Commercialisation: Bridging the University-Industry Gap

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Bridging the University-Industry Gap

City-REDI Research Brief

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The Industrial Strategy Green Paper (2017) highlighted that whilst the UK ranks first in many key global measures of research quality; in terms of intellectual property income generated against research resources and the number of successful spin-off companies the UK performs far behind US institutions. This paper investigates this long-term, systemic problem of the UK university-industry gap which limits the adoption and diffusion of new technologies. The aims and objectives are as follows:

Aims

To develop a stage-gate product development framework to map the selection mechanisms and drivers for commercialisation pathways of University technologies.

To better-understand the different forms of commercialisation pathways within the University of Birmingham (UoB), the main stakeholders and their incentives and decision-making factors that influence the selection processes and outcomes.

Objectives

To examine the differences and similarities between UoB technology clusters through deep-dive studies into the commercialisation pathways of different technologies.

To identify the key stakeholders (research specialists, funding agencies, market adopters, investors, regulators etc.) that influence the selections processes and outcomes for each of the case technologies.

To explore the extent to which the impact of the successfully commercialised technologies is expected to be in the host region, with a positive effect on local growth or well-being.

Introduction

The focus of this project was inspired by the increasing number of 'third mission' or 'third stream' activities led by UK universities (teaching and research being first and second mission activities), concerned with the generation, use, application and exploitation of knowledge and other university capabilities outside academic environments. There are five different technology transfer mechanisms from universities: spin-outs (new firms created to exploit commercially knowledge, tech or results developed within a university), licencing, consultancy, publications and cooperative R&D agreements (academics often consulting with industry, to help shape research and development).

The research was timely, given the UK government's recent proposal for the development of a Knowledge Exchange Framework (KEF) to compare how effective universities are at fostering knowledge sharing and commercialisation of research. KEF would sit alongside the existing Research Excellence Framework and the Teaching Excellence and Student Framework, to provide a more holistic view of the contributions made by universities. Therefore, the development of a university-specific commercialisation framework could potentially become a valuable tool for UK universities in the near future, for understanding how to better support and promote third stream activities for KEF. A framework such as this will be presented in the conclusion.

Methodology

The research was divided into three phases. The first phase involved a detailed review of the academic literature. The review identified empirical examples and theoretical frameworks on the commercialisation of technology and research. Based on the review, a stage-gate product development framework was developed.

The second phase of the project involved selecting specific technologies currently in development, in four innovation clusters at the University of Birmingham (UoB). The clusters were as follows: (i) Energy Capital; (ii) Medical technologies; (iii) the Birmingham Centre for Rail Research and Education (BCCRE; digital systems); and (iv) the Quantum Technology Hub. The motivation for exploring four different research clusters was to reveal relative differences in the kinds of impacts, barriers, influencers that exist across different industry sectors, targeted by different university technologies. However, it is worth noting that these clusters are all relatively new, thus much of the research is still early stage.

The final phase involved interviews with industry and academic lead stakeholders linked to the four technology clusters, to test the relevance of the theoretical framework developed from the literature. For example, the stakeholders were asked to describe the 'regulatory ecosystem' which their technology would have to comply with before it could be diffused into the market e.g. 'Who are the regulators?' 'How much influence do they have?' 'What do technology manufacturers have to comply with?' These findings were compared to the selection mechanisms (stage-gates) identified in the sector-blind commercialisation framework. There was a mix of both internal (university) and external stakeholders, which included representatives from the University tech-transfer officer to understand UoB's in-house procedures.

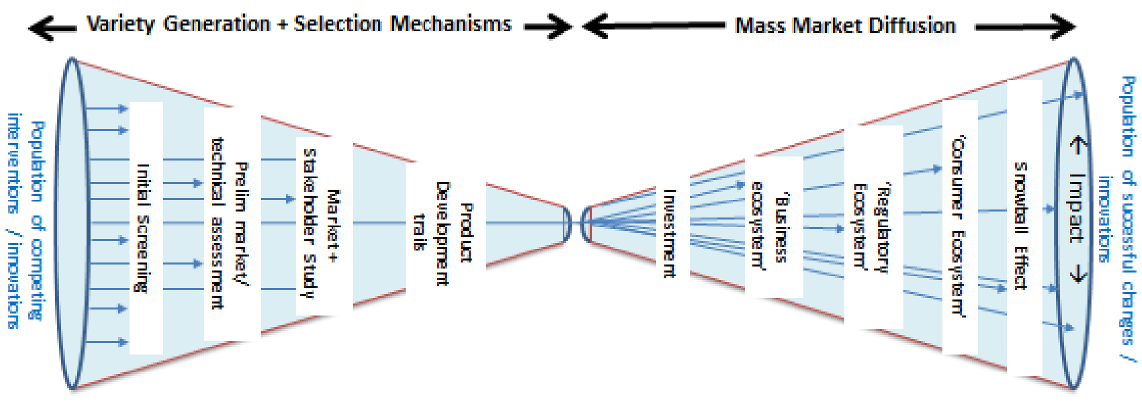
Commercialisation Framework

Based on the review of the literature, we developed a framework to represent commercialisation pathways. The aim was to test the relevance and applicability of this framework with the different stakeholders involved with our case technologies at the University of Birmingham. Most commercialisation processes involve a series of decision stage-gates (go or no-go decision points), which were applied to our framework. We divided our stage-gates into two clusters of activities, which we visualised as two adjoining funnels.

The first cluster of activities or funnel (left-hand side) represents the stages that would typically happen within a University, where a wide variety of ideas are narrowed by a series of strict 'innovation decision stage gates' selecting in and out. These stage gates test the technological feasibility, value proposition and price point of the technology.

Example Stakeholders – Influencing likelihood of development, adoption and regional impact

Research specialists, scientists, engineers. Universities and R&D-intensive firms.. Is the proposed technology / product / process feasible?	Latent market. Potential adopters: start-ups, SMEs, large firms, final users / consumers. Is there latent demand? Does the new functionality meet a clear and significant need?	Investors, funders, venture capitalists. Relevant infrastructures. Regulators and other intermediaries. Are the barriers to adoption outweighed by the promotors?	Real market. Start-ups, SMEs, large firms, final users / consumers. What scale and scope of adoption? What level of realised benefits for users e.g. firm-level increases in sales, productivity, competitiveness etc.



Collinson and Billing, 2018

The second funnel (right-hand side) represents the journey of a technology outside of a university, the technology has been commercialised but has not yet reached the mass market, and as the funnel progresses the degree of impact becomes greater.

The point in the middle where these two funnels meet represents the 'valley of death' or moment the technology is invested in (where the tech will be used for a new spinout, it will be licenced, published or form part of a cooperative R&D agreement). The time scale for both funnels will vary depending on the technology. Different stakeholders will influence the likelihood of development, adoption and diffusion, depending on the stage in the process. Our data collection aimed to identify the focus of the different stage-gates and the stakeholders involved.

Incentives/decision-making factors

Example stakeholders that influence the selection processes and outcomes for each of the case technologies include research specialists, market adopters, research funders, private investors and regulators. Depending on the stakeholder, they will be influenced by different incentives and decision-making factors.

The research found that there are three competing factors that drive decision making in the commercialisation of University research:

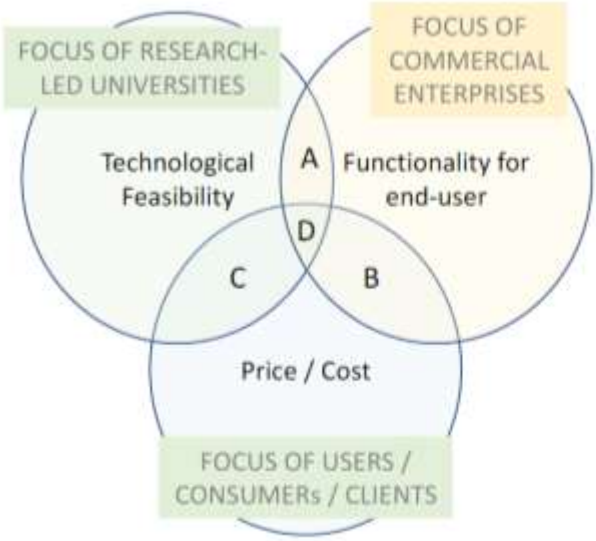
(i) Technology feasibility e.g. is the proposed product technologically feasible? But at the same time, how novel is the technology as this is an important consideration for patentability?

(ii) Functionality for end-user e.g. does the product address a need? Is it easy and safe to use? ;

(iii) Price/Cost e.g. is the price point correct? What is the potential upside (return on cash and investment).

These three factors are interdependent, as they impact on one another. For example, the function can influence the cost, whilst the available budget for resources can determine the technological feasibility.

The degree to which these factors are weighed in importance will vary between stakeholders and depending on the extent of their influence, it may determine the selection decisions/outcome of the product in different ways. These competing product types are shown in the Figure above. Other factors that impact the product include the availability and interest of the research team.



Key for image above:

A = Alignment between science-push and market-pull. Scientific frontier coincides with functionality by users. (Not necessarily at an acceptable price / cost).

B = User values and is willing to pay for functionality (Not necessarily at price point that will cover costs of the technology).

C = Cost of new technology aligns with price (Not necessarily at the point when it provides the desired level of functionality

D = Full alignment between feasibility, desired functionality at a cost which users are willing to pay (although it might be only at a certain scale).

The factors determine the selection decisions/ outcome of the product by defining the selection mechanisms at various stage-gates (go or no-go decision points). For example, 'technology feasibility' stage-gates will assess the technological readiness level of the product; 'functionality' stage-gates will assess the market size and 'Unique Selling Proposition' of the product; 'cost' stage-gates will compare to the price of existing products in the market.

Case Study 1: Med Tech

This section outlines the context in which the technology cases are situated (highlighting the similarities and differences) and provides a summary of each illustrative example. The context covers the key stakeholders who influence the technology and the regulatory system in which the technology has to comply with.

Ecosystem Context

There are distinct differences in the markets for health technologies between national health economies. While the UK has the publicly funded National Health Service, purchasing decisions are devolved to the local level (commissioning groups, NHS Trusts). The NHS has interest in the adoption of new technologies that support innovation in care that lead to improved outcomes for patients and potentially release limited resources. The National Institute for Health and Care (NICE) guidance influences the adoption of these new technologies. The other users of health technology include private health organisations, industries or manufactures or businesses, external investors and the ultimate end user, the patient.

The main regulators in medical technology development are the Medicines and Healthcare products Regulatory Agency (MHRA), The National Institute for Health and Care Excellence (NICE) and government departments. MHRA regulates medicines, medical devices and blood components for transfusion in the UK by providing standards that ensure their safety, quality and efficacy. NICE reviews clinical and cost effectiveness of specialised treatments and reviews new diagnostic technologies/new medical devices for adoption in the NHS. The government provides the infrastructure and conducive environment for the development of medical technologies as well as funding some of the innovations.

In Medtech the focus is on how the technology might be used in care pathways and the people who will use the technology not start ups or SMEs who might commercialise it and bring to market. It is the NHS commissioners who make decisions on whether to adopt a technology not the eventual beneficiaries (patients, general public) and are consulted in preliminary market/technical assessment and market and stakeholder study.

Synthetic, transparent, anti-scarring eye drop

- The technology has been under development since 2008, when two staff from UoB patented a novel technology to deliver a particular type of cells (£377k BBSRC grant).
- So far £5 million has been invested (including £20K EPSRC grant, £1.88m Welcome Trust and Department of Health; £2.5m MRC DPFS) and 15 researchers have been involved in the development of the underpinning technology and its application.
- The underpinning technology has a number of potential different applications (ligament repair, fluid gel particles for skin repair, anti-scaring membranes) - it was based on a technology originally developed in the food industry to change viscosity.
- Its development shows how academics transition different areas of clinical research during the process of translating and commercialising technology.
- It is liquid with < 1% sugar that has the molecular structure perfect for eye drops, as it enables the medicine to 'hang around' on the surface of the eye.
- The team is currently looking to implement the technology with human tissue products service a large-scale eye drop supplier.
- The viscous medium can be also be injected, as well as, sprayed so has a range of potential other uses including for the treatment of burns and wounds.
- To date expenditure is estimated to be £15k on external regulatory consultants and preparing an Investigational Medicinal Product Dossier (IMPD). This is one of several pieces of product related data required.

- Estimated costs for the development of the manufacturing process so far are £1.5m, which the research team had the foresight to include in their research grant application.

Case Study 2: Rail

Ecosystem Context

The British rail industry covers both passenger and freight services, and the stakeholders include both private and public bodies. These stakeholders determine the selection mechanisms at different stage-gates along a commercialisation pathway of a new rail technology.

The Office of Rail Regulation (ORR) is an independent body that regulates safety and the rail economy. It monitors compliance with the health and safety regulations of all organizations operating on the railways, as well as the performance of Network Rail. Network Rail operates the physical infrastructure of the railways. The Secretary of State of Transport is its sole shareholder. The role of Network Rail is to operate, maintain and improve the British railways, not only on the tracks but also on bridges, viaducts, signals, tunnels, level crossings and major stations of the network.

The train fleet for passenger and freight services is provided by private rolling stock companies (ROSCOs). They are divided into rolling stock leasing companies and train builders. The leasing half is dominated by three companies: Angel Train, Eversholt Rail Group and Porterbrook Leasing Company Ltd (Parliament UK, 2018). The train builder has four companies overall (ORR, 2019): Alstom, Bombardier Transportation, Hitachi Rail Europe Ltd and Siemens Mobility Ltd. Train companies (TOC & FOC & ROSCO) manage most of their stations and are responsible for the day-to-day running of services. Of the UK train operators companies (TOC), 28 out of 30 are contracted through a local franchise system, and the government makes the industry a complex mixture.

There are also a number of non-governmental influencers including Passenger Focus, which is the independent transport user watchdog, and the Rail Safety and Standards Board (RSSB), which works to improve safety, performance and value for money across the industry.

MONI-RAIL

- MONI-RAIL is a spinout company formed from the University of Birmingham Centre for Railway Research and Education. It aims to monitor trains and track maintenance issues on a daily basis.
- The rail centre has developed an 'inertial measurement unit' (IMU) that measures the degradation of rail track; they are now developing software to interpret the data.
- This was originally an EPRSC large funded project with support from Network Rail. The total amount of External govt. / UKRI. Other funding that has led to the development of IMU (direct or indirect) is £1.5M since 2003 (EPSRC, Railway Safety and Standards Board, Network Rail).
- Network Rail spends 1.2 billion maintenance every year and 18% relates to track faults – so if the introduction of a new system could save 10% then it could potentially save £120 million.
- If technology were able to monitor degradation on a daily basis, then it would allow the operators to know their maintenance needs and plan for it.

- ICURe is an Innovate UK led programme of commercialisation support for teams of academic researchers wishing to explore the commercial potential of their research. In this case, the early career researcher involved was awarded £35,000 to take a technology from the lab and test the value proposition in the market. At the end of the initial funding-period, they were awarded a £240k grant by Innovate UK which was required to be matched with private investment.
- A number of companies were interested in investing in the company. The MONI-RAIL directors selected an investment from a large rail company who can support with the productisation and rollout of the technology.
- The anticipated timescales to the technology reaching the market is approximately 6 months to 1 year of company formation. The target market is global. The business plan is to sell around 400 units worldwide in the first 3 years, with then ongoing revenue income coming from each unit annually.

Case Study 3: Energy

Ecosystem Context

There are a number of public/private stakeholders in the electricity generation sector, which influence the commercialisation of new technology. For instance, The Office of Gas and Electricity Markets (OFGEM), is the government regulator for the electricity and downstream natural gas markets in Great Britain.

The electricity transmission network is owned and maintained by regional transmission companies, while the system as a whole is operated by National Grid Electricity Transmission plc (NGET). They are responsible for connecting power stations and major substations and ensuring the stable and secure operation of the whole transmission system. Suppliers buy the transmitted energy in the wholesale market and sell it on to customers.

A considerable barrier to energy solutions in this sector is the regulations imposed by Ofgem on the safety of energy storage solutions. Furthermore, Ofgem and National Grid cannot afford to introduce or even test energy storage solutions because the risks of disrupting service at peak times is too great.

These interconnected issues shape a comparably large part of the UK renewable energy landscape, with stakeholders building local and regional private-wire networks and joint ventures to bypass structural resistance to change. For example, the West Midlands Combined Authority, in partnership with its local LEP's and private partners has established 'Energy Capital', a network dedicated to de-risking energy systems transition in the region. Energy Capital has backed the creation of an urban Energy Innovation Zone (Tyseley Energy Park) – a large-scale demonstration of what a local alternative energy ecosystem can achieve. Tyseley is focussed on the concentrated on the production and distribution of sustainable fuels for industrial transportation.

The Dearman Engine

- The Dearman engine is "a novel piston engine driven by the expansion of liquid nitrogen or liquid air".
- Instead of CO2 or other pollutants, the Dearman engine emits nitrogen, but as this is the main constituent in air and the liquid nitrogen is taken out of air then this emission is harmless. Therefore, is a competitive choice when compared to other low or zero carbon solutions.
- Dearman Energy Company Ltd currently has 80 employees. Dearman holds £30 million in private equity and Regional Growth Fund Investment.
- The fuel can be produced sustainably – the production of liquid nitrogen only requires air and electricity, which can be generated, sourced and used sustainably.
- The Dearman engine was invented by Peter Dearman, but has been spearheaded by Professor Toby Peters (University of Birmingham). Toby has championed the development of sustainable engines, refrigeration and energy storage.
- The Dearman engine serves a double purpose: since it is able to power both vehicle propulsion and TRUs (transport refrigeration units). Together with the Dearman engine, the Dearman-Hubbard TRU therefore eliminates the need for both primary and secondary diesel engines for propulsion and refrigeration respectively.
- Development of the Dearman engine started in 2014 in partnership with the University of Birmingham's Centre for Low Carbon Futures (£148k feasibility study funded by Innovate UK). 2014-2015 saw a proof of concept involving Loughborough University, Horiba-MIRA (an automotive engineering and development consultancy), and Air Products (a gas manufacturing multinational). Between August 2015 and July 2017, Innovate UK issued a further £848k of funding to Dearman Engine Company and the University of Birmingham to build a liquid nitrogen prototype of the engine.
- Additional organisations that indirectly shape the regulatory and commercial ecosystem are BEIS, UKRI, and the Industrial Strategy Challenge Fund.

Case Study 4: Quantum Technology

Ecosystem Context

Satellite geodesy, provided by detailed gravity measurements from space, provides a unique perspective on the dynamics of the earth system (solid earth physics, hydrology, glaciology and oceanography).

The stakeholders that determine the selection mechanisms along a commercialisation pathway of a new space technology involve public and private sector organisations engaged in space-related activity. These include launch providers, satellite operators, satellite application providers, government agencies and regulators. The roles of the most influential government agencies and regulators are outlined below.

The UK Space Agency (UKSA) manages the statutory duties of HM Government under the Outer Space Act, developing space regulation policy that supports economic growth. The UKSA collaborates with the European Space Agency (ESA), who coordinate and fund European programs and activities. ESA were responsible for the proof-of-concept GOCE and GRACE missions, which first made space gravity data available to the scientific community.

Ofcom is the independent regulator and competition authority for the UK communications industries. One of its main areas of activity is licensing and protecting the radio spectrum from abuse. The 'International Telecommunications Union' (ITU) is the United Nations agency that allocates the portion of radio frequency spectrum needed by operators to communicate between the satellite and ground stations.

Other influential public sector bodies include the Met Office (the UK's national weather service) and the British Geological Survey (aims to advance geoscientific knowledge of the United Kingdom landmass and its continental shelf).

Quantum Gravity Sensors

- UoB hosts one of four Quantum Technology Research Hubs, as part of the UK National Quantum Technology Programme. The programme is aimed at securing economic and social benefit through the exploitation of the opportunities enabled by Quantum Technology (QT).
- At UoB the team is of order 70 (students and postdocs, academics) plus around 10 support staff, with many more across the rest of the Hub partner universities.
- UoB Enterprise, the University's TTO, have embedded IP staff at the Quantum hub to ensure the capture of IP>.
- UoB is working on developing a range of quantum applications, including cold atom gravity sensors. One ambition is for these sensors to be hosted on a small satellite platform, to provide an alternative form of Earth Observation technology, which goes beyond the typical 2D surface view and provides insight on what lies beneath the ground.
- The technology uses clouds of laser-cooled atoms as perfect test masses and uses lasers to measure extremely small changes in the effect of gravity on these test masses.
- The QT UoB Hub is also focussing efforts on the development of a ground-based gravity sensor, intended for use in urban mapping, underground navigation, subsea mapping and archaeological prospecting. However, a satellite-based sensor offers the potential opportunity of performing global survey campaigns that would be unachievable using ground based sensors.
- The amount of University funds, separate to external sources of funding (such as Innovate UK), that has led (directly or indirectly) to the development of the gravity technology is estimated at over £12M in the last 5 years. The value of all the (2014-19) gravity sensing research at UoB is over £40M. This includes awards from DSTL, EPSRC, European Space Agency, Innovate UK and UK Space Agency.

- Teledyne e2v is a key industrial partner for the hub, who are building a gravity gradiometer based on the UoB technology. They are expecting to make their first sale in the next year and grow in the next 3 to 5 years.

Findings

This section outlines general findings on the key influencers of the likelihood of development, adoption and diffusion of university technologies. These were found to be common across all four of the case studies researched.

Selection Mechanisms

Stakeholders that influence the selection processes and outcomes for each of the case technologies include research specialists, market adopters, research funders, private investors and regulators. These stakeholders are influenced by different incentives and decision-making factors.

Depending on the technology, and therefore the stakeholders, the order and details of the stage gates the entrepreneurial academics will need to overcome will vary. Across all four case technologies, regulation creates specific stage-gates. Medical science in particular, is highly regulated via a series of sequential steps.

A framework, such as ours, could be used a practical tool to identify these different stages the academics need to prepare for, and progress through, to bring their idea to market. This will help them to strategically plan, identify the level of resource they need and the timescales.

University Environment

A key challenge to the commercialisation of university technology is that academics are motivated by a number of competing incentives and performance indicators as part of 'their day job'. These include their civic role, teaching responsibilities and the 'Research Excellence Framework' (REF). Therefore, although academics might be connected commercially, they don't always have the available time or resource. The research found that it is rare for an academic to have the capacity to effectively research, teach and commercialise.

It is worth noting that success at technology commercialisation (in the context of REF) has recently, been very helpful to three UoB academics when they applied for/were considered for promotion to Professor. This is a relatively recent change and demonstrates that the University is adapting to external pressures.

'Entrepreneurial academics' who have effectively combined their academic skills with business acumen are unusual. Moreover, their development is not always encouraged by the funding and reward schemes at Universities.

There are also other contextual factors that are specific to a University environment which must be considered. For instance, academic researchers often do not have the opportunity to take a long-term strategic view to develop a product or concept over time. The reality is that their research progresses on a project-by-project model, often involving hiring a research fellow for a brief, fixed period. This has implications for retaining knowledge and expertise relating to the technology under development. Leadership may also change during product development projects, making effective hand-overs essential.

How regional is the impact?

The research found that the return benefits of the commercialisation of university technology are unlikely to be confined to the region. The primary aim is to find a willing partner; "*for any bit of IP, we aim to find the one company in the world that actually wants it*". Nevertheless, the product development trials and system demonstrations can be done locally and bring regional benefits, with initial investment, prior to widespread adoption and dissemination. Rail and energy contrast with med-tech and quantum in this study, in terms of current and likely medium-term regional economic impact. Further research is needed to quantify regional economic impacts over different timescales under different conditions.

Do stage-gates 'kill' the innovation?

Innovation decision stage-gates are not necessarily 'go or no-go decision points', as there can be multiple exits. Depending on the selection mechanism, possible outcomes are:

i. The product progresses closer to being licensed/becoming a spinout opportunity.

ii. Additional resource is allocated to further develop the product;

iii. Replaced by an alternative technological solution;

iv. The innovation is 'killed'.

Commercialisation is rarely a linear process. There are feedback loops, changes of direction and alternative pathways considered at every decision-making stage-gate.

Consequently, academics often have to transition between different areas of research during the process of translating and commercialising their technology. This adds to the complexity of collaborative innovation, where external partners need to be clear about the commercial proposition. Market assessment is also more challenging for 'blue sky' technologies, where specific applications have been identified and the potential market is unclear.

This study found significant differences in terms of the stage-gate decision-making structures in place across the case study technologies. Some appeared to be more effective than others, but none took a full 'portfolio' approach, with robust assessments comparing different propositions. There are a number of lessons on how university stage-gates could be organised more effectively to leverage the portfolio of technology projects in play at any one time.

Research Funding as a Driver

The costs of commercialising transformative technologies can be very high, whilst translational funding and investment are hard to secure. Therefore, academic entrepreneurs rely on both funding (grants from Research Councils, charitable bodies) and investment (Business Angels, venture capital) at different points along a commercialisation chain. The availability of this funding and investment acts as a screening mechanism, determining whether specific ideas are taken forward. Therefore, there need to be targeted approaches to securing both.

Funding is preferred over investment in the early stages of product development where the market opportunity is very specific and potentially limited. Across the four case technologies, research council funding has been used to:

- Fund the core research teams and infrastructure;

- Test the functionality, feasibility and readiness of the products;
- Raise the visibility of the product to help generate market interest and private investment.

Private investment is more common in the later stages of a products' development and if a knowledge transfer partnership will determine that once developed the technology will go straight into the business.

We found significant variation in the degree to which, and mechanisms by which, different funding organisations influenced the development pathways for different technologies in the study. This has important implications for the ways in which universities standardise / vary R&D policies and incentives for different faculty disciplines or departments and manage external partner relations.

Technology Transfer Office

University of Birmingham Enterprise supports the commercialisation of UoB technology. It is made up of a team of 30 members of staff, who help provide an end-to-end service for academic innovators, including practical and financial support for proof of concept studies and market research; training for academics; incubation services; and facilities for high-tech and biomedical start-ups.

In terms of Intellectual Property (IP), they "find, protect, license and sell". In addition to the core members of staff, the larger technology hubs across campus, have embedded and dedicated IP staff to support their commercialisation activities.

The IP team follows a very detailed process, starting with a record of invention (a documented description of the invention) at the earliest possible stage. Only 1 in 10 of these records of inventions will be patented. To determine whether they should invest in patent protection, the IP team calculate the perceived market potential of a technology using a matrix of indicators. These indicators are taken from the UoB commercial assessment criteria (based on the COAP parameters developed by the universities of Warwick and Sheffield),

The COAP parameters include the following factors (they are weighted differently depending on their importance): (1) Competitive Edge; (2) Market Fit; (3) Readiness; (4) Value sales of Market; (5) Defensibility of Patent; (6) Inventor Commitment; (7) Scope; (8) Royalty Rate; (9) Intensity of Competition; (10) Customer Attractiveness; and (11) Development Facilities.

This assessment acts as an innovation decision stage-gate for UoB technology, specifically focused on whether to invest in patent protection, at 12 months and 30 months (when additional funds are required to progress the patent application). It is a key stage in the UoB technology commercialisation pathway. Many researchers who engage with TTO's say that their research is enriched as a result. UoB Enterprise also has a clear set of questions in relation to determining whether there is a rationale to spinout new companies.

'Readiness levels'

The Technology Readiness Level (TRL) scale was originally defined by NASA in the 1990's as a means for measuring or indicating the maturity of a given technology.

It continues to be a useful tool to help inventors keep track of their progress during the commercialisation of technology. This research observed that at each of the nine TRL levels, there are different decision-making stage gates, which would be useful for academic entrepreneurs to be able to anticipate and prepare for. For example, customers in the private sector are used to normally buying an advanced prototype – universities are under pressure to get up to this standard.

The research also identified 'manufacturing' and 'supply chain' readiness levels as being important and central to the successful market adoption and diffusion of university technologies. All three are partly determined by external players in the market. These include collaboration with supply chain contractors and coordination with the R&D activities of other institutions. This improves the knowledge exchange required to adapt the technology for specific users and markets and builds interest amongst potential investors and customers. Universities need to develop relationships with external stakeholders and relevant firms as early in the process as possible. UoB Enterprise sometimes use funds or other initiatives to facilitate this (including EBF, MICRA, iCURE, RAE Fellowships).

The Technology Readiness Levels span over nine levels as follows:

TRL 1 – BASIC RESEARCH: You can describe the need but have no evidence

TRL 2 – TECHNOLOGY FORMULATION: Concept and application formulated

TRL 3 – NEEDS VALIDATION: Initial offering with positive support from stakeholders

TRL 4 – SMALL-SCALE PROTOTYPE: Developed in Lab environment

TRL 5 – LARGE-SCALE PROTOTYPE: Tested in target environment

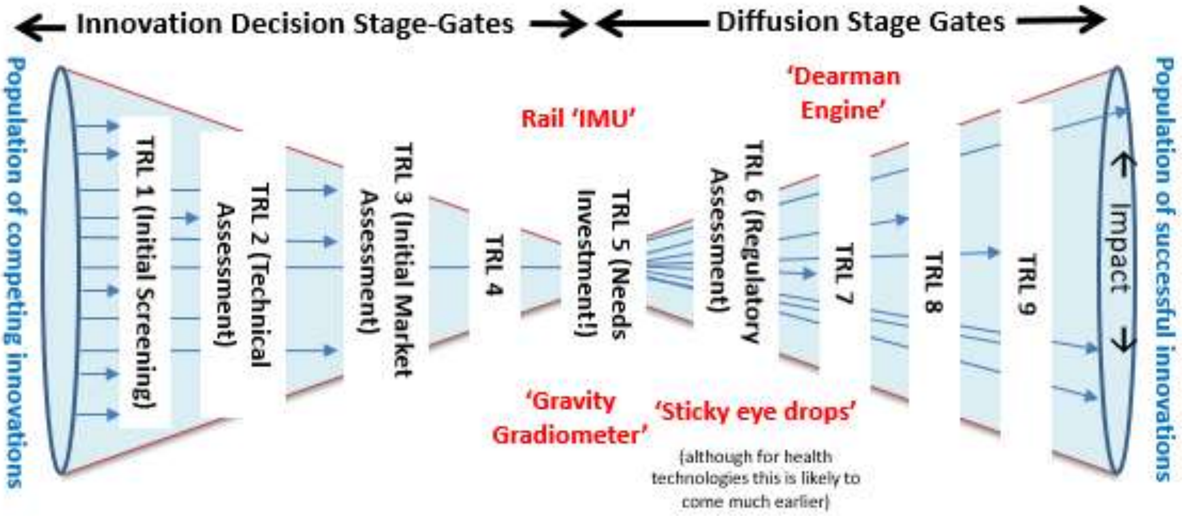
TRL 6 – PROTOTYPE SYSTEM: Tested in target environment, close to operating expectations

TRL 7 – DEMONSTRATION SYSTEM: Fully operational at pre-commercial scale

TRL 8 – FIRST OF A KIND COMMERCIAL SYSTEM: Technology and systems ready for commercial application

TRL 9 – FULL COMMERCIAL APPLICATION: Technology ready for adoption and diffusion

The case technologies are at different TRL levels (as shown below) and therefore are faced with different decision-making stage-gates. Opportunities often need investment at very early stages (TRL 2-3). It is worth noting that Medical device TRL's are often different.



Conclusions and Recommendations

- Our study has identified a range of factors that affect the commercialisation process, including the disconnect between academic goals and technology commercialisation activities; regulation; and gaps in seed funding and investment. It is important that these potential barriers are considered at the start of any commercialisation process, so that they can be appropriately managed.
- We need to consider when the commercialisation process actually starts. Is it from the moment the academics applies for some research for something they think might end up having commercial value, or just the time they disclose it to their Technology Transfer Office (at whatever stage of maturity that might be)?
- Academics are generally good at research but 'not good at business'; they have other incentives and key performance indicators. Therefore, although some might be connected commercially, they normally do not have a remit or incentives to deliver commercial success. For academics, research funding is often seen as a key outcome, rather than an input to create something that adds value elsewhere.
- Commercialisation of university technology is rarely a linear process; there are 'swerves' (you start out going in one direction but as it matures, the market directs you somewhere a little different) and feedback loops at every decision-making stage-gate. However, a strategic portfolio view should be taken to assess the relative probability of success, costs, benefits and timescales, within and across different technologies and sectors to optimise resource-allocation.
- There is a distinction between funding (grants from Research Councils, charitable bodies) and investment (Business Angels, venture capital) both of which can be used to fund product development trials. Funding is more common over investment in the early stages of development where the market opportunity is very specific and potentially limited (investment is hard to attract at the earlier stages). There need to be different approaches in targeting funding and investment.
- The stakeholders which determine the funding environment, culture and regulations vary between industry sectors, influencing the selection processes and outcomes for each of the case technologies in different ways. Customised approaches by staff are needed to effectively navigate these. Users, regulators and funders all influence the pathway to commercialisation.
- Technology Readiness Levels (TRLs) continues to be a useful tool to help keep track of progress through the commercialisation pathway. The research also identified 'manufacturing' and 'supply chain' readiness levels as being important and central to the successful market adoption and diffusion of university technologies.
- Universities should build relationships with market players (large or small\medium sized enterprises) and other institutions as early in the process as possible. This may present opportunities such as being to able scale up research through already existing enterprises.
- A successful partnership between an academic team and the Technology Transfer Office team is required if the technology is ever to be leave the University to be further developed. Neither can be successful without the other.