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That troublesome 'E' word: entrepreneurship in the context of public research commercialisation, technological innovation and the wealth of nations.

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Abstract
Entrepreneurship and the accumulated tacit knowledge and culture of the entrepreneur are the resources essential to create wealth from research commercialisation leading to technological innovation. The authors explore in definitional terms, entrepreneurship as an essential element in the interaction between all types of tacit knowledge (technological, managerial, risk management, financial etc.), and the institutions (sets of rules), organisational culture and external business environment, and how these interact with the entrepreneur's own background and personality. This leads to a wider analysis of the importance of such tacit knowledge as the glue bringing together effective mechanisms for wealth creation out of research commercialisation.

Introduction: mapping a complex territory
It is unfortunate that three phenomena of central importance to economic and social development can still be seriously discussed and researched in a definitional haze. It is uncontroversial that research commercialization, entrepreneurship and technological innovation are closely linked phenomena that are vital to the creation and maintenance of national wealth. What is controversial is the precise nature of the relationship between these three phenomena. This paper seeks to resolve some of the confusion, which may exist, by careful definition leading to effective conceptual integration. As such, it is the first stage of a longitudinal qualitative research study that will involve grounded theory based case studies (Yin 1994, Strauss & Corbin 1998) of early stage public research spin-off companies established in Australia in the years 1998 to 2000. For this larger study, it has been particularly important to understand the nature of the knowledge inputs (background and new intellectual property, codified and tacit knowledge) and the entrepreneurship and entrepreneurial skill inputs involved in the process of technological innovation through the spin-off company as a commercialisation channel.

In the recent Yellow Pages® Special Innovation Report*.* (Yencken at al 2001) innovation was defined as 'taking up and converting new ideas into a commercial market success'. Innovation narrowly defined can of course also involve commercial failure. Catherine Livingstone in the Warren Centre Innovation Lecture 2000 further developed the definition:

> *I will interpret (successful) innovation as meaning the process whereby 'new ideas are transformed, through economic activity, into a sustainable value-creating outcome'. There are two key words in this interpretation which are worthy of emphasis: 'Process': innovation is not just the idea – innovation is only achieved when the idea has been transferred into an outcome which has value…The second key word is 'sustainable':.. Sustainability requires good integration with those who assign value ie. the customers, the market, and it implies rigour and continuous measurement.* (Livingstone 2000: 3).

Gurr (2001) recently quoted 3M's definition as: **An Idea_Applied_To Create Benefit**.

For the technological innovation that results from the commercial exploitation of new knowledge, the ultimate objective is wealth creation, whether it be through the creation of a new business entity or by the establishment of a new venture within an existing company. The exploitation of such new knowledge essentially changes the production function (Schumpeter 1939 pp. 87 and 94).

The innovation domain involved is illustrated in Figure 1 below. This illustration has been designed to show the various inputs and outcomes in technological innovation and how they may be linked both into the wealth creation process and with each other. It is intended to be illustrative rather than exhaustive.

The links to be explored include new knowledge, that may be codified in the various forms of intellectual property and a range of other knowledge inputs that may be codified or tacit. Other codified knowledge will include the disciplinary learning of the inventor and the management and entrepreneurship training of the manager/entrepreneur. The tacit knowledge brought in by the various players will include the technological understanding of the inventor/technologist in relation to the development of the specific new knowledge being commercialised and the experience and skills of the entrepreneur, both as a manager of new technological ventures and possibly also from his familiarity with the industry in which the venture will operate. Finally successful entrepreneurial activity requires certain key personal traits, such as toughness of mind, doggedness and ability to survive potential and actual disasters. Inventors and entrepreneurs are shown as separate branches in Figure 1 with a link based on entrepreneurial education, training and experience. While it shows the need for both types of inputs, the inventor, in many new technology based firms (NTBVs), will also be the entrepreneur. However experience shows that a research scientist without entrepreneurship training and experience is often not well suited to the entrepreneur or "jockey" role needed to drive the NTBV forward.

The literature (Stanforth & Curran 1986, Smith 1997) has identified many motivations or 'triggers' other than wealth creation for establishing new small companies. These include: artisans wanting to own their own businesses; being retrenched; being unhappy with a current working environment and seeking a comfortable and satisfying way of life. In the specific case of public research organizations, the motivation for creating spin-off companies can also embrace the desire to market specialist skills and tacit knowledge held within the host organisation, with the primary focus on technology transfer through consultancies and research contracts. These latter types of new ventures involve only limited risk and therefore in their early stages are much less likely to require the input of the experience and risk management skills that lie at the core of successful entrepreneurship. They do not necessarily involve product or process innovations and they are unlikely in Schumpeterian terms to change the production function in their product/market sector (Schumpeter 1939 pp.87 & 94).

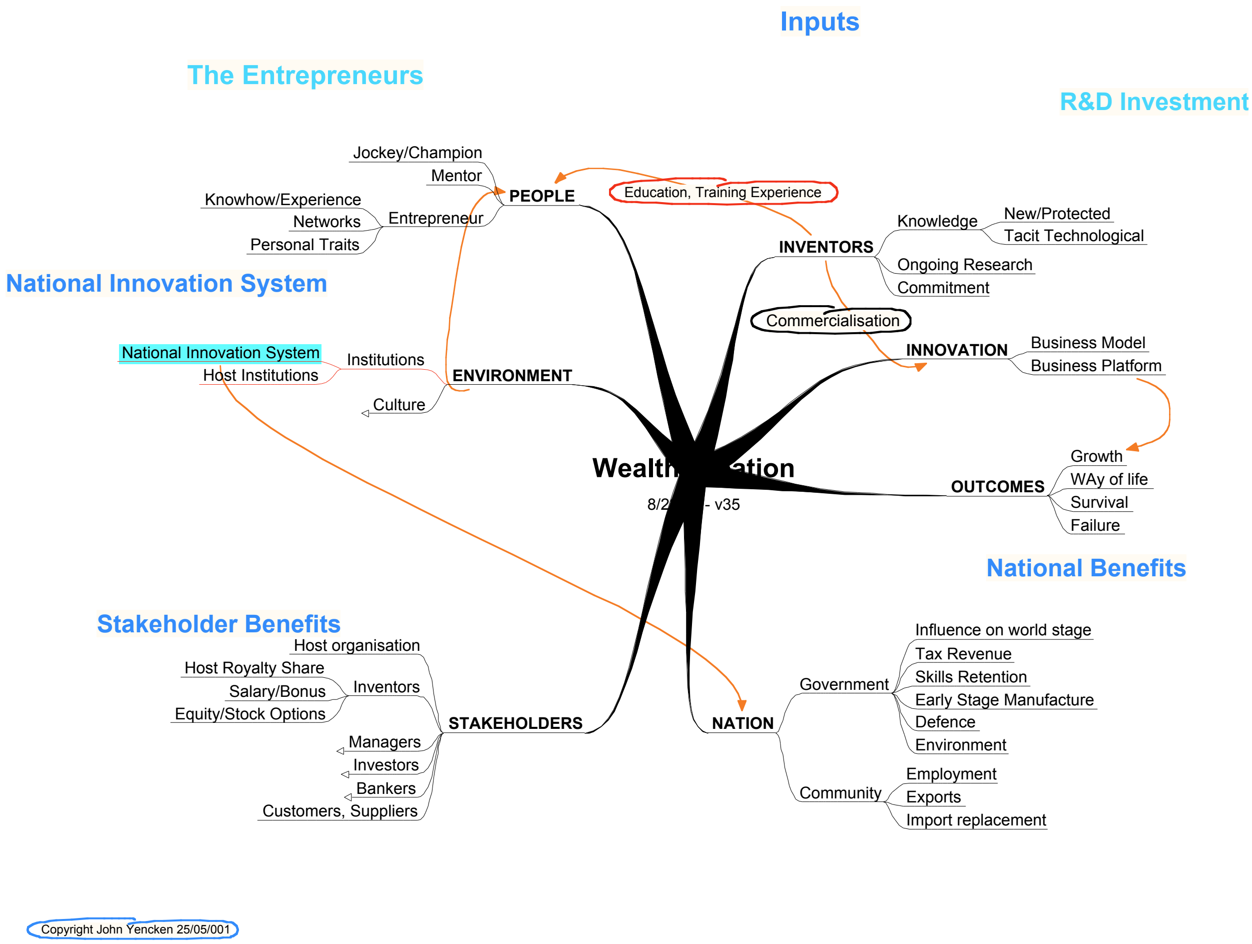


Figure 1 - The technological innovation domain

Definitional problems of the word ‘entrepreneurship’

An historic ‘split personality’

Of French derivation, the word 'entrepreneur' literally means an 'in-between taker'; someone who gets 'in between' a supplier and a market and takes a profit by facilitating the exchange process. Positive connotations revolve around the concept of 'making it happen'. In this perspective, the entrepreneur can be seen as a creator: one who turns a potential exchange into an actual exchange, one without whom the transaction may never occur. Extrapolating, in the case where the demand exists but the supply does not, the entrepreneur may actually create the supply as well as effect the exchange. In the specific case of the exploitation of new technological assets and platform or disruptive technologies, the entrepreneur may even have to create a market where none exists. There are also negative connotations. Such a person may be construed in some minds as a mere 'middleman' or worse, someone who takes an 'unearned' profit by actually obstructing the 'natural' process of exchange by inserting him or herself into the channels of distribution and actually distorting an efficient flow from producer to consumer. This was well recognized by Laurie Cox, the Chairman of the Australian Stock Exchange Limited, in his foreword to Hartwell and Lane’s history of Australian entrepreneurship. (Hartwell & Lane, 1989). Cox wrote:

The late 1980s witnessed an unprecedented attack on corporate Australia and more specifically the so-called entrepreneurs who were the golden boys prior to October 1987. It also saw the misuse and abuse of the word entrepreneur which, in Australia, has come to mean anything from a risk taker or gambler to an innovator, creator or manager.

Fortunately, there is, in the entrepreneurship literature, an emerging concensus about at least the 'ingredients' that any comprehensive and useful definition of entrepreneurship should encompass. They are these:

- creation of a new organisation to pursue an opportunity (Bygrave and Hofer 1991; Gartner 1989)
- innovation management (Schumpeter 1939/1942)
- speculation and risk bearing (Cantillon 1775 – quoted in Jennings 1994: 42-43)
- coordination of disparate elements (Say 1828 – cited in Koolman 1971)
- decision making in an uncertain environment (Knight 1921)
- leadership (Marshall 1949)
- arbitrage (Kirzner 1973)
- product development and ownership (Hawley - discussed in Jennings 1994: 56-57) *and*
- a focus on managing rapid growth in a volatile environment (Legge and Hindle 1997).

Entrepreneurs are seen as participating in a complex, plural and interactive network (Jennings 1994: op.cit.), embracing 'all' or most of the above concepts in complex interaction. The proportions of these ingredients will vary from case to case and context to context. One entrepreneurial process may, for instance, involve a high level of risk management and a low degree of organization building. Another may involve high levels of leadership and low levels of arbitrage. The same fundamental ingredients, mixed according to different recipes, can be used to bake many dishes.

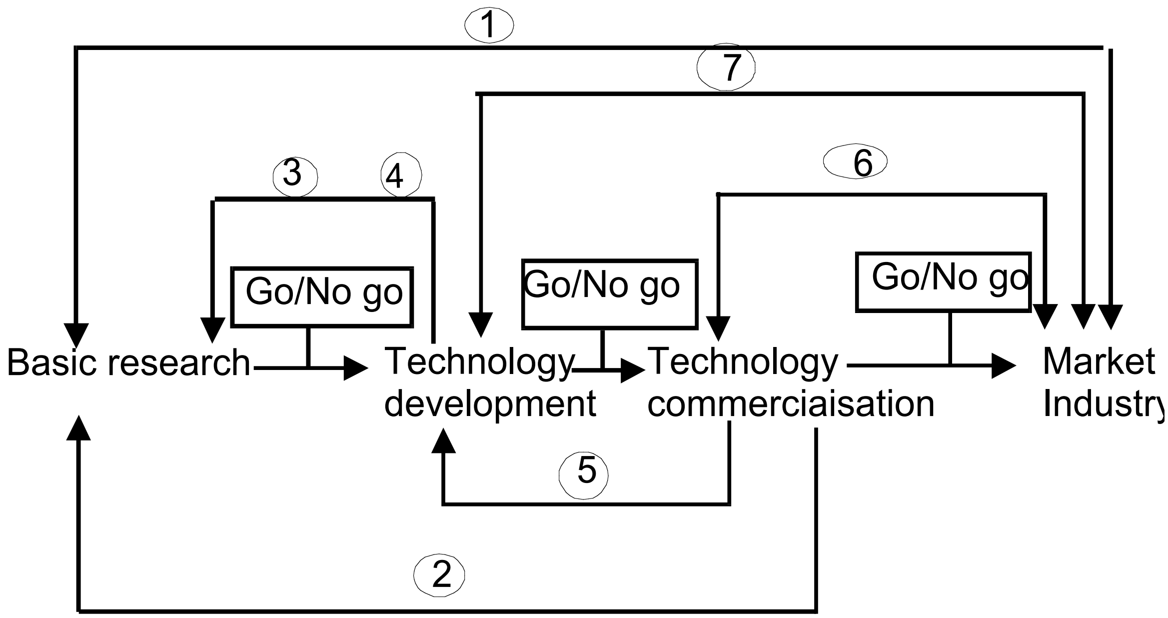
As indicated in the Introduction, this paper focusses on the particular 'recipes' for entrepreneurship and the entrepreneurial skill and tacit knowledge inputs needed to achieve successful innovation in the early stage commercialisation of public, particularly university research.

Entrepreneurship inputs into research commercialization and technological innovation

Commercialisation channels and options

The Scottish Enterprise strategy study quoted by Cripps et al (1999) identifies a number of channels by which innovation from the commercialisation of university and other public research can take place: *viz.* education/training, collaborative research, contract research, industrial consultancy, licensing, spin-off companies and joint ventures This paper is concerned with spin-off companies as New Technology Based Firms (NTBV) rather than with the licensing of intellectual property to established companies. Thorburn (2000) has shown the importance of transferring the tacit knowledge of the inventors across into such new ventures. Legge & Hindle (1997) have equally demonstrated the importance of the tacit knowledge of the entrepreneur in "managing rapid growth in a volatile environment".

The manager of a company's industrial research group has traditionally seen the research process as starting from an identified problem or market need that is potentially solvable by research and its subsequent development and application_essentially a linear market driven process. Smith and Barfield (1996 p.1) however commented that 'classification schemes that describe the innovation process as a straight line progression fail to capture its essential messiness and serendipitous nature'.



Legend
1,7 Market needs
2 Commerciaisation possibility
3 Technolological feasibility
4 Additional research problems involved
5 Design, redesign, further testing
6 Quality improvement, economising

Figure 2 - The University Model of Technological Innovation (Source: Lee & Gaertner 1994)

For new knowledge arising from basic research, the more complex model of Lee and Gaertner (1994) (Figure 2) may be more relevant.

Recent R&D management literature distinguishes four types, or what is known in the literature as 'generations' of R&D strategies (Miller & Morris 1999, Liyanage & Greenfield 1999, Niosi 1999):

> *Ist generation R&D is the unbounded search for scientific breakthroughs…2nd generation R&D shifts the focus to applicability (in the market place) using project management… while 3rd generation R&D uses surveys to establish existing customers' needs to create products and services to fulfil those needs. Constrained by the inherent limits of explicit market knowledge, however, 3rd generation R&D is predominantly occupied with continuous innovation (Miller & Morris 1999.*

In the mid-eighties, a fourth stage or 'generation' of R&D strategies arrived: "…characterised by cooperative R&D and systematic links between independent research agents; technological alliances between corporate users and producers became widespread' (Niosi 1999). This well describes the strategies of well managed user driven Cooperative Research Centres in Australia.

Public research spin-offs may operate quite successfully and survive in any one of these disparate modes, but particularly in second and third generation modes. However, the literature shows that spin-offs operating in these latter modes_and indeed they constitute a significant proportion of public research spin-offs as we will show later_may survive, but are unlikely to show significant growth (Stankiewicz 1994).

To have the potential for high growth_to become the new mini-multinationals, small ventures need to develop strategies to compete on a level playing field with existing mature larger enterprises. This requires discontinuous innovation, that generates disruptive technology, not just continuous improvement, 'not just managing discontinuities in the market place, but creating new discontinuities' (Miller & Morris op. cit. p.10, Hamel 2000).

Discontinuous innovation is driven by questions about the 'future' needs of customers; these needs are rarely articulated (Miller & Morris op. cit. p.10). Discontinuous innovation will most likely result from 1st generation research, the unbounded search for scientific breakthroughs. It will involve '…breakthrough inventions …that are based on fundamental scientific research that leads to new markets…and are almost impossible to predict'. They can also result from the fusion of separate disciplines to create new ones,…biotechnology, nanotechnology, mechatronic. 'Discontinuous innovation is unbounded because it is driven by the discovery of unmet, tacit needs' (Miller & Morris op. cit. p.21).

The need is for a new business model and process focussed on innovation as a whole, not just on its constituent parts_R&D, technology development, product/service development (Miller & Morris op.cit. p 22). Particularly, it must integrate tacit and explicit or codified knowledge from all sources.

The role of and need for the entrepreneur may be quite different for the different R&D domains. Such environments will be particularly critical where breakthrough inventions are involved.

The taxonomy of new venture spin- offs

The literature shows the importance of the host organisation in the creation of public research spin-offs (eg Dahlstrand 2001). Recent studies of public research spin-off ventures in Australia (Thorburn 2000, Upstill and Symington 1999) have suggested three main classes of new ventures derived from public research agencies, classified primarily by the relationships back to the host or parent organisation. These classes have been further expanded in this paper to four classes :

> *1. Direct research spin-offs (DRSO) are companies which have been created in order to commercialise intellectual property arising out of a research institution where intellectual property (IP) is licensed, involving a patent or copyright, from the research institution to the new firm to form the founding IP of the firm and staff may be seconded or transferred full or part-time from the research institution to the new firm.*
>
> *2.Technology transfer companies (TTC) are companies set up to exploit commercially the University's tacit knowledge and know how, usually but not solely in the area of process rather than product innovation, where no formally protected (eg patents) IP and/or exclusive licensing is involved.*

There is a third class of university derived spin-off companies for which information is difficult to obtain.

3. Spin-outs or Indirect spin-off companies (ISO) are companies set up by former or present university staff and/or former students drawing on their experience acquired during their time at the University, but which have no formal IP licensing or similar relationships to the University. It is unlikely that University administrations will have formal records of such companies, but it will be important to have any, even limited, information on such companies to allow later follow up by the researcher.

Little or no Australian data is available on this group of companies. Studies in Sweden (Chalmers 1992, McQueen & Wallmark 1984, Wallmark 1997) show that for Chalmers University of Technology indirect spin-offs occurred more than twice as frequently as direct spin-offs (Table 1).

Table 1 Spin-off enterprises from Chalmers University, Sweden 1992

Type of enterprise	Direct spin-offs	Indirect spin-offs	All spin-offs
Spin-off companies	183	300	~500
Number of new spin-off companies per year	15	40	55
Number of employees in spin-offs	3000	13,500	16,500

Source: Chalmers Innovation Centre Annual Report 1992.

Finally there is a further class that may be called ‘spin-ins’:

4. Spin-ins (to existing companies) can be defined as new ventures deriving from the licensing or other agreed exploitation of new knowledge generated by public research agencies, whether or not separate incorporated entities are set up or they operate as discrete ventures within the existing company.

The performance of new ventures spun off by public research agencies has been variable. It has been seen to be disappointing and not living up to early experience, particularly in the USA in the fields of electronics and computers. Sceptics like Feller (1990) have suggested that the role of universities in technological development should be essentially indirect. Stankiewicz (1994) however has challenged the conceptual foundations on which such assessment of spin-off performance has been based. He has suggested a taxonomy of such NTBFs based on their main modes of activity:

Consultancy and R&D contracting (CC) that exploit competence shortages and R&D environments; they are the technology transfer companies in the earlier Upstill and Thorburn taxonomy. These are essentially based on 1st and 2nd generation R&D activities.

Product oriented mode (PO), organised around a well developed product (or process) concept and focussed on the advanced development, production and marketing of that product (or process). These are typical 3rd or 4th generation R&D based companies and are traditionally Schumpeterian in concept.

Technology asset oriented mode (TA), concerned with the development of technologies which are subsequently commercialised through spinning-out new firms, licensing, joint ventures or other types of alliance; these firms are based on business models derived from new mixes of fusion and discontinuous and potentially disruptive innovation. The *genesis of such new ventures typically can come from 1st or other generation R&D modes.*

Stankiewicz (op.cit.), Samson and Gurdon (1993), Stanforth & Curran (1986) and Smith (1997) all point to the need to resolve institutional tensions, which commercially oriented activity creates within the public research agency, without radically severing the protagonists' link to academia. The CC companies are the primary result from such tensions. They are the most common among academic spin-offs (Stankiewicz op. cit., Oloffson and Wahlbin 1993). Their activities are an extension of the research activities that are core competencies of academic researchers. Capital requirements and risk are low. There appears to be little need for entrepreneurial skills and inputs unless such companies grow to such a size that they separate off from their parent organisation.

PO mode spin-offs match more closely the classical entrepreneurial model. They are organised around a well-developed product (or process) concept and focus (Stankiewicz op.cit.). They will need almost *ab initio* access to technology and product development skills, business network access and experience and familiarity with their chosen_and existing_product/market sector. Research discussed in the next section shows these skills as critical for new PO mode ventures survival and growth.

The TA mode spin-offs require a business concept focused on the creation, development and management of technological assets. To become technological assets, research results and even the specific technologies have to be sufficiently packaged to make them saleable (Stankiewicz op.cit.). Resource needs include a whole new range of competencies ranging from intellectual property and knowledge protection to the identification and even creation of a market and the development of the technology to the point where its market value is optimal. These needs extend beyond the traditional skills and experience even of the serial entrepreneur, particularly in relation to IP and technology management, and require an exceptional level of commitment at all levels in the new venture.

The analysis and inter-relationships of the various classes of spin-offs are shown in Table 2.

Table 2 Classification of public research spin-offs

Class	Output	Most common R&D mode	Activity mode	Risk	Potential wealth creation	Entrepreneurial inputs
1. Direct research spin off	New product / process / service	3rd generation	PO Product oriented	Medium to high	Medium to high	Start-up management, including business model Risk management Market sector familiarity Finance Product

						development
	Discontinuous innovation or new platform technology	1st to 4th generation	TA Technological asset oriented	High	High	1-4 As above PLUS IP Technology management Product/market creativity and development
2. Technology transfer companies		1st and 2nd generation	CC Consultancy & R&D contracting	Low	Low	Very limited until critical size is reached
3. Spinouts or indirect spin-offs	Full range	May not be R&D new knowledge based	CC or PO	Low to medium	Low to medium	Traditional serial entrepreneur skill mix
4. Spin ins to existing companies	Continuous innovation	3rd generation	PO	Low	Medium	Supplied by existing company

The preliminary results of a recent survey of spin-offs from Australian Universities with 32 universities responding and data from CSIRO showed 137 Direct Research Spin-offs, 65 (44 poer cent) in the period from 1998 to the present, and 43 Technology Transfer companies, 14 (33 per cent) in the period from 1998 to the present. Only 14 Indirect Spin-offs were identified. However of all of these, only one or two spin-offs appear to fall into Stankiewicz's Technology Asset class, the potential knowledge based mini-multinationals. This is the real challenge for Australia.

Synthesis: an integrated model

Ideas, opportunities, new venture survival and growth

Lundvall (1992) identifies three important characteristics of national innovation systems: the generation of new knowledge, the ability (absorptive capacity, closely related to R&D investment) to use this knowledge and an external environment that is not prejudicial to innovation. This paper is focussed on the absorptive capacity of an innovation system, particularly that part of it that derives from tacit knowledge of various types.

Three inputs facilitate this absorptive capacity that determine the genesis, survival and growth of new ventures exploiting technological innovation: ability to find ideas convertible into opportunities, access to resources, access to knowledge:

Ideas and opportunities

Johnson et al (1999) identify as critical stages in the university research commercialisation process 'commercialisation readiness and scanning and reporting'. They see commercialisation readiness as being ready to exploit future IP requirements. They suggest that in Australia the triggering and conversion of ideas to become opportunities is inhibited by academic time constraints and by cultural hostility to 'managerialism' by researchers'. In a similar context, the recently established technology management company of the Linköping University in Sweden has two staff with the designation on their business cards as 'Idea Finder'*.* Fiet (2001) has reported recent research that suggests that interventions and training can help a group of public sector researchers to be more effective finders of ideas that can be converted into opportunities.

Resources

Cooper et al (1994) tracked the new venture performance of 2,994 entrepreneurs over a three year period. Their dependent variables were survival and growth (as number of employees). The study identified that the significant resource factors affecting growth were experience in a similar business, number of partners, initial capital and industry sector. The factors affecting both growth and survival were experience in a similar business and initial capital. Bruderl & Preisendorfer (1992) also reported human capital specific factors as strong predictors of future success, with a strongly significant effect of industry specific experience on venture survival.

Later work by Dahlquist et al (2000) confirmed the significance of initial capital and industry sector, but found that the significance of management know-how and specific industry know how appeared 'less robust to changing contexts and measurements'*.*

Klofsten (1988, 1998, Davidsson & Klofsten 2001)) identified eight 'pillars', relating to resources utilised by new ventures, as predictors of their ultimate survival and growth. 'The Business Platform Model suggests that a young firms' likelihood to survive and take off is contingent upon how well developed the firm is as regards *the business idea, the product, the market, the organization, core group expertise, core group drive/motivation, customer relations* and *other relations'* (Davidsson & Klofsten 2001 p.1).

Knowledge

Knowledge inputs in the early stage of new ventures include background and new intellectual property and both codified and explicit knowledge and tacit or implicit knowledge:

Codified knowledge inputs include:

- the published knowledge base of the science or engineering involved in the 'discovery'
- new knowledge, contained in patents, copyrights, registered designs etc.
- the codified content of postgraduate or undergraduate training in entrepreneurship and/or technology management

Tacit knowledge inputs are no less important and include:

- the ability to find ideas that can be converted into opportunities (Johnson et al 1999, Fiet 2001),

- technology and scientific background brought to the new ventures by the ongoing involvement of the original inventors (Thorburn 2000)

- familiarity with the particular product/industry sector (Cooper 1994)

- entrepreneurial experience, including startup management, risk management, established access to business networks, finance raising (Legge & Hindle 1997).

The literature shows the importance of environmental or border scanning on firm performance (Yoo 2001, Audet & d'Amboise 1998, Barringer & Bluedorn 1999). Knowledge is not a static resource. It requires frequent checking and updating. Scanning is also an important source of new ideas and opportunities

The final group of success factors relates primarily to personal traits, commitment and personal past history as it interacts with the new venture's environments (Chell 1996, Dahlstrand 2001).

Entrepreneur traits (Welsh & White 1983)

Good Health, Basic need to control and direct, Self-confidence, Never Ending Sense of Urgency, Comprehensive Awareness, Realistic, Superior Conceptual Ability, Low Need for Status, Objective Approach to Interpersonal Relationships, Attraction to Challenges, not Risk

The process most usually involved in the initial stage of development of an NTBF to exploit new knowledge and research outcomes is illustrated in Figure 3 (developed by the authors). Across the middle, the diagram shows the sequence of stages with the researcher generating *new knowledge* that leads to an *idea* that is converted into an *opportunity* and a *vision* that leads through *technology development* or *proof of concept* up to the first exit point, when typically a venture capitalist or other investor might get interested. While for simplicity this has been represented as a linear process. It will normally be iterative and messy as illustrated in the earlier Figure 2. The lower circles show the various knowledge inputs, reinforced by border scanning. The upper triangles show important events, including finding the idea, the trigger that leads to it becoming an opportunity, resource inputs from innovation support programs, involvement of an entrepreneur, and resource inputs from investors and other interests such as customers and suppliers.

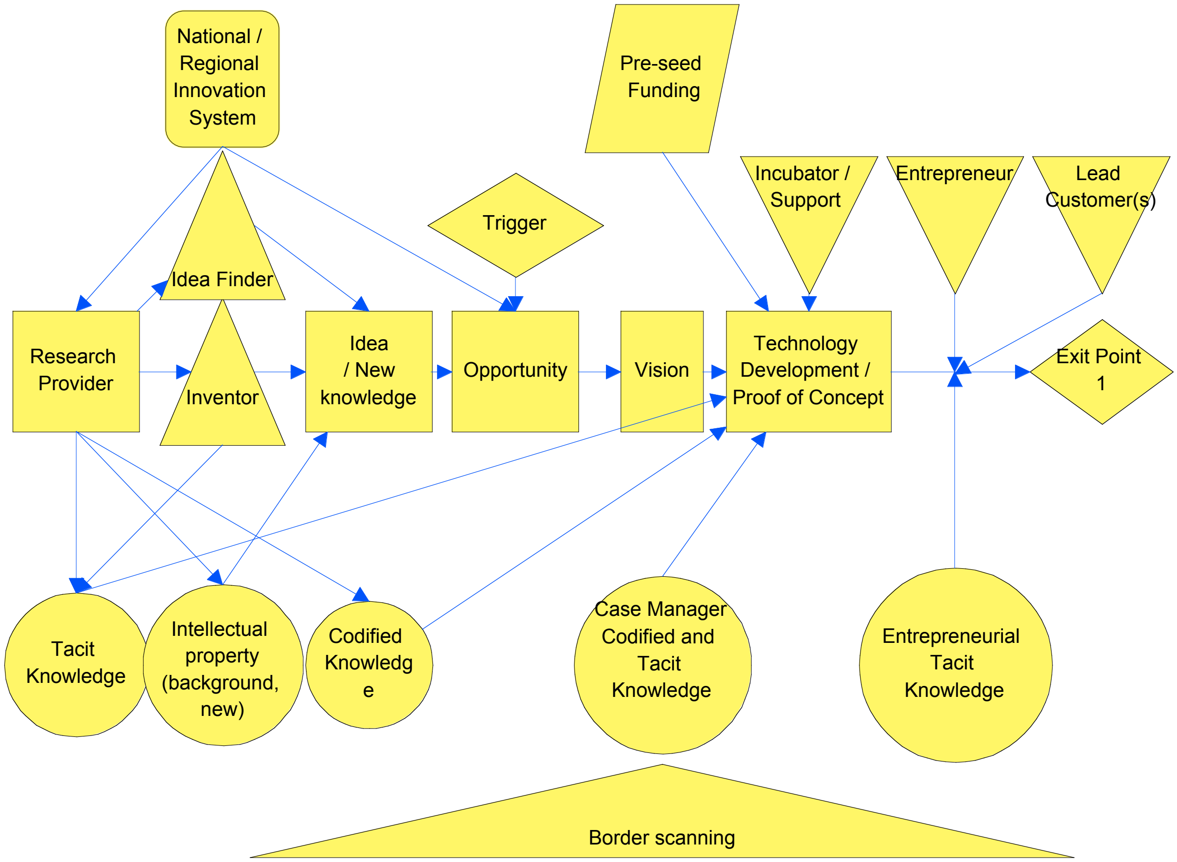


Figure 3 - Inputs into new venture development and technological innovation

Conclusion: Entrepreneurship's role in technological innovation

New ventures based on research-derived new knowledge usually have a high growth objective, even if this is not always achieved. Growth involves risk and usually giving away equity to obtain the necessary financial resources. Success requires commitment and does not necessarily, in the early stages, provide a comfortable life style to the inventors and technology developers. These are however the ventures that have the potential to become new mini-multinationals. For these new ventures, the identification of the business concept and business model is much more demanding because of greater uncertainty about the optimal product/market positioning. In the extreme case there may be no existing market for the innovative product, process or service that results from the technological innovation, and the business model has to address what may be the potential market and how to create it.

The developers of such ventures require access to the skills, tacit knowledge and experience of the entrepreneur, either by further developing their own competencies and experience or alternatively by bringing in an experienced entrepreneur as a new partner. These competencies include technology management, management of start up enterprises, product/market strategy development, risk assessment and management, total commitment and the personal traits of doggedness in the face of adversity and of being a doer rather than an observer_key entrepreneurial skills. In summary, the process of innovation has many component parts _from early stage elements, such as codified and tacit knowledge of various types, to product development and other late stage aspects of commercialising a finished product. Entrepreneurship and the associated tacit knowledge is the glue required to meld all the elements to convert an opportunity into a commercial success.

Ongoing research plan

The research plan to explore further the validity of this model and the various knowledge inputs will involve a number of case studies based on theoretical sampling of public research spin-off ventures established in Australia between 1998 and 2000. This will allow comparative analysis between differing classes of public research providers (universities, CRCs and CSIRO) and differing economic activity sectors (biotechnology, ITC hardware, mining/minerals). The case studies will include qualitative data collection by interview on decisions and decision-makers during the early stages of the venture and on the various types of knowledge inputs. They will also include comparative and longitudinal quantitative data collection based on the survey methodology of Daviddson & Klofsten (2001) using their Business Platform and its eight pillars as a means of predicting survival and growth, both looking back two years and repeating this quantitative data collection in two year's time_a total elapsed time of six years.

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