Standing on the Shoulders of Giants: Coherence and Biotechnology Innovation Performance

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Introduction

According to Industrial Organizational (IO) economics, structure involving the concentration or size of a firm has historically played an important role in explaining a firm's innovative performance (Cohen, 2010). However, numerous empirical studies have found that concentration or size is not sufficient in explaining a firm's innovative performance (Cohen, 2010). This is because aside from differences in scale, the industry level aggregation of IO economics does not account for firm level "structural" considerations (Cohen, 2010).

More recent development have found that a firm's innovation performance is attributed to the technological relationships held amongst a firm's portfolio of technologies (Flemming and Sorrenson, 2001, 2004). These structured relationships have been described by a concept of "coherence" (Teece et al., 1994). Coherence involves a structured set of technologies where their technological relationships offer opportunities to combine technologies in new and unique ways..

Research Objective

The primary objective of this study is to examine firm level factors that impact a biotechnology firm's innovation performance. This involves the following:

1) to propose a firm level measure of technological "coherence" using a firm's cited history of patent references
2) to empirically estimate the influence of coherence –as well as other covariates- on a biotechnology firm's innovation performance

Conceptual Development

As innovation is based on a combination of technologies, Teece et al.'s (1994) concept of coherence, suggest that firms survive in an industry when they develop "knowledge" about those combined technologies that have succeeded in the past. This coherence reduces the search space of possible combinations and thereby increasing a firm's innovative output.

Hypothesis 1: A firm's technological coherence has a positive influence to a biotechnology firm's innovation performance.

Firms with a greater access to a diversity of technologies –either within or across firms- offer greater opportunities to recombine their prevailing technologies and thus a greater likelihood of innovation. (Cohen and Levinthal, 1990; Ng, 2011). However, these prior studies have not examined the arguments of diversity in a patent context. Namely, the diversity of patent classes held by a firm influences a firm's potential to seek new combinations of patent technologies (see also Fleming and Sorenson, 2001, 2004).

Hypothesis 2: A firm's diversity of patent class holding has a positive influence to a biotechnology firm's innovation performance.

Empirical Measures

Innovative performance: Patent counts are used because they are strongly correlated with a firm's commercial success (Hall et al., 2005).

Coherence: A biotechnology firm's patent portfolio industry consist of *K* firm patent applications. We let $P_{ik}=1$ if firm is assigned to technology class *i*, where *i* consists of any one of the 400 technology classes identified by the U.S.P.T.O. The total number of patents assigned to biotechnology class *i* is denoted by $O_i = \sum_k P_{ik}$. Furthermore, each patent application requires a disclosure of its' prior art or "cited patents" (i.e. backward citations) (Criscuolo & Verspagen, 2008). Each of the cited patents in a patent application is classified in accordance to j technology classes that also belong to any one of the 400 classes identified by the U.S.P.T.O. The number of joint occurrences of biotechnologies between the patent application class *i* and its cited classes *j* in a firm's patent portfolio is denoted by $Jij = \sum_k P_{ik} P_{jk}$. By repeating this process for *K* other patents held by a firm's patent portfolio, we can then construct the joint occurrence of patent applications J_{ij} in classes *i* and *j* for the firm's patent portfolio. Yet since two patented technologies can occur due to random chance, we define a random variable Xij involving the number of patents assigned to both biotechnology classes *i* and *j*, under the assumption of a random joint occurrence with the following equations:

1) $\mu ij = E(Xij = x) = \frac{OiOj}{K}$

2) $\sigma ij = \mu ij \left[\frac{K - Oi}{K}\right]\left[\frac{K - Oj}{K - 1}\right]$

In order to determine the statistical likelihood that the number of joint occurrence J_{ij} of two biotechnological classes occurs over and above that of a random occurrence, this statistical likelihood is explained by a biotechnology class relatedness measure τ_{ij}: :

3) $\tau_{ij} = \left[\frac{J_{ij} - \mu ij}{\sigma ij}\right]$

By drawing on this relatedness measure τ_{ij}, a weighted average relatedness $WARi$ measure is weighted by a firm's patent counts pj in cited class j:

4) $WARi = \frac{\sum_{i \neq j} \tau_{ij} pj}{\sum_{i \neq j} pj} \quad i \in K$

A biotechnology firm's coherence or COH is the weighted average of the $WARi$ measure across all technology classes in a firm's patent portfolio:

$COH = \sum_i \left[\frac{pi}{\sum_i pi} WARi\right] i \in K$

Herfindahl Index Measure of firm's diversity of patent holdings: a firm's Herfindahl Index using the patent shares amongst the *i* patent classes.

5) HHI Index$=\sum_i \left[\frac{pi}{\sum_i pi}\right]^2 \quad i \in K$

Other covariates (Controls): As IO explanations attribute a firm's innovation to size, a firm's size is commonly measured by a firm's revenue and total assets (Cohen, 2010). The Schumpeterian (1934) hypothesis argues that a firm with greater profits is more likely to invest in such profits in the development of new innovations. A firm's Net Income is included. Absorptive capacity research (Cohen and Levinthal, 1990) finds that a Firm's R&D expenditures positively influences the assimilation of external technologies and thus has a positive influence to a firm's innovative performance.

Data Sample and Method

A firm's innovative performance is measured by a firm's patent counts (Hall et al., 2005) where a negative binomial estimation procedure is used to estimate a biotechnology firm's innovative performance. A firm's patent count and the related patent class data that is used in the construction of this study's coherence and Herfindahl index are drawn from the U.S.P.T.O. database. The sample of biotechnology firms are drawn from the BioScan database (Rothaermel and Deeds, 2006). The financial data used in the construction of the control variables are sourced from Mergent Online. A sample of 138 biotechnology firms in 2004 was used to empirically estimate the relationships proposed by this study.

Empirical Results and Findings

Negative binomial regression		Number of obs =	138
		LR chi2(3) =	249.76
Dispersion = mean		Prob > chi2 =	0.0000
Log likelihood = -391.79633		Pseudo R2 =	0.2417

patents	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lagPatent	.0093084	.0018659	4.99	0.000	.0056513	.0129656
Coherence	.0069662	.0019247	3.62	0.000	.0031938	.0107385
Herfindahl	-2.258485	.2396861	-9.42	0.000	-2.728261	-1.788709
Firm_Revenue	-1.12e-10	2.69e-11	-4.15	0.000	-1.64e-10	-5.89e-11
RDExpense	2.49e-10	1.47e-10	1.69	0.090	-3.89e-11	5.36e-10
Total_Assets	4.61e-11	1.70e-11	2.71	0.007	1.27e-11	7.94e-11
Net_Income	1.52e-10	1.18e-10	1.29	0.198	-7.94e-11	3.83e-10
_cons	2.790277	.1682008	16.59	0.000	2.460609	3.119944
/lnalpha	-1.228366	.1724351			-1.566333	-.8903997
alpha	.2927705	.0504839			.2088095	.4104916

Likelihood-ratio test of alpha=0: chibar2(01) = 347.04 Prob>=chibar2 = 0.000

Hypothesis 1 and 2 are statically significant and cannot be rejected. Consistent with empirical studies in IO, scale effects have an ambiguous relationships to a firm's innovative performance.

Conclusions

One of the unique contributions of this study is the development of a firm-level measure of coherence that relates the technological classes of a firm's patent portfolio with its scientific lineage (or cited patent classes). Prior studies have developed a measure of coherence but at the industry level of aggregation (Teece et al., 1994). An important implication of this contribution is it not only offers a unique firm level measure of coherence, but this measure has an empirically statistically significant effect on a biotechnology's firm innovation performance. In addition to this coherence measure, a firm's diversity of patent classes also has a statistically significant effect. These findings address an important shortcoming of IO size explanations of innovation. It suggests that firm level measures of innovative performance are not only "statistically" significant, but the magnitude of these estimates is "economically" more significant than those found in IO explanations. Consistent with Cohen (2011) conclusion on innovation studies, this study empirically demonstrates a need to examine firm as opposed to industry level factors in explaining a firm's innovative performance.

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