strict and monolithic, thus the ratio of "good" to "poor" innovations will be largely unchanged. Figure 3 shows that under these circumstances the best management structure for the TTO is competent teams of co-operators where decisions can occasionally be referred to a manager.

4. Conclusions and future work

In the smallest 10% of universities, managers may find ways of promoting innovations, but even when that manager is mistaken, the losses incurred are not very high. In such cases the implication is that the best approach may be *ad hoc,* without the overheads that having a TTO entails.

Large universities exist in a highly regulated environment, which enforces a rather rigid management architecture, as reported by Albats et al (2022). This paper simulates the uptake of innovations from lab researchers up the hierarchical managerial decision pathway to a senior management decision in a large university. From that point those innovations that have won approval (whether they are "good" or not) are referred to the TTO for further processing and eventual transfer to recipients outside the university (Harmon et al, 1997).

Interestingly, innovations transit across different types of environments from their conception; climb the university hierarchical management structure, across a hierarchical or co-operative/hybrid TTO into what is possibly a startup (typically with flat or co-operative management structure), to Science Parks whose ambidextrous management structures are considered by e.g. Al-Kfairy and Mellor (2020). Distance working post-Covid may also be profoundly changing the nature of technology transfer to businesses, and "centres versus networks" is a rapidly evolving question (see e.g. Mondal et al 2023) and clearly more work needs to be done in this area to achieve better clarity.

There are limitations to a modelling approach; Radko et al. (2022) emphasised the organisational architecture across different stages of entrepreneurship and the various profiles of the universities involved. Indeed, Johnston (2020) has been joined by Audretsch and Belitski (2022) in finding that university–industry technology transfer depends on factors that include social as well as technological and organisational alignment, factors that are not considered here.

Nonetheless, modelling as presented here gives clues what to look for. We envisage future studies using e.g. panel data as in e.g. Vaninoa et al (2019) to identify high achieving universities, which in turn can be analysed for their TTO management structure. This work predicts that in large universities, competent cooperative team structures are the most productive management architectures for TTOs.

Abbreviations

TTO: Technology Transfer Office, any kind of department involved in the commercialization of original research; University: Any kind of institution performing original scientific research.

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Conflict of Interest

The authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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