

Patenting strategies and valuation of science-based start-ups

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Abstract

The patent portfolio of a Science-Based Start-Up (SBSU) not only constitutes its core intellectual assets. It also *represents* those assets in a form validating its claims for novelty (via the patent examination), defines ownership rights, and renders them (at least partially) observable to outsiders. From early on these intellectual assets play a key role for the SBSU in signaling its (potential) *value* to venture capital and to other critical partners. These value signals, it appears from the literature and from experts in the field, do not refer to assessment only on a patent by patent basis. The assessment also refers to the portfolio as a whole in terms of the *complementarities between multiple patents*.

While important aspects of these complementarities have been theorised a shortage remains in methodologies offering relevant empirical characterisation of asset complementarities in patent portfolios. For the same reason little has been possible in terms of rigorous examination of the effects of these complementarities on the value of firms.

This paper introduces a novel methodology for identifying complementarities in portfolios and for translating them into indicators of value-driving dimensions. We apply these indicators to the portfolios of a sample of same-type SBSUs, and we use econometric models to examine effects of these indicators on firm value, confirming that consistency in the build-up of intellectual assets and their IP protection is rewarded by investors.

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1 Introduction

External assessment of the intangible assets of firms poses a number of inherent challenges, not least when it comes to assets relating to R&D and technological capabilities (Chan et al, 2001). The value of young high-tech firms hinges on these capabilities and their future potential. But several years may pass before these firms achieve outputs observable by conventional metrics (Deeds and Hill, 1996; Mc Namara and Baden-Fuller, 2007), and before financial statements begin to reflect actual value (Hand, 2005). In this initial stage the patent portfolio is among the few types of information on intellectual assets of these firms accessible for external observation of their intellectual assets (Parida et al, 2008). While patents only imperfectly reflects total firm value they do offer important indications, derived partly from single patents (Bessen, 2008; Harhoff et al, 2003), partly from their coherence at the portfolio level (Hall et al, 2005). Some aspects of this coherence, and of its effects on portfolio value, has been theorised (Cohen, Nelson, and Walsh 2000; Deng et al, 1999; Merges and Nelson, 1990; Shapiro, 2001). But a shortage remains of methodologies allowing more precise empirical characterisations of portfolio coherence. Improved characterisation is of considerable interest not only to investors scanning the venture market, but also to other firms surveying potential partners or suppliers of technology, or identifying strengths or soft spots of competitors. Therefore, methodological advances in this respect have implications also for efficiency in financing of complex R&D, in markets for technology, and in technology-based competition.

The present paper examines effects of the *configuration of patents* on firm value. A novel methodology is presented identifying dimensions of the configuration of patent portfolios. Effects of these dimensions on valuation of young science-based firms are examined in a set of regression models. Using panel data we follow a sample of firms over eight years, examining how changes in the portfolio configurations affect changes in firm value. While our methodology has fairly broad potentials for patent-based characterisation of such firms the present paper focuses on firms in biotechnology, specialised as Drug Discovery Firms (DDFs). This category of firms is particularly useful for demonstrating our methodology and for testing its potentials for explaining the value of firms (Lerner, 1994). Drugs and biotechnology have high patenting intensities, and each drug candidate requires protection from a fairly standardised set of patents referring e.g. to its composition of matter, process technology etc. This allows meaningful comparisons of firms regarding their configuration of these standard patent types. Furthermore, the DDFs we study are typically young, smaller firms, with resource restraints inducing them to prioritise patenting to inventions assessed as valuable and necessary. This absence of “noise” from excessive tactical patenting allows more direct relationships to be brought out between portfolio configuration and firm value.

The paper is structured into five sections. In the next section the key analytical dimensions of the paper are derived from or related to extant literature and. Section three presents our methodology. Models are presented and interpreted in Section 4, while Section 5 discusses implications.

2 Theory

While the coherence of patent portfolios, measured by (intra-portfolio) self-citations, has been shown to enhance the value to firms (Hall et al, 2005) our understanding of the translation of coherence into value still is highly incomplete. Key dimensions of this coherence has been associated with a distinction between *discrete* vs. *complex* technologies (Levin et al, 1987;

Merges and Nelson, 1990), and some steps have been taken to demonstrate implications of this distinction for the value of portfolios (Blind et al, 2009; Reitzig, 2004).

In complex technologies, e.g. computers or engines, single inventions comprise a large number of complementary patentable elements. The competitive edge of these inventions rests on the configuration of these elements, and the inventor firm rarely has proprietary control over all of them. Consequently firms take out patents *also* for the purpose of using them as bargaining chips in cross-licensing arrangements with firms controlling critical complementary elements, giving rise to *patent thickets* (Shapiro, 2001). Typically thickets therefore consist of a large number of functionally heterogeneous patents, brought together by their complementarity roles for the same focal technology (Cohen, Nelson, and Walsh 2000; Von Graevenitz et al, 2009).

In discrete technologies, such as chemicals, each invention builds on few elements. Effective protection hinges on the uniqueness of the invention in terms of the space it leaves for substitution from rival versions of its basic principle. To block competitors from this space inventors often take out patents also on these substitutive versions, increasing number of versions required the less unique the core patent. The resultant configuration of functionally similar patents is referred to as a *patent fence* (Granstrand, 1999), and it is typically smaller than patent configurations forming thickets. Configurations of patents relating to same focal invention, either as thickets or fences, are jointly referred to as *patent bulks*(Schneider, 2008).

Industries applying patent bulks typically do so either in the form of thickets or fences(Cohen, Nelson, and Walsh 2000)but some industries also blend them based on quite complex rationales (Clark and Konrad, 2008). In this regard discovery and development of drugs, addressed in the present paper, forms an interesting mixed case. On the one hand a drug compound typically maintains its functionality only within a limited set of modifications, therefore requiring relatively few substitutive patents for effective fence protection. On this basis we expect the patent portfolios of DDFs to have configurations offering fence protection. On the other hand, successful appropriation requires control *also* of a set of complementary inventions covering, in addition to the compound, the utility of the drug, the formulation by which it achieves efficacy, and also the process technologies for its production (Business Insight, 2003; Gaythwaite, 1999). To this traditional set of complementarities in IP protection of drugs the biotech revolution has added further elements in the form of novel tools and informational assets, typically protected in platform patents. Patent portfolios of DDFs, in other words, also should be expected to comprise thickets formed from functionally distinct inventions protecting one and same drug candidate. The literature commonly sees thickets as a basis for negotiation and exchange between firms inventing within the same complex technology (e.g. Schneider, 2008). However, rather than building thickets for bargaining purposes DDFs apply them primarily in an effort to pursue full control of the different technologies underpinning their drug candidate (Thumm, 2004). Control of only one of the complementary technologies would allow a third party in a hold-up to extract a disproportionate share of the potential value of the drug candidate, hence diluting the value of the DDF, significantly affecting its basis for generating venture capital.

Combining these characteristics we expect the patent portfolios of DDFs to comprise both fences and thickets, and we expect the consistency in pursuit of these bulk-types to affect the value gradually formed by DDFs.

Thickets and fences are constructs referring to the level of bulks. To our knowledge the methodology submitted by this paper is first in suggesting a network approach to measure the configuration of different types of bulks and to assess their effects on firm value. Therefore we lack prior studies against which our findings on bulks can be compared. However, other aspects of the configuration of patent portfolios are better covered by previous research, allowing fairly direct comparisons of our findings against previous research. That is the case e.g. for the

question of scope advantages across the entire patent portfolio, which even has been studied with particular reference to firms in biotech and pharmaceuticals. For pharmaceutical firms (Henderson and Cockburn, 1996) found scope advantages derived from capturing internal and external spillovers. In a sample of biotech firms (Lerner, 1994) identified scope advantages at the level of both single (broad) patents and of the portfolio as a whole. (Danzon et al, 2005) found that biotech firms drawing on a broad experience pool have higher probability of success in early stage development, although subject to diminishing returns. Focused experience, on the other hand, is advantageous for development in later stages. Studying pharmaceutical Contract Research Organisations (Macher and Boerner, 2006) found scope economies only in combination with specialised experience from a particular field of knowledge. The DDFs in our sample are fairly young, with most of their activity in pre- or early clinical development, hence finding their closest parallel in the study of Danzon et al. To examine whether our methodology offers same or different results from those of Danzon et al. we test for a positive, but diminishing, impact of portfolio scope on firm value.

In summary, the research question addressed in this paper is as follows: *To what extent is the valuation of biotech firms affected by the configuration of their patent portfolio regarding particularly thicket and fence formations at bulk level and regarding scope effects at portfolio level.*

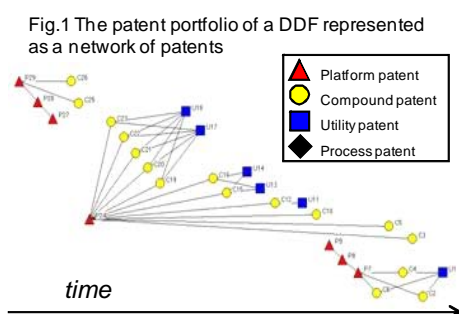
3 Method

3.1 Characterising portfolio architectures

We characterise the patent portfolio of DDFs through the four following steps:

First, applying a text-mining algorithm developed by the authors (Jensen, Vikram, and Valentin 2008) each patent (reduced to patent families) categorized into *patents types*. Based on configurations of IPC codes and abstract keywords this algorithm obtains 92% correct classification into patent types, also including the comparatively few patents filed to cover more than one dimension of the drug candidate. From this classification a distinction emerges between six different patent types: platform, composition of matter, process, utility, formulation, and instruments (e.g. delivery devices).

Second, patents are coded as nodes into network matrices specific to each firm, with patent type, filing year and additional patent characteristics coded as attributes of each node. A tie between two patents is identified by co-occurrence(s) in their titles or abstracts of compound names, disease target(s), methods or processes, or by the information that patent is an improvement or modification of a previous patent. The example graph presented in Fig. 1 is a network output generated from the matrix mapping the entire portfolio of one DDF, the different shapes of nodes signifying different patent types. In calculation of network metrics we apply directed graphs to capture sequentiality, so that a linkage between two patents would be directed from the earlier to subsequent patent.



3) Patents and their ties are manually categorised into bulks, following two simple combinatorial criteria referring to their network structure only, disregarding their content in terms of patent types. First, to form a bulk at least three patents must be connected by ties sufficient to form either a string or an imperfect triad, giving rise to the two *basic forms* (a and b) shown in Fig 1. Second, offshoots from basic forms comprising two or more interlinked patents are considered new bulks if, including the patent from which they branch out, they unambiguously build one of the two basic forms. The criterion of non-ambiguity means that network structures which could

be broken down to two bulks in multiple ways of equal plausibility are left as one bulk. This procedure also reveals stand-alone patents or dyads that have not been subject to more complete patent protection, indicating either abortive explorations of drug opportunities, or inventions requiring no further protection.

4) On this basis the portfolio of each firm and each patent bulk becomes accessible for characterization by standard network metrics, such as density, centrality, path-distance etc. (Wasserman and Faust, 1994). These network metrics express characteristic dimensions of the configuration of bulks. In fences, the different versions of same-type patents (typically compounds) fan out from the core invention they are designed to protect, resulting in bulks characterized by high degree centrality and homogeneity across patent types (Fig. 3) Thickets on the other hand would appear in the form of interlinked, heterogeneous patents, not radiating from any particular core invention, i.e. heterogeneous patents linked at low level of centrality (Fig. 3).

Fig. 2: Combinatorial rules in the coding of bulks.

Basic forms



Offshoot examples

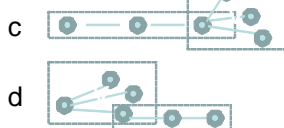
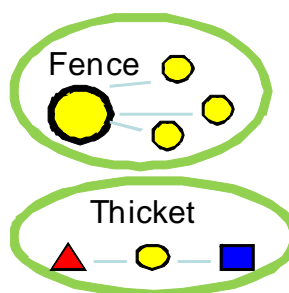


Fig.3 Network representations



3.2 Data

Data was extracted from SCANBIT (Scandinavian Biotech), a proprietary database covering all Scandinavian DDFs, developed and maintained by the authors at *Research Centre on Biotech Business* at Copenhagen Business School (<http://www.cbs.dk/biotech>). For the period examined, 1997-2004, SCANBIT includes 112 DDFs with a total filing of 1306 patent applications (excluding variations of same original patent). A number of variables were extracted, including firm valuations. The latter were calculated from data on financing rounds and stock listings (Valentin et al, 2008), and were available for 85 firms. For these firms we have a total of 267 valuations, which provide the data on financial performance in the form of Post-Money Value (PMV) for the 8 years included in our study. Characterization of the patent portfolio of each firm corresponds to these valuation data, allowing us to identify exact portfolio changes occurring up to any given financing Round₀ and after the preceding Round₁.

In the time span covered by our data few firms develop more than two bulks of patents. At bulk-level we include in our analysis attributes only of the two first bulks, whereas measures characterizing the portfolio as a whole refer to all its patents. In size bulks range from three to nine patents, with averages of 4.0 (first bulk) and 3.9 (second bulk). Bulks were sequenced according to the filing date of their first patent, but it is recognized that to a large extent they grow out of concurrent streams of R&D.

3.3 Variables

The *dependent variable* is *Post Money Value* (PMV). For listed firms, PMV is the market capitalization value, calculated as the average daily closing price in each year for a given firm multiplied with the number of stocks committed. PMV for non-listed firms is calculated as share value multiplied by the total number of shares committed as per each round of capital inflow. This value corresponds to the amount an investor has to invest to acquire the whole firm if buying at the price resulting from the latest round. A natural log transformation of the heavily right-skewed distribution of PMV returns the normally distribution applied as our dependent variable. For previous use of this PMV measure see (Valentin et al, 2008).

Independent variables

Two indicators are applied to measure *scope* at the level of the portfolio as a whole. First we simply apply a Herfindahl-Hirshman index of heterogeneity (HET) to the distribution of all patents across the six patent types. Second, employing network metrics we calculate “un-relatedness” (UNREL) across the entire portfolio, measured as the inverse value of network density. By definition bulks are internally linked, hence in directed graphs giving only modest differences in UNREL across different bulk structures. Variation in UNREL for the portfolio as a whole therefore indicates primarily whether bulks are entirely disconnected from each other, or if they interweave through one or several patents, typically forming their joint point of departure early in the formation of the portfolio (say different drug candidates originating in the same platform patent, as in the example of the structure in the middle of Fig. 1). Disconnected bulks therefore signify broader scope of the portfolio as whole. Firms also have stand-alone patents or patents linked only as dyads. Their presence also signify scope, since they indicate the extent to which the firm has developed intellectual assets that are distinct and disconnected from their main drug candidates protected by bulks consisting of three patents or more. Scope effects are tested in Model B, Table 2.

To indicate *fence* configurations we characterise bulks by two variables. First, from the network matrices covering each bulk we calculate degree centrality (DGRCENT) for patents accumulated within the bulk up until each financing round. As argued above (see also Fig 1) high degree centrality captures configurations where two or more patents fan out from the same prior patent. Second, for the same patents we calculate their Herfindahl-Hirshman heterogeneity across patent types, transforming it into a dichotomous variable, scoring 1 for the least heterogeneous quartile among all bulks (else zero) (D-HET25). High values on the interaction of these two variables capture bulks comprising homogenous patents configured in the shape of fans, in other words an obvious representation of fence protection. At the same time, in regression models including both single and interacted terms DGRCENT as a single term picks up the effects of having fan-shaped configurations for *heterogeneous* patents, in other words exhibiting ambiguous or incomplete patenting strategies. Effects of fence configurations are tested separately for Bulk one and Bulk two in Models C and D in Table 2.

Thickets are indicated by the way bulks combine network structure with the presence of functionally distinct inventions, playing complementary roles for the overall innovation (see Fig. 2 above). High patent diversity is indicated by values at or above the mean of HET (HET50). Whereas fences appear as network structures of multiple patents radiating from one original patent at a path-length of 1, thickets will appear as more sequentially ordered configurations of path-length of 2 or higher. At the same time thickets offer complementarity between different types of patents. Therefore we indicate increasing strength of thicket protection by increasing tie-length of a bulk, combined with high heterogeneity of its patent

types. Effects of thicket configurations are tested separately for Bulk one and Bulk two in Models E and F in Table 2.

All models control for a number of factors known from previous studies to affect firm valuation.

- To control for *firms size* we use the average number of employees in the year of the financing round from which the dependent variable is extracted.
- We control for the *number of clinical and preclinical projects*, known to have considerable effect on firm value, often reflecting both its future and present value (because these projects already may have been the source of significant revenues through alliances formed with pharmaceutical firms). The value of a drug candidate increases as it progresses through Clinical Phases I-II-III (Valentin et al, 2008).
- To control for the *volume of the patent portfolio* (as distinct from its configuration) we control not only for total number of patents accumulated by each firm up until the point of valuation (labelled *port-sz*), but also separately for the the number of patents in bulks one and two (*B1:Bulk-sz* and *B2:Bulk.sz*).
- Two *industry dependent variables* are added to control for sector specific issues, i.e. the effect of being listed on the stock exchange (*listed*) and receiving investment around the 2001 bubble. The dummy BUB, is coded 1 for financing rounds subsequent to the investment bubble in 2001, else 0. And the dummy Listed is coded 1 for firms listed on the stock exchange, else coded 0.
- To control for other assets or experience accumulated by the firm we control for *firm age* at the point of valuation.

3.4 Models

The firm data extracted from ScanBit contains a total of 112 DDFs from 1997 to 2004. The data forms an unbalanced panel dataset, since we include also late entries and early exits.

Unobserved effects should be expected since we observe same firm across time. They may be addressed through either fixed or random effects approaches, subject to results from Breusch and Pagan Lagrangian multiplier test for random effects and from the Hausman Test.

For the five models these tests indicate that random effect models are appropriate for Models A, E, and F, while OLS models are appropriate for models B, C, and D, addressing firm fixed effects using the cluster option in STATA.

All final models are tested negative for multicollinearity and the white correction of standard errors is performed by the robust heteroscedastic correction in STATA. For all models results are presented as standardized beta estimates.

4 Findings

Descriptive statistics are presented in Table 1. The 267 valuation points refer to 85 firms at different stages of their development. On average these valuations refer to firms barely six years old, at a point when their pipeline includes two projects, and their portfolio comprises ten patents (families). During their earliest years firms have not enough patents to meet our bulk criteria and therefore first bulk characteristics are available for 113 valuations, while second bulk characteristics refer only to 63 valuations. Both first and second bulks are measured at points when on average they include about 4 patents, connected at average path-lengths of 1.8 and 1.5 ties.

Turning to the regression models (Table 2) the baseline model (A) presented first includes control variables only, returning positive, significant estimates for listed over non-listed firms

and for firm size. Interestingly, when entered alongside these two controls both the size of the portfolio as a whole and of bulks one and two separately return non-significant estimates. What matters for the valuation of firms, in other words, is the standing of firms of being listed (having been through a successful IPO) along with their overall size. Once that is accounted for the *number* of patents controlled by the firm has no separate effect.

Table 1: Descriptive statistics

Variable	N	Mean	Std. dev.	Min	Max
Ln(PMV)	267	18.4189	2.0059	11.5129	23.7953
PMV (mio. DK kr)	267	738.7321	2259.9620	0.1000	21584.9200
Firm-Age	267	5.6179	5.5023	0.0000	21.0000
Firm-Sz	256	31.6250	62.7538	0.0000	508.0000
Projects	264	2.5076	4.0846	0.0000	19.0000
Port-sz	268	10.9583	21.2199	0.0000	159.0000
HET	232	0.3915	0.2707	0.0000	0.8235
UNREL	144	10.0483	9.8031	2.0000	46.8666
B1:Bulk-sz	113	4.1217	1.3646	3.0000	9.0000
B2:Bulk-sz	63	3.8889	1.0178	3.0000	6.0000
B1:Het	113	0.3263	0.2541	0.0000	0.6667
B1:DGRCENT	113	65.9039	32.7101	0.0000	100.0000
B2: DGRCENT	63	78.3862	28.8225	40.0000	100.0000
B1:Path-Length	117	1.7778	0.7324	1.0000	5.0000
B2:Path-Length	63	1.492063	0.5350	1.0000	3.0000
Bub	181 (67.79%)				
Listed	59 (22.10%)				
B1:D-HET25	46 (16.79%)				
B2:D- HET 25	14 (22.58%)				
B1:D- HET 50	67 (58.26%)				
B2:D- HET 50	31 (49.21%)				

Model B tests the effect of *scope* in the patent portfolio as a whole. Heterogeneity across different patent types (HET) has a strong, linear effect on the value of firms. Firms are clearly rewarded by their investors for research leading to the different types of inventions playing roles in the protection of drug candidates. The positive, strongly significant estimate of non-squared UNREL indicates the high value attributed by investors to portfolios comprising several different (disconnected) bulks or smaller separate configurations (dyads), hence confirming the presence of scope advantages. The moderately significant negative estimate for UNREL² indicates diminishing returns for portfolios of wide scope. Both of these findings are consistent with previous studies of firms of the same type firms (Danzon et al, 2005; Lerner, 1994) indicating good reliability for of the novel method developed in this paper.

Table 2: Regression estimates of firm value (PMV). Standardized beta estimates [⊠]

	Model A	Model B	Model C	Model D	Model E	Model F
UNREL		0.901*** [0.272]				
UNREL ²		-0.315* [0.175]				
Het		0.150*** [0.047]				
B1:D_HET25			-0.255 [0.155]			
B1:DGRECENT			-0.122 [0.088]			
B1:D- HET25*B1:DGRECENT			0.230** [0.109]			
B2:D-HET25 (a1)				-0.529* [0.294]		
B2:D-DGRECENT				-0.132 [0.165]		
B1:D-HET25*B2:DGRECENT (a2)				0.481* [0.265]		
B1:Path-Length					0.095 [0.402]	
B1:D-HET50					-1.018 [0.635]	
B1:D-HET50*B1:Path-Legnth					1.161** [0.481]	
B2:Path-Length						-0.262 [0.213]
B2:D-HET50						-0.328 [0.215]
B2:D-HET50*B2:Path-Legnth						0.486* [0.291]
Controls:						
B1:Bulk-sz	0.078 [0.143]	0.061 [0.081]	0.032 [0.068]		0.115 [0.170]	
B2:Bulk-sz	0.019 [0.130]			0.188 [0.173]		0.013 [0.142]
Bub	-0.062 [0.076]	-0.193*** [0.048]	-0.049 [0.110]	-0.216* [0.114]	-0.078 [0.092]	-0.063 [0.070]
Listed	0.498*** [0.106]	0.386*** [0.094]	0.380*** [0.119]	0.198 [0.233]	0.482*** [0.150]	0.429*** [0.102]
Firm-age	0.041 [0.145]	0.081 [0.089]	0.198** [0.087]	0.279* [0.145]	0.068 [0.382]	0.089 [0.124]
Firm-sz	0.295** [0.117]	0.312*** [0.072]	0.145 [0.088]	0.101 [0.139]	0.125 [0.089]	0.272** [0.108]
Projects	0.087 [0.144]	0.118 [0.093]	0.115 [0.128]	0.058 [0.207]	0.133 [0.179]	0.054 [0.140]
Port-sz	-0.107 [0.176]	-0.483** [0.201]	0.163* [0.092]	0.180 [0.128]	-0.169 [0.277]	0.006 [0.138]
R-square:						
Within	0.307	0.434			0.335	0.406
Between	0.531768	0.7429236			0.250844	0.5103856
Overall	0.6197414	0.7251012			0.2663702	0.6175865
No of Obs	60	107	112	62	111	61
No of Groups	26	40	42	27	41	27
F			9.293424	26.39642		
Chi2	60.69227***	18.2698***			162.6762***	98.02219***

Note: The star notation indicates the level of significance * p<0.1, ** p<0.05, *** p<0.01 and number in hard brackets are associated standard deviations

⊠) Model A, B, E and F are random effect models, model C and D is ordinary least square models.

Models C and D test effects of fence configurations of Bulk one and Bulk two respectively, showing essentially the same pattern: The interactive terms capture fence attributes in the form of bulks predominantly including same type of patents, in a configuration where a set of derived patents fan out from a focal patent. The positive significant estimates for these interactive terms indicate that the stronger this combination of attributes is expressed in the patent bulk, the higher the valuation of the firm. For the second bulk a negative estimate appears for the single term (a2), referring to bulks with same type of patents but lacking a network structure defining a predominant role to one particular patent. Wald tests in Table 3 confirm the significant difference between estimates for single and interacted terms. I.e. meeting only parts of the requirements for effective protection has a penalising effect on firm valuation. Similarly, having the right network structure, but for patents of different types, constitutes a patenting strategy with no effect on firm valuations (non-significant estimates for DGRCENT). In summary, producing inventions forming clear and consistent fence protection is rewarded in the valuation of firms. Ambiguous and inconsistent pursuit of fence protection leads to either negative effects on valuation or at best inventions unable to affect valuation of the firm.

Tabel 3: Chow Wald tests

	Parameter equation	Value	Chi-Square
Model D	Subtracting B2:D-Het25 from the interactive variable	- a2 - a1	-1.010 0.0789*

Note: * P<0.1, ** P<0.05, *** P<0.01

Models E and F test effects of thicket protection for both Bulks one and two. The two variables referring to network structure (path-length) and to heterogeneity across patent types, in both models remain non-significant as single terms, while obtaining positive significant estimates when combined as interacted variables. Again we see clear indications that ambiguous and inconsistent pursuit of a patenting strategy, this time in the form of thickets, remains inconsequential for firm valuation, whereas consistency is clearly rewarded.

5 Implications

The methodologies developed in this paper offer advances in the empirical identification of thicket, fence and scope-related configurations, along with other attributes of patent portfolios. Based on this methodology we identify effects on firm value of configurative attributes of portfolios, as distinct from the number of patents in bulks or in entire portfolios. Our empirical findings support theoretical arguments on the nature and effects of patent thicket and fences, and on scope advantages in R&D.

To the management of science-based start-ups our findings emphasize the need to pursue inventions and patents not as single achievements, but as advances requiring several years of follow-up inventions, building the bulks that offer real value differentials and effective control. In this respect a delicate balance is required since investors also reward pursuit of

scope both in the form of patent heterogeneity and of different avenues of development that are not too densely intertwined.

Our findings also bring out the valuation penalties experienced by firms building indistinct patent configurations. Investors apparently do not react to half-heartedness in this respect merely with indifference; rather indistinct bulk configurations directly detract from valuations.

Finally, external assessment of science-based start-ups, based on freely available data, is of considerable interest to venture capitalist, and to pharmaceutical firms monitoring the market for strategic partnerships or acquisitions. The patent-based methodology presented in this paper enhances external assessment of the value-building potentials of science-based start-ups. In this sense this methodology submits a small contribution to the development of more efficient markets for knowledge and technology.

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