Using intellectual property to map the organisational evolution of firms: Tracing a biotechnology company from startup to bureaucracy to a multidivisional firm

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Abstract

The concomitant rise in the number of technology firms, US issued patents, and patent communications has forced researchers to investigate how such publicly known information can reveal characteristics and/or verify predictive models to describe the R&D-intensive firm. Here, we propose viewing the Boisot Information Space model through the lens of intellectual property as a means to describe and trace the organisational evolution of a technology firm. We map the model's dimensions – viz., codification, abstraction, and dissemination – onto publicly available forms of tangible (eg, patents, publications) and intangible (eg, trade secrets) knowledge assets to show that the model may accurately describe the social dynamics of a biotechnology company as it evolved from a 17-person startup to a >500 person multinational drug development company. This result relates to the firm's abilities to manage both tacit and explicit knowledge. A discussion of the limitations of the proposed model is described.

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INTRODUCTION

There has been a concomitant rise in the number of technology firms and the number of issued US patents (see Figures 1 and 2). Also, and most interestingly, there seems to have been a statistically significant concomitant rise in the communication of patents with that of the number of issued US patents over the recent years (see Figure 2). The Spearman coefficient of 0.85 ($r_s = 0.8452$, p-value < 0.0001) suggests that there is a strong positive correlation between patent issuance and patent communication and

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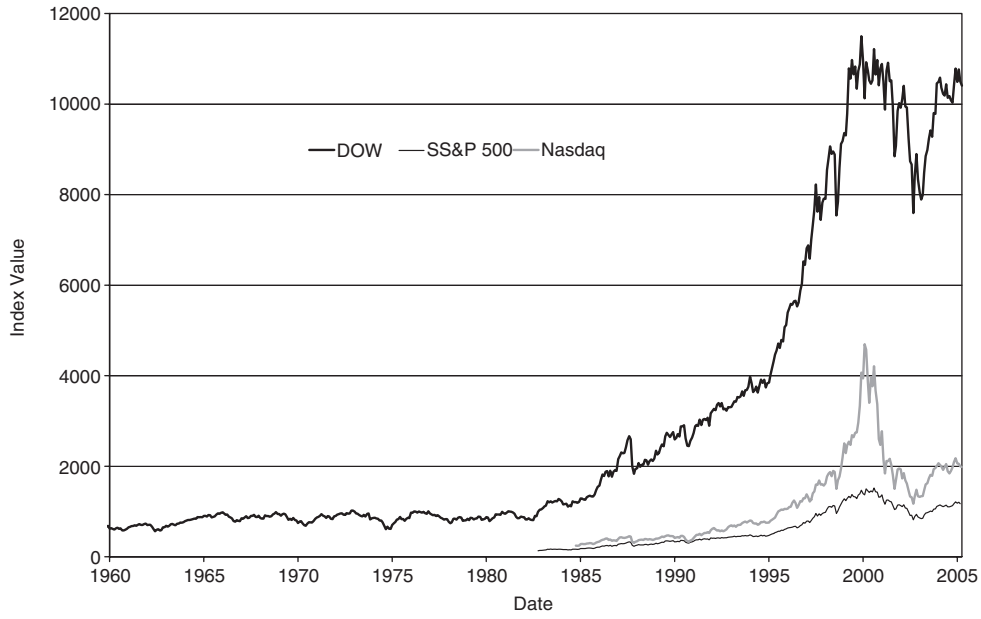

Figure 1: Time evolution of index value for the various US stock exchanges. Notice the rapid rise in index value since the late 1980s

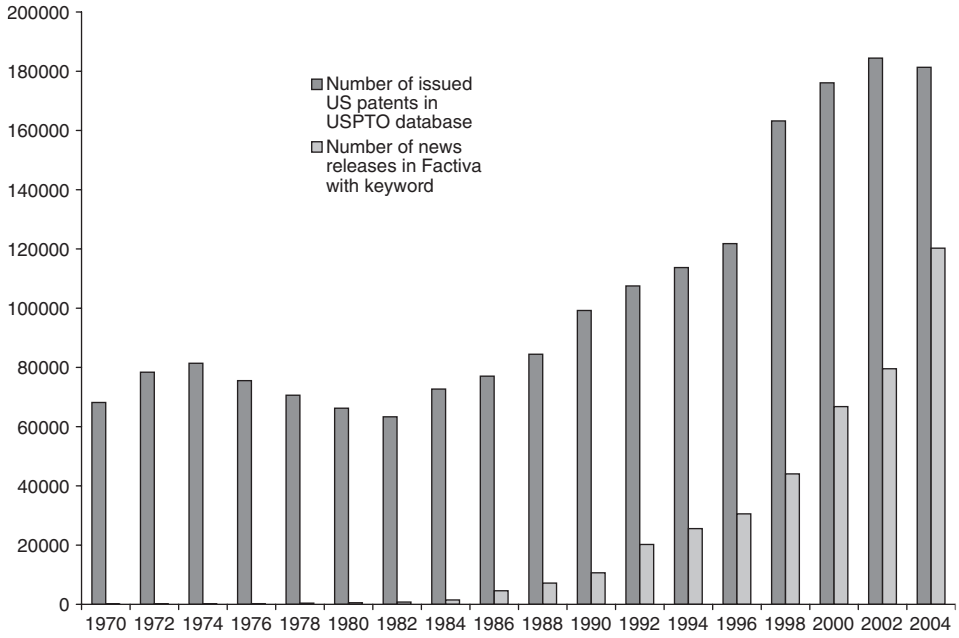

Figure 2: Time evolution of the number of patents in the US Patent and Trademark Office database and the concomitant rise in the number of news releases in the Factiva database with keyword 'patent'[24]. Since we were interested in the absolute value of the number of patent journal articles, normalisation was not performed. The Spearman correlation coefficient between the two distributions was calculated on the SAS system. We note that there is probably an aetiological link between patents issued and their communication; however, a more robust calculation is warranted to understand the exact nature of this correlation since many Factiva news releases describe drug discovery ethical issues, among other contentions media related data

media coverage (using Factiva as a proxy measure for patent-related business information). Anecdotally, these pieces of information have led researchers to investigate intellectual property (IP)-oriented organisational features of the R&D-intensive

firms.[1–4] The goal of such research is to elucidate and/or assess challenges and practices of IP-producing firms as they attempt to create and appropriate value.[5,6]

One unique feature of such R&D-intensive firms is its focus on knowledge assets (KAs) since such firms are noted by their dependence on data and information – particularly those typically found within the various biopharmaceutical industries. KA arose from these firms' attempts to economise data processing; the transformation of raw data into meaningful information that can be commercially exploited.[7] One approach to qualitatively measure the degree of data economisation of KAs was that of Boisot,[7–12] who introduced a 'single integrated conceptual framework' – termed the Information Space (or I-Space) – that takes into account the degree to which data are codified, the degree to which the data can be understood, and the degree to which the data are effectively communicated over large audiences. The proposed three non-overlapping and independent unit vectors for constructing the I-Space were called: codification, abstraction, and diffusion, respectively. Points within the I-Space detail the degree of their respective vectors for a particular unit of data or information, while flows within the cube can be interpreted either sequentially or chronologically. The I-Space model has been used to investigate firms, industries and countries, including theories of learning and culture,[8] organisation growth,[9] database comprehensiveness comparisons,[13] among other applications.[12]

In this paper, we use and define KA and IP as being in all respects equivalent. That is, types of knowledge[14] can be categorised into types of IP. For example, at one extreme, tacit knowledge in which the process cannot be codified (such as riding a bike) is simply a type of trade secret; whereas, at the other extreme, explicit knowledge in which the process can be well codified (such as a chemical reaction) can be represented as a copyright, defensive or offensive publication, patent or a codified trade secrete.[15] An e-company's list of client e-mails, its main knowledge (complementary) asset, would be protected by the firm as a trade secrete and would represent another illustration wherein a KA type is actually an IP type. Further, we have interpreted patents and patent applications as highly codified (tangible) embodiments of data and interpretations of data to support the creation of commercially interesting inventions. There is, however, a difference between patents and their applications. The former has been affirmed by the appropriate federal organisation (eg, the US Patent and Trademark Organisation) to meet certain legal requirements, while the latter contains the information as thought to be necessary by the inventor or technical writer (eg, a patent agent or patent attorney). Trade secretes may be considered in most cases as intangible embodiments of individual, group, tribal (see Discussion below), or firm-wide knowledge. In the typical case, the levels of codification between patents and trades secrets are different, and as can be seen can be qualitatively and relatively mapped onto the notions of codification as defined to formulate Boisot's model explained below.[4]

Lastly, we also define firm publicly available 'generic' information (such as press releases, media reports, publications, important published regulatory documents) as a form of IP (one can argue as copyright or high-level notions of its trade secretes). This offers the opportunity to utilise publicly available publications to learn about the organisational features of the firm. This feature of leveraging IP to understand the firm's social structures, an unique application to areas of organisational design, human resource competitive intelligence, and IP due diligence important for mergers and acquisitions, competitive benchmarking, executive (and technical) recruitment, and other important managerial areas.

In this note, our goal was to utilise the Boisot formalism as our theoretical schema to build a 'predictive' model of the organisational evolution of a technology firm; we define all company data and information as a form of tangible or intangible IP leveraged to create and appropriate economic value. To the author's knowledge, such an approach has not been previously presented in the literature.

Here, the IP-viewed I-Space model was applied to assist in understanding the organisational evolution of a biotechnology firm: from its startup as a 17-person spin-off to its recent position as a >500-person multinational drug development biopharmaceutical company. This paper is outlined as follows: the next section reviews and further defines the I-Space model. We then describe the firm's growth from startup to multinational company using information gathered from the firm's website and other publicly available sources. We focus on learning more about the firm's 'foci of power', wherein key staff is found to hold the most powerful levers of the company's intelligence. We conclude with a discussion of the merits and limitations of the approach.

THE I-SPACE MODEL: ELEMENTARY DEFINITIONS

Here, we briefly review the I-Space model; interested readers are referred to Boisot's works[8,9] for further information. The following definitions of Boisot's unit vectors were used as the basis to define the various stages of Biotech's development.

Codification

Boisot defines codification as the degree to which the knowledge is written into transmittable form, for example, laboratory notebooks, books, patents, etc. A recipe or a patent may be considered a well-codified document since the practitioner, who has followed the required steps, can reproduce – within some small level of uncertainty, such as altitude effects – the results of the experiment. In the limit of codification 'then allows a task to be performed entirely by machine without human intervention'.[9] On the other hand, the precise process of making a car, for example, following Toyota's just-in-time model, would be very difficult to write down in a series of simple steps, and thus poorly codified. Boisot has defined tacit knowledge – knowledge that is inarticulate, complex, and non-codified – in this limit.[9,14] Thus, in Boisot's formulism, tacit knowledge includes existential, endemic, and experiential knowledge as well.[16]

Abstraction

Abstraction corresponds to the degree to which the (economised) data can be understood. To illustrate the extremes of this dimension, one can consider elementary ideas in physics vs those in biology. Newton's equations can be used to track the location of any mass moving classically in physical three-dimensional space. These equations are sufficiently general that any path of a traveling particle – irrespective of size and behaving within the classical and non-relativistic regime – may be mathematically traced in three-dimensional space. On the other hand, knowledge of glucose-6-phosphatase and its use in converting glucose-6-phosphate into glucose is only one reaction within a large and complex metabolic pathway. In Boisot's formulism, this latter extreme may be considered 'predominantly perceptual and local' and thus definable as a single concrete manifestation or single instantiation of knowledge, while abstraction illustrated within Newton's formulism supports an extendable conceptual knowledge capable of extensibility.[17] According to Boisot, there is a proportion between the degree of abstraction and the generality of the outcome, and thus efficiency in economising data.[9]

Diffusion

The degree of diffusibility corresponds to the 'proportion of a given population of data-processing agents (e.g., individuals, firms, industries, countries) that can be reached with information operating at different degrees of codification and abstraction'.[9] As an example of highly diffuse data or information, a recipe can be easily distributed in an e-mail to thousands of individuals, irrespective of cooking experience, with the exact methodology for cooking a pie. In the other extreme, esoteric or inarticulate knowledge, such as wants and desires are difficult to diffuse to a given population, since such vernacular illicit different meanings to different individuals within a population.

THE I-SPACE MODEL: APPLICATION TO FIRM GROWTH

Following our discussion above, and using the Boisot I-Space Cube and its relations with organisational evolution (see ref. 9, page 134) with corresponding definitions (see ref. 9, page 127) as reference for the discussion, we assume that the firm begins its existence as a startup, which can be generally characterised as a fiefdom: information diffusion is limited due to its un-codified and concrete (non-abstract) nature, thus, requiring informal and frequent face-to-face meetings. In theory, this state recognises that employees have a need to share the goal of rapid and complete industry dominance. This result probably stems from the employee's notion of importance and long-term reward structure (eg, corporate stock options) as opposed to a short-term rewards structure, such as a robust benefits package afforded by established firms. As the firm grows, it generally becomes a more functional organisation (more bureaucratic), an increase in 'red tape', with well-codified, highly abstract paper work, regulations, compliance policies, and guidelines. In the biotechnology industry, in particular, the need for compliance with regulatory requirements becomes a corporate mandate. Information relevant to the corporate strategy of the firm becomes contained 'up above' in the firm – away from functional units. Employees, while still submissive to the firm's 'mission', no longer need to have common values and belief systems. Employee relationships have grown impersonal and are guided by the position in the firm's hierarchy – a focus on titles. As the firm moves up the I-Space, *viz*., as they continue to become more codified and bureaucratic, due to the formation of standard operating processes, the firm begins to lose data richness due to the lack of tacit knowledge. Thus, 'data economies are achieved at the expense of data richness'.[9]

Continued growth leads the firm into a multidivisional organisation similar to a bureaucracy but with a more independent, competitive spirit, wherein within the functional hierarchy, horizontal groups become 'self-regulating' and 'self-propagating'. Competing business units may offer senior managers the potential for rapid innovation, at the expense of company-wide cohesion. Information becomes widely diffused geographically with relatively no control. Further growth leads to a large firm that is broken-up into a network of clans – with potentially a tribal mentality – where individuals with similar shared values and belief systems form 'cliques'. These units may follow 'unwritten rules' by which personal relationships create new socially based hierarchical paradigms and structures.[18]

One may consider the above discussion within the paradigm of Nonaka's knowledge spiral.[19] Here, as explicit knowledge becomes tacit, agents are incrementally or radically learning-by-doing – building new ways of doing things simply through experiential learning (startup, fiefdom). As this new learning is communicated (diffused) through dialogue and showing-by-doing (socialisation and externalisation) (functional structure, bureaucracy), it becomes slowly inculcated in the firm's processes (combination and internalisation), offering opportunities for codification and generalisation (abstraction) through actual implementation (multidivisional structure, network clan). Thus, the dynamic information flow of Boisot is conceptually similar to that of Nonaka. Additional research into this area would be of interest to knowledge theorists.

In the next section, an application of the I-Space model to the bio-entrepreneurial firm is presented.

BIOTECH'S GROWTH: FROM CLAN TO STARTUP

Here, we describe the firm, and our application to Boisot's formalism. While all sources used below are from previously published and publicly available materials as presented on the firm's website and elsewhere, given the strategic content we have moved toward the side of a discretion; we hope that this does not distract the reader from the main tenets of this report. Here, we call the firm 'Biotech', the parent pharmaceutical firm is called 'Pharma', a competitive pharmaceutical firm called 'Pharma2', and all personnel are

termed in a non-meaningful character set such as AA. The Biotech specialises in the discovery, development, and marketing of pharmaceutical products for skin-cell-related conditions. As an example of the Biotech's success, it developed and commercialised a drug to address a major cardiovascular disease, pulmonary arterial hypertension (PAH). The Biotech's founders designed and researched the drug and learnt its basic biology while employed at Pharma, a global pharmaceutical firm. The drug was licensed to the Biotech in 1998, the same year as the firm's incorporation. By 2002, the firm had subsidiaries in key markets worldwide; each operational affiliate had full rights to the drug and corresponding marketing and sales activities.

Analyses of the founders' biographies described on the website reveals: AA (CEO), BB (senior vice president, head drug discovery), and CC (non-executive director). Tables 1 and 2 show that AA was a well-known researcher in the scientific and patent literature. CC probably contributed more to the construction of the firm via non-scientific routes, due to his lack of presence in these literatures. Most of AA's publications and patents revolve around the key biological target. Tables 1 and 2 show that many of the Biotech's senior managers worked with AA at Pharma; inspection of the publications and issues patents reveal that most of AA's publications and patents were co-authored by these individuals. Thus, AA played a key role not only in leading the scientific vision for the firm but also in constructing its management team. BB was a subordinate of AA (see Table 2).

Table 2 illustrates the corporate structure of the firm; notice that 11 out of the 14 managers were previously at Pharma. Since these parties left Pharma to join Biotech, it can be assumed that many unwritten rules (various psychological contracts[20]) bound the various members of AA's group together.[18] Given the size and maturity of Pharma, it can be further argued that AA and his group comprised a clan within Pharma.

While business press and market research how the founders left to create the firm, the publications did not state the exact reason.

Table 1: Biotech's founders' research activity as gauged by their number of peer-reviewed publications and number of issued US patents

Person	Number of peer-reviewed publications[22]	Number of issued US patents[23]
AA	127	11
BB	54	4
CC	None found	None found

Thus, various scenarios could be constructed as to the motivation of the clan becoming a startup, including AA and his colleagues were excited about the science, but frustrated with the bureaucracy of a slow-moving, big pharmaceutical company; the founders thus decided to break from Pharma. Or, alternatively, Pharma and the founders recognised the commercial import of a firm dedicated to this field of research, and with the aid of Pharma (via incubation and licensing) leapt to construct Biotech – as a team. While the exact cause of the formation of Biotech was not found by the author; nonetheless, given any of these scenarios, the Pharma clan, a small collection of individuals within the company, spawned Biotech in 1998.

BIOTECH'S GROWTH: FROM STARTUP TO BUREAUCRACY TO MULTIDIVISIONAL STRUCTURE

As a startup, Biotech quickly grew. As mentioned above, the founders brought with them expert knowledge from Pharma. For Biotech's complete basic research to worldwide drug commercialisation paradigm to be fully operational, the firm needed to recruit (and socialise) additional expert talent many highly skilled employees.[18] Even though not mentioned in Table 2, the other managers had previous 'big pharma' experience – most notably at Pharma2 – the main competitor in PAH drugs. Thus, Biotech may have believed that selective recruitment would combine explicit and tacit knowledge – bringing much needed regulatory experience (working with the federal drug agencies) (tacit knowledge)

Table 2: Corporate organisational structure, taken from Biotech's website in February, 2004

Last name	Affiliation	
Board of Directors		
MM	Senior Principal, VC1	
NN	Chairman, Retired Chairman and CEO, Pharma3	
AA	**Founder, CEO**	
DD	Senior Vice President, Pharma	
OO	Former CEO	
PP	Retired Vice President, VC2	
QQ	Senior VP, Head of Strategic Development	
RR	Professor of Entrepreneurship & Innovation, School	
SS	Vice-Chairman Founder, Senior VP Head of Business Development	
Last name	**Title**	**Previously at Pharma?**
Business Executive Board		
ZZ	Pres, Head US, Canada, Asia Pacific	YES
YY	Pres, Head Europe, Israel, Latin America	NO
AA	**CEO, Member of Board, Founder**	**YES**
WW	Sr VP, Head Clinical Development	YES
UU	Sr VP, Member of Board, Member Business Executive Board	NO
VV	VP, CFO	NO
XX	Pres, Representative Director, Japan	NO
TT	VP, Head Corporate Operations	YES
Management		
DD	VP, Head Project Management	NO
EE	Senior VP, Head International Medical Marketing	YES
AA (Martine)	Senior VP, Head Drug Discovery Pharmacology and Pre-clinical Development	YES
FF	**Senior VP Head Drug Discovery Molecular Biology & Biochemistry, Founder**	**YES**
GG	Director, Head Global Quality Management	YES
HH	VP, Head Business Development	YES
II	VP, Head Corporate Communications	YES
JJ	VP, Head Scientific Business Affairs	NO
KK	VP, Head Regulatory Affairs	YES
LL	VP, Head Biotech Switzerland, Austria, CEE, Mid-East, Africa	YES
LLL	VP, Global Controller, CAO	NO
MMM	VP, Head Research Collaborations	NO
NNN	VP, Head Drug Safety	YES
OOO	VP, Head Drug Discovery Chemistry	YES

Individuals with VC1 and VC 2 are affiliated with a 'Venture Capital' fund.

Note: Sr VP=senior vice president; Pres=president; CFO=Chief Financial Officer; CEO=Chief Executive Officer; CAO=Chief Accounting Officer. Founders and a key Pharma figure in **bold**.

coupled with the scientific expertise (codified knowledge) of the key scientists in the firm.

Table 3 presents data relevant to firm growth. Notice that from 1998 to 2002 the firm grew nearly 3,000 per cent, with presence in over 16 countries. From 1998 to 2000, the firm internationalised to the US from Europe, and by 2005, the firm had presence globally in all the key drug markets. Thus, in a rapid way, the startup evolved through the various stages, rapidly becoming a small, but global biopharmaceutical firm from a startup firm.

The rate of increase of the firm's employees may be hypothesised that there were clan-like structures within Biotech, partly due to the geographical isolation of these various divisions. The process of marketing and selling drugs to doctors varies by geographical location, given cultural and language differences, where a strong degree of local tacit knowledge must exist.[21] This

Table 3: Distribution of Biotech's employees as a function of date; data culled from Biotech's website in February 2004

Year	Number of employees	Geographical sector
1998	17	Switzerland
1999	40	Switzerland
2000	110	Switzerland, USA, France, Germany, Italy
2001	>250	Switzerland, USA, France, Germany, Italy, Canada, UK, Australia, Japan
2002	>500	Switzerland, Austria, France, Germany, Greece, Italy, Netherlands, Nordic, Spain, UK, Ireland, USA, Canada, Brazil, Australia and Japan

is reasonable due to the higher data economies present in the lower part of the I-Space cube.

CONCLUSION

In conclusion, we have presented an interesting model to describe the organisational development of an IP-oriented R&D-intensive firm, a biotechnology company, in light of the knowledge-based theory of Boisot. We have defined KA as IP in order to facilitate this analysis. We note that the rapid growth rates experienced by firms within these industries, however, may cloud the exact location (or growth trends) of a particular knowledge-intensive firm within the Boisot cube. Another limitation of the model is the reliance on publicly available information by external researchers. However, the firm itself may benefit from realising its own growth challenges through a more rigorous application of the topics mentioned within this paper.

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Disclaimer

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