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Technology-driven entrepreneurship: how technology shapes the way entrepreneurs start and run their businesses

5th Inter-RENT Online Publication

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TECHNOLOGY-DRIVEN ENTREPRENEURSHIP: HOW TECHNOLOGY SHAPES THE WAY ENTREPRENEURS START AND RUN THEIR BUSINESSES

Started in 2004, the INTERRENT is an on-line ECSB publication initiative aimed at creating a forum where ECSB members, and particularly post-doc scholars at the early stages of their academic career, can debate around a selected theme from the previous RENT conference, leading to the publication of a number of high-quality articles. This initiative has an exciting potential for ECSB as an organization and, more specifically, for its members. It tries to provide support to young scholar to improve their work by promoting the progression from conference papers into published articles. Furthermore it contributes to develop further debate and understanding of a new topic each year.

The fifth edition of the INTERRENT contains a selection of four papers presented at the 2007 RENT conference in Cardiff (UK) on the following theme "Technology-driven entrepreneurship: how technology shapes the way entrepreneurs start and run their businesses".

The idea behind this topic proposal is that technology is not only a driving engine for economic growth and entrepreneurial ventures but also that it acts like a powerful force able to shape entrepreneurs' behavior, values and mindsets. In this perspective technology is not a neutral tool, but something that at the same time supports and constraints human action, thinking and even deepest values. Each technological innovation brings with it a wave of new start-ups and new entrepreneurs, but probably the way entrepreneurship is deployed changes in any major technological revolution. The literature on technological entrepreneurship is often obviously focused on the most recent technological trends and high-tech companies, but we think that interesting insights could come from comparative and longitudinal studies about how entrepreneurship develops in different technological areas (low and high tech) and in different times.

A few words to illustrate the criteria used for papers selection and the review process. The criteria for papers selection have been the following: authored by at least one post-doc, quality, coherence with the topic, and absence of overlapping with the RENT anthology. The papers underwent a two steps review process: a cross-review phase, in which each participant has reviewed his/her peers' work using the on-line forum available on the ECSB web site www.ecsb.org; a second step with a more traditional blind review by anonymous experts.

Papers include a certain variety in terms of industries like ICT and biotech. All report empirical studies, with a mix of qualitative and quantitative approach. They deal with several topics like access to capital for new technology-based companies (Minola and Giorgino), the management of uncertainty in the venture creation process of technology-based ventures (Mauer and Brettel), the

spill-over effects in knowledge-based industries (Senyard, Pickernell, Clifton, Kay and Keast), and the investments in IT as drivers for entrepreneurship (Leitão and Baptista).

A word of thanks goes to all the participants to the INTERRENT 2008 and the anonymous reviewers for the quality of their efforts, their responsiveness and the ability to cope with the constraining deadlines imposed by a tight schedule.

The 2008 INTERRENT Editor

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INWARD FDI AND ICT: ARE THEY A JOINT TECHNOLOGICAL DRIVER OF ENTREPRENEURSHIP?

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ABSTRACT

This paper investigates whether inward Foreign Direct Investment (FDI) and investment in Information and Communication Technologies (ICT) advance the development of entrepreneurial activity in the host economy. We propose that the combination of inward FDI with investment in ICT is a joint technological driver of entrepreneurship. Under a feedback causality context, a Co-integrated Vector Autoregressive approach is used to examine the 'pull' effect of ICT and the 'push' effect of FDI. On the one hand, ICT 'pulls' FDI; on the other hand, FDI 'pushes' investment in ICT. Under a neo-Schumpeterian approach, the long term economic relationship among entrepreneurial activity, FDI and ICT drives creative destruction through the creation of further SMEs, thus revitalizing the entrepreneurial innovative capacity of the host economies.

INTRODUCTION

Inward Foreign Direct Investment (FDI) is considered a strategic action for the advancement of entrepreneurial activity in domestic firms networked with multinational companies (MNCs). The spillover effect of MNCs intensifies competition, enhances innovative capabilities, aids the development of Research and Development (R&D) activities, and also contributes to reducing social exclusion (Parker, 2005, 2006). The seemingly weak evidence on positive effects of the presence of MNCs on entrepreneurial activity might hide their significant impact on industrial re-structuring (Acs & Szerb, 2006; Barbosa & Eiriz, 2007).

Studies of the impact of inward FDI on entrepreneurial activity are relatively scarce. Of particular importance are those by Sleuwaegen & Dehandsschutter, 1991; Jovanovic, 1994; Van Praag & Cramer, 2001; De Backer & Sleuwaegen, 2003; Barbosa & Eiriz, 2007; and Burke *et al.*, 2007. However, these studies focus on the impact of imports and/or inward FDI on entrepreneurial activity or the survival of start-ups without paying specific attention to the mechanisms through which such spillover effects occur. This particular study contributes to the literature by focusing on the role played by investment in information and communication technologies (ICTs) in driving spillovers originating in FDI.

There is growing empirical evidence of the dynamic role of entrepreneurial activity in promoting innovation, economic growth and employment (Audretsch *et al.*, 2006; Van Stel, 2006; Fritsch & Mueller, 2004; 2008). Acs *et al.* (2006) speak of entrepreneurship as a conduit for spillovers of knowledge into the economy, enhancing productivity and growth. But entrepreneurial activity itself is also driven by spillovers, acting either through the transmission and availability of innovative ideas, or through the existence of an infra-structure which supports new entrepreneurial efforts. We propose that two dynamic drivers of spillovers that increase entrepreneurial activity are FDI and investment in ICT.

Schumpeter's (1940) theory of creative destruction proposes that non-innovative firms and products are replaced with innovative ones. The concept of innovative firm may here include those firms who take advantage from opportunities arising spillovers available in the environment. The environment here comprises both physical infra-structure and the pool of knowledge and demand for new services generated by existing firms. Investments that contribute to the creation of sources of spillovers in the environment drive creative destruction whenever new or existing firms take advantage of these spillovers. In order to take advantage of the aforementioned spillovers, new and existing firms are required to make more investments that, in turn, generate more sources of spillovers.

In the present paper, we examine evidence of this sequence of dynamic relationships that are established between entrepreneurial activity and its dynamic drivers, looking more specifically at

FDI and ICTs. The main contribution of the paper to the literature of entrepreneurship and technological change is the analysis of inter-relationship between these two dynamic drivers of entrepreneurial activity, and of their joint impact on entrepreneurial activity and, indirectly, economic performance.

More specifically, we assess the causality relationships that are established between ICT investment and FDI, and economic variables used in the literature to assess entrepreneurial activity – the business ownership rate – and economic performance – gross domestic product (GDP) and the unemployment rate. The present study examines data for two different countries – Finland and Portugal, providing a comparative analysis between two European countries with different technological profiles: Finland[2] (a high-tech producer) and Portugal[3] (a low-tech producer) that experienced significant FDI and investment in ICTs.

In order to assess causality in the relationships between these variables, a Co-integrated Vector Autoregressive (CVAR) approach is used. The CVAR approach provides a dynamic analysis of the experience effects that result from the adoption of public policies oriented to FDI and ICT on the performance of two European countries with different technological profiles.

The remainder of the paper is divided into five additional sections. In the second section, a brief literature review motivates the need for linking the FDI 'push' and the ICT 'pull' effects within the context of public policies for fostering entrepreneurship, looking at the role played by FDI as an investment 'push' and ICT as a technological driver. The third section examines two streams of research on spillovers affecting entrepreneurial activity and economic performance: spillovers originating on FDI; and the catalysing role of enhanced ICT infra-structure in fostering other sources of spillovers leading to innovation and entrepreneurship. As a product of the analysis of these two streams, the hypotheses of the study are presented. The fourth section introduces the data used in the study and describes the methodology. The fifth section presents the empirical findings and discusses the main results. The final section discusses the results and presents some possible explanations for the main findings of the study, while referring its limitations.

LITERATURE REVIEW

According to Baumol (1968:p.69), public policies should be directed to "induce the appearance of increased supplies of entrepreneurial skills" and the policy-maker should be "interested primarily in what determines the supply of entrepreneurship and in the means that can be used to expand it". The theoretical model proposed by Baumol (1990) for the determinants of the 'allocation' of

[2] In this context, the country has a major manufacturing industry of Electronic and ICTs.

[3] In the current framework of analysis, the country presents generally production activities oriented to the use of earlier or less developed technology.

entrepreneurship suggests that the regulatory framework plays an important role in the determination of the success of entrepreneurship, whether it will be a productive or an unproductive driver of the national productivity growth.

A related question that centres on how public policies vary according to the level of economic development has been widely explored in the economics literature, under different approaches: (a) economic development (Lucas, 1993), (b) regional science (Acs & Storey, 2004), and (c) entrepreneurship (Acs, 2006; Acs & Szerb, 2006). The empirical studies by Van Stel *et al.* (2005), Wennekers *et al.* (2005) and Acs & Varga (2005) revealed that, for highly developed economies, entrepreneurship has a positive effect on economic growth. Nevertheless, developing economies may be better, if they pursue the exploitation of scale economies, fostering foreign direct investment and promoting management education (Wennekers *et al.*, 2005). Thus, so far in the literature there seems to be a lack of empirical research of the role played by technological drivers on entrepreneurial activity, at an aggregate level.

Acs *et al.* (2006) suggest that the differentiating factor of an entrepreneurial economy is the way how entrepreneurs are used to facilitate knowledge spillovers. This kind of spillover and knowledge commercialisation can be inhibited through the 'knowledge filter' (Audretsch & Stephan, 1999; Audretsch & Lehmann, 2005). Acs *et al.* (2006) as well as Audretsch *et al.* (2006) argue that entrepreneurship promotes economic growth, by permeating the 'knowledge filter' and commercialising ideas declined by established firms.

FDI is defined as investment made to acquire a lasting interest in a firm operating in an economy other than that of the investor. FDI is intimately linked to the activities of multinational corporations (MNCs). The attraction of FDI plays an important role in public policies for entrepreneurship promotion since MNCs have been argued to impact positively on indigenous entrepreneurial activity (Acs *et al.*, 2006). FDI is also associated with technology transfer and knowledge spillovers, channelled through product and process technology, management practices (Findlay, 1978; Dyker, 1999), information about access to foreign countries (Rasiah, 1995) and intensified competition (Blomström & Kokko, 1997; Markusen & Venables, 1999). Several authors have argued that the economic activity of a foreign investor will help to accelerate technological development in the host economy to some degree (Hunya, 2000; Lim, 2001; Dyker & Stolberg, 2003; Barbosa & Eiriz, 2007).

During the second half of the last century, the services industries played an increasingly important role in the introduction of technological innovations. As a consequence of this, several economists focused their research on the framework of technological change (Barras, 1986; Andersen *et al.*, 2000; Metcalfe & Miles, 2000; Devezas, 2005). Studies in the neo-Schumpeterian literature, namely, Gershuny & Miles (1983), Barras (1990), Evangelista (2000) and Miles (2005) consider ICTs to be a technological driver which promotes economic growth through a dynamic

process of creative destruction based on innovation. Services – such as, for instance, banking, insurance and transport – are considered to be the main adopters of new technologies – especially ICTs – which, through enhanced productivity, are the main engine of their increasing contribution for national economic growth (OECD, 2000).

There is a growing literature about technological innovation in services that is grouped in three approaches (Gallouj, 2002): (i) technologist (in which is stated that the introduction and diffusion of ICT may improve productivity and economic performance); (ii) service oriented (which advocates that innovation in manufacturing and services industries are different); and (iii) integrative (that explores the boundaries between goods and services, and try to fill up the gap between them). In this paper we follow a technologist approach, arguing that ICTs promote economic growth and act as a technological driver that 'pulls' both technological and non-technological innovations associated with FDI. Although certainly other factors are also essential sources of spillovers that foster entrepreneurial activity, in this paper we concentrate on the investment in ICTs and its pull effect on inward FDI.

THE IMPACTS OF FDI AND ICT INVESTMENT

In this section we review the prior empirical research, establishing a bridge between two frameworks: (i) the 'traditional' focus on FDI as a source of spillovers; and (ii) the more recent focus on ICTs. The first framework is concerned with the relationships established between FDI, trade, economic development and entrepreneurship. The second deals with the impact of the technological driver ICT on economic growth, employment and productivity. From the review of the two frameworks, three hypotheses are derived.

FDI Framework

Fontagné & Pajot (1997) conducted empirical research on France, Sweden, and the United States, revealing complementarities between trade and inward FDI. In the case of France and the US, outward FDI is found to be a complement for exports, but substitute for imports. Inaba (1999) analysed the effect of FDI on the Japanese balance of payments. The results revealed that, on the one hand, FDI did not necessarily contribute to reducing the huge Japanese trade surplus, and on the other hand, the worldwide structural changes may have had a great impact on the trade balance.

Ericsson & Irandoust (2001) used a Vector Autoregression (VAR) model in order to detect the relationship between FDI and economic growth in Denmark, Finland, Sweden and Norway. The

authors found the existence of a feedback relationship in Sweden and a unidirectional relationship in Norway. For Denmark and Finland no causality relationships were detected. The results were justified through the existence of a larger number of MNCs, in Finland, especially, in services industries.

De Backer & Sleuwaegen (2003) studied the relationship between FDI and domestic entrepreneurship, and their findings are in line with theoretical occupational choice models that predict FDI would crowd out domestic entrepreneurs through their selection in product and labour markets. Nevertheless, empirical work has also found that the referred crowding effect may be moderated or even reversed in the long run due to the long term positive effects of FDI on domestic entrepreneurship as a result of experience, learning, demonstration and networking effects between foreign and domestic firms (Rodriguez-Clare, 1996; Markusen & Venables, 1999).

A significant work by Gani & Sharma (2003) has shown that diffusion of new ICT instruments are major pull factors of FDI.

Chang (2005) analyses the dynamic relationships among FDI, economic growth, unemployment and trade in Taiwan, by making use of a Co-integrated Vector Autoregressive (CVAR) approach. The results pointed out that both economic growth and exports have positive impacts on inward FDI, whereas the expansion of exports impacts negatively on outward FDI. Other significant empirical finding pointed out that there is no relationship between inward FDI and unemployment. Additionally, a positive relationship exists between economic growth and exports, and a negative one exists between unemployment and economic growth.

Barbosa & Eiriz (2007), by using firm-level panel data for the Portuguese manufacturing and services industries, for the period 1986 – 2000, analyse the conditions of whether FDI had a positive impact on entrepreneurial activity or not, by using as measure the net creation of firms. The authors reveal that the impact of first foreign investment is, in general, positive, but that the marginal impact of additional investments appears to be negative. One of the limitations revealed by the authors constitutes an important guideline for the present research: weak evidence on positive effects of MNCs on entrepreneurial activity might hide a relevant action of MNCs, as levers of technological development, on industrial reorganisation.

ICT Framework

During the 1990s ICTs contributed in a remarkable way to productivity growth in several economies (Vu, 2004). For example, the US labour productivity revived with a significant acceleration during the period 1995-2000, and ICT investment accounted for more than one fifth of Gross Domestic Product (GDP) growth throughout the last decade of the 20th century (Jorgenson & Stiroh, 2000; CEA, 2001; Oliner & Sichel, 2001). The impact of ICTs on growth was also significant

in Australia (Parham *et al.*, 2001), Canada (Armstrong *et al.*, 2002), Korea (Kim, 2002), United Kingdom (Oulton, 2002) and the Netherlands (Van der Wiel, 2001).

Antonelli (1998) analysed the co-evolution of ICTs and the knowledge intensive industries. The results revealed that ICT affect the actual conditions of information, in terms of their basic characteristics of appropriation and tradability, by favouring the role of business services as forces of interaction amongst knowledge components in the generation of new technologies. Gretton *et al.* (2002), studying firm-level data from the Australian Business Longitudinal Survey, found positive and significant links between the use of ICTs and growth in both manufacturing and services industries.

Pilat & Wolf (2004) examined the role of ICT producer and key ICT consumer sectors in explaining overall productivity growth in OECD countries; they found that the impact of ICT producer sectors is most significant in Finland, Ireland, and Korea, whereas ICT consumer sectors in some countries, such as, the US and Australia, had an impressive growth in the second half of the 90s. Hempell *et al.* (2004) analysed comparable panel data of the Dutch and German firms in the services industries and found that broadening the intensity of ICT capital and innovation have a complementary impact on productivity.

Leitão & Ferreira (2008) analyse the impact of the liberalisation of European Telecommunications Markets on the Business Ownership Rate. In the case of Germany, the Gross Domestic Product precedes decreasing Business Ownership Rates, whereas, in the case of Portugal, the Business Ownership Rate pulls for additional investments in ICT. Besides, a creative entrepreneurial destruction is somehow ratified, since the Business Ownership Rate impacts, negatively, on the level of employment.

Hypotheses

In this context, the analysis of the relevance of the Schumpeterian mechanism of creative destruction through entrepreneurial activity arising from spillovers originating from the combination of inward FDI and ICT investment requires the examination of three different hypotheses regarding the causality relationships established between these two variables, and between them and entrepreneurial activity:

- *Hypothesis 1 (H_1)*: Inward FDI causes the level of entrepreneurial activity in the host economy;
- *Hypothesis 2 (H_2)*: Investment in ICT causes the level of entrepreneurial activity in the host economy;

- *Hypothesis 3 (H_3)*: Inward FDI and investment in ICT jointly cause entrepreneurial activity in the host economy.

DATA AND METHODOLOGY

Research about the aggregate impact of inward FDI and ICT investment on the level of entrepreneurial activity of the host economies is, as far as we can tell, inexistent. To address this caveat in the literature a comparative analysis between a high-tech producer (Finland) and a low-tech producer (Portugal) is performed. The selection of these two European countries is justified by two reasons. First, during the period of analysis, we observed in both countries an evolution from a market dominated by one telecommunications operator totally or partially owned by the government towards a liberalized market. This is particularly interesting for observing the impact of the end of institutional monopolies and, as a consequence, the entry of new competitors on investment. Second, both countries were affected, at different points in time by a major exogenous shock that changed political, economic and regulatory governance. Portugal entered the European Community in 1986, whereas in the case of Finland became a member in 1995.

Three databases are used covering the period 1976–2002. From *COMPENDIA 2002*[4], information about Business Ownership Rate (*BOR*), Gross Domestic Product (*GDP*) and Unemployment (*UNEMP*) was collected. The BOR is given by the ratio between number of business owners and total employment. UNEMP is given by the ratio between the number of unemployed persons and total workforce.

The data on inward Foreign Direct Investment (*FDI*) were collected from *UNCTAD 2005*[5]. This variable is defined by UNCTAD as an investment involving a long term relationship and reflecting a lasting interest in, and control by, a resident entity in one economy (foreign direct investor or parent enterprise) of an enterprise resident in a different economy (FDI enterprise or affiliate enterprise or foreign affiliate). Such investment involves both the initial transaction between the two entities and all subsequent transactions between them and among foreign affiliates. For statistical purposes, FDI is typically defined as an incorporated or unincorporated enterprise in which the direct investor, resident in another economy, owns 10% or more of the ordinary shares of voting power (or the equivalent). However, this criterion is not strictly observed by all countries reporting[6].

[4] The data set is called COMPENDIA, which means COMParative ENtrepreneurship Data for International Analysis. It presents a harmonized data set over the period 1972-2002 for 23 OECD countries. It has been constructed making use of OECD statistics as well as other relevant sources (Van Stel, 2005).

[5] The United Nations Conference on Trade and Development (UNCTAD) compiles statistics on FDI. The data are presented in two separate products: an interactive database for the aggregate figures and an electronic publication with the detailed information by country (http://stats.unctad.org/fdi/).

[6] For detailed information please consult: www.unctad.org.

The data on investment in Information and Communication Technologies (*IICT*) were collected from the *ITU World Telecommunications Indicators 2006*[7]. According to the definition considered in this database, this variable includes the total amount of investment in ICTs made both by public and private agents in an economy.

The CVAR approach employed in the present study provides the possibility of carrying out longitudinal studies and identifying long term economic relationships (Juselius, 2007). After reviewing the empirical evidence, the econometric methodology follows an outline of four sequential steps: (i) selection of an initial model specification; (ii) study of the integration order of the variables; (iii) estimation process of the CVAR model; and (iv) dynamic analysis.

The Initial Model Specification

The *BOR* is used for measuring entrepreneurship in the studies by Audretsch and Thurik (2001), Carree & Thurik (2006), Van Stel (2006), and Leitão & Ferreira (2008). Unemployment and Gross Domestic Product are also considered in the initial model specification.

The VAR model applied to the cases of Finland and Portugal presents as differentiating element the simultaneous inclusion of the variables related to the two determinants of entrepreneurial activity being studied here: inward FDI and investment in ICTs.

The initial model specification is represented through a system of five equations by considering five endogenous variables:

$$\begin{bmatrix} BOR_t \\ GDP_t \\ UNEMP_t \\ FDI_t \\ IICT_t \end{bmatrix} = \begin{bmatrix} \alpha_{1t} \\ \alpha_{2t} \\ \alpha_{3t} \\ \alpha_{4t} \\ \alpha_{5t} \end{bmatrix} + \begin{bmatrix} \beta_{1,1} & \sigma_{1,2} & \theta_{1,3} & \Omega_{1,4} \\ \beta_{2,1} & \sigma_{2,2} & \theta_{2,3} & \Omega_{2,4} \\ \beta_{3,1} & \sigma_{3,2} & \theta_{3,3} & \Omega_{3,4} \\ \beta_{4,1} & \sigma_{4,2} & \theta_{4,3} & \Omega_{4,4} \\ \beta_{5,1} & \sigma_{5,2} & \theta_{5,3} & \Omega_{5,4} \end{bmatrix} \times \begin{bmatrix} BOR_{t-p} \\ GDP_{t-p} \\ UNEMP_{t-p} \\ FDI_{t-p} \\ IICT_{t-p} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \\ u_{4t} \\ u_{5t} \end{bmatrix} \quad (1)$$

where: BOR_t, GDP_t, $UNEMP_t$, FDI_t and $IICT_t$ are the variables representing Business Ownership Rate; Gross Domestic Product; Unemployment; Foreign Direct Investment; and Investment in ICTs. The number of lags is given by: $p = 1,\ldots,k$, where k corresponds to the optimal number of lags$(p_{\max})$; t corresponds to the year; and u_{it} are the errors or the random disturbances.

[7] The International Telecommunications Union (ITU) publishes The World Telecommunication/ICT Indicators Database that contains data from 1975 to 2006 for around 100 communications statistics covering telephone network size and dimension, other services, quality of service, traffic, staff, tariffs, revenue and investment (http://www.itu.int/publ/D-IND-WTID-2007/en).

The Integration Order of the Variables

The first step in the determination of the kind of relationship between the variables under study is the application of unit root tests. First, we will evaluate if the time series are integrated or not, and, then, if so, we will determine the integration order of the variables, in order to find the best way of making it stationary[8].

The procedures for detecting the existence of a unit root make use of the Dickey-Fuller (*DF*) Test and of the Augmented Dickey-Fuller Augmented (*ADF*) Test (Dickey and Fuller, 1979). In order to specify the model which provides the best adjustment, we make use of the Akaike Information Criteria (*AIC*) and of the Schwarz Bayesian Criteria (*SBC*). For detecting error autocorrelation, the *LM* test is used, and the probability of the *Q* statistics, originally, proposed by Ljung and Box (1979), is also computed, taking into consideration the correlogram generated from the estimation process. Differentiation of the time series showed that all the variables are stationary and integrated of order one (Table 1 and Table 2).

Table 1 The ADF tests and the PP tests, including a constant, and without tendency

Variables	First Differences	
	Finland	Portugal
	ADF	ADF
BOR	-3,723*(5)	-5,341*
GDP	-4,801*	-4,473*
UNEMP	-4,819*	-3,878*
FDI	-3,202*	-4,458*
IICT	-4,645*	-7,738*

* It denotes the rejection of the null hypothesis that is related to the existence of a unit root.
\+ The number of lags is presented under brackets, when it is not automatically specified.

Table 2 The ADF tests and the PP tests, including a constant and tendency

Variables	First Differences	
	Finland	Portugal
	ADF	ADF
BOR	-4,009*	-5,206*
GDP	-4,718*	-4,154*
UNEMP	-4,720*	-3,772*
FDI	-3,923*	-4,663*
IICT	-4,784*	1,603

* It denotes the rejection of the null hypothesis that is related to the existence of a unit root.

The Estimation Process of the CVAR Model

In the selection process of the optimal number of lags (p_{max}), the values of five different information criteria were computed. After detecting the inexistence of error autocorrelation, through

[8] For information about selected descriptive statistics and correlation coefficients of the variables, see Appendix.

the use of Lagrange Multiplier (*LM*) tests, and considering the results obtained through all the criteria, we retain that in the estimation process two lags should be considered (Table 3)[9].

The analysis of error autocorrelation was carried out using the simulation of two different estimation processes, and by making use of LM tests. For both cases, two lags were considered in the estimation of VAR models. In order to detect the number of cointegration relationships, we follow Johansen and Juselius (1990). The principle of the maximum likelihood is taken into consideration, by using the Trace Statistic and the Max-Eigenvalue Statistic (Table 4).

Table 3 The selection process of the optimal number of lags

Lags	LR	FPE	AIC	SBC	HQ
			Finland		
0	NA	4.22e+25	73.19478	73.43856	73.26239
1	140.3517	2.03e+23	67.80785	69.27050	68.21353
2	77.43235*	7.81e+21*	64.27697*	66.95850*	65.02071*
			Portugal		
0	NA	1.10e+28	78.75701	79.00079	78.82463
1	108.8216	2.78e+26	75.02956	76.49221	75.43524
2	68.68361*	2.00e+25*	72.12359*	74.80511*	72.86733*

* It identifies the optimal number of lags selected through each one of the information criteria.

Table 4 The Cointegration Tests

	Hypotheses		λ_{Trace}		Hypotheses		λ_{Max}	
EV	**H_0**	**H_1**	**Observed**	**Critical**	**H_0**	**H_1**	**Observed**	**Critical**
				Finland				
0.955797	r=0	r=1	122.3235*	69.81889	r=0	r>0	74.85523*	33.87687
0.671868	r=1	r=2	47.46830	47.85613	$r \leq 1$	r>1	26.74414	27.58434
				Portugal				
0.971734	r=0	r=1	162.4114*	69.81889	r=0	r>0	85.58602*	33.87687
0.870264	r=1	r=2	76.82540*	47.85613	$r \leq 1$	r>1	49.01417*	27.58434
0.518193	r=2	r=3	27.81123	29.79707	$r \leq 2$	r>2	17.52506	21.13162

[+] The first column corresponds to the Eigenvalues (EV).; [++] The critical values of the Trace Statistic and of the Max-Eigenvalue Statistic, at a 5% significance level, were collected from Osterwald-Lenum (1992); * It denotes the rejection of the initial hypothesis, at a 5% significance level.

According to the results previously displayed in Table 4, we reject the null hypothesis of nonexistence of cointegration relationships among the variables. From the remaining lines of the test, we conclude that, in the case of Finland, just one co-integrating vector is required, whereas in the case of Portugal, two co-integrating vectors are considered in the subsequent estimation process of the CVAR model. Following Engle & Granger (1987) the use of Error Correction Terms (ECT) aims to assure that the disequilibrium proportion observed in the set of variables, in a certain period, is corrected in the next one[10].

[9] For a discussion about the use of different information criteria, see Lütkepohl (1999, 2004).

[10] According to Engle & Granger (1987), an example of this is given by the fact that a change in prices, in a certain period, can result from excess demand on the previous period.

In the present analysis, for the Finnish case, the *ECT1* term is incorporated into the specification of the model to be tested, whereas in the case of Portugal, two more terms are considered for accomplishing the same aim, namely, the *ECT2* and the *ECT3*.

RESULTS AND DISCUSSION

Following Granger (1969), a dynamic analysis based on the evaluation of the causality relationships was performed (Table 5). In addition, the results regarding feedback causality relationships are discussed by making use of the Cholesky's variance decomposition of the forecasting error and of simulated coefficients of impulse-response functions (Table 6).

Table 5 The Contrasts of the Granger Causalities

Dependent / Independent	ΔBOR	ΔGDP	$\Delta UNEMP$	ΔFDI	$\Delta IICT$
	Finland				
ΔBOR	-	0.460220	0.433286	10.39003*	1.099391
ΔGDP	3.805439	-	2.436646	18.48589*	6.684646*
$\Delta UNEMP$	5.409202**	1.615022	-	20.36600*	0.052119
ΔFDI	6.175823*	4.287294	8.003672*	-	49.56665*
$\Delta IICT$	8.396432*	6.307559*	3.832082	8.650869*	-
Block	11.53676	15.36291**	22.54837*	26.59668*	84.97624*
ECT1	0.176836	-31102.23	105.4301	687226.6*	-3.08E+10
	Portugal				
ΔBOR	-	0.516053	2.815914	11.99136*	3.133633
ΔGDP	1.503691	-	14.45955*	13.84465*	10.39995*
$\Delta UNEMP$	2.195985	0.696415	-	4.442577	6.315380*
ΔFDI	0.725456	2.023997	34.68989*	-	18.77583*
$\Delta IICT$	2.911339	3.140926	42.02979*	28.75726*	-
Block	7.674842	4.767031	68.36573*	48.91318*	21.01871*
ECT2	-0.904856	13906.42	-48.98935	-177494.8	1.21E+13
ECT3	4.20E-05	0.228865	-0.006116*	13.82023*	5.74E+08*

[+] The contrasts of the causality of the variables are made by using the χ^2 statistic, with one degree of freedom, while the contrasts of the significance of the Error Correction Terms (ECT) are made through the use of the *t* statistic. * Significance level: 5%. ** Significance level: 10%.

Finland

In the case of Finland, the results provide the identification of feedback causality relationships comprising the following pairs of variables: (*FDI*, *BOR*), (*IICT*, *GDP*), (*FDI*, *UNEMP*) and (*IICT*, *FDI*).

In what concerns *Hypothesis 1* (H_1), the pair (*FDI*, *BOR*), after two years, *FDI* does not present a significant impact on the *BOR* (its weight is less than 5%). Nevertheless, after the fifth year, *FDI* starts to have persistently growing significance on the determination of the *BOR*. The sum of the first ten coefficients obtained through the use of the forecasting technique of impulse-response functions, revealed a negative signal for the relationship between the *FDI* and the *BOR*. Thus, by considering

the summing up of the coefficients, we may state that the bigger the *FDI* is, the smaller the *BOR* will be in case of Finland. On the contrary, the result obtained for the causality relationship established from the *BOR* towards *FDI* is extremely important, since it suggests that promoting an entrepreneurial and dynamic environment contributes to attract further *FDI*. According to the results obtained, the *BOR* impacts positively and significantly on inward *FDI*, by explaining 17.65% of its forecasting error after two years.

Table 6 Dynamic Analysis of the Feedback Causalities: Finland *vs* Portugal

Pairs of Variables	Feedback Causalities	Dynamic Analysis	2 Years	3 Years	10 Years	Signal of the Relationship
		Finland				
(FDI, BOR)	$\Delta FDI \rightarrow \Delta BOR$ *	VDC	2,42E-05	1,815	7,483	-
		IRF	-1,56E-06	-0,0005	-0,005	
	$\Delta BOR \rightarrow \Delta FDI$ *	VDC	17,654	13,188	14,164	+
		IRF	1002,636	520,526	333,424	
(IICT, GDP)	$\Delta IICT \rightarrow \Delta GDP$ *	VDC	0,129	3,321	5,136	+
		IRF	-14,345	74,739	555,212	
	$\Delta GDP \rightarrow \Delta IICT$ *	VDC	7,696	15,456	36,087	-
		IRF	-1,60E+08	-5,10E+08	-4,07E+09	
(FDI, UNEMP)	$\Delta FDI \rightarrow \Delta UNEMP$ *	VDC	2,081	9,326	7,241	+
		IRF	0,192	0,667	2,260	
	$\Delta UNEMP \rightarrow \Delta FDI$	VDC	0,826	0,719	2,891	-
		IRF	-267,294	-127,125	-775,012	
(IICT, FDI)	$\Delta IICT \rightarrow \Delta FDI$	VDC	1,858	1,710	1,461	+
		IRF	-307,669	-79,338	433,639	
	$\Delta FDI \rightarrow \Delta IICT$ *	VDC	84,22	69,30	47,58	-
		IRF	-8,85E+08	-1,41E+09	-5,00E+09	
		Portugal				
(IICT, UNEMP)	$\Delta IICT \rightarrow \Delta UNEMP$	VDC	0,030	0,956	1,288	-
		IRF	0,010	-0,093	-1,132	
	$\Delta UNEMP \rightarrow \Delta IICT$ *	VDC	13,720	9,451	16,255	+
		IRF	3,59E+10	4,62E+10	6,15E+10	
(IICT, FDI)	$\Delta IICT \rightarrow \Delta FDI$	VDC	0,051	0,113	1,515	+
		IRF	18,511	46,024	797,033	
	$\Delta FDI \rightarrow \Delta IICT$ *	VDC	3,042	1,966	13,087	+
		IRF	1,95E+10	1,65E+10	1,15E+10	

Legend: VDC is the Variance Decomposition of Cholesky; IRF corresponds to the Impulse-Response Functions.
* It is significant when the impact is higher than 5% (Goux, 1996).
[+] The sign of the percentage weight is obtained through the sum of the coefficients of the first 10 periods (Goux, 1996).

The pair (*IICT, GDP*) also provides interesting results in the sense that, on one hand, *IICT* has a positive impact on *GDP*, although it should be considered a long term impact because it only becomes significant from the fifth year onwards; on the other hand, the *GDP* impacts in a negative way on the behaviour of the *IICT* variable. It presents a significant and growing impact starting from the second period. This is justifiable by decreasing levels of *IICT* in more developed countries that were observed during the 1980s, and also in the first half of the 1990s.

With respect to the pair (*FDI, UNEMP*), it should be stressed that *FDI* impacts positively on the *UNEMP* variable. This is an expected result, especially if we are dealing with foreign investment that leads to the downsizing of existing local firms and promotes efficiency gains through competitive

pressure. The other side of the feedback causality relationship reveals that *UNEMP* does not have a significant impact on the *FDI*.

In what concerns *Hypothesis 2* (H_2), and taking into consideration the results obtained in terms of unidirectional causalities, it should be stressed that *IICT* impacts the behaviour of BOR negatively, but not significantly. Additionally, the *GDP* has a positive and significant impact on *FDI*. This result is quite important, since it reveals how the creation of wealth is an effective mechanism of signalling that makes possible the attraction of *FDI*.

In what concerns *Hypothesis 3* (H_3), the pair (*IICT, FDI*), *IICT* has a positive impact on inward *FDI*, which is not significant in the case of Finland. Inward *FDI* negatively the *IICT*, and it contributes for explaining 84.22% of the variance decomposition of IICT's forecasting error, which provides further insights for the aforementioned decreasing levels of *IICT* during the 1980s and the first half of 1990s. This result also provides useful insights about the way the combination of investment in ICTs and inward FDI impacts on the dynamics of the entrepreneurial activity in the host economy.

Portugal

In the case of Portugal, the results from the dynamic analysis do not provide any significant support for both *Hypothesis 1* (H_1) and *Hypothesis 2* (H_2). In fact, it is only possible to detect that the *GDP* (starting from the first period) and the *FDI* (starting from the eighth period) have a significant and positive impact on the behaviour of the *UNEMP* variable.

Nevertheless, the *BOR* and the *GDP* have a significant impact on the *FDI* variable. On the one hand, the *BOR* has a positive impact on the *FDI*, which reveals the importance of promoting a dynamic and entrepreneurial environment, in order to attract additional *FDI*; on the other hand, the *GDP* has a negative impact on the *FDI*, although this causality relationship has a different sign from the second period until the eighth period of the simulation of impulse-response coefficients. Finally, the *GDP* has a negative impact on the *IICT*, as it was previously detected in the case of Finland, although the impulse of one standard deviation innovations reveal the existence of a much reduced impact on the behaviour of the *IICT* variable.

In terms of feedback causality relationships, two pairs of variables were detected, namely: (*IICT, FDI*) and (*IICT, UNEMP*). In what concerns *Hypothesis 3* (H_1), the first pair of variables provides interesting insights, since *IICT* impacts positively, although not very significantly, on *FDI*. This is a very important result, since the argument goes that, for attracting additional values of inward *FDI*, increasing values of *IICT* should be ensured. This is a quite important feedback relationship, since *FDI* has a positive effect on IICT, explaining 9.55% of the forecasting error of *IICT* after just one

year. In the fourth period it presents a positive impact of 11.05% of the variance decomposition of the forecasting error of *IICT*.

Although the causality relationship established from *IICT* to *UNEMP* presents a negative signal, this does not represent a significant impact, at least for a forecasting period of ten years. There is, however, a positive and significant impact of *UNEMP* on *IICT*, which is probably due to increasing public investment in ICTs, during the first half of 90s, a period of low economic growth and increasing unemployment. Government policies dealing with the long term causes of unemployment included the improvement of infra-structure and education, strongly associated with investment in ICTs.

CONCLUDING REMARKS

This study has provided evidence that, in disagreement with expectations, both inward FDI and ICT impact negatively on business ownership rates. This result suggests that, while FDI and investment in ICTs may represent sources of spillovers in a Schumpeterian process of creative destruction, it is likely that these spillovers benefit mostly existing and not new firms. Moreover, any positive effects that these two variables may have on entrepreneurial activity are likely surpassed by an effect of displacement of existing firms by MNCs or by competitive new firms, leading to a net effect on the business ownership rate that is negative. In the case of FDI, under a neo-Schumpeterian approach, the exit of entrepreneurs in the host economy reveals the pressure for eliminating the more inefficient (or less innovative) entrepreneurial units that is provided by the entry of MNCs, which follow innovative conducts that tend to reinforce the entrepreneurial innovative capacity of the host economies.

A possible reason for the result is the metric used for entrepreneurial activity: the business ownership rate, measured as the proportion of business owners in the labour force. This measure does not gauge entrepreneurial activity as consistently as, for instance, the number of start-ups in the economy. Also, in particular for the case of Portugal, business ownership rates tend to include a high proportion of necessity-based, subsistence entrepreneurial activity, which is not really innovative and oriented towards growth, but simply an occupational choice derived from the lack of better alternatives (Baptista and Thurik, 2007). If a large proportion of entrepreneurial activity is of this kind, than business ownership rates are likely to respond positively to increases in unemployment and reductions in the amount of job opportunities in the economy. Inversely, the increased job opportunities that are typical of a growing economy experiencing high levels of FDI (and ICT investment) will likely yield reductions in business ownership rates, as individuals leave subsistence entrepreneurship because they found better alternatives in wage employment.

In the Finnish case, FDI plays a particular important role as a determinant of domestic entrepreneurship, since it contributes significantly for decreasing values of entrepreneurial activity. This may be due to large average firm size and the significant entry barriers that are associated with the dominant technological profile of the high-tech activities specialisation in this economy. Also, the creation of high-productivity, high wage jobs by increased levels of FDI in these sectors increases the opportunity cost of entrepreneurship.

The feedback causality between investment in ICTs and FDI revealed a positive impact of FDI on investment in ICTs, in the case of a low tech producer (Portugal), and a negative impact of FDI on investment in ICTs in the case of the high tech producer (Finland). This feedback causality relationship provides important insights for public policy makers about the role played by the inward FDI, as a technological driver, in terms of the determination of future investments in ICTs, in countries with different experience curves and technological profiles.

Revealing this contrasting result is very important since, in the case of Finland, the implementation of public policies oriented to inward FDI precedes decreasing values of investment in ICTs, which reveals the growing importance of the private sector in ensuring investment in this technological driver, which was previously supported by public funding. In the case of Portugal, FDI plays an important role, in the long term, since it impacts positively on investment in ICTs which are the catalyst driver for promoting a sustainable process of technological change. This justifies the design of further public policies oriented to the attraction of FDI in order to modify the technological profile of a small dimension nation and to revitalize its entrepreneurial innovative capability, through a technological process of creative destruction based on the creation of further SMEs networked with MNCs.

Another interesting result provided by the comparative analysis performed is with regard to the impact of FDI on unemployment. In the case of Finland, there is a negative impact which is significant starting from the third period, and the positive signal never changes during the simulation for the next ten periods, suggesting that, after an initial effect of increased unemployment, possibly due to increased competition and displacement of local firms, FDI serves as sustained a boost for competitiveness and economic growth. The case of Portugal is quite different. While in the first period the impact is null, and in the next two periods the effect is negative, afterwards the signal becomes positive. Hence, for the Portuguese economy, inward FDI seems to contribute for decreasing levels of UNEMP in the short run, possibly through direct effects associated to new jobs created by MNCs, but this effect is not sustained over time, and seems to fluctuate depending on the internal policies of MNCs regarding local investment and divestment.

The present study has four limitations. First, no measure of each country's technological profile was included in the analysis due to data constraints. Second, the use of aggregate data does not allow for the examination of potential spillovers generated through networks of MNCs and high-tech

SMEs. Third, only two European countries are included in the comparative analysis. Further research is needed in a European context, for contrasting the role played the dynamic drivers of entrepreneurial activity. Fourth, the role played by human capital and organizational capital is not explored in the present analysis, although it seems important to study how they act as determinants of the 'allocation' of entrepreneurship, under an internationalisation context.

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APPENDIX

Table A Selected Descriptive Statistics of the Variables for Finland

	BOR	GDP	UNEMP	FDI	IICT
Mean	0.072089	321.6823	0.233333	1746.582	1.99E+09
Median	0.075623	341.7458	-0.300000	406.7509	1.82E+09
Maximum	0.081754	871.8411	4.800000	12143.49	4.30E+09
Minimum	0.058854	-920.4193	-1.918378	-246.5381	7.74E+08
Std. Dev.	0.008421	441.2262	1.790152	3117.576	1.10E+09
Skewness	-0.338145	-1.437614	1.240858	2.168159	0.619625
Kurtosis	1.466140	5.417612	3.963561	6.704628	2.174249
Jarque-Bera	3.161357	15.87575	7.973282	36.59391	2.494808
Probability	0.205835	0.000357	0.018562	0.000000	0.287250
Sum	1.946416	8685.422	6.300000	47157.72	5.38E+10
Sum Sq. Dev.	0.001844	5061695.	83.32076	2.53E+08	3.14E+19
Observations	27	27	27	27	27

Table B Correlation Matrix of the Variables for Finland

Variables	BOR	GDP	UNEMP	FDI	IICT
BOR	1				
GDP	0.142645	1			
UNEMP	-0.134770	-0.904493	1		
FDI	0.553026	0.366402	-0.309737	1	
IICT	0.567294	0.132589	-0.128518	0.069988	1

Table C Selected Descriptive Statistics of the Variables for Portugal

	BOR	GDP	UNEMP	FDI	IICT
Mean	-0.000470	198.0634	6.475926	1396.465	6.57E+10
Median	-0.000643	191.1397	7.100000	921.5800	2.97E+10
Maximum	0.010469	471.1203	8.600000	6635.315	2.71E+11
Minimum	-0.008915	-109.1587	4.100000	57.91000	1.58E+09
Std. Dev.	0.005066	175.5194	1.503737	1721.217	7.76E+10
Skewness	0.362685	-0.018478	-0.186934	1.896270	1.209056
Kurtosis	2.791856	2.101646	1.585934	6.234974	3.460427
Jarque-Bera	0.640671	0.909457	2.406778	27.95446	6.816669
Probability	0.725905	0.634620	0.300175	0.000001	0.033096
Sum	-0.012678	5347.711	174.8500	37704.54	1.77E+12
Sum Sq. Dev.	0.000667	800983.7	58.79185	77027268	1.56E+23
Observations	27	27	27	27	27

Table D Correlation Matrix of the Variables for Portugal

Variables	BOR	GDP	UNEMP	FDI	IICT
BOR	1				
GDP	0.034046	1			
UNEMP	-0.334594	-0.308468	1		
FDI	0.124628	0.204099	-0.736967	1	
IICT	0.424908	0.207737	-0.249285	0.182683	1

CREATING TECHNOLOGY-BASED COMPANIES – ABOUT THE SIGNIFICANCE OF EFFECTUAL LOGIC IN THE EARLY PHASE OF THE VENTURING PROCESS

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ABSTRACT

Studies in technology entrepreneurship acknowledge a high degree of uncertainty in connection with both the notion of technology and the early-stage process. However, only few studies have examined in detail how technology entrepreneurs encounter this uncertainty. Cognition-based literature on the other hand has come up with the theoretical concept of effectuation – a logic of non-predictive control that expert entrepreneurs apply successfully to overcome uncertainty. Our study presents empirical data on 8 case studies of early-stage technology ventures, differentiating causal and effectual approaches within the dynamic entrepreneurial process and connecting the findings with a performance measure that builds upon the concept of gestation steps. We find that variation among our set of technology entrepreneurs can be explained through varying sophistication levels of uncertainty management, which we define as the capability to combine effectual with causal behaviour with respect to the type of uncertainty that dominates the situation. The results suggest that a more contingent application of the toolboxes depending on the type of uncertainty in connection with teaching of effectual logic can add successfully to venture performance.

INTRODUCTION

Personal experience with technology entrepreneurship projects showed us an interesting variation among the performance of technology ventures in their early phase, on their way to develop a technology into a product and creating a company on this basis. Being confronted with this phenomenon, we were not content with explanations that pointed to singular aspects like team structures, the elaboration of business plans, etc. We asked two questions: Is the phenomenon of technology entrepreneurship important enough to engage with research in the difficult to capture early-stage process? And if so, what might explain the variation in terms of a more comprehensive framework?

In 2007, Kirchhoff et al. provided us with latest results on university R&D expenditures and new business formations, once again confirming a positive economic impact of technology-based entrepreneurial activity. According to this study, university R&D expenditures are positively related to the creation of new firms as well as to employment level and change (Kirchhoff *et al.*, 2007). Similar studies with different notions on how technology entrepreneurship reveals its positive impact all support this basic claim that Schumpeter had referred to as the innovative power of the entrepreneur in the middle of the last century (e.g. (Autio, 1997).

However valuable this economic activity seems to be, it also seems to be difficult to induce. German policy makers, for example, worry about a decreasing number of technology-based companies due to a strong job market for technology experts, displaying economic alternatives that seem to carry lower levels of risk and uncertainty (Niefert *et al.*, 2006). This current study once again supports an old discussion – in this case Knight's ideas about this trade-off by each individual which he formulated in this work in 1921 (Knight, 1921).

There has been quite a lot of research on technology or technology-based entrepreneurship due to the growing interest of policy makers interested in the economic benefits (Bell & Pavitt, 1993; Bullinger, 2002; Hsu *et al.*, 2007; Licht & Nerlinger, 1998; Shane, 2004a, 2004b). However, the phenomenon is facing a paradox. On the one hand there is the desire to create new economic artefacts (new firms) on the basis of newly developed technologies, implying a high level of uncertainty on several dimensions. On the other hand, research on the creation process mainly draws from the knowledge about established companies. Although, in general, it has been supported that opportunity recognition and business planning procedures are key determinants of the early-stage process (e.g. Ardichvili, Cardoso, Ray 2003; Hills 1995; Kraus, Schwarz 2007; Shane, Delmar 2004), both concepts fail in the face of high levels of uncertainty. They stop short of offering viable explanations for the early stages of the venturing process where key issues are still unclear: unidentified market need, a new technology which still has to be developed into a product, an

undefined market and an unknown customer group (Bygrave & Hofer, 1991; Diochon *et al.*, 2007; Klofsten, 2005; Mellewigt & Witt, 2002; Reynolds & Miller, 1992).

We continue to introduce the principles and the dynamic model of effectuation into that discussion as behaviour based on non-predictive logic as opposed to prediction-based causal logic. An effectual process mainly starts with a given means base and develops a project through a series of commitments by self-selected stakeholders. That said, it offers ideas for the early phases of the venturing process that do not require prediction of the future (S. D. Sarasvathy & Dew, 2005a). Our study thereby extends previous work on the early stage of technology-based entrepreneurship which is sparse and contradictory. It bases the argumentation on the unclear significance of planning activities in the context of entrepreneurial activity. The theoretical work on effectuation has produced a logic that seems a valuable addition to the tools offered in the context of planning and prediction. Accepting a certain significance of planning or causal reasoning, the basic assumption in this study is that in the venturing process we can identify both causal and effectual activity. To our knowledge, there has so far been no study on the phenomenon of effectuation in real-life context. Studies so far were mainly based on thought experiments or single case histories.

Based on this discussion, we therefore ask the following research questions: Which kind of behaviour does effectual vs. causal logic induce in venture projects? How do patterns in the combination of effectual and causal approaches relate with a variation of process performance? How do effectual and causal behaviour merge into a mechanism for the early-stage process that allows to cope with uncertainty?

We enhance the research activity field of technology entrepreneurship by looking into the early phase of technology ventures, adding the concept of effectuation and its differentiation from causation to the discussion of facing uncertainty. Through in-depth case studies of 8 technology-based venture projects, we specify the role of uncertainty in the early-stage process, differentiating between resource and knowledge uncertainty as the predominant types of uncertainty in the early-stage process and environmental uncertainty as predominant in later stages. We further find that a variation in gestation process performance (range: 0,05 to 0,27 gestation steps per month over all cases) matches 4 different patterns of effectual and causal approaches in the early-stage process.

The article begins by providing an overview of the entrepreneurial process literature and the need for an exploration of uncertainty in this context. We then detail the models of causation and especially effectuation from entrepreneurial cognition literature in connection with a resource-based perspective as the theoretical underpinnings to our work. After presenting our research design, we summarize our data to illustrate and finally discuss our key findings.

UNCERTAINTY AND PERFORMANCE IN THE ENTREPRENEURIAL PROCESS

Process

The outcomes of entrepreneurial activity and their benefits have been shown quite often. However, we still have very limited information on how new businesses come into existence. Gartner et al. state that "we can see the success of entrepreneurial activity, yet we have few insights into why particular entrepreneurial efforts were successful while other efforts failed" (Gartner *et al.*, 2004). They continue that "we have almost no information on the number and characteristics of the nascent entrepreneurs who attempt to start businesses and the likelihood that such attempts will result in the formation of new businesses."

We therefore adopt for our study a process view on technology entrepreneurship in order to generate more information about how technology entrepreneurs proceed in their process of technology commercialization. Clarysse and Moray used a similar approach in their study (Clarysse & Moray, 2004). We seek to explore the same research objective with our qualitative approach to develop an in-depth understanding of the early-stage entrepreneurial process. A variety of process models have been offered in the literature so far, amongst some of the more widely accepted of which are those of Kazanjian, Bhave and Timmons (Bhave, 1994; Kazanjian & Drazin, 1989; Timmons, 1999). As we are specifically interested in the early-stage process, we draw upon a process model developed by Gartner et al. which originates from the context of the PSED panel study (Gartner et al., 2004). This model focuses on the early stage venturing process and will be used with modifications in setting up our preliminary research framework.

Uncertainty

Uncertainty is one of the main influence factors for new firms and especially technology-based ventures. As a consequence it is a conceptual cornerstone for most theories of the lentrepreneur (McMullen & Shepherd, 2006). Historically the theory of uncertainty in the context of entrepreneurship has been first picked as a central theme by Richard Cantillon in 1752. He defined an entrepreneur as "someone who engages in exchange for profit; specifically, he or she is someone who exercises business judgment in the face of uncertainty" (quoted in (Link & Siegel, 2003)).

Knight focussed on the distinction between risk and uncertainty in his fundamental work from 1921. According to him, risk can be calculated beforehand and transferred into direct costs whereas uncertainty is unspecific and unpredictable, meaning that e.g. certain unique events can not be foreseen and thus be connected to probabilities within a-priori decision-making processes (M. Brouwer, 2002; Wu & Knott, 2006). Uncertainty in the Knightian way is the precondition for profit making by investors/entrepreneurs: "It is true 'uncertainty' and not risk which forms the basis of a

valid theory of profits and accounts for the divergence between actual and theoretical competition. If profits could be calculated before the act, or even if there is a mathematical or a-priori type of probability of success, these risks can be insured and will be changed into costs" (Maria Brouwer, 2000). Brouwer argues that Knight's understanding of uncertainty describes the uncertainty of the economy as an entire system and the outcome of personal ventures of investors/entrepreneurs.

With regard to current research on this topic a general differentiation can be made between research that has so far mainly concentrated on system-level insights and research with a focus on the individual-level (McMullen & Shepherd, 2006). The main research target of the latter is the entrepreneur and its individual actions (authors in this context are e.g. Sarasvathy or Shane). Furthermore, the action-oriented research stream is of specific importance when analyzing why and how entrepreneurial action is taking and also not taking place. This second one highlights the ability and willingness to cope with uncertainty, thus dividing those who act entrepreneurially from those who do not by their different levels of motivation or risk propensity (e.g., (Douglas & Shepherd, 2000; Knight, 1921; Schumpeter, 1934).

Within the research progress on uncertainty theory in the context of entrepreneurship, different classifications of the topic have been developed that try to include the different research streams mentioned above. Milliken differentiates three types of uncertainty from a mainly organizational/system-level point of view: state, effect and response uncertainty namely unpredictability of future environment, its influence on the organization and the possible responses to this state (Milliken, 1987). Looking at Milliken's dimensions, it becomes obvious that this environment-related definition of uncertainty does not seem to help a lot for early-stage processes where there does not yet exist much of an environment to worry about.

In comparison to Milliken, Van Gelderen et al. present a broader view, enhancing the uncertainty definition and proposing a differentiation of uncertainty in six forms structured along the level of their analysis within the economic theory. According to them uncertainty occurs on the industry, firm and personal level (Van Gelderen *et al.*, 2003). These dimensions seem to develop the concept of uncertainty further towards the situation of the technology entrepreneur. In addition to his five basic forms of uncertainty spread over the three levels of analysis, Van Gelderen et al. introduce a sixth form of uncertainty, the information/knowledge uncertainty, as a meta-category of uncertainty that seems to correspond with the dimensions described by Milliken in 1987.

We conclude that the early-stage entrepreneur would not have to worry about industry-level uncertainty at this early point in time. It is rather firm-level resource uncertainty and the meta-category of knowledge uncertainty in terms of goal-ambiguity which is important from early on. Personal level uncertainty, lastly, is incorporated in the effectual model. If the entrepreneur did feel uncertain about his capabilities, he would never start the process.

Process performance

In order to grasp the variation we liked to look at, we had to think about performance. Performance issues have been and are still discussed intensively in management literature as a whole. While entrepreneurship as a field of research is undoubtedly dominated by research work on success factors, the concept of performance at the same time creates complicated issues in the context of entrepreneurial activity (Ma & Tan, 2006; Murphy *et al.*, 1996). This is due to the emergent character of the phenomenon, and researchers still discuss the whole spectrum from classic performance indicators like sales, employee or profit growth to the notion of mere survival.

It is not our aim for this study to create a viable performance measure in terms of venture or even technology transfer performance. We much rather incorporate the simpler proxy of gestation process performance in order to match it with findings about behavioural patterns within the process. To approach the idea of performance in the early-stage venturing process, we therefore draw on the literature of gestation process steps (Alsos & Kolvereid, 1998; Carter *et al.*, 1996; Diochon *et al.*, 2005; Gelderen & Frese, 2000; van Gelderen *et al.*, 2006). This stream of literature suggests that it might help to differentiate between more and less successful early-stage venturing processes by looking at speed and intensity of a row of gestation steps that have been carried out. We will use data on gestation process steps in relation to the gestation time as a proxy to judge upon the gestation process performance of the technology ventures. Gestation steps that are included in this study as a synthesis from the mentioned literature are: team formation, business planning, grant acquisition, patent application, prototype presentation, full time engagement, funding acquisition, formal incorporation, product presentation, facility procurement, employee hiring, sales. We summarize that we will include a process view, the idea of an initial resource base and a notion of performance in terms of the gestation process performance in our preliminary research framework.

CONNECTING THE RESOURCE BASE, CAPABILITIES AND THE CONCEPTS OF CAUSATION AND EFFECTUATION

Among others, Alvarez and Busenitz dicuss that the entrepreneurial task involves resource seeking, accumulation and combination to a large extent, especially in early phases (Alvarez & Busenitz, 2001). Hence, a study of the early-stage entrepreneurial process is likely to also be a study of resources and resource-related activities. The effectual approach will show to be rather means- or resource-driven. However, literature on a more advanced and dynamic version of the resource-based view has shown that it is about what is being done with the resources what counts (Foss & Ishikawa, 2007; Helfat & Peteraf, 2003; Hjorth, 2007). It is therefore interesting to ask how organization theory might apply to the context of the emergent organization. We see the initial resource base as the critical base for the venture, whether or not it finally ends up to be creating a competitive advantage

for the future organization. However, we feel that there is definitely need for a capability to move forward. With resource uncertainty being assumed as one of two predominant uncertainty dimensions, it is of interest how this issue is being solved. Being interested in how the initial resource base of a venture project is being leveraged and how uncertainty is overcome, we finally draw upon the concept of dynamic capabilities, trying to find some proof of a dynamic capability that allows technology entrepreneurs to navigate through the highly ambiguous early stage (Teece *et al.*, 1997; Zahra *et al.*, 2006).

So far start-up companies have mainly been studied as institutions built around opportunities in the context with tools like business planning, market research, competitive analysis, acquisition of resources, etc. (Bygrave, 1989; S. D. Sarasvathy & Dew, 2005b; Shane & Venkataraman, 2000). Yet, this toolset leaves the entrepreneur with unanswered questions concerning a favourable behaviour when facing high levels of uncertainty as we find in the context of early-stage technology entrepreneurship. A couple of recent studies already argue in favour of a more specified and diversified toolset for entrepreneurs. Ozgen and Baron discovered that specifically three sources of social opportunity-related information (mentors, informal industry networks and participation in professional forums) had positive effects on opportunity recognition by entrepreneurs (Ozgen & Baron, 2007). The study shows the growing interest in a more detailed catalogue of advice for the early phase of the venturing process. Corbett discusses opportunity recognition in connection with learning (Corbett, 2007), Gruber propose a more sophisticated view on planning (Gruber, 2007) and others emphasize the importance of engaging with other parties (Rickne, 2006; Rothaermel & Deeds, 2006); (Morse *et al.*, 2007). Sarasvathy in her work has identified the traditional toolset as being prediction-based. She labelled it with the term *causation* to differentiate it from her newly developed concept of *effectuation*.

Effectuation tries to solve the problem of uncertainty by introducing an approach for an opportunity creation process as opposed to opportunity recognition and development. It stems from the rather young research stream of entrepreneurial cognition, more explicitly from a study on expert entrepreneurs (S. D. Sarasvathy, 2001), and builds on work of March who proposed a technology of foolishness to complement the technology of reason (March, 1982). Entrepreneurial cognition again is based in cognitive psychology which examines internal mental processes such as problem solving, memory or language. A couple of studies have laid the ground for the nexus of entrepreneurship and cognition research (Mitchell *et al.*, 2004); (Baron & Ward, 2004); (Gaglio, 2004); (Hindle, 2004). It is finally Sarasvathy who gives an introductory view on the effectuation logic, claiming that we need to move to a theory of firm design (S. D. Sarasvathy, 2004).

Sarasvathy developed five principles which form the basis of the effectual logic (S. D. Sarasvathy, 2001); (S. D. Sarasvathy, 2008). Throughout other studies on effectuation, this number varied (e.g. (Wiltbank *et al.*, 2006). For our discussion we altered the set of dimensions to four,

assuming that the fifth principle distinguishes between the general notion of action- versus prediction-based, which can be found in any of the four remaining dimensions as the basic reasoning. Table 1 contrasts effectual and causal logic along four dimensions.

Table 1: Causal versus effectual processes (Source: Based on (S. D. Sarasvathy, 2008)

Process dimensions …	*… in causal logic*	*… in effectual logic*
Start of process with …	Goal (ends)-driven action	Means-driven action (Bird-in-hand)
Investment decision based on …	Expected returns	Commitment limit (Affordable loss)
Moving forward through …	Prediction of the future	Stakeholder commitments (Patchwork quilt)
Dealing with contingencies by …	Avoiding surprises	Leveraging contingencies (Lemonade)
	↓	↓
	Linear, planned process that deduces the necessary means by breaking down predefined goals	**Iterative, converging process that produces a growing set of means and a convergence on goals, thereby creating a firm**

A causal process starts with goal-driven action, deducing the necessary resource-base by breaking down the goals. Investment decision are made on the basis of expected returns, all assuming that scenarios of future states of the environment can be envisioned. Every step that carries the project further in the process is based on prediction of the future which logically leads to the reasoning behind the last dimension that on the predicted way towards the defined goals surprises are rather to be avoided.

An effectual process on the other hand starts with means-driven action, literally a rigorous analysis of who I am, what I know and whom I know. With that bird in hand subsequent investment decision by any party are made on the basis of a commitment limit in terms of an affordable loss. In a worst case scenario, this investment criterion leads to limited and acceptable loss on the stakeholder's side. The direction of development is highly influenced by stakeholders who self-select themselves to the project through concrete commitments, thereby enhancing the resource-base and adding their own ideas and goals to the process. The unforeseen, in terms of contingencies, changes here in character, almost becoming a resource itself, being embraced and leveraged into new options for the project.

The discussion of the basic principles in terms of process dimensions already hinted at the dynamic process model that will be applied in our study (S. D. Sarasvathy & Dew, 2005b; Wiltbank et al., 2006). The shape of the product, the market and eventually the firm comes into existence through various iterations of this process, incorporating a growing set of means as well as considering a growing set of goals. The process ends when stakeholder commitments have converged to precise goals that can no longer be easily changed. From here the company develops either through switching to causal logic and tools or because the project is being abandoned. Harting has displayes the dynamics of such a transition in his working paper on Circuit City's CarMax used car retailing unit (Harting, 2004).

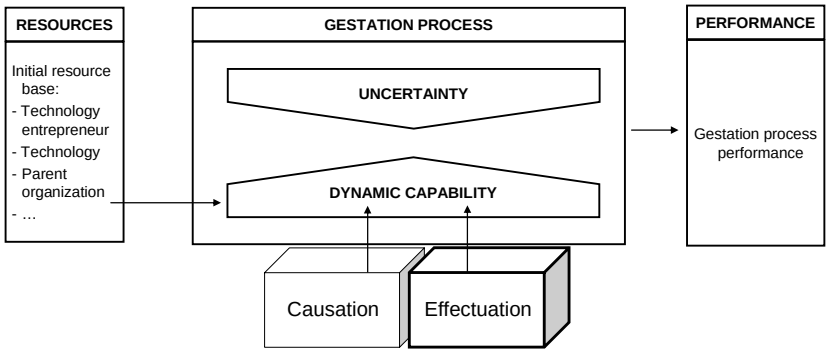

Figure 1: the preliminary research framework

We conclude our theoretical discussion by adding the concepts of causation and effectuation to our preliminary research framework in Figure 1, proposing that it is a valuable research endeavour to analyze case study material in order to learn more about the concepts' significance within the early-stage technology entrepreneurship process.

METHODOLOGY AND EMPIRICAL DESIGN

A couple of studies have looked into what is called the nascent stage of entrepreneurial activity so far (Diochon et al., 2005, 2007; Liao et al., 2005; Wood & Brown, 1998). However, in general the field is characterized by difficulties in access to emerging projects and data collection within the field so that not many studies have focussed on the venturing process in very early stages. By using a multi-case case study approach, we examine the early process steps in the context of technology-based entrepreneurship and the creation of new technology-based firms. We have chosen 8 cases that are based on technologies, and we focus on the venture development process. The projects in this study's sample are originating from Germany's two leading technological universities, Aachen and Munich. In order to enhance validity of results, we first gathered data at RWTH Aachen University and then replicated in two out of three groups one case each at the Technical University of Munich in order to enhance validity.

Choosing a case study approach

The choice for a qualitative approach was made for two reasons. First, the nature of the research question requires the collection of in-depth qualitative data. Effectuation has been detected in expert entrepreneurs as a cognitive process. Hence, examining to what extent and how the development process of a technology-based venture is characterized by effectual elements requires a cumulative and partially iterative process of information gathering from parties that influenced the period of early venturing activity. Yin and Eisenhardt both agree that one ore more cases can be used and that

the data should usually come from multiple data sources (K. M. G. Eisenhardt, Melissa E., 2007; Yin, 2003). Experimental settings do not allow for information about the current level of effectual behaviour in the context of real venture projects. Survey-based settings only catch very limited and pre-structured information.

Second, research on the early process of technology-based entrepreneurship has been sparse and contradictory. Research in the field of effectuation has been conducted since 1998 (D. K. Sarasvathy *et al.*, 1998). Therefore we are coping with a rather underdeveloped field of research which, however, gains more and more attention. Recognizing this stage of development, the study employs an explorative approach towards the research questions (Yin, 2003). This loosens the restrictions on data gathering and allows, in turn, for a more multi-faceted view on reality. We also refer to Edmondson and McManus who claim that qualitative research answers how and why questions in comparably unexplored areas (Edmondson & McManus, 2007). Eisenhardt defines case study research as an empirical research strategy with the goal to inductively build or develop theory (K. M. Eisenhardt, 1989). With regard to theory, researchers have yet to converge on clear-cut constructs in order to operationalize effectuation for large-scale testing. The case study method might therefore also allow for a more comprehensive description of the notions of causation and effectuation in order to further develop the theory.

Sample selection

We have aimed at purposeful sampling of cases to the extent possible (Neergaard, 2006), (Patton, 2002). The total list of cases we looked at came from a project list of the center for entrepreneurship at RWTH Aachen University. We explicitly excluded all companies that were not spin-offs from Aachen University in the first place. The preliminary list of German spin-off projects from RWTH Aachen University contained 59 projects. Out of these 59 projects we selected cases by applying the following selection criteria: first of all they had to be technology-based. However, we excluded any projects with a pure biotech, pharma or medical device focus for their specificities in terms of gestation process. With regard to the age of the projects, we agreed to look for projects with gestation activities having started at least 3 years ago and incorporation not having occurred more than 3 years ago. Through these criteria we wanted to make sure that internal and external stakeholders could still remember the nascent stage but would also be able to comment on a reasonable gestation phase. We ended up with 8 projects, eliminating most projects for a too short gestation phase or unavailability for an in-depth study. After a first round of interviews, we eliminated another 2 projects for a strong market-pull basis or too complex technology development process, leaving us with 6 cases to present. In the replication processes with started out with 3 cases and eliminated one due to a market-pull basis again. We will therefore present data on 8 cases in total.

Data and measures

For each case, information was gathered in interviews and from company documents. We structured the interview guideline along our preliminary research framework, inquiring for the initial resource base (technology, technology's organizational background, personal background and involvement), the early-stage process and the current development stage. Interviews were carried out with three to four stakeholders, both internal and external. Further data was gathered from the internet and material that the entrepreneurs provided. The data was transcribed and coded, differentiating the semantic chunks as indicators for either causal or effectual behaviour in one of the 4 process categories. The coding allowed us to create the measure of effectuation rate (effectuation-related semantic chunks over the sum of causal and effectual semantic chunks) as a proxy measure for effectuation intensity. As a second important measure we used gestation speed as a proxy for success, calculating it as the quotient of the number of gestation steps over the number of gestation months. Results were evaluated within a case-based as well as a cross-case analysis.

We have taken a number of measures to try to ensure as much objectivity as possible in the data collection and interpretation process. Theses activities strive for a triangulation of data, in our case mainly through multiple data sources (interviews and documents). For coding reliability, we appointed a second coder and discussed all divergent classifications. Finally, we are aware of further concerns with regard to the case method, e.g. retrospective bias and self-justifying explanations in connection with interviewees which we also try to address through triangulation of both internal and external stakeholders.

CASES VARY IN THEIR APPLICATION OF CAUSATION AND EFFECTUATION TO COPE WITH UNCERTAINTY

In the following two sections we turn to present and discuss our analysis and results. Causal mechanisms and tools have been predominantly studied in the context of early-stage entrepreneurial activity and technology entrepreneurship. However, current research still comes up with new insights into these toolsets and keeps adding notions of networking, personal resources and the role of uncertainty. Sarasvathy, coming from a different angle, finally developed the compelling process of effectuation that seems to fit our research object (S. D. Sarasvathy, 2008). This discussion and our own experiences about variation among technology ventures in terms of gestation process performance led us to carry out this study.

We found that the variation in terms of gestation speed can be explained through a different level of effectuation intensity in the early-stage process (correlation of 0,62). Our data revealed three different groups that are displayed in Table 2. We have disguised the company names, referring to

them through names of Saturn moons with Calypso and Narvi being the replicated cases at the Technical University of Munich.

Table 2: Summary of case studies

Venture project*	(Potential) Product	Number of interviews (founders/ other)	Gestation steps	Gestation months (until 12/07)	Gestation Speed (steps/ month)	Effectuation Rate (percentage of effectual statements)	Group description
Methone	Biotech fermentation tool	2 / 1	11	41	0,27	63%	„high speed“ Pattern: switch from effectual to causal activities
Calypso	Wafer handling machines	2 / 2	12	45	0,27	70%	
Pan	Laser components	1 / 3	10	51	0,20	74%	„moderate speed“ Pattern: effectual outset but no clear switch to causal activities Greip: rather causal approach from beginning
Greip	Special surface products	1 / 2	9	54	0,17	50%	
Atlas	Quality inspection tool	1 / 2	8	66	0,12	64%	
Narvi	Long-term electricity provider	2 / 0	3	32	0,09	39%	„low speed“ Pattern: rather causal approach
Mimas	Biotech chips	1 / 2	4	46	0,09	46%	
Bestla	High-energy pellets	1 / 2	2	40	0,05	57%	Bestla: comparably high level of effectuation
Correlation (gestation speed / effectuation rate): 0,62 (without Bestla: 0,71)							

In group 1 we see projects that not only showed effectual elements in their early stage. They also seemed to be able to transition to a more causal approach once a resource base was established and a development path for the project definable. However sophisticated their current development seems to be, they still started with very basic questions and answers rooted in the bird-in-hand principle:

“And about me – I really did not feel like going to a large company. And then the question came up, whether I want in some small company, well, some responsibility there, or actually doing it myself. And so we said to ourselves: we got this option to use this technology – let’s try and see how we can fund that … So, from that point of view, I always enjoyed to lead a team, to lead a team and work conceptually. And I did that in many areas. I also led a project management group once, as a tutor. And, yes, creative work is just exciting. And where can I work better creatively than either as head of a development department or right away in my own company.” (Quote from an interview with Calypso)

Group 3 is easy to define as well. We found only very few or no effectual elements in these processes showing that the projects relied more on the causal approach. We conclude that these projects could need training in effectuation to move forward. Up to now, these cases would probably have been discarded with the explanation that the individuals are not entrepreneurial enough. Of course, we are not able to evaluate whether teaching effectuation can fundamentally change a believe in causal mechanisms. This quote shows some confusion in terms of causal concepts:

"The plan was to put the whole thing to reality as quickly as possible. That might have been a little too ambitious. Then of course the search for funding … is actually much more difficult than I would have expected. And then you also need a team, that wants to be built – which again is quite a dilemma. Without money you can hardly build a team, or only with difficulties. And without a team you don't get money. There the cat bites its own tail." (Quote from interview with Mimas).

Group 2 is a little more difficult to grasp. The projects either show quite a lot of effectual elements within the process but seem to have trouble to transition to more causal approaches. The project Greip forms its own subgroup on the other hand due to an interesting reliance on causal elements. The project took a long time to develop but achieved a reasonable process performance in terms of building up a company.

In many of the more effectual cases, it can be shown that personal preferences, knowledge and networks are important sources for early venturing activities. This usually also holds for the cases that then relied more intensely on causal approaches. We were also able to trace the process of stakeholder acquisition. Many entrepreneurs sought exposure to a variety of possible stakeholders, allowing for the self-selection process to take place.

Interestingly enough, in group 1 and even partly in 2, even when a formal business plan had been written, this tool did not guide the venture creation process but served as a communication tool targeted towards the acquisition of stakeholders that did not belong to the entrepreneur's peer group. What is more, many projects have successfully created products and did so under the influence of stakeholders.

OVERCOMING UNCERTAINTY BY COMBINING EFFECTUAL AND CAUSAL APPROACHES

Enhancing the toolbox of early-stage technology entrepreneurs (and maybe even entrepreneurs in general) through elements of effectuation seems to pay off. Cases that were able to start out effectually and then transition to more causal approaches went quickly through their gestation process. Other projects that relied more intensely on causal concepts took much longer or actually got stuck in their process, which might hint at a necessity to apply more effectual elements in their process. With regard to our specific research questions, we can now enhance the discussion of the effectuation/causation toolboxes as follows.

In a first step, we deepened the understanding of the concepts of effectuation and causation. This was realized through a category-based analysis of the codings and a respective refinement of the coding scheme as part of the coding process and the subsequent discussion between first and second coder. It turned out that the four coding categories (Process start, Investment decision basis, Moving

forward in the process and Dealing with contingencies – see Table 1) varied in their importance in terms of the number of respective semantic chunks. Process start and Moving forward were by far and over all cases the predominant dimensions. Looking more closely, the categories also differed as to their character: either logic or behaviour. Moving towards operationalization, this implies that focus should be on Process start and Moving forward in the process, while the logics of investment ideas and contingency approaches are tied to the core categories. Lastly, it was possible in this step to depict the notion of predictability as the relevant connector between causation and effectuation. This three-step analysis (category importance, category character and connector) will facilitate further work on operationalization in future research.

In a second step, we found that patterns in the combination of effectual and causal approaches relate with a variation of process performance. Three cases (Methone, Calypso and Pan) showed a comparably quick movement through the venture process in connection with a high level of effectuation intensity. Narvi, Mimas and Bestla, on the other hand, showed a comparably slow venture process in combination with lower levels of effectuation intensity. These results suggest that effectual behaviour in the early-stage process fosters venture development while causal behaviour is not as effective in the early stage.

In a last step, we found that effectual and causal behaviour merge into a mechanism that could be labelled uncertainty management, as both toolboxes seem to address different kinds of uncertainties in the early stages of the venture development. While effectuation helps the projects in the early phase to create a resource base and choose a development path without relying on prediction, it is the prediction-based causal toolset which later helps to define both the environment (e.g. market) for the venture as well as its prospective position within this environment. It was interesting to see that most projects showed effectual behaviour especially in the pre-firm phase and switched to causal behaviour after building a formal company. Especially in the case of Calypso, it was interesting to see that most effectual behaviour took place at a very early stage, when the staff was still part of the parent organization, using those resources there to create the resource base for the future venture.

Our data show that it might be worthwhile to further explore the connection between types of uncertainty and causal and effectual approaches, respectively. While there is not better or worse in terms of causal or effectual approaches, we grew more confident that causation and effectuation answer to different types of uncertainty: Effectuation rather addresses early-stage uncertainty in terms of resource and knowledge uncertainty while causation might rather solve later-stage uncertainty in terms of environmental uncertainty.

With regard to our theoretical basis, we also see implications in terms of the dynamic resource-based view and the concept of dynamic capabilities. Given the fact that especially technology entrepreneurs need to cope with uncertainty in their early venturing process, we would like to stimulate the discussion about a dynamic capability of *uncertainty management* for the emergent

organization that combines uncertainty identification and distinction with the appropriate application and combination of both the causal and the effectual toolset.

An important practical implication hints at the set-up of teaching and support programs for entrepreneurs in general and more specifically technology entrepreneurs. Introducing effectuation to technology entrepreneurs might help to move from a more "accidental" employment of effectual logic to a more structured use in start-up processes. If it can be shown to be a reliable success factor, there is a good chance that explicitly conceptualizing the phenomenon and teaching it can foster technology transfer within technology ventures. As much, the results could allow for further empirical insight and feed back to the concept of effectuation and enhance the theoretical understanding of it.

Limitations

There are of course certain limitations to this study. The most obvious concern is that of statistical generalizability. A case study, or even eight, can never hold to prove relationships between constructs. However, it is the goal to enhance theoretical knowledge through case study research, not to prove theory. A variety of influencing factors can be assumed for any case presented. Although we tried to look at equally complex technologies, the variation among different technological fields hinting at an even broader and diverse set of possible markets is definitely a strong influence. We address this issue by arguing that the high level of uncertainty and the early stage allow for a comparison between the cases. As much as current literature mainly refers to technology that is being created at university, we also looked exclusively at spin-offs from university. We argue that universities are both a strong technology source and not as far developed in terms of transfer mechanisms which led us to hope that we would be able to find more variation among cases in terms of the gestation process as would have been possible in more professional environments. Autio even labels the university spin-off as the "classical case" in terms of spin-off activity (Autio, 1997; Autio & Yli-Renko, 1998).

Future research

The research opens up some avenues of further research. First of all, in terms of the technologies' organizational background it is probably worthwhile looking at projects coming out of non-university public research institutions as well as from the corporate world. Secondly, with regard to methodology, it would be interesting to look at experimental set-ups. Founders could be taught the toolset of effectual logic, finally being compared to a control group with founders that did not go through this kind of teaching. What is more, next steps could aim at statistical generalization for effectuation as a success driver in new technology-based firms, maybe broadening these endeavours

in terms of an a more detailed conceptualization or even operationalization of uncertainty management, including both causal and effectual approaches.

CONCLUSIONS

The findings in this study are important because they shed light on the early stage of technology entrepreneurship. Most importantly, we show that venture projects differ in their way of applying both causal and effectual approaches in their early-stage development process. Our data propose that those projects that add effectual elements to their toolbox are able to overcome resource and knowledge uncertainty through expanding means and converging on goals at the same time. However, at some point the projects have to turn to causal mechanisms in order to build the organization.

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FUNDING NTBFS: BEYOND VENTURE CAPITAL, THE ROLE OF DEBT

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ABSTRACT

The objective of our research is to understand which factors at the firm level influence access to external capital for new technology based firms (NTBFs), a puzzle that the extensive literature has not solved. We specify a multi-level framework for the empirical analysis of determinants of NTBF financing performed on a UK dataset. The original contribution of our research is the use of an expert system (Bayesian network) to shape the model of the NTBF fundraising process. Our research results in weak acceptance of pecking order theory (POT) and identifies some qualifying accompanying factors, variables at firm level that have a clear and significant role in the fundraising process. Contrary to the mainstream view, banks can play a role in fostering technology-based entrepreneurship, especially in advanced contexts such as the UK, where the availability of public guarantee schemes has proved effective.

Keywords: Pecking order theory, debt financing, NTBFs, Bayesian network

INTRODUCTION

The generation and exploitation of knowledge play a large part in creating economic value (Gibbons et al 1994) in a globalised world; knowledge, human capital and technology development are central to the growth and wealth of nations (Harris 2001).

Small and medium-sized enterprises (SMEs) and new technology based firms (NTBFs) – the main players in the knowledge economy – have become the focus of investigation by scholars and policy makers, because, in OECD economies in particular, 'radical changes in ICT and biotechnology have created market opportunities that are more effectively developed by new firms than by established companies. The shift to knowledge-based economic activity is said to be the driving force underlying the emergence of the entrepreneurial economy' (Stam and Garnsey 2007).

This emphasis on the entrepreneurial economy has generated much of policy makers' and academics' interest in NTBFs. We adopt Rickne and Jacobsson's (1999) definition of an NTBF as 'a firm whose strength and competitive edge derives from the know-how within natural science, engineering or medicine of the people who are integral to the firm, and upon the subsequent transformation of this know-how into products or services for a market' (Rickne and Jacobsson 1999). NTBFs operate in innovative and technology intensive industries, such as electronic engineering, computer science, engineering physics, industrial economics, chemical engineering, mechanical engineering, civil engineering and medicine (Rickne and Jacobsson, 1999). For some authors, 'new' means firms that are no older than 25 years; for the purpose of our research, since our interest is in the financial attitude of firms at start-up, we focus on early stage companies, in the very first years of their development.

Before they can show significant growth and success, one of the most significant constraints new firms have to face is the lack of resources. It seems that NTBFs face a particular financial gap since the combination of high-tech risk, information asymmetries and low collateral contribute to funding gaps (Carpenter and Petersen, 2002).

We are interested in external sources of capital for NTBFs, borrowing from Berger and Udell's (1998) general scheme of external financial sources for SMEs. According to Berger and Udell, the modern information-based theory of security design predicts that the mix of external equity and debt sources will be affected by three dimensions of informational opacity/costly state verification, adverse selection (tending to favour debt), and moral hazard (tending to favour equity). Differences in the relative severity of these information problems may help explain how SMEs obtain money.

Cosh et al (2005) found that completely new start-ups are not likely to attract finance from banks, and equity financing is often said to be the best solution for the financing of young high-tech companies – because of the high uncertainty of returns, the low probability of financial success, limited collateral and substantial information asymmetries between firms and investors (Carpenter

and Petersen 2002). However, there are NTBFs that do receive debt capital but not equity. In previous research, we studied those firms and tried to understand which factors enable this phenomenon. In-field pilot interviews allowed us to focus on the main aspects of the problem (Minola and Giorgino 2008). For the literature, we specified a multi-level framework of analysis that was used, refined and preliminarily validated on UK and Italian cases (Minola et al 2007). The object of our present research is an empirical analysis of the determinant of NTBF financing using this framework and performed on a dataset on UK NTBFs.

One of the original contributions of our research is the use of an expert system to shape the model of the NTBF fundraising process. An expert system is a software system that incorporates concepts derived from experts in a field and uses their knowledge to provide problem analysis through rules. An expert system may also provide statistical analysis of the problem and have the great advantage of being able to handle complex phenomena, where the definition of variables and relationships is mainly uncertain and vague.

Although there is evidence that the pattern of lending to young and technology based businesses can be inverted by innovative bank-lending programs (as described below), bank financing may be inadequate to fund NTBFs – if it is restricted to the traditional banks. A mismatch of expectations between banks and technology firms – often referred to as 'the empathy gap' (Gill et al 2007) – has proved a persistent barrier to greater engagement by banks in the tech sector.

Nevertheless banks remain the most common form of external financing for small businesses and, despite theoretical issues and general declaration, do lend to NTBFs, under certain circumstances. Fluck et al (1997) stated that information opacity does not prevent firm's attempts to obtain external financing, particularly debt to start-up firms, and Berger and Udell (1998) found that debt appears to be an important source for young firms, contrary to conventional wisdom, thanks to substantial recourse to personal wealth and collateral.

Banks play a central role in the development of SMEs in general, since almost 8 out of 10 firms reportedly use bank debt, while only 11 per cent of them receive capital from public institutions. An even smaller percentage are financed by private investors (seven per cent) and venture capital companies (two per cent) (Flash Eurobarometer 2005).

In the UK, banks remain the most common form of external financing for small businesses (according to the British Bankers' Association, BBA), the main UK retail banks have 3.1 million small business customers with under £1m turnover). There are four main reasons for this: familiarity with bank managers; easy access to information; the cost of financing (only the fastest-growing companies will be able to access large sums of venture capital or other equity finance); and flexibility (see Pavlov et al 2004).

UK banks also work with organisations such as the Prince's Trust, which guarantees small business lending, and the government to fund the Small Firms Loan Guarantee (SFLG) scheme. The SFLG covers 75 per cent of the lenders' exposure, with the borrower paying a two per cent premium to the government. The aim of the SFLG is to help viable, debt-appropriate businesses that lack sufficient collateral to access loan financing in the market.

The object of our present research is to understand which factors, at the firm level (i.e. technology, financial constraints, assets composition, market, and size of business) influence the access to external capital, in particular bank loans and venture capital financing. Our research question is: when is debt viable for NTBFs? And furthermore, which factors influence the choice of the source of external financing for an NTBF?

The issue is relevant primarily for scholars, since financial theory creates a puzzle: 'Some authors argue that high-risk entrepreneurs choose debt contracts instead of equity contracts since risky but high returns are of relatively more value for a loan-financed firm' (Schäfer et al 2004). Contrary to this view, entrepreneurial finance theory commonly states that the more risky their projects, the more likely entrepreneurs are to seek equity contracts. Our work aims to take a first step toward resolving this puzzle, providing an empirical specification of the variables that influence choice at firm level.

Our research is also relevant to entrepreneurs: we attempt to develop a framework to help technology-based entrepreneurs match their business plans with the most appropriate financial strategy. As we have already said, the literature, although vast, has not solved the puzzle of entrepreneurial financing; yet, from an empirical point of view, banks are moving toward innovative offers, trying to meet the financial needs of start-up, and addressing situations where entrepreneurs are unlikely to attract VC investment but whose projects are nonetheless worth financing. On the other hand, spreading awareness of the financial strategies of NTBFs may support entrepreneurs who are VC-worthy but unaware of it.

Finally, our research also concerns policy makers. NTBFs are an important focus for those who deal with competitiveness policies, as they give significant propulsion to economic growth, in terms of employment (Acs 2004), and are a primary source of radical innovation (Audretsch 1995). Governments should be concerned about the possibility of (eventual) market failure preventing NTBFs from accessing the financial resources they need – although as far as the existence of a real gap in financial markets is concerned, the literature shows contrasting patterns (see Cosh et al 2005; De Meza and Webb 1987).

In Section 2 we describe empirical evidence of NTBF financing and review related literature streams. Section 3 and 4 describe the data and the methodology we adopted. Section 5 develops the

empirical analysis, and the results are analysed in Section 6. Section 7 summarizes and concludes the paper.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

The acknowledged starting point for all entrepreneurial finance theories is irrelevance theory (Modigliani and Miller, 1958), according to which, in a perfect capital market – that is, one without taxes, information asymmetries and transaction costs – the market value of a company does not depend on its financial gearing. The interesting point of this approach is that it shows that, because capital structure does indeed matter, one or more previous assumptions have been violated. In fact, irrelevance theory generated concern in modern economical theory about information asymmetries and principal-agent relationships (Rothschild and Stiglitz 1976 and Holmstrom and Tirole 1997), maintaining that entrepreneurs always have more complete information about their ventures than the investors to whom they turn for support. These asymmetries can become a serious issue and result in moral hazard (De Meza and Webb 1987) and adverse selection problems (Ackerlof 1970).

It has been proven that equity and credit rationing occurs in markets with strong asymmetric information (Stiglitz and Hellman 1998 and Myers and Majluf 1984). This also affects equity capital. As we wrote in Section 1, the mix of external equity and debt sources will be affected by differences in the relative severity of these information problems.

Jensen and Meckling (1976) raised the problem of agency costs. They said that the operating management of firms involves a number of contractual relationships with the various stakeholders in the company (owners, managers, customers, suppliers, and creditors). All these relationships imply agency costs deriving from the potential conflict of interests that may arise between them, and from the possibility of any of the stakeholders extracting private benefits from the firms, compromising its economic efficiency in pursuit of the maximization of its value. For this reason, the optimal financial structure is the one that minimizes the agency cost associated with debt in relation to its benefits. Myers (2001) suggests that conflicts between managers and investors can be solved by the latter taking on some responsibility for monitoring company performance, and by incentive systems that link managers' remuneration with firm performance.

An important contribution to the topic of the financial structure of firms was made by Myers and Majluf's (1984) pecking order theory (POT) and signalling theory. They suggest that because of information asymmetries, only managers know the real value of the firm and its investment opportunities. Investors do not know the real distribution of company income. This affects the market value of the company, which can be over- or under-estimated, depending on the information available in the market. Since managers will only decide to issue new stocks for investors if they

think that they are over-valuated by the market, this strategic decision will be considered a 'bad signal,' which will cause a reduction on the market value of the firm. Dierkens (1991) highlights that this shrinkage is more pronounced if there are more problems of information asymmetry between managers and investors. In order to avoid this, managers will seek finance if their firms have instruments that limit information asymmetries. If there are sufficient internal funds, every project that should create value (i.e. has a positive forecasted NPV) will be undertaken. This is unlikely in the opposite case, because, to avoid penalizing the market value of the firm, managers could decide not to ask for capital in the market, even if this implies abandoning potentially profitable projects. For the same reason, they may decide to subscribe debt rather then equity capital, once internal funds are extinguished, as it is less influenced by information asymmetries. Myers himself (1984) extends this theory, establishing that companies confront investment opportunities and financial needs in a hierarchical order. Internal funds will be preferred, followed by debt capital and, at a lower level, the issue of equity.

At first, POT and most of the other theories we have discussed were formulated to explain the financial strategies of large quoted firms. These companies are characterized by a clear separation between control and ownership, which is divided among a large number of shareholders, and by the possibility of using stock or bond issuing as a source of financing. Several authors have argued that POT is also valid with SMEs (Ang 1991, Holmes and Kent 1991, Cosh et al 2005 and Cosh and Hughes 1994).

According to traditional POT, debt finance is preferable to equity; recent research, however, has shown this pecking order can be reversed when investors' skills and value-added are relevant Garmaise (2000). Sau (2007) and Paul, Whittam and Wyper (2007) suggest that the traditional hierarchy can be inverted with innovative firms when VC performs the evaluation function (reducing the extent of information asymmetries) after which innovative firms can turn to bank credit (revised POT).

Which of the two paradigms (POT and revised POT) explains the behaviour of NTBFs better is strongly debated in the literature. Åstebro (2002) developed an empirical analysis of start-ups' search for bank funding, finding that a large portion of them do not even apply even though a significant proportion of applicants do receive loans. Schäfer et al (2004) use project and financial dimensions to proxy the overall risk. They analyse the likelihood that NTBFs will obtain external financing, looking at size, assets, project and novelty. According to their findings, risk does not have a predictive power concerning the likelihood of a company receiving debt or equity. Carpenter and Petersen (2002) say that, for small hi-tech firms, equity financing has some advantages compared to debt: first, risk capital does not require any collateral to guarantee the funds conceded; second, returns for investors are potentially superiorly unlimited, representing an incentive for VC

funds to invest money and time in potentially highly profitable firms; third, equity financing does not increase the probability of company default and consequent bankruptcy costs.

Audretsch and Lehmanns' (2003) findings show that the likelihood of obtaining venture capital is inversely related to the extent to which the firm is financed by debt, as venture-backed firms have significantly less debt. Therefore it appears, consistently with the greater part of the literature, that equity provided by venture capital appears to be a substitute for debt rather than a complement to it.

Cosh et al (2005) produced a very interesting piece of research on the role of POT in the financial strategy of SMEs. Although the sample was drawn from generic SMEs, not NTBFs, they found the most significant determinant of applications for external finance to be the ratio capex/profits, indicating support for the traditional pecking order whereby firms finance new projects internally before seeking external finance. As we said earlier, the issue is no longer whether or not firms follow a defined hierarchy of funding source; it is which of the two – POT or revised POT – is adopted by NTBFs. Cosh et al found that start-ups with higher capital expenditures and/or profits are more likely to obtain capital from a bank than from VC funding. In this paper we try to solve this dilemma, borrowing Cosh et al's approach (i.e., using capital expenditure and profit profiles as the first determinants of the financial structure of a NTBF).

We also control for the role played by the size of the firm at the start up, a dimension often investigated in the literature in relation to the funding strategy of NTBFs. As we noted earlier, Schäfer et al's (2004) empirical analysis failed to find a robust risk measure to predict access to debt and equity for NTBFs. There is an interesting exception, however, concerning the indicators of financial risk. The amount of money needed for a project is a powerful predictor of whether the project will be equity financed. In Minola et al (2007), we showed that size of investment seemed to have the highest predictive power of NTBF financing choice: larger amounts of money are likely to be funded by venture capitalists or business angels, smaller amounts by a bank loan.

Similarly to Ueda's (2004) predictions (larger projects are financed by VC), Sau (2007) suggests that, although VC enhances the efficiency of the financial system, it is not suitable if projects are at an embryonic stage and call for limited financial resources. Marked scale diseconomies in management and monitoring discourage VC financing. We therefore expect a stronger relation between size and VC financing than between size and debt financing. We proxy the size of the firm with number of employees and turnover.

R&D intensity, technological uncertainty, innovativeness and asset intangibility constitute a third, closely examined group of determinants of NTBF financing. According to Cosh et al (2005), firms that have recently developed an innovation are approximately 35 per cent more likely to seek and obtain capital from a VC fund. Higher asset intangibility is associated with risk (Garnsey 1995),

information asymmetries, agency costs and increased costs of external finance, both debt and equity.

Collateral (all the assets a business can pledge as a guarantee for a loan) is often the principal determinant for access to debt capital. The literature argued unambiguously that entrepreneurs with little collateral tend to go to VC (Ueda 2004). We will check for the relevance of a well established scheme of public guarantee to debt, like SFLG (described earlier).

The impact of market competition (Porter 1998) on a firm's financing decisions has been identified (Shepherd et al 2000). Profitability tends to be lower in more competitive industries (especially when competitors are larger and dominant), which makes these companies less attractive to investors. Firms that face more and bigger competitors are less likely to obtain the amount of external capital they seek (Cosh et al 2005). We expect this phenomenon to be more pronounced for obtaining equity, since it could be argued that banks are eager to finance a company in a highly concentrated market, where the number of competitors proves the business idea is viable and the project sustainable.

Finally, we control for the way the business originated. Cosh et al (2005) say that brand new start-ups and businesses founded to implement an invention are more likely to be equity financed.

Business that originate within universities are referred to as university spin-offs (USO) and can be viewed as a subset within the broader category of NTBF start-ups (Tang et al 2004). For the purposes of our research, USOs are defined as new companies created by an academic/researcher who forms a new company to exploit the outputs of university research and where the university retains an investment in the company (typically in return for licensing the right to use university-owned IP). USOs represent one specific way in which universities disseminate technologies and deserve particular attention as some of the most relevant players in promoting innovation and technology transfer.

USO management teams may lack a proven commercial track record (Steffensen et al 2000), and university technology transfer offices are often short on critical business development and business venturing skills (Vohora et al 2004). These USOs may have long gestation periods and substantial resource requirements and may take many years to reach the market with products or services that produce revenue. In addition, many USOs operate in new, emerging and sometimes as yet undefined markets. The convergence of these factors and other variables leads to a significant proportion of USOs being undercapitalized and deficient in the requisite knowledge and social capital to access and acquire financial capital for development (Vohora et al 2004).

According to the taxonomy of USO developed by Heirman and Clarysse (2004), where parent organization, business model and available (financial and technological) resources are matched with possible financers, it is more likely that USOs will access equity capital.

Conversely we do not expect NTBFs established as a spin-offs from existing businesses or M&A/MBO activity to be capital rationed, since the former are accompanied by collateral and resources from mother companies and the latter by definition are accompanied by large funds and the banks that support the entrepreneur

DATA

The sample we selected was retrieved from the UK Data Archive, database SN 4431, Cambridge Centre for Business Research SME Dataset (second panel, 1997) – the same database used by Cosh et al (2005). It is a longitudinal panel database of SME data relating to a wide range of non-financial and attitudinal characteristics, and a limited number of financial variables not normally available in modified company accounts, taken from a national postal survey.

The database forms the beginning of the second panel; the first panel was started in 1991. A postal survey was sent to over 10,000 independent SMEs in the manufacturing and business services sectors in England, Scotland and Wales. Just over half of the firms (5,430) were contacted by telephone before the questionnaire was sent out to them, and 4,640 firms were sent the questionnaire blind.

The questionnaire covered the following topics: general business characteristics; workforce and training; commercial activity and competitive situation; innovation; factors affecting expansion and efficiency; acquisition activity, capital expenditure and finance. A summary of the most relevant information on the database is presented in Table 1.

Table 1 Information about the dataset (source: www.data-archive.ac.uk and Cosh et al 2005)

Country	Great Britain
Coverage (time period covered)	1994–1997
Dates of fieldwork	June 1997–September 1997
Population	Independent SMEs in Great Britain with fewer than 500 employees in 1997
Time dimensions	Cross-sectional (one-time) study
Sampling procedures	One-stage stratified or systematic random sample
Number of units	2,520 (obtained)
Method of data collection	Postal survey
Date of release	First edition 12 December 2001
Copyright	Copyright University of Cambridge, Centre for Business Research

The original dataset was focused on SMEs in general, whereas our interest is explicitly focused on NTBFs; therefore it was necessary to filter the original dataset, with regard to firm age and industrial sector, in order to obtain a sample that would be relevant to our research.

NTBFs are normally less than 25 years old. Since our research explicitly focuses on the financial issues linked to the initial phases of the firm lifecycle we concentrated on firms that were less than six years old (the time taken, on average, to run the three initial phases: seed, early stage and start-up). As to industrial sector (classified in the dataset through the SIC 1992 code), we selected high-tech sectors – it is not an easy definition and there are differences in definition and taxonomy in the literature. We adopted the definition of high-tech derived from the Greater Cambridge Annual Profile 2007[11] and eventually obtained a sample of 303 NTBFs.

The sample is representative of NTBFs in the UK, since the original dataset was obtained through a sample selection process. Detailed information on the methodology used to build the sample can be found in Bullock and Hughes (1998).

METHODOLOGY

An original contribution of our research is our use of an expert system to shape the model of NTBF fundraising processes (expert systems are used not to create theory but scientific knowledge); in particular we used the methodology of Bayesian Network, also called Bayesian Belief Networks (henceforth BBN), which is a compact model representation for reasoning under uncertainty, based on the computation of the probability of different events or hypotheses given number of observations.

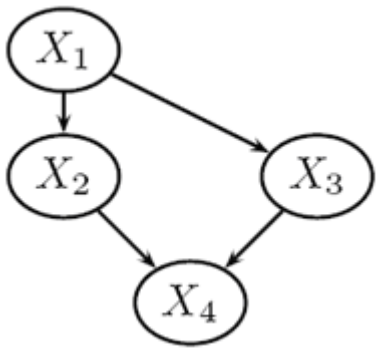
G	P
	$P(X_2 \mid X_1)$ $P(X_3 \mid X_1)$ $P(X_4 \mid X_2, X_3)$

Figure 1 BBN: nodes, links and conditional probabilities

A Bayesian network N = (G,P) consists of a qualitative part (G), which is the direct acyclic graph (DAG) structure G = (V,E), made by a set of nodes V and a set of directed edges E between

[11] www.gcp.uk.net/downloads/G_C_Profile_07.pdf

nodes, and a quantitative part (P), which is the set of conditional probability distributions. Each node has a finite set of states; attached to each node X_4 with parents $X_1 \ldots X_n$ there is a conditional probability table (CPT), which provides $P(X|X_1 \ldots X_n)$. Figure 1 shows a simple example of a BBN.

There are many advantages of expert systems; among others, they provide consistent answers to repetitive decisions, processes and tasks, and represent significant support for decision making. Within the broad field of expert systems, general rule-based systems have a series of problems. For example, it requires substantial effort to construct and maintain them; they do not represent causal knowledge explicitly; and numerical representations of uncertainty may be unsound. BBNs can be a powerful tool, since they model the problem, not the expert, domain and support – rather than substitute – the expert. BBNs use classical probability calculus and decision theory, not an incoherent uncertainty calculus. This can be a great advantage, compared with fuzzy logic: the robust statistics that back BBNs help to avoid the so called 'black box' risk, i.e. rules and conclusions that have no strong evidence for their meaning). Furthermore, every type of variable can be processed since BBNs allow the treatment of ordinal, binary and qualitative variables.

A BBN can represent the topology of a problem clearly and intuitively, within a robust mathematical framework. Both the structure and the numerical parameters of a BBN can be elicited from an expert. They can also be learned from data, as the structure of a Bayesian network is simply a representation of dependences in the data; the numbers are a representation of the joint probability distributions that can be inferred from the data. This represents a significant advantage, as it means BBNs can help shape complex and holistic models, where multiple variables are mutually interrelated and statistical dependent.

BBNs are probabilistic networks, capturing a set of (conditional) dependences and independences associated with variables in the network; they get their name because the computation of the probability from both data and knowledge is made on the basis of Bayes' theorem.

There are three-steps to the process of building BBN learning from data: data discretization, structure learning and parameter learning. Each step can be performed in several ways using different parameters and algorithms, not necessary to detail here. Once our data had been cleaned (or pre-processed), we proceeded with the linear discretization process, since BBNs work with discrete values for the variable (there are continuous BBNs, but the complexity of the problem required a more detailed exercise). Each continuous variable had to be segmented in groups of intervals, whose number and width are set by the user, whereas the ordinal variables (such as Likert scale answers), dummy variables and label variables are by definition discrete.

We performed structure learning with two pieces of software. The first was GeNIe, a development environment for building graphical decision-theoretic models developed at the

Decision Systems Laboratory, University of Pittsburgh; the second was Hugin, probably the most used management and industrial processes control software in the world. Both contain comprehensive, flexible and user-friendly graphical interfaces, with an editor, compiler and runtime system for the construction, maintenance and usage of knowledge bases using Bayesian network technology.

We used Hugin to build the network, since it allows a very flexible process of structure learning; in particular it provides *p-value* for each connection and allows the user to set a threshold on the *p-value*, below which not significant links are disregarded. Hugin is also smart for parameter learning as the user can add and drop links and the software recalculates CPTs very quickly. Conversely GeNIe has a more friendly interface and performs the simulations process and sensitivity analysis very well on existing networks.

As to structure learning, the user is asked to formalise prior knowledge on the topology of the domain. The software then calculates the significance of all possible connections through the K2 algorithm, plotting a provisional framework with user-set arcs and some others that are suggested because they are significantly supported by data. At this point the user can accept or modify the network.

Once the network is built, parameter learning can be performed. The software calculates the CPT that is subsequently provided for each node. After this the network is ready and the user can play with it, setting some evidences on one or more nodes of the framework and observing how this affects the joint probability of other nodes (this is known as propagation).

DATA ANALYSIS

In this section we describe an empirical analysis of a sample of 303 UK NTBFs, in which we aimed to shed new light on the role of the determinants detailed in Section 2: capex, profit, reason for firm creation, R&D activity, collateral (SFLG), size and market competition.

Variables definition is illustrated in Annex 1. In Table 2 we report some descriptive statistics about the sample that provide some interesting insights. Fifty-one per cent of firms in our sample did seek external finance, a high level that confirms pecking order theory: given their low ability to generate internal finance (retained earnings), NTBFs are under more pressure than SMEs in general to target external finance providers. Firms also managed to secure – on average – 80 per cent of the external capital sought; this may not be fully explained by banks and VC provision, since the dataset also investigates other forms of funding (leasing, factoring, invoice discounting, etc.)

The first significant surprise comes from the access to bank loans: 41 per cent (=1–0.59) of firms approached banks and 80 per cent (=0.33/0.41) managed to secure some debt funding, which

is in sharp contrast to the stereotype that NTBFs do not (or cannot) access debt, although this may be mitigated by a self selection bias. In particular, a large proportion of the samples (53 per cent, =0.26/0.41) managed to secure the whole amount they were seeking from a bank.

There seems to be low credit rationing, since approximately only eight per cent of firms have been rejected by banks (19 per cent of those who applied for a bank loan); the rejection rate from VC is higher (three per cent, that is approximately 43 per cent of applicants), which is not surprising.

Table 2 Descriptive statistics

Variable Name	Not approached	Approached and rejected	Approached and financed (some)	Approached and financed (full)	Observations
External finance sought from banks	0.590	0.080	0.070	0.260	290
External finance sought from VC funds	0.930	0.030	0.010	0.030	290

Variable Name	Mean	Median	Standard Deviation	Observations
External finance sought	0.510	1.000	0.501	298
Amount sought	416.826	80.000	1415.632	132
Percentage obtained	80.408696	100	35.013756	115
External finance obtained from banks	49.081	50.000	39.589	99
External finance obtained from VC funds	35.765	25.000	39.919	17
R&D last year	0.493	0.000	0.501	272
R&D expenditure	47.787	0.000	333.970	239
Turnover	2189.458	408.500	8432.829	262
Employees	25.778	7.000	46.847	284
Profit	130.425	35.000	386.281	241
Capital expenditure	441.505	25.000	3767.279	234
SFLG	0.137	0.000	0.345	270
Total competitors	29.610	4.000	311.589	267
Larger competitors	27.101	3.000	293.180	238
Overseas competitors	0.980	0.000	2.462	249

Variable Name	Never	Occasionally	Continuously	Observations
R&D integration	0.350	0.350	0.300	276

Variable name	MBO or M&A	Business spin-off	University spin-off	New start-up	Observations
Reason for firm establishment	0.250	0.250	0.060	0.440	294

Firms on average have a turnover close to £2 million, 25 employees, are profitable (£130,000) and have capital expenditure of about £400,000, which is similar to the amount of funding sought. These are considerable amounts for start-up companies and may be explained by the large proportion of corporate and industrial spin-offs in the sample – larger-scale when they start – and by the presence of a high number of manufacturing NTBFs, which are highly capital intensive.

The vast majority of firms perform some R&D, but only 30 per cent are engaged in continuous R&D activity; 49 per cent did R&D in the previous year but the average R&D expenditure appears pretty low (only 2.18 per cent of turnover).

SFLG schemes are accessed by 14 per cent of firms, which indicates this public scheme as a successful initiative. Finally, market competition has few entrants, almost exclusively larger and with a domestic provenance.

In Annex 2 we represent the correlation matrix, calculated on both dependent and independent variables. It seems no multicollinearity phenomenon is present among the variables in the sample, since no theoretically relevant correlation coefficient is found to be strong, but we can gather some interesting evidence from the correlation analysis. In particular, it appears that continuous R&D activity is correlated with smaller, more fragmented but more internationalized markets (see correlation with Total competitors, Larger competitors and Overseas competitors), which is unsurprising for new-technology based markets.

Judging by numbers of employees, all kinds of spin-offs and independent start-ups are smaller in size, whereas firms that grow out of MBO and M&A activity are strongly correlated with larger size. As concerns profit and capex, independent start-up results are negatively correlated with profitability and capital intensity, whereas firms starting from MBO have strong and positive correlation. Neither of these results is surprising.

Finally, accessing SLFG schemes is surprisingly positively correlated with performing continuous R&D activity, which may indicate that the scheme targeted innovative firms, although the theoretical prediction that university spin-offs are unlikely to target debt sources and access guarantee schemes is confirmed.

The next step for the data analysis consisted of creating BBNs (described in Section 4). In this paper we analyse the impact on access to debt and equity capital of a given subset of independent variables: capital expenditure, profit, R&D activity, collateral (SFLG), size (turnover and employees) and market competition. We preloaded a network where each independent variable was linked to both dependent variables (see Annex 1). The software first returned the significance of each link (dependency) through the *p-value* calculation (see Table 3), then suggested links among independent variables that were not preloaded.

Most statistical dependencies were found to be strongly significant, except for impact of R&D activity and capital expenditure on VC financing and – most surprisingly – the impact of the number of competitors on both debt and equity financing. These non-significant links were deleted.

Table 3 The statistical significance of dependencies between input and output variables

p-value	External finance sought from VC	External finance sought from banks
Reason for start-up	0,0742	0,0267
Employees	0,005	0,0001
Turnover	0,04	0,0075
Profit	0,0383	0,0435
SFLG	0,0089	0,0294
Capex	0,1481	0,015
R&D activity	0,6024	0,042
Competitors	0,5668	0,5019

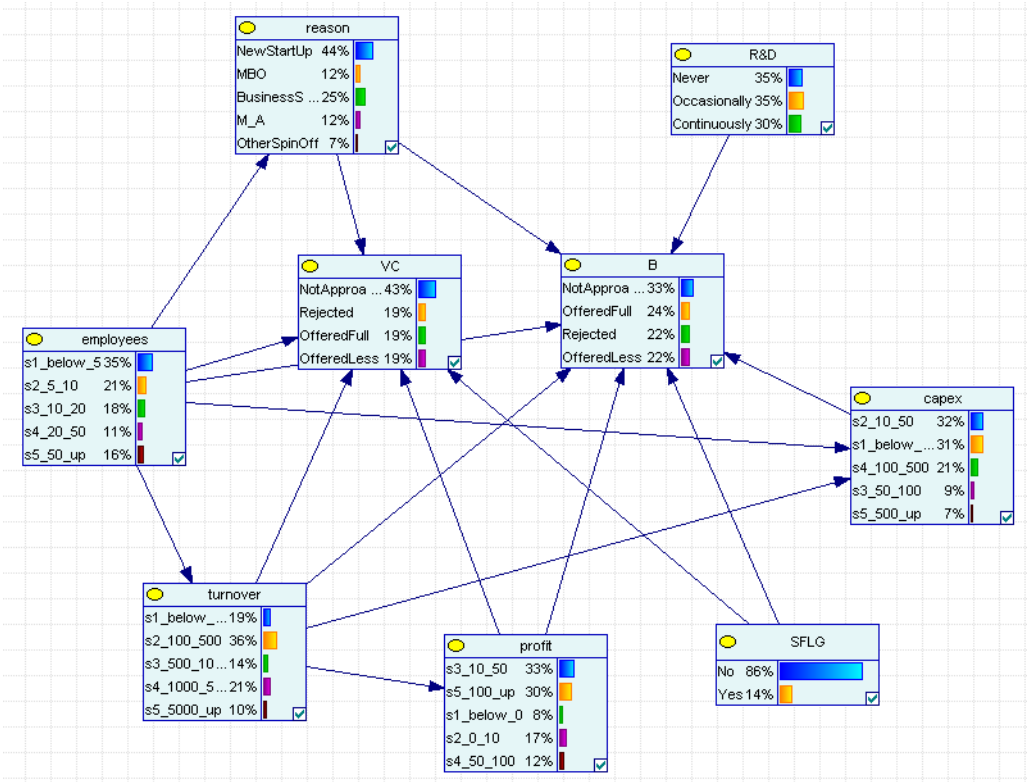


Figure 2 BBNs derived from data

Our empirical findings point out conditional dependencies between profit and turnover, turnover and capital expenditure, employees and turnover, and employees and reason for establishing the firm. We want to stress the importance of this feature of BBN methodology. The discovery and construction of the topology of the domain is an extremely important feature of BBN methodology.

It captures indirect dependencies that univariate or classic direct inference may not be able to show. The final network is represented in Figure 2.

As we indicated earlier, once the network had been built, the software (specifically GeNIe) allowed us to play with it, i.e. to set one or more evidences on some nodes and observe the impact on other nodes and the network as a whole. We set three sample cases, illustrated in Table 4, with relative impact on the two output variables (probability distribution of debt and equity financing).

Table 4 Summary of the examples of propagation

	Variable	Case1	Case2	Case3
Evidences set on independent variables	Reason for start-up	New start-up		
	Employees		<5	<5
	Turnover		<100	<100
	Profit			
	SFLG		No	Yes
	Capex	100<x<500		
	R&D activity	Continuous		
Effects on dependent variables	B	- Not approached: 25% - Rejected: 23% - Offered less: 23% - Offered full: 29%	- Not approached: 46% - Rejected: 17% - Offered less: 20% - Offered full: 17%	- Not approached: 31% - Rejected: 22% - Offered less: 22% - Offered full: 26%
	VC	- Not approached: 37% - Rejected: 21% - Offered less: 21% - Offered full: 21%	- Not approached: 71% - Rejected: 10% - Offered less: 10% - Offered full: 10%	- Not approached: 71% - Rejected: 10% - Offered less: 10% - Offered full: 10%

Case 1 was set with features typical of a company likely to seek VC funding, according to theoretical observation: a high level of R&D activity, a completely new start-up with no parent organization providing support and collateral, and a considerable amount of funding needed because of the high level of capital expenditure. As a matter of fact, with respect to average distribution of output node probability, we can observe an increased likelihood to access equity financing, comparable to likelihood to access debt. Cases 2 and 3 were as small-scale start-ups; in these cases, as expected, the likelihood of obtaining debt financing is much higher than the likelihood to getting VC backing. Interestingly, debt is much more viable when a public guarantee scheme is available as collateral (as in Case 3, compared to Case 2, where it is not available) whereas the likelihood of receiving VC backing does not change at all.

Case 1 is also graphically illustrated in Figure 3; the nodes whose values were set by the user can be identified through a unique symbol at the bottom right, whereas the ‘propagated’ nodes have a solid box in the same position. Finally, we performed a sensitivity analysis in order to observe the impact of variation in independent variables (input) on the two dependent variables (output) and, because of the topology of the network, on the overall structure.

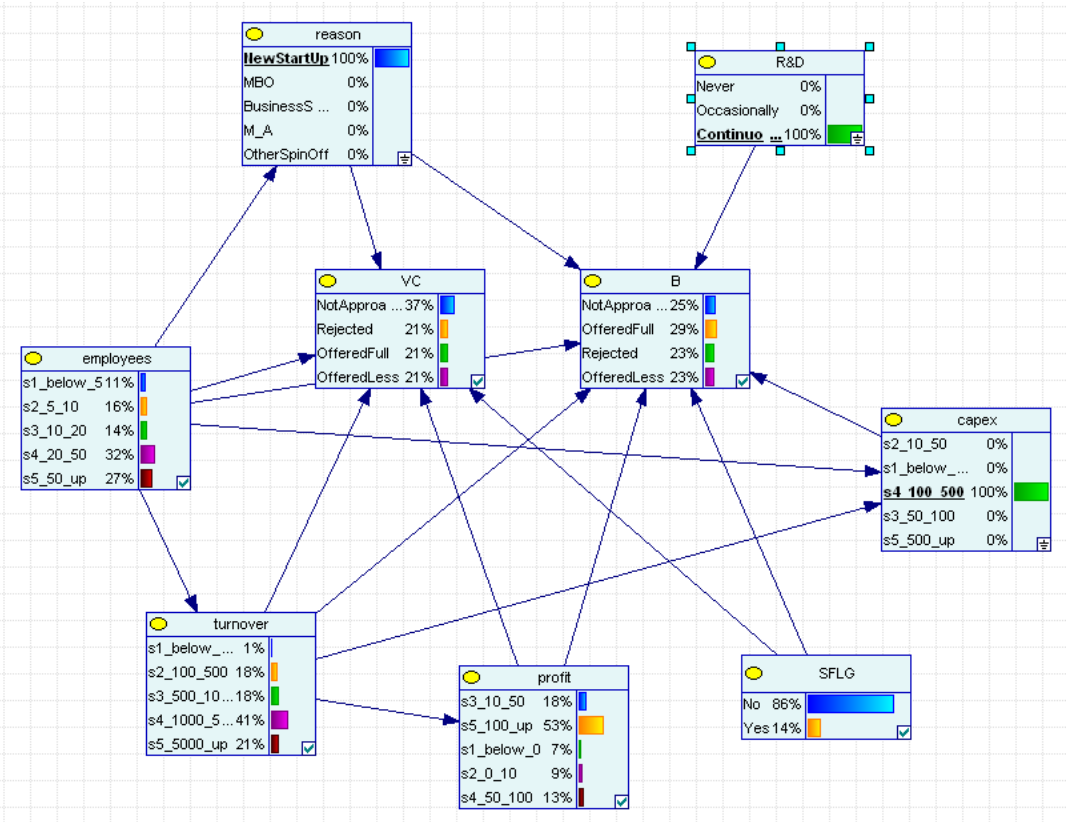


Figure 3 Examples of BBNs after propagation

Changing one input variable at a time, we analysed the variation in probability of the CPT of the output nodes. To determine the relation we simply searched for monotone positive or negative variations of probability distribution in output along with monotone positive variation in input. The intensity of the relation was determined by the slope of the variation. In some cases it was not possible to define univocal relation (see '/'), whereas non-significant relationships are defined as 'ns'.

Results are summarized in Table 5, together with expected results on the basis of the theoretical analysis developed in Section 2.

DISCUSSION OF THE RESULTS

We have only a partial confirmation of pecking order theory since *Capex*, as expected, raises the likelihood of being external financed (both sources) but no univocal relation is found between financing sources and *Profit*. We also tested for the ratio *Profit/Capex* (on a different BBN not illustrated here), finding no significant relation with VC financing and a significantly positive relationship between the ratio and access to debt. These results, together with observations based on descriptive statistics, suggest that the extreme financial needs of NTBFs, especially with high

capex, force the appeal to external sources of finance. However, no hierarchy can be revealed on the bases of profitability as a measure of a firm's ability to generate internal funds; i.e. it does not appear to be possible to distinguish as a separate segment which NTBFs adopt the POT rather than revised POT paradigm on the basis of the simple operationalization we have proposed.

Table 5 Results of sensitivity analysis

	B		**VC**	
	Expected	Sensitivity analysis	Expected	Sensitivity analysis
Profit	++	/	+	+
Capex	+	+	+	+
Reason for start-up				
MBO or M&A	+	+	+	+
Business spin-off	+	/	+	+
University spin-off	-	-	+	+
Independent start-up	-	/	-	-
R&D activity				
Occasional	-	+	+	ns
Continuous	-	-	+	ns
Employees	+	+	/	++
Turnover	+	+	/	++
Competitors	+	ns	-	ns
Overseas competitors	+	ns	-	ns
Larger competitors	+	ns	-	ns
SFLG	+	+	/	/

As far as reasons why the firm was established are concerned, as expected USOs are prevented from receiving debt and are likely to be financed by a VC (Heirman and Clarysse 2004) because of the high level of knowledge and expected growth associated with the low level of managerial attitude that can be reduced by investors' added value. Independent start-up is the only type for which it is difficult to receive equity financing and represents the stereotype of businesses that have to bootstrap to secure resources. Business that begin within a larger financial operation (spin-offs, MBOs or M&As) are more likely to secure money from VC, which is coherent with our discussion in the literature review above.

The level of R&D activity is not found to have a statistically significant relation to equity financing. Continuous R&D activity, as expected, is negatively correlated with debt financing, but

this does not hold true for firms involved in only occasional R&D. This may once again indicate that debt financing must be seen as a determinant player in fostering entrepreneurship: 'Bankers must be prepared to look as much to the future cash flow and maturity of the new technology company as to security and gearing considerations […] But are technology firms really more risky than other small companies? Or is it just that the banks believe that tech firms are riskier and so do not proceed with appraising lending propositions in the tech sector?' (Gill et al 2007)

Size is the strongest predictor of financing choice, with smaller NTBFs more likely to be debt financed and larger ones likely to receive money from VC. This is expected and coherent with theoretical predictions by Ueda (2004) and Schäfer et al (2004).

Finally, SFLG schemes have a positive impact on debt financing, whereas no significant relation is found between NTBF gearing and the level of market competition (proxied by number of competitors, overseas competitors and larger competitors).

CONCLUSION

'Do firms, especially small, young firms, get enough money to fund viable projects? If not, what, if anything, should be done about it? These questions are beguilingly simple to ask, and, needless to say, much less easy for economist to answer' (Cressy, 2002). The objective of our research was to understand if debt is a viable source for NTBFs and to understand which factors influence choice of sources of external financing.

We analysed factors at the firm level such as capex, profit, reason for firm creation, R&D intensity, collateral (SFLG), size and market competition and found that, contrary to general theoretical prediction, NTBFs *do* access debt. In particular, firms that start on a small scale, are innovative but not extremely R&D focused, less capital intensive, and assisted by public guarantee schemes have easy access to bank financing.

The likelihood of obtaining external financing increases with capital expenditure and is not affected by profitability, R&D intensity and market competition, with the exception of bank debt, which is higher for firms that perform occasional R&D activity and lower for firms that have continuous R&D activity. NTBF funding is also influenced by the reasons why the firm was established (university spin-offs and firms resulting from M&As are more likely to receive equity financing than independent start ups) and by firm size (larger firms are more likely to get money from venture capital funding). Many banks do take risks, but inevitably the latest financial crisis is posing a severe challenge to the global banking system. If they are to continue fostering high tech small businesses, banks will have to strengthen both their evaluation capability and accompanying services in the start-up phase, which may benefit the growing entrepreneurial culture. Banks will

also have to provide personalised services and favour a shift in their business model, from a pure service selling approach to one of more flexible risk-sharing with the entrepreneur.

From a theoretical point of view, our research results in weak acceptance of pecking order theory; we suggest some empirical qualification of the pecking phenomenon by identifying so-called accompanying (or mitigating) factors, i.e. variables at firm level that have clear and significant roles in the fundraising process. We also found that, contrary to the larger part of theoretical literature, banks can play a role in fostering technology-based entrepreneurship, especially in an advanced context such as the UK, where the availability of public guarantee schemes has proved effective.

From the methodological point of view, we believe our research enables an interesting holistic analysis of the determinants of NTBF gearing, through the aggregation of quantitative, qualitative and heterogeneous variables. Furthermore the use of BBNs, with significant dependencies and topology elicited from data, help build a knowledge base that can be adopted to spread awareness to policy makers, academics, practitioners and – most importantly – entrepreneurs on the determinants of the fund raising process.

The use of expert systems is particularly useful when handling complex phenomena, where the definition of variables and relationships is uncertain or unknown. Although numerous previous studies, many cited in the literature review above, have focused on this topic and explored the relationship of the variables with other methodologies, we think an expert system proved useful in the context of our research. The variables examined were very heterogeneous and the network collected them in a comprehensive topology. Furthermore many variables were qualitative, subjective or nominal and therefore difficult to operationalize in a classic manner.

We acknowledge some limitations of the present work. First, we decided to design a model and develop the sensitivity analysis on an example of BBN that takes into account only 10 independent and two dependent variables. The BBN methodology allows for much larger models and more complex topology to be handled, which we will consider in future studies. Second, we checked for R&D intensity and public collateral schemes as indicators of knowledge intensity in firms, but did not check for the role played by intangible assets that determine access to external finance; further research could introduce dimensions such as patents, brand value and advertising intensity. Interesting exploration may also be done on the role played by human capital, but this would require moving from firm level analysis and approach to entrepreneur level. Third, we acknowledge the existence of different development stages for NTBFs: seed, early stage and start-up firms may represent very different organizations, with different financial dynamics and this can influence results. We concentrated on generic fundraising actions occurring within the first three years of a

NTBF. Future studies might analyse the different dynamics underlying different stages within the development cycle (Berger and Udell 1998).

Further research developments could include: more characterisation of debt contracts used by NTBFs (what do they look like? collateral, impact on cash flow, repayment mode, etc.); the extension of quantitative analysis on other country samples; a definition of optimality – in the present work, accompanying factors have been identified on the basis of their occurrence in the BBNs learned from data; no evaluation or inference can be made on the basis of any optimality driver or performance measurement. Decision theory introduces a measure of preference, known as utility (a function mapping the attributes of the possible outcomes of a decision process on a set of real numbers), which can be implemented through a version of BBN, called influence diagrams. This could help us derive from the knowledge base a predictive tool to guide entrepreneurs in start-ups who are challenged by choices of financial strategy.

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ANNEX 1: VARIABLES DEFINITION

Variable name	Definition
External finance sought from banks	An ordered variable equal to 0 if a bank was approached but no finance offered, 1 if a bank was approached but offered less than the full amount, and 2 if a bank was approached and offered the full amount
External finance sought from VC funds	An ordered variable equal to 0 if a VC fund was approached but no finance offered, 1 if a VC was approached but offered less than the full amount, and 2 if a VC was approached and offered the full amount
External finance sought	A dummy variable equal to one if the firm attempted to obtain external finance (i.e. additional to internal cash flows)
Amount ought	Thousand pounds
Percentage obtained	The percentage of external finance obtained by the business in the 1996-1997 period (as a fraction of the amount sought)
External finance obtained from banks	The percentage of external finance obtained by the business in the 1996-1997 period (as a fraction of the amount sought)
External Finance Obtained from VC Funds	The percentage of external finance obtained by the business in the 1996-1997 period (as a fraction of the amount sought)
R&D last year	A dummy variable equal to 1 if the firm did R&D last financial year
R&D expenditure	Firm's total R&D expenditures in 1996–1997. Measured in thousands of 1997 pounds
Turnover	Firm's total turnover in 1996–1997. Measured in thousands of 1997 pounds
Employees	Firm's total number of employees in 1996–1997
Profit	Pre-tax profits (losses) before deduction of interest, tax, and directors', partners' or proprietors' emoluments. Measured in thousands of 1997 pounds
Capital expenditure	Firm's total capital expenditures in 1996–1997. Measured in thousands of 1997 pounds
SFLG	A dummy variable equal to one if the firm accessed the DTI SFLG support scheme
Total competitors	Total number of serious competitors of the firm
Larger competitors	The number of the firm's primary competitors that are larger than the firm
Overseas competitors	The number of the firm's primary competitors that are overseas competitors
R&D integration	Does the firm do R&D continuously, occasionally or never?
Reason for firm establishment	How was the firm established? MBO, M&A, business spin-off, university spin-off or new start-up?

Annex 2 Correlation matrix

		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)	(xii)	(xiii)	(xiv)	(xv)	(xvi)	(xvii)
External finance sought from banks	(i)	1																
External finance sought from VC funds	(ii)	0,192172	1															
R&D activity (occasional)	(iii)			1														
R&D activity (continuous)	(iv)	0,166127	0,101084	-0,48154	1													
Dummy business spin-off	(v)					1												
Dummy MBO	(vi)		0,169489			-0,17952	1											
Dummy M&A	(vii)	0,249303				-0,13075	-0,10046	1										
Dummy independent start-up	(viii)			-0,12249		-0,51361	-0,39462	-0,28742	1									
Dummy university spin-off	(ix)	-0,11569				-0,12278			-0,26989	1								
Turnover	(x)	0,1968			0,1728						1							

		45			54													
Employees	(xi)	0,318914	0,132488		0,169572	-0,10442	0,41958	0,240143	-0,22272	-0,11234	0,636425	1						
Profit	(xii)						0,285778		-0,12844		-0,43572	0,213049	1					
Capex	(xiii)						0,293411		-0,10115			0,150909		1				
Total competitors	(xiv)	-0,1615			-0,11878										1			
Larger competitors	(xv)			0,10818	-0,20431										0,336164	1		
Overseas competitors	(xvi)				0,159875		0,233855						0,142008		0,251968	0,175022	1	
SFLG	(xvii)	0,250747	0,288069		0,155424					-0,12672						-0,11802		1

EXTENDING THE KNOWLEDGE SPILLOVER THEORY OF ENTREPRENEURSHIP FOR ANALYSIS OF THE AUSTRALIAN BIOTECHNOLOGY SECTOR

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ABSTRACT

Current research suggests that the process of knowledge creation is both networked and iterative. Synthesising the literature highlights a range of factors for analysis in knowledge-based industries. These factors are then used to examine the biotechnology sector in Queensland Australia, utilising available secondary literature, interviews with a range of broad stakeholders and 3 case–study companies. The results highlight issues regarding government policies for biotechnology, due to potential weaknesses in the network of relationships and governance between the key stakeholders (particularly within universities), the absence in some cases of relevant education (training and learning) for academics, and issues of entrepreneurial orientation and knowledge management in the use of created knowledge.

INTRODUCTION

The multi-faceted nature of innovation processes highlighted by Leyesdorff (2000) suggests that this phenomenon involves a range of relationships (e.g. with other firms, government agencies, universities) and learning and innovation occur through interactive, iterative and networked approaches (Weick, 1990; Cooke, 1998). The supply of such knowledge and its characteristics, also requires capable knowledge users and effective knowledge transfer/translation (Cooke et al., 1997; Braczyk and Heidenreich1998) to create commercialised outcomes in terms of product and process innovation and improved firm capacity and growth.

The arguments surrounding this can be encapsulated within the knowledge spillover theory of entrepreneurship. This argues, essentially, that knowledge developed in some institutions might be commercialized by other institutions, and that entrepreneurship is one way that the 'economic agent with a given endowment of new knowledge' can best appropriate the returns from that knowledge (Acs et al. 2004). Audretsch and Lehmann (2005) demonstrated, for example, that the number of new firms located close to a university is positively influenced by it's knowledge capacity. The complexity of knowledge intensive entrepreneurship, however, often creates barriers to exploitation. This may be result from (1) failure of private firms and public institutions to generate new knowledge; (2) failure of that knowledge to be disseminated efficiently; (3) failure of individuals to exploit new knowledge; (4) a range of other factors that make entrepreneurship difficult.

Spatial proximity also often positively affects knowledge spillovers from firms and research organisations, reinforcing the asymmetric economic geography of prosperity and accomplishment (Cooke et al, 2005). There is also evidence, however, that knowledge-creating collaborations as well as disseminating mechanism can be non-local in nature. A recent study into the effects of social capital found that both faster growing and more innovative small firms tend to make greater use of non-local networks (Cooke et al. 2005). In addition, Acs et al (2007) highlight that new knowledge can be imported into a region through the activities of foreign multinationals.

This paper, therefore, examine these issues, using the knowledge-intensive biotechnology sector in Australia as a case study, due to its nature as a knowledge-intensive industry, with clear knowledge spillovers potential in domestic and international markets, and strong government policies at both national and regional levels. The paper is structured as follows. First the literature surrounding the creation, dissemination and utilisation of knowledge, and the role of geographical proximity highlights a range of inter-related factors for analysis. Second, the methodology section evaluates the biotechnology industry against these factors, to establish its relevance, and the methods for analysing the Australian biotechnology industry specifically are outlined. Third, the results from the Australian biotechnology industry are then analysed in terms of knowledge creation, dissemination, and utilisation. Finally, conclusions are drawn concerning future policy for this his industry, and the potential focus for future research is discussed.

LITERATURE: KNOWLEDGE CREATION, DISSEMINATION AND UTILISATION MECHANISMS AND THE IMPORTANCE OF PROXIMITY

Knowledge Creation: Government, Universities and Industry

Etzkowitz and Leydesdorff (1997) developed the 'Triple Helix' framework, arguing that innovation creation occurs at the intersections between government, university and industry. Frenz et al (2005) discovered, however, that the level of UK firm-UK university cooperation is very low, concluding more generally, that firms must have a certain level of absorptive capacity (defined by the proportion of science and engineering graduates in the workforce, level of firm R&D expenditure, and organizational capability) before entering into cooperation with a university. Once established, however, this cooperation was found to have a positive and significant effect on innovation. They also argued that the most consistent finding to come out of regional total factor productivity growth studies was that the stock of human capital enhances the absorptive capacity of firms, facilitating local technology transfer, local and regional knowledge spillovers and growth.

In the knowledge-spillover theory of entrepreneurship (Acs et al. 2004), however, it is also argued that levels of knowledge-based entrepreneurship might be affected by (1) the ability of private firms and public institutions to generate new knowledge; but also

by (2) the degree to which this new knowledge is disseminated to the wider economy as well as (3) the degree to which individuals and firms are able to exploit this new knowledge. The absence of a domestic industry base and/or the absence of domestic knowledge-creating institutions, such as public research institutes, might mitigate against the emergence of knowledge-based entrepreneurship (Audretsch and Lehmann 2005), as might the absence of foreign multinationals in a region, able to import such knowledge from outside.

Additionally, however, individuals or organizations with market knowledge or other resources may not be aware of the new knowledge because of a lack of dissemination, and therefore fail to invest, or under-invest, in the knowledge or in new firms (Audretsch, 2004). Individuals may also fail to commercialise new knowledge via entrepreneurship, if they underinvest in commercialization activities or fail in their attempts to commercialize due to a lack of market knowledge, ability to manage the new knowledge effectively or insufficient entrepreneurial ability. As regional knowledge and innovation systems are dynamic and evolving, these issues can also be affected by the nature of the region itself.

Knowledge Dissemination: Structures, Learning and Governance

The role of knowledge and its characteristics therefore also needs to be evaluated through the lens both of the capabilities of knowledge users and effectiveness of knowledge transfer/translation (Cooke et al., 1997; Braczyk and Heidenreich, 1998). Links between entrepreneurial growth, innovation, and networking, for example, has also led to an increasing focus on entrepreneurial firms networked together in various ways (Asheim and Coenen, 2006), Gordon and McCann (2000) identifying three sets of advantages in geographically based clusters and networks, derived from agglomeration (i.e. from external economies of scale, scope and complexity).

Crucial here, are issues surrounding the management of networks, the structures and forums in which the actors operate and the role of education and training and processes of learning, to enable networked knowledge processes (Pickernell et al, 2008). There are a range of forums and structures, for example, in which and through which knowledge creation, but also dissemination can occur, including direct spinouts of companies, and collaborations with various stakeholder groupings from industry supply chains, government institutions and universities. Cluster and network-based

approaches also suggest a range of other formal and informal mechanisms in which knowledge creation and dissemination can also be encouraged. The suitability of the structures and for a used, however, will be factors of crucial importance in determining the success or otherwise of the knowledge creation and dissemination process.

Encouraging the take-up of new innovations through dissemination via education and training-based processes also allows individuals to be provided with knowledge about the innovation itself, as well as being inspired and convinced of the possibilities for success and mutual gain (Goffin, and Mitchell 2005). Such explicit, codified knowledge can, however, be encapsulated in formats and transferred to users who are able to interpret and utilise it independently from the context in which it was created, (Howells, 2002). The transfer of codified knowledge is not seen as strongly dependent on geography as codified knowledge can be transferred across geographic regions fairly readily, and reductions in costs and improved communications increase access to codified knowledge, rendering it less important as a source of competitive advantage. Tacit knowledge, it has been argued, however, does not always travel well, making it a key source of 'the *geography* of innovation' (Asheim and Gertler, 2005). This includes knowledge flows between firms, research organisations, institutions and public agencies that are embedded in a regional context. Frenz and Ougthon (2006), therefore, argue that, since proximity facilitates the transfer of tacit knowledge transfer and learning - both of which are important determinants of innovation - innovation activity takes on a strong regional dimension that may be reinforced by agglomeration economies in production and pools of skilled labour/human capital.

Effective and appropriate management of innovation creation and diffusion structures and forums are also vital to this process. In this respect, the three basic modes or mechanisms that can be applied are hierarchical state or corporation based, or the market, or social networks (Lowndes and Skelcker, 1998). Markets are sometimes, however, perceived as unable to adequately bundle the relevant resources and capacities between science and industry, and the complete vertical integration inherent in hierarchy restricts flexibility and incentives (Menard, 2002). Conversely pure networks of relationships based on trust and reciprocity are often insufficient forces to secure necessary directed outcomes (Rhodes 1997; Keast, and Brown 2002). Hybrid approaches therefore have the ability to limit or balance out the negative

effects of an over-reliance on one governance mode (Menard 2002), through exhibiting a number of possible combinations and re-combinations of contract and trust to form effective strategic partnerships (Schaeffer and Loveridge 2002). Again, the suitability of the management mechanism used in the situation at hand will be important in determining the success or failure of the creation and dissemination process, particularly given that there are a range of processes and motivations of importance when examining these issues, depending on the nature of the network being utilised.

The relationship between learning, structures and governance modes provides the mechanisms to bring participants (and the various stakeholders) together to share resources and knowledge that are present in individuals or organisations. One scenario, for example, might see a myriad of key stakeholders from industry, government, and institutions (including universities and government research departments), utilising these interconnected mechanisms to generate and disseminate knowledge, innovation, skills, and training, and to operate management and governance structures appropriate to their own particular circumstances.

Knowledge Utilisation: Knowledge Asymmetry, Knowledge Management and Entrepreneurial Orientation

In order to exploit knowledge created and disseminated through networks, there is also the crucial role that entrepreneurship itself plays in the process. In particular, entrepreneurs require appropriate personal 'knowledge', resources and management abilities, encapsulated in the factors of entrepreneurial orientation, appropriate strategic evaluations seen in asymmetric knowledge provision between existing activities and the innovation, and appropriate knowledge management (Senyard, 2007). The issue of knowledge asymmetry, however, is a complex one as new knowledge by its very nature creates knowledge asymmetry (or lack of proximity between old and new knowledge – Boschma, 2005). This asymmetry cannot be too large for firms receiving knowledge, however, as they will be unable to use the knowledge received, and some symmetry of information is thus critical for relationships development and success as it develops trust (Fukuyama, 1995, Baranson, 1990), which positively affects decisions to maintain the relationship and creates stability through shared understandings and norms. Knowledge asymmetries

exist because of differences in knowledge, business processes and resources (Brooksbank et al. 2007). Cimon (2004) further evaluated and categorised asymmetries as (1) information asymmetries; (2) knowledge asymmetries; and (3) learning asymmetries, with all three recognised as having a role to play in the process of organizational knowledge creation (Nonaka and Takeuchi, 1995; Ancori *et al.*, 2000), and arising from differing resource endowments (e.g. Barney, 1991) and absorptive capacity (Cohen and Levinthal, 1990).

The way in which this new knowledge is then managed will also be crucial for the strategic direction of the firm in many industries (Dyer et al., 2001). It is argued that firms should be able to increase their competitive performance through effective knowledge management, strategic learning and knowledge orientation, and that these are positively related to long term survival and growth (Salojarvi et al 2005; Matlay 2000). Salojarvi et al (2005) also state that firm success often depends upon an organisation's ability to create, utilise and develop knowledge-based assets. Despite this it is somewhat surprising that relatively few studies have examined the links between knowledge management and firm growth, instead concentrating on knowledge management alone (e.g. Kautz and Thaysen, 2001; Wickert and Herschel, 2001). Successful innovation requires managers to match 'technical' expertise, in areas such as technology and project management, with 'soft' skills in people management, to promote creativity. Few managers are either educated or experienced in both of these areas (Goffin, and Mitchell 2005, p. 27). Kirby (2004) thus advocates the use of Higher Education Institutions (HEIs) in promoting and reinforcing the development of such entrepreneurial skills in communication, creativity, critical thinking and assessment, leadership, negotiation, problem-solving, social networking skills, and time-management. These are all equally applicable to the creation and utilization of knowledge, the links with HEI also highlighting ways in which links can be made between external network and internal-firm-based processes.

Effective entrepreneurial behaviour is also necessary to prosper in competitive environments (Covin and Slevin, 1988, Lumpkin and Dess, 1996, Miller, 1983 and Zahra, 1993a). Within this context entrepreneurship, plays a pivotal role in facilitating links between research and industry (Abramson et al., 1997). Utilising Covin and Slevin's (1989) "basic uni-dimensional strategic orientation" concept a firm's behaviour can be categorised along a continuum that ranges from highly conservative to highly entrepreneurial behaviour in which a firm's position is referred to as its

entrepreneurial orientation (EO) (see Barringer and Bluedorn, 1999; Lumpkin and Dess, 1996). The three main dimensions of EO are innovation, pro-activeness and risk. Previous studies (see Table 1) have consistently highlighted a positive relationship between EO and performance.

Table 1: Dimensions of Entrepreneurial Orientation

Author	Dimension	Sample	Statistical Analysis	Study Conclusion
Lee, et al (2001)	Innovation, Risk Taking Pro-activeness	137 Korean Tech Start Ups	Regression, Correlation	EO has positive, marginally statistically significant effect on performance.
Voss et al (2005)	Innovation, Risk Taking, Pro-activeness, Competition Scanning, Autonomy	324 US Theatre Groups	Regression, Correlation	Relationship between stakeholder influence and EO behaviours is transparent, managers develop reciprocal, strategic relationships that reinforce valued behaviours. When the interaction between stakeholder influence and EO behaviours is less transparent, managers must perform a balancing act to contend with complex, pluralistic and conflicting stakeholder demands and responses.
Zhou et al (2005)	Opportunity Recognition, Environmental Sensitivity, Environmental change and challenges	China 350 respondents to brand	Structural Equation Modelling Factor Analysis	EO has a more positive impact on tech based and market-based innovation when competition is intense
Wiklund and Shepard (2005)	Pro-activeness, Innovativeness, and Risk taking	465 Swedish Manufacturing and services firm	regression analysis and correlation	EO positively influences small business performance. High EO, high access to capital, and environmental dynamism did not increase performance.
Poon et al (2006)	Innovation, Risk Taking, Pro-activeness	96 small firms	Regression, Correlation	EO did not mediate the relationship between internal locus of control and firm performance. EO is a necessary mediator of the link between generalized self-efficacy and firm performance.

The Issue of Proximity: local and Cross Local Linkages

Despite the importance placed on geographical proximity in the literature (highlighted earlier for example in relation to tacit and codified knowledge), there is also evidence that knowledge creation, dissemination and utilisation processes can also have a wider geographical dimension. Boschma (2005), in particular, identifies five dimensions of proximity that can have an impact on learning and knowledge, and which, crucially, do not necessarily require geographical proximity. He argues that the need for

geographical proximity for learning to occur is weak when there is a clear division of precise tasks that are coordinated by a strong central authority—organizational proximity—and the partners share the same cognitive experience—cognitive proximity (Boschma 2005: 69). He further suggests that spatial lock-in may be solved or even avoided by establishing non-local linkages. Findings from several empirical studies also suggest that non-local as well as local relationships are important sources for interactive learning (see Asheim and Coenen 2006, Jaffe et al. 1993, Feldman 1994).

Boschma (2005) suggests that shared formal institution structures [such as laws, rules and regulations that are the subject of governance] are not necessarily bound by geographic proximity. Instead, institutional structures can reflect a kind of balance between institutional stability (reducing uncertainty and opportunism) openness (providing opportunities for newcomers) and flexibility (experimenting with new institutions). To satisfy the need for co-presence to exchange tacit knowledge, cross-location networks could also bring people together through, for example, occasional travel (Boschma 2005). Asheim and Coenen (2006) argue, therefore, that there is a need for both local and distant networks for effective process and product innovation. This highlights the need, for factors related to knowledge (and its influence upon innovation and growth) to be examined within firms' entrepreneurial processes at both local and cross-local levels.

Summarising the Factors for Analysis

Synthesising these multi-faceted relationships between knowledge, how it is disseminated through the network, innovation processes and growth, creates a comprehensive range of factors for analysis, which can be listed under the following headings:

- *Knowledge-creation* relationships between firms, government and its agencies, and institutions, such as universities).
- How *knowledge-dissemination* occurs though the structures for disseminating knowledge (e.g. via spinouts, alliances, collaborative networks etc.), management and governance of the relationships between the sets of

stakeholders, and the education, training and learning required for effective dissemination.

- *knowledge-utilisation by the companies themselves for innovation-specific and more general growth-related outcomes*, by examining knowledge asymmetry (degree to which the knowledge is new / overlapping with existing knowledge), its management and synergy with strategic behaviours and plans that relates to entrepreneurial orientation in maximising the benefits of the knowledge.
- *Proximity issues* by evaluating the role and importance of local versus cross-local creation, dissemination and utilisation mechanisms

METHODOLOGY

In order to examine the absolute and relative importance of the identified factors, however, there is a need for in-depth study within knowledge-based industries. This requires a methodology that determines first a suitable industry for analysis, then a suitable region / nation, to provide a case study setting. Lastly, relevant methods of gathering the data are required.

Case-Study Industry Identification

Available literature recommends that owing to the myriad of stakeholders (governments, between university and within university relationships, external businesses including domestic and international partners, venture capitalists, contractors etc), and the complexity in both knowledge seeking and knowledge requirements, the biotechnology industry may be suitable for the in-depth study.
Governments assist in the development of a biotechnology industry through a policy framework aiming to compensate for market failures (Orsenigo, 1989). Access to resources and incentives, in particular financial resources from government, is of great importance in any theory explaining biotechnology (Harman & Harman, 2004),

as without this, the level of R & D spending may be less than the optimum for the economy (Erskinomics Consulting, 2003).

Knowledge in the biotechnology firm also often evolves as a result of synthesis of scientific, technological and business knowledge, and managerial skills, these knowledge systems coevolving as the firm develops (Liyanage & Barnard, 2003), often occurring between university and within university relationships. Therefore a firm's capability is a continuous synthesis of scientific, technological and managerial skills and knowledge requiring input from organisational learning and management strategies (Lane & Lubatkin, 1998; Zahra & George, 2002; Zollo & Winter, 2002) The advancement of the biotechnology industry is thus critically bound by knowledge and information asymmetries associated with scientific, technological and business related knowledge (Murray, 2002). Finally, in terms of the geography of relationships, Cooke and Laurentis (2006) found, for example, that UK universities and firms in the UK biotech sector, commonly enter into collaboration with overseas partners in addition to partners within the UK, for product innovation, distribution, licensing deals and supply contracts; and as such the UK biotechnology sector operates in a global marketplace. With specific regard to innovation, as distinct from other interactions such as research, joint patenting, purchasing or supplying, and other more informal collaboration, the act of commercialising new knowledge in the form of a product or service new to the firm or new to the market, Cooke and Laurentis (2006) found that UK biotechnology firms also innovate collaboratively. In the absence of distant spillovers from other sources, these firms often form collaborator relations with 'distant networks' to augment R&D knowledge for themselves. These occur broadly equally in the EU and North America, as well as more extensively in the home country itself.

This suggests that the biotechnology industry generally exhibits the knowledge generation, dissemination, utilisation mechanisms highlighted in the literature. In order to examine these processes in more depth, however, the cases were developed using Australian firms. Australia is often perceived to suffer from "smallness of domestic markets" (Felsenstein and Portnov 2006) and owing to this, their spatial proximity relationship profiles are of interest. This research and analysis occurred within the 2005-2006 period, when Australia's biotechnology industry was experiencing growth. Market capital as at December 2005 for biotechnology, medical devices and other healthcare companies whose stocks are listed on the Australian

Stock Exchange (ASX) is A$42.4 billion (157 companies) up from A$27.1 billion in 2004 (Australia Government Initiative, 2006). Partly as a result, Australia now has more biotechnology companies relative to GDP than any country except Canada **(**IMB 2005). In 2006, there were 427 core biotechnology firms with 625 firms in medical devices (Ausbiotech 2007). The majority of these being small to medium enterprises, recorded in the Australian biotechnology industry (Hopper & Thorburn 2005). There is, however, a relative paucity of research of this important industry in the Australian context (Senyard, 2007), and in particular, an evaluation of the factors of importance to government policy when seeking to encourage the industry's successful development and growth.

Table 2: Summary of Case Study Firms' Background Data

Title	Case One (TT)	Case Two (PB)	Case Three (GT)
SUMMARY DATA:			
Type of Firm	Start Up (R & D)	Private	Ceased Operating
Fora for Knowledge	University	Industry	Incubator
Knowledge (IP)	Patents Secured	No Patent until later	8 Patents
Product Definition	Platform is a patented, defined, set of protein complexes	Diagnostic technical platforms includes enzyme-linked immunosorbent assay (ELISA), indirect fluorescent antibody test (IFA) and rapid lateral flow devices	Blood-based monitoring tests for performance animals, initially the performance horse
Stakeholders	Academic Scientist Director Commercialisation Manager	Scientist/CEO, Founding Members, Board of Directors	Academic Scientist, CEO, Board of Directors
University Role	Positive Start Up, Continuing Relationship	Negative Prior Start Up Experience with University	Minor prior commercialisation role at university , Indirect use of university resources (knowledge) translated to own IP
Government Role (Funding)	Yes	Yes (later)	Yes
Board of Directors	Scientist did not want to be on Board	Scientist is currently on Board	Scientist wanted to be on the Board but did not
Strategic Orientation	Technology Driven: Target: Big Pharmaceutical (further funding)	Customer Driven, Target End customer (Hospitals	Technology/Market Driven. Target: Equine Industry

Data Selection Methods

A 3-stage data selection process was chosen to examine the issues in the Australian context, with questions concerning proximity also built into each of these stages. First analysis was conducted into available secondary literature sources, to establish the knowledge creation environment. This was combined with (15) in-depth face-to-face semi-structured interviews, to explore knowledge dissemination. The interviewees were purposively selected (e.g. see Patton, 1990), according to their differing roles in the management and governance, fora and structures, and learning processes which surround knowledge dissemination. These stakeholders in the 'triple helix' came from Industry (industry association Ausbiotech members, commercialisation managers, venture capitalists, biotechnology employment specialists, entrepreneurial managers of established start ups) Government (both Federal and State-level), and University (science academics, commercialisation managers).

Finally, 3 case study companies (again purposively chosen, this time for their divergent experiences, summarised in table 2) were also analysed in-depth, to examine the role and importance of the internal firm-level activities in knowledge utilization (commercialisation) processes.

The three case studies of firms show varying stages of firm development.

The first case study is still conducting clinical trials and is publicly listed on the Australian Stock Exchange. It retains close links with its affiliated university (who retains share ownership) and is, at present, looking for large global pharmaceutical partners to continue product development.

The second firm, the most established of the three, has been very successful in the global markets and continues to develop new products.

The third case study evaluates a business which no longer operates. The cases were purposively selected to highlight different outcomes, product definition, age, and provide a snapshot of knowledge utilisation behaviours (entrepreneurial orientation), knowledge asymmetry, and knowledge management characteristics of the companies.

The three key individuals chosen for interview from each case-study company were: the scientist who developed the science/technology and sought to commercialise the product/service; the individual who provided the key relationship for business information and processes during start up; and the current CEO.

The case-research again used a semi-structured interview guide on topics of knowledge asymmetry, entrepreneurial orientation, relationship characteristics including proximity themes and impacts on relationships developed.

Data Gathering and Analysis

Bothe the secondary literature review/industry interviews and cases including interviews were used to examine knowledge creation, utilization and dissemination processes. First, owing to confidentiality arrangements, the individuals and companies are not explicitly identified in the results. The interview-based research in industry interviews and case interviews developed protocol that included open-ended questions to allow a natural conversation flow around the common set of issues (Patton, 1987). The interviews conducted lasted between one and a half and two hours. Individuals sought were first telephoned, explaining the request and research being conducted. This was followed up by an e-mail document and request for interview. A follow up telephone call the week after the e-mail was sent guaranteed a high response to requests. Interviews were then conducted during the two weeks following the follow-up telephone call where possible, in environments that were suitable for the respondent, in most cases, their offices.

The interviews were recorded on mp3 audio. This was transcribed into a hard copy format. Where necessary, the initial interview was followed up by a further interview to clarify responses. A database of responses was then created, containing the answers of all the interviewees to the specific topics. Analysis of the interview data was then undertaken using the five stage analysis process suggested by McCracken (1988). The first stage involves treating the statements in the interview on their own, without making connections to other parts of the interview. In the next stage observations are developed, individually, then according to the evidence contained within the interview and then according to the literature. The third stage involved interconnecting these developed observations by use of previous literature. The interview schedule/transcript was then used only to check the ideas as the observation comparison process is undertaken. The fourth stage involved collective analysis of the collected, developed observations and statements, to subject them to analysis, to investigate any consistent themes or inconsistencies which may be developed. In the fifth and last stage, these themes and patterns were investigated through the interview programme as a whole, to examine the themes amongst the interviewees.

Table 3: Official Knowledge Creation Strategies

Package	Overview	Total Funding and Duration	Key Knowledge Support Strategies
Backing Australia's Ability (BAA I and II)	General science and Innovation package, focused on three key elements in the innovation process: • strengthening Australia's ability to generate ideas and undertake research; • accelerating the commercial application of ideas; and • developing and retaining Australian skills.	Total duration: 2001-11. Total Funding: $8.3billion.	**Developing and Retaining Skills** The package supports the long-term sustainability of Australia's skill base in the enabling sciences and the encouragement of positive attitudes toward science and innovation in the community. It promotes this by: • Funding an extra 5740 higher education places in ICT, mathematics and science at Australian universities ($350.5m) • Improve teaching in Innovation, Science, Technology and Mathematics ($38.8m) • Enhance capabilities of government schools to build stronger scientific, mathematical and technological skills of Australian students and to encourage school-based innovation ($373m). • Questacon Smart Moves: an initiative to raise awareness of science and innovation among young Australians and encourage participation in science and innovation industries ($15.1m) • Science Connections Programme: initiative to raise awareness of the contributions of science and innovation in the broader Australian community ($25.8)
National Biotechnology Strategy (NBS)	Provides a framework for the development of biotechnology in Australia. The strategy addresses six key themes: • Biotechnology in the community; • Ensuring effective regulation; • Biotechnology in the Economy; • Australian biotechnology in the global market; • Resources for biotechnology ;and • Maintaining momentum and coordination	Total duration: 2000-08. Received initial funding of $30.5m in 2000, followed by additional contributions of $66.5m and $20m through BAA I and II.	**HR for Biotechnology Development** The key objectives are: • enhance management skills in the biotechnology sector; • attract high quality researchers and experienced leaders; • encourage entrepreneurship; and • monitor demand and supply for specialist skills. The key strategies are: • Improve management of research, intellectual property and technology within established firms and new enterprises; • Develop, attract, motivate and retain high quality researchers, particularly in those fields where Australia has strong capacities to commercialize research outcomes; • Maximize technological awareness and capabilities throughout industries that will be developing and applying biotechnology • Develop programs and systems to foster entrepreneurship • Monitor emerging skills needs in the biotechnology sector and develop appropriate responses.

Source: Stephens et al (2006)

RESULTS

Knowledge Creation: Overall Context

The results of the industry interviews conducted are now briefly outlined in terms of examining the context and role of the 3 main sets of stakeholders (the industry and its firms, government and university). In terms of the Australian biotechnology industry's stakeholders and knowledge creation policies, there has been a particularly strong Australian federal government policy in place, in conjunction with university institutions and the government, as highlighted in table 3.According to Stephens et al (2006), Australian biotechnology, has a research strength underpinned by its universities, its federal research body (Commonwealth Scientific and Industrial Research Organisation (CSIRO), and other leading institutions. The majority of Australian biotechnology firms in 2004 (60 per cent) are less than six years old (Department of Industry Tourism and Resources, 2004) and the industry is developing through small, dedicated entrepreneurial firms staffed mostly by scientists (Curtis et al, 2006). Australian State Government initiatives have also shown an increased focus on biotechnology research creation, dissemination and utilisation agendas. Specifically, current programs developed by the Smart State Strategy (Queensland Biotechnology Strategic Plan 2005) include:

- Smart State Innovation Projects Fund: Consists of $60 million over the next four years to support national and international alliances and collaborations between research organisations and industry.
- Biotechnology Commercialisation Pipeline: Assists new biotechnology firms to access private sector finance and enables them to progress along the commercialisation pathway.
- BioStart Fund: Provides access to early stage financing for startup firms.
- Current commercialisation training opportunities will be extended through the
- Mentoring for Growth and Innovation Start-Up Scheme program.
- Queensland Biocapital Fund: Through the QIC to l stage later venture capital financing to ensure the establishment of globally competitive bio-businesses.

- The Government will raise investor readiness by encouraging participation in the Commercialisation Bootcamp and Masterclass Program through the Australian Institute for Commercialisation.
- Smart State Innovation Skills Fund: Providing A$ 12 million to attract and retain leading scientists and build skills in Queensland.

The biotechnology industry provides a context of strong government support and policy initiatives related to the creation and use of knowledge, with a strong potential role for universities in developing the industry, but also with key governance issues concerning how these knowledge processes can be managed and developed for the most effective outcomes, given the different stakeholders involved, both domestically and internationally.

Knowledge Dissemination Processes

Interviews with (15) key industry stakeholders indicated question marks over the (strong) role of government hierarchical-based management in focusing university agendas in particular, in biotechnology and commercialisation. As previously shown, governments through financial provision to biotechnology programs also influence knowledge dissemination processes through funding reporting requirements that impact what type of information is disseminated, to whom and frequency of this dissemination. An inability to satisfy these reports places doubt on future funding and further development. Traditionally responsible for funding basic vs applied research, governments are now shifting greater commercial responsibility on universities and a focus on managing outcomes:

> '*The main change has been really almost foisted upon universities by government policy and that is the sense that they have to manage the outcomes of their research, which was never ever something that was really on the agenda in universities. Ten years ago it was that there would be papers published, there would be a contribution to the academic arena, but there would not be necessarily be any transfer of that information into commercial value or into industry.*' JC

Unsurprisingly, therefore, management and governance conflicts occur between the commercialisation agenda and the university bureaucracy and traditional social agendas:

> '*There are additional pressures of managing the conflicting roles within academia. It's actually very difficult to be entrepreneurial in a professional bureaucracy and universities are the classic professional bureaucracy…Essentially universities as professional bureaucracies have really got to – well the mantra is that everybody is equal, okay. But in business, everybody is not equal and that's the dilemma that you have when you're an entrepreneurial scientist in a university.*' JC

The more-market based current approach to exploitation of university knowledge, in a university model otherwise characterised by more hierarchy-based mechanisms also highlights the key role of the commercialisation manager, who has to act as a conduit between government and university policy, and the needs of industry and academic scientist. The process of undertaking this role, however suggested much greater use of network-based governance for commercialisation managers, particularly with regard to their relationships with academic scientists.

> '*Researchers understand that they've got to have a conversation with someone that's knowledgeable before they take that particular publication. [However] clearly you can't have a commercialisation officer company vetting every publication*.' AMB

The university context also adds another dimension that affects the relationship between the scientist and commercialisation manager, because the commercialisation process is an additional role to the one traditionally carried out by academics.

> '*Remember as business manager, commercialisation manager, you've got no power to make people do anything, particularly in universities. I mean in business you say "Okay, if you don't want to do that, you'll have to leave the*

organisation." In the universities "If you don't want do that, I can't stop you." There's no power within the system.' JC

This highlights the varying motives and outcomes that the commercialisation manager has to manage: the scientist and their motive to publish, the university and their motive to dissuade the scientist to publish if it will reduce the value of the IP and potential returns for the university, and the motives of the commercialisation manager who wants to manage the information to give industry and government a compelling proposition to attract significant funding. Developing a cooperative culture between the business units, universities, and government was therefore recognised as integral to the relationships needed:

'*So you need people in universities – and there are not many of these people – who can bridge that gap between the science and the science culture and the business and the business culture*.' PR

In contrast to the hierarchical governance push on universities and industry from government, commercialisation can occur through spinouts as a way of disseminating knowledge seemed to be more towards a market-based approach than hierarchical. An examination of the commercialisation structures utilised by universities themselves, also highlights a focus on more market-based governance modes, separated from other parts of university management, with continuing conflicts between this and more traditional university approaches.

'*Commercialisation is not a core business for the University. That's why – I think that's why [a University name omitted] puts it out into [its commercialization unit name omitted], because it's not actually a core business. Whereas their core business is education, teaching*.' JC

In terms of the impacts on learning processes, however, the inherent challenge for the academic scientist however, is how to manage the additional commercial responsibility produced by these changes:

'*There's always this tension. When you're outside the system you think "why don't they do this? Surely they want to commercialise what they've done". But when you're in a university you're fighting for grants, you've got PhD students, you've got your teaching work, you've got your research, you've got your administrative duties, and then they want you to commercialise. Yeah, and you've got insecurity of tenure. …*' AMB

This also had a knock-on effect on perceptions of the structures and fora for dissemination in place. Specifically respondents recognised similar results in start-up behaviour in universities, questioning the "forum" (i.e. starts- ups), as a result being utilised for knowledge dissemination (and utilisation) :

'*And part of [the university] their charter was to create X number of spin-outs in a certain amount of time…Whether any of them would be useful or not is another thing and also the state government at that stage had a particular funding scheme that allowed, [name omitted], to set up spin off companies and get funding for them. …They have a certain amount of intellectual property; they're managed by the head of the [name omitted, commercialisation unit] plus a commercial development officer who's working on it part time and it's pretty much a cart without wheels. It just sits there and does nothing*.' RIB

The appropriateness of the allocation of funds to public institutions including universities for research and developments versus private institutions and research centres was therefore questioned by several industry respondents:

'*You look at the major recipients of funding out of government. Go back and look at the last seven years, since they announced in 1999 that they were going to concentrate on biotech. Have a look at all the funding for life scientists you'll find about 95 percent has gone to universities*.' KA

Following this agenda, government funding and start-up programs have reflected in changes of start-up behaviour. Several respondents argued that this may just be an indication of being able to access funds, rather than the policy creating sustainable firms or growth.

'*For instance, the state government in grants that invest in commercialisation of new technologies have to be granted to a company. So you see universities doing things like forming a small, really, shell company, so they can take an $80,000 ISIS grant or a $100,000 COMET grant because they have to, not because it's necessarily the right vehicle to put that piece of IP in at that point in time.*' AMB

The evidence presented therefore highlights a number of different knowledge governance modes at work simultaneously in this industry in knowledge dissemination processes. Specifically, a strong government hierarchical mode is seemingly in place between the main stakeholders of government, industry and universities. Simultaneously there appears to be an incomplete move towards a more market-based regime for universities in dealing with commercialisation, and seemingly more reliance on network-based modes within universities between the scientists and the commercialisation manager, to deal with the additional emphasis for universities to commercialise their knowledge.

Table 4 : Knowledge Utilisation Processes: Case Study Results

Process	Case One (TT)	Case Two(PB)	Case Three (GT)
Knowledge Asymmetry	No	No not for management team, Yes between scientist and board	Yes Various forms
Knowledge Relationship EO: Risk Taking for Scientist	Calculated (Remained in position, though uncertain outcomes, support by stakeholders)	Very High Risk (Customer/market driven) Market Leader	Very High (Scientist left job, International set up)
Knowledge Relationship EO: Proactiveness	Very High (Prioritised)	Very High (Left job, mortgaged house)	High (Opportunities recognised, difficulty with timing and funding)
Knowledge Relationship EO: Innovativeness	Suite of Potential Applications for Platform	Very High (Customer/market driven) Market Leader	Product Definition failure
Knowledge Management: Trust	Yes	High between founding members	None (Board and CEO)
Knowledge Management: Communication	High Weekly, Informal	High, Weekly, Informal at commencement, Reduced as progress (Board vs Management) More Structured as more established	Low ties with Board (proximity?) High level of communication between staff and management
Knowledge Management:	High	High commitment at commencement	High at commencement Low at cessation

Commitment			

Knowledge Utilisation Processes

The case study firms exhibited different outcomes, product definition, age, and thus provide a snapshot of differing categories of knowledge asymmetry, knowledge relationships seen through entrepreneurial orientation and knowledge management. This did allow, however, analysis of how the factors highlighted as of importance to knowledge utilisation worked differently in the 3 case study examples, as table 4 illustrates

In comparing the three cases in terms of the key constructs of knowledge asymmetry, entrepreneurial orientation and knowledge management, the following key differences can be noted.:-

- The failed case (3) displayed more knowledge asymmetry, compared with other two. In terms of knowledge relationships, the failed case exhibits, in particular, a product definition failure in innovativeness, compared with the other cases. In terms of knowledge management, trust and communication were particularly poor in the failed company compared with the others. Knowledge asymmetric behaviour was exhibited in two cases, both between the scientist and the board of directors with restricted information flow on strategy and science. This lack of communication has further implications for accurate strategic decision making and the 'best way forward' with the potential to make less effective decisions as a team.
- All three cases show high levels of knowledge relationships through entrepreneurial orientation. This is not unusual based on the inherent nature of the biotechnology industry. High levels of pro-activeness and risk taking behaviours were seen in cases two and three, with the first case shown moderate risk behaviour.
- There are interrelationships not only between knowledge management characteristics of trust, communication and commitment but also between elements of communication and commitment and asymmetric behaviours, risk and trust constructs, and knowledge asymmetry and perceived risks.

To summarise, therefore, unlike cases one and two, case study three experienced faults particularly in knowledge asymmetry, knowledge relationships and knowledge management characteristics. The three cases also highlight the complexity of the interrelationships between the factors in these biotechnology firm start-ups.

Proximity Issues

In terms of the role of local and cross-location national and international linkages with a variety of stakeholders for knowledge creation, there are specific issues related to attracting and retaining talent in the Australian biotechnology industry highlighted by Stephens et al (2006). Fontes (2006) has also recently highlighted that biotechnology firms also form collaborator relations with 'distant networks' (Fontes, 2006) to augment access to their own research (often-non networked) knowledge spillovers from their own localities.

Knowledge Dissemination Overall

In terms of knowledge dissemination, the interviews with key industry stakeholders highlighted that the role and importance of geographical clustering of the industry was not clear-cut:-

> '*What is happening is that with the [name omitted] and the [name omitted] and a few other smaller features we are getting clustering but it's not in the like industry. So you are going to get a few biotechnology firms coming together and we are still getting minor cross fertilisation and some synergy but not to the extent of the actual clustering theory*.' JK

This also highlights the use of universities in knowledge spillover indirectly through the provision of centralised facilities, education and training. This may assist in innovation dissemination in ways other than spinouts, university proximity also being discussed in terms of providing (agglomerational) access to resources.

> '*You are also finding more satellite-like clusters coming out of universities. I don't think it's an issue of dependency on the universities. It's more like a security blanket, of the university is right there, and from the scientists who utilise not only the human capital but also the equipment capital*.' JK

Knowledge Dissemination Cases

Finally, in terms of knowledge dissemination, table 5 below indicates that for cases one and two international linkages seemed to be beneficial to utilization. For case three, however, the cross-local linkages seemed to increase knowledge asymmetric behaviours, re-emphasising the lack of effective knowledge management in this case.

Table 5: Proximity Issues in the Case Studies

Title	Case One (TT)	Case Two(PB)	Case Three (GT)
PROXIMITY ISSUES			
International Linkages	Use of International and bonding networks (informal) in product development, bridging networks in business development	During start up, limited international links as business developed further extensive links including international markets and further links including international partners in continuing product development	International bonding for processes for product development, and sought international markets. Potential to move internationally with pressure from the board increased asymmetric behaviours within the team and created further complications during business development.

Thus, the role and importance of proximity seems to differ depending on whether the process in question is knowledge creation, dissemination, or utilization based. In addition, for utilization processes, it may also be interdependent with knowledge asymmetry, EO, and knowledge management processes at work within individual companies.

CONCLUSIONS

These results indicate the heavily government-influenced nature of Australian biotechnology industry-policy both in knowledge creation and knowledge dissemination mechanisms, the evidence suggesting a very hierarchy-based approach from government. This contrasts with the more market-based approach towards which university management of spinout processes seems to be moving, and the seemingly more network governance based approach that commercialisation managers are employing in their dealings with the academic scientists, highlighting hybrid governance currently at work, with respondents questioning the effectiveness of such behaviour. Commercialisation managers are the conduit of information flows between

government and policy, the central university research program and academic scientist. They therefore need to separately manage a plethora of complex relationships being generated from disparate motivations and stakeholders seeking differing outcomes, using and being affected by different governance modes. These include the relationship between the commercialisation unit and scientist, the relationship between the commercialisation unit and the central university research programs. In terms of knowledge utilisation processes, the case-study evidence indicates that the factors identified in the literature were of both of relevance and are interlinked both with each other and also with issues related to the impact of local and cross-locational linkages.

Broadly, the data presented indicates that the factors identified from the literature in terms of knowledge creation, dissemination and utilisation are of relevance. There is, however, also a clear need for further research which allows a more developed understanding of how the factors interact with each other and with issues of proximity. In particular, a wider range of firm cases needs to be examined in order to examine more fully the constructs of knowledge asymmetry, entrepreneurial orientation and knowledge management, in order to both analyse their importance and their interrelationships with knowledge creation and dissemination mechanisms.

In terms of policy for the Australian biotechnology industry, however, the results as they stand suggest the need for improved dialogue between the stakeholders in such new firm development, both in the external environment and internal to the firm itself. Recognising differing research agendas, expectations and motivations of knowledge creating actors involved, and their perceptions of knowledge dissemination processes, may also create better appreciation and understanding of knowledge utilisation outcomes. The role of the university commercialisation manager seems one key area for focus, as is, potentially, knowledge management within the firm itself.

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