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Public research commercialisation, entrepreneurship and new technology based firms: an integrated model

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Abstract

Entrepreneurship is the *engine of innovation*. The accumulated tacit knowledge and culture of the entrepreneur are the resources essential to create wealth from research commercialisation leading to technological innovation and the creation of New Technology Based Firms (NTBFs). The authors explore, in definitional terms, discovery of entrepreneurial opportunity and entrepreneurial capacity as the essential elements in the interaction between all types of tacit knowledge (technological, managerial, risk management, financial, etc.). These both derive from and affect interactions between the institutions (sets of rules), organisational culture and external business environment. They also interact with the entrepreneur's own background and personality. This leads then 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.

Keywords: Discovery; Commercialisation; Entrepreneurship; Innovation; Tacit knowledge; Spin-offs

1. Introduction: mapping a complex territory

Lundvall (1992) identified three important characteristics of national innovation systems: the generation of new knowledge, the absorptive capacity or ability (closely related to business R&D investment) (Yencken and Gillin, 2002a) to exploit 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 involved in the development of new NTBFs. For countries like Australia with low levels of technology absorptive capacity (directly related to business R&D expenditure per employee) but with many highly creative research groups, high-tech start-ups have been shown to have much higher R&D expenditure per employee than existing businesses and thus make a proportionally greater contribution to technology absorptive capacity (Yencken and Gillin, 2002a).

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 commercialisation, 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 and Corbin, 1990) of early stage public research spin-off companies established in Australia in the years 1998–2000. For this larger study, it has been particularly important to understand resource based theory applied to entrepreneurship (Alvarez and Busenitz, 2001) with knowledge the critical resource. The paper also explores the nature of the knowledge inputs (prior, background and new intellectual property, codified and tacit knowledge) and the entrepreneurship capacity inputs involved in the process of technological innovation through the spin-off company as a commercialisation channel for university and other public research agency research outcomes.

The paper first discusses definitions relating to inno-

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vation and entrepreneurship relevant to the discussion of research commercialisation leading to New Technology Based Firms (NTBFs). It then discusses entrepreneurship, entrepreneurial capacity and other resource inputs into the research commercialisation processes and technological innovation. This is followed by an analysis of the various types of public research agency spin-off ventures. Finally it proposes an integrated model for the analysis of knowledge and entrepreneurial inputs in the early stage development of NBTFs spun-off from public research agencies.

2. The innovation domain

In the recent Australian Yellow Pages® *Special Innovation Report* (Yencken et 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 i.e. the customers, the market, and it implies rigour and continuous measurement (Livingstone, 2000).

Gurr (2001) recently quoted 3M's shorter definition as: **An Idea—Applied—To Create Benefit**.

It is important to distinguish early on between *small-i* and *large-I* innovation. Much of the public policy effort in Australia appears to be overly focused on *small-i* innovation—that is synonymous in this interpretation with invention and is all, and only, about newness. The extension to generating commercial success is lost. Fig. 1 illustrates this difference between *small-I* innovation and *Large-I* innovation. This figure shows the central importance of entrepreneurship as *the engine of innovation* (Drucker, 2002, p. 1). This issue has been developed further by Hindle (2002).

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 leading to discovery of a commercial opportunity essentially changes the production function (Schumpeter, 1939, pp. 87 and 94).

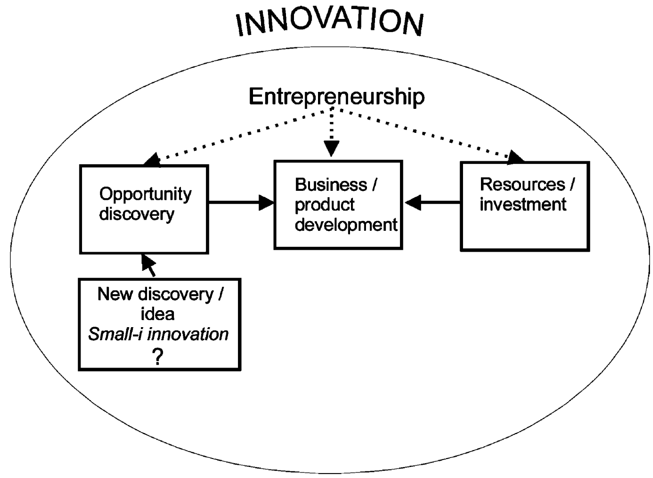

Fig. 1. Innovation and entrepreneurship. Source: Yencken and Gillin (2002). Unpublished.

2.1. Knowledge inputs

The links to be explored include knowledge resources derived from entrepreneurial capacity, 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 starts with the technological understanding of the inventor/technologist in relation to the development of the specific new knowledge or technology being commercialised. To this has to be added entrepreneurial capacity, that is the experience and skills of the entrepreneur (whether home-grown or recruited from outside), both as a manager of new technological ventures and possibly also from his familiarity with the business sector in which the venture will operate. Vohora et al. (2002) identify the imported CEO as a surrogate entrepreneur. The inventor, in many NTBFs, will also be the initial entrepreneur or technology champion, but will often be replaced by an externally recruited Chief Executive Officer, or *surrogate* entrepreneur. Experience has shown that a research scientist without entrepreneurship training and experience, while competent to be the initial technology champion, is often not well suited to the entrepreneur or *jockey* role needed to drive the NTBF forward (Daniels and Hofer, 1993; Venkataraman et al., 1992; Samsom and Gurdon, 1993).

3. Definitional problems of the word 'entrepreneurship'

3.1. 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 and Lane, 1989).

Fortunately, there has been, in the entrepreneurship literature, an emerging concensus about at least the *ingredients* that any comprehensive and useful definition of entrepreneurship should encompass. They are as follows:

- creation of a new organisation to pursue an opportunity (Bygrave and Hofer, 1991; Gartner, 1989),
- innovation management (Schumpeter, 1934, 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 have been 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 situation may, for instance, involve a high level of risk management and a low degree of organisation 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 has focussed on the particular *recipes* for entrepreneurship and the entrepreneurial capacity and tacit knowledge inputs needed to achieve successful innovation in the early stage development of NTBF spin-offs in the commercialisation of public, particularly university, research. The literature has suggested that the concept of entrepreneurship is holistic. However, we will argue that the need for and nature of entrepreneurial capacity inputs will be different for the different phases of a new venture's development.

4. Research commercialisation and technological innovation

4.1. Research strategies

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 have commented that "classification schemes that describe the innovation process as a straight line progression fail to capture its essential messiness and serendipitous nature". For new knowledge arising from basic research, the more complex model of Lee and Gaertner (1994) (Fig. 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 (Liyanage and Greenfield, 1999; Miller and Morris, 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 and Morris, 1999).

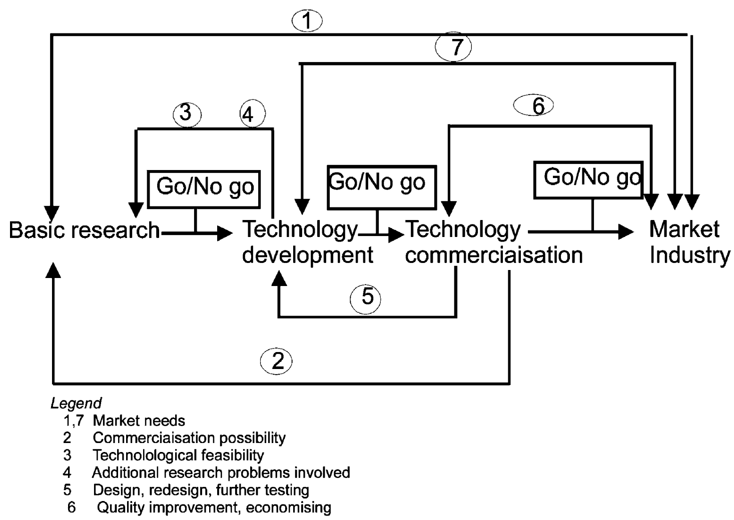

Fig. 2. The University model of research commercialisation. Source: Lee and Gaertner, 1994

In the mid-1980s, 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 (see website <www.crc.gov.au>).

Public research spin-offs may operate quite successfully and survive in any one of these disparate modes. However, the literature suggests that spin-offs operating in these second and third generation modes 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 and 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 and 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" (Miller and Morris, op. cit.). They can frequently result from the fusion of separate disciplines to create new ones, e.g. biotechnology, nanotechnology, mechatronics. "Discontinuous innovation is unbounded because it is driven by the discovery of unmet, tacit needs" (Miller and 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 and 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 innovation domains. Such domains will be critically different where breakthrough inventions are involved.

4.2. Commercialisation channels and options

The Scottish Enterprise strategy study quoted by Cripps et al. (1999) identified a number of channels by which innovation from the commercialisation of university and other public research can take place: viz. publication, education/training, collaborative research, contract research, industrial consultancy, licensing, spin-off companies and joint ventures. The sources and potential outcomes from these various commercialisation channels for public sector research are illustrated in Fig. 3. This paper is concerned with spin-off companies as NTBFs rather than with the licensing of intellectual property to established companies. In this context, the critical decision is not about choice of commercialisation channel but about whether there is the potential to spin-off a new start-up NTBF with high growth potential, however defined (Yencken, 2001).

4.3. Entrepreneurial capacity as a knowledge resource

F.A. Hayek (1945) was an early proponent of the importance of knowledge and its distribution in a well functioning economy…Hayek's pioneering work provides a starting-point for analysing how the distri-

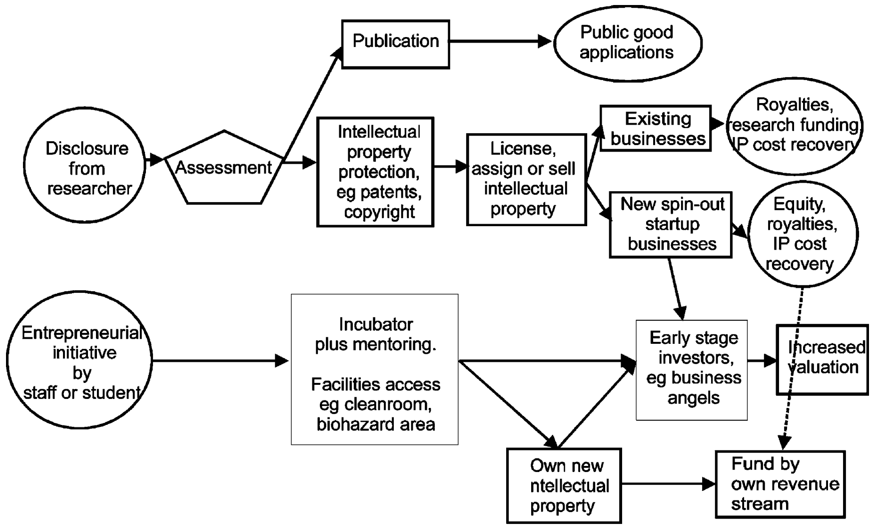

Fig. 3. Source: Yencken and Gillin (2002). Unpublished.

> bution of knowledge affects organisational structure… (Jensen and Meckling, 1992, p. 252).

Penrose (1995–1999) first drew attention to the issue of heterogeneity of resource mixes as a key consideration in strategic analysis and management. For established businesses, her concepts have since been further developed and refined (Barney, 1991; Eisenhardt and Martin, 2000; Peteraf, 1993; Rugman and Verbeke, 2002; Teece et al., 1997). More recently, Alvarez and Busenitz (2001) have expanded resource-based theory to include entrepreneurship. They showed how entrepreneurship related resources could be identified in their own right (Alvarez and Busenitz, 2001, p. 770). They identified three specific knowledge resources that the entrepreneur brings to a new venture and are critical to "the creation of heterogeneous output through the firm that are superior to the market": the founder's unique *awareness* of opportunities, ability to acquire the *resources* needed to exploit the opportunity, *organisational* ability to recombine homogeneous inputs into heterogeneous outputs. Our analysis suggests that, for start-ups involved in the process of technological innovation, these usually do not come from the one individual.

For such ventures the knowledge resource and skills of the *technology champion* in managing technology development are also important. Thorburn (2000) has also shown the importance of transferring the tacit knowledge of the inventors across into such new ventures. Legge and Hindle (1997) have equally demonstrated the importance of the tacit knowledge of the entrepreneur in "managing rapid growth in a volatile environment".

> It is the firm's unique bundle of resources that is different from competitor firms that are potentially valuable and contribute to a firm's competitive advantage (Alvarez and Busenitz, 2001, p. 756).

5. The taxonomy of new venture spin-offs

Achs and Andretsch (1990) have thoroughly reviewed the role of small firms and their contribution to commercially valuable innovation. The literature (Stanworth and Curran, 1986; Smith, 1967) has identified many motivations or *triggers* other than wealth creation for establishing new small companies. These have included 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 organisations, the motivation for creating spin-off companies can also embrace the desire to market specialist skills and tacit knowledge held within the host organisation through consultancies and research contracts. These latter types of new ventures are described later as Technology Transfer Companies. The literature has also shown the importance of the host organisation in the creation of public research spin-offs (e.g. 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 IP arising out of a research institution where 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 (e.g. patents) IP and/or exclusive licensing is involved.

(3) *Start-ups 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.

Little or no Australian data are available on this last group of companies. Studies elsewhere (Chalmers, 1992; McQueen and Wallmark, 1984; Wallmark, 1997; van der Meer and van Tilburg, 1999; Edinburgh Research and Innovation, 2001, p. 3) have shown that indirect spin-offs occurred more than twice as frequently as direct spin-offs, particularly when regional development has been the driver for new business creation.

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 may operate as discrete ventures within the existing company.

There is a related but equally important class of spin-outs from existing companies that lies in the domain of corporate entrepreneurship (Bhidé, 2000) and which is outside the scope of this paper. Fig. 4 illustrates the taxonomy and differing access to initial resources of the different classes of new venture spin-offs and startups.

Skeptics 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 this assessment of spin-off performance has been based. He has suggested a taxonomy of such NTBFs with differing wealth creation characteristics, 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's CC companies and the Upstill and Symington (1999) Technology Transfer (TTC) companies, identified earlier, are common among academic spin-offs (Stankiewicz op. cit., Oloffson and Wahlbin, 1984). 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 unless such companies grow to such a size that they separate off completely from their parent organisation. 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 and 94).

Product oriented (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 product/market sector. Research discussed in the next section shows these skills as critical for new PO mode ventures survival and growth.

Technology Asset (TA) 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. The strategic objective will be to develop 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. Start-ups involved in pharmacology and new drug development can usually be classified as TA companies. Commonly they will licence their new products to major

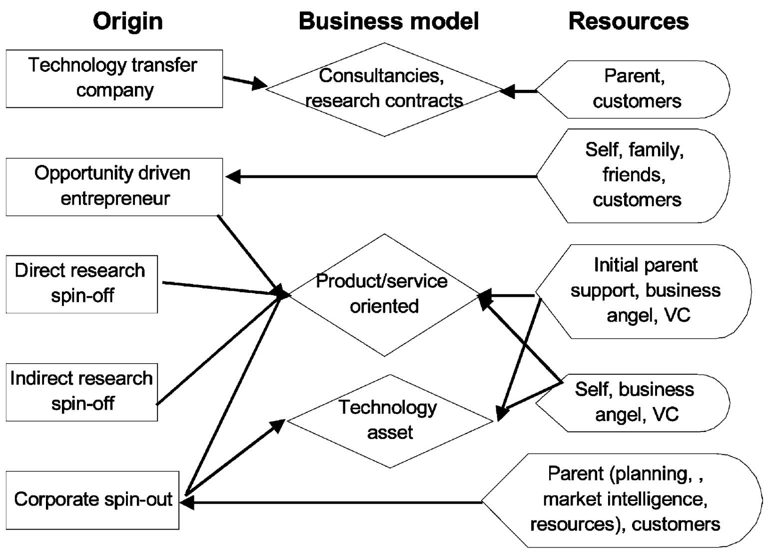

Fig. 4. Taxonomy and sources of initial resources of spin-off companies. Source: Yencken and Gillin (2002b).

pharmaceutical companies after successful Phase 1 clinical trials.

The focus in this paper is on Direct Research and to a lesser extent Indirect Research Spin-offs, including both Product Oriented and Technology Asset companies. A recent survey of spin-offs from Australian universities (Yencken and Gillin, 2002b) with 32 universities responding, showed 175 Direct Research Spin-offs, 86 (49%) in the period from 1998 to 2000, and 43 Technology Transfer companies, 14 (33%) in the period from 1998 to the present. Several spin-offs in the biotechnology/pharmaceutical and a smaller number in other technology sectors appeared to fall into Stankiewicz's Technology Asset class. The recent study managed by the Association of Technology Managers and published by the Australian Research Council (ARC, 2002) identified 35 DRSO-type start-ups out of universities in Australia in the year 2000.

6. Synthesis: an integrated model

Three inputs particularly facilitate technology absorptive capacity and determine the rate of generation, survival and growth of new ventures exploiting technological innovation: that is, the ability to find ideas convertible into opportunities, access to resources (human and financial), access to knowledge.

6.1. Ideas and opportunities—the discovery process

Discovery of entrepreneurial opportunity has become an increasingly important area of entrepreneurship research (Venkataraman, 1997). Johnson et al. (1999) identified as critical stages in the university research commercialisation process 'commercialisation readiness and scanning and reporting'. They have seen commercialisation readiness as being ready to exploit future IP requirements.

The most important recent work on discovery processes (Shane, 2000) has suggested that in the identification of opportunities the most critical factor is the prior knowledge and personal history of the incipient entrepreneur. Current case studies by one of the present authors suggest that the key trait in the discovery process is the ability to think laterally in applying prior knowledge in the identification of an entrepreneurial opportunity. This trait was not specifically identified in the earlier literature as an entrepreneurial trait (Welsh and White, 1983). Chell (1986) in her earlier review suggests the importance of "the products of each individual's total history…*(including the interaction between personal traits and immediate environments*) that in turn regulate how new experiences affect him or her".

For the incipient entrepreneur, Shane's prior knowledge can be seen as a *trigger* of equal importance as individual environments or situations.

6.2. Knowledge and other resources

Cooper et al. (1994) tracked the new venture performance of 2994 entrepreneurs over a three-year period. The 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 and 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.

However, 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 et al. (1988), Klofsten (1998) and Davidsson and Klofsten (2002a,b) identified eight *cornerstones* relating to resources utilised by new ventures, as predictors of their ultimate survival and growth. This Business Platform Model suggests that a young firm's 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 organisation*, *core group expertise*, *core group drive/motivation*, *customer relations* and *other relations* (Davidsson and Klofsten, 2002a, p. 1).

6.3. Knowledge inputs

Knowledge inputs in the early stage of new ventures include prior knowledge in the discovery stage, 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., and
- 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 and Migliore, 2001); Shane's prior knowledge (Shane, 2000),
- 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 et al., 1994), and
- entrepreneurial experience, including startup management, risk management, established access to business networks, finance raising (Legge and Hindle, 1997).

The literature has shown the importance of environmental or border scanning on firm performance (Yoo, 2001; Audet and d'Ambroise, 1998; Barringer and 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).

6.4. The integrative model

The process most usually involved in the initial stage of development of an NTBF to exploit new knowledge and research outcomes is illustrated in Fig. 5 (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 be interested. This relates closely to the five-phase model and the associated analysis of the critical junctures between phases developed by Vohora et al. (2002).

For simplicity the model has been represented as a linear process, but it will normally be iterative and messy as illustrated earlier in Fig. 2. The lower circles show the various knowledge inputs, reinforced by border scanning. Border scanning includes both awareness of external economic and regulatory happenings and being a source of new ideas and opportunities. The upper triangles show the importance of access to entrepreneurial capacity at the various phases of business development, including finding the idea that leads to an opportunity and acquiring and managing the resources needed. They also show resource inputs from public sector innovation support programs, seen by Mustar (1997) as essential to the development of university spin-offs, and resource inputs from investors and other interests such as customers and suppliers.

7. 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. Their markets are necessarily global if they originated in a small domestic market such as Australia. These are however the ventures that have the potential to become new mini-multinationals ('$50 million businesses') and improve national technology absorptive capacity. They will contribute to economic development from equity earnings, new high technology jobs and by keeping prototype/technology development and early stage manufacturing in the country where the new knowledge was developed. For these new ventures, the identification

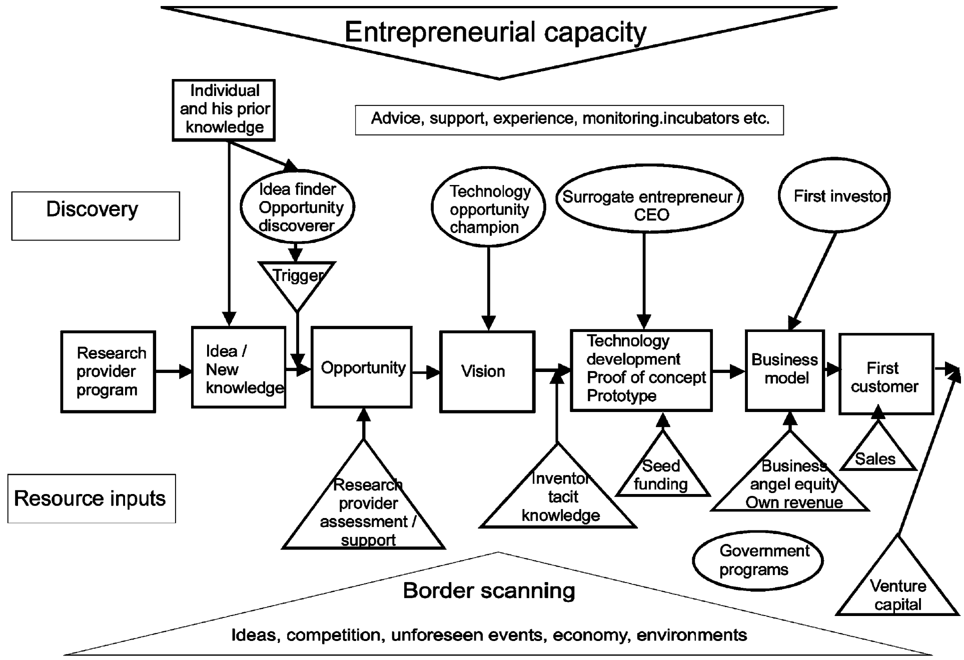

Fig. 5. Entrepreneurial capacity and new TBF development. Source: Yencken and Gillin (2002b). Unpublished.

of the market opportunity, 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 discovery of a potential commercial opportunity requires both prior knowledge and lateral thinking ability. The developers of such ventures then require access to differing inputs of entrepreneurial capacity according to the phase of development. This may come, either by further developing their own competencies and experience or alternatively by bringing in an experienced (or surrogate) entrepreneur/manager as a new partner (Vohora et al., 2002). These competencies include corporate strategy development, technology management, management of start up enterprises, product/market strategy development, risk assessment and finance and other resource management. Equally essential are 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 a number of phases, from the initial research and discovery phase, through definition of the opportunity to product development and other late stage aspects of commercialising a finished product. Each phase will need a different mix of tacit and codified knowledge inputs. Entrepreneurship and the associated tacit knowledge, identified by Drucker (2002) as *the engine of innovation*, is the glue required to meld all the elements to convert an opportunity into a commercial success.

7.1. Ongoing research plan

The research plan to explore further the validity of this model and the various knowledge inputs involves over 20 case studies based on theoretical sampling of public research spin-off ventures established in Australia and overseas 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, instrumentation, ITC hardware, engineering, 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 Davidsson and Klofsten (2002a, b) using their Business Platform and its eight Cornerstones 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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