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Benefits of Persistence in Aspects of Patenting Strategy

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Abstract- Although some firms followed persistent patterns of patenting activity over time, results from the technology-intensive electronics industry indicated that patenting may have only a fungible competitive effect, i.e., frequent patenting has become an activity that raises the ticket of admission to compete therein without necessarily improving firms' relative financial returns. Results also suggested that persistence in filing many patents was helpful to improving performance within electronics, as was having radical patent antecedents. Having above–average numbers of uncited patents was associated with an external indicator of firms' efforts to amass patent thickets and associated with increasing firm profitability. Resource recommendations from results are mixed since patenting persistence has an effect on performance, but some types of patenting activity appear to have diminishing returns.

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Benefits of Persistence in Aspects of Patenting Strategy

Kathryn Rudie Harrigan [α] & Yunzhe Fang [σ]

Abstract- Although some firms followed persistent patterns of patenting activity over time, results from the technology-intensive electronics industry indicated that patenting may have only a *fungible* competitive effect, *i.e., frequent* patenting has become an activity that raises the ticket of admission to compete therein without necessarily improving firms' relative financial returns. Results also suggested that persistence in filing *many* patents was helpful to improving performance within electronics, as was having *radical patent antecedents*. Having above–average numbers of uncited patents was associated with an external indicator of firms' efforts to amass patent *thickets* and associated with increasing firm profitability. Resource recommendations from results are mixed since patenting persistence has an effect on performance, but some types of patenting activity appear to have diminishing returns. Future evaluation of the benefits of patenting activity should consider which additional persistence effects might have the strongest effects upon technology strategy, as all firms within an industry do not benefit equally from patenting efforts and some industries are less hospitable to long-lived strategic trajectories than are others.

Keywords: persistence, patenting strategy, patent thickets, firms' performance, radical inventions, frequency of patenting, number of patents.

I. Introduction

Technology strategy determines how firms renew themselves vis-à-vis scientific knowledge that may be used to create new, commercializable products and processes. Patenting activity is one manifestation of a firm's technology strategy that may not always be cost-justified. Our objective herein is to isolate the effects of the *persistence* aspect of patenting upon firms' performance in order to gauge its efficacy. In other words, we ask which aspects of firms' year after year patenting activities contribute most significantly to their respective financial performance and how does persistence in performing those activities amplify performance effects?

Although patents are considered to be valuable resources to possess, it may be that patenting is not directly influential upon firm performance. From an accounting perspective, patenting is an expenditure that is deducted when calculating profits. It harms profitability when patent applications are filed. Patenting has become so commonplace within some technology-intensive industries that it is almost like a "ticket of admission" for competing therein. In such settings, the financial benefit of patenting activity may be less than straightforward and links to achieving superior financial performance may be *indirect* if patenting must be undertaken merely to keep pace with industry evolution.

Is persistence in patenting inventions important in such competitive settings? Is it plausible that—within high-tech industries where firms must compete on research productivity— annually-produced patents have become a necessary, but somewhat fungible, competitive activity that has a less-than-expected impact upon performance? To test this conclusion, it would be useful to compare the varying effects of firms' patenting activities in order to know which activities seem to be most impactful, albeit incremental, in their financial effects.

To isolate the consequences of patenting activity, we suggest a novel approach to estimating how competitive advantage may be manifested in firms' patenting activity. Briefly, we argue that, within some industries, the key to successful patenting performance may be *persistence* in performing such research activities year after year. Unlike a one-time event that may be attributed to luck (*e.g.,* inventing and patenting a one-off, ground-breaking discovery that sometimes has no follow-up), the cumulative positive financial effects of persistence may be observed over time. Persistence in performing programmatic annual research may be rewarded more than where patenting activity has been intermittent in nature. Therefore, when decomposing the longitudinal patterns of firms' patenting activity within the electronics industry, we asked whether patterns that indicated patenting had persisted over time had a positive financial effect on performance and whether this finding would be a simple case of success breeds success (or might there be other forces in play vis-à-vis success in patenting activity)?

II. Persistence in Patenting Activity

It is consistent with the resource-based view of strategy that firms should develop patents to have resources that may provide relative competitive advantage (Peteraf, 1993; Wernerfelt, 1984). Under this viewpoint, firms would also develop internal processes to enhance organizational capabilities (such as creating

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patentable inventions) that may be used to renew firms' relative competitive advantage over time (Teece, Pisano, and Shuen, 1997).

Patents are competitive resources—capitalized as intangible assets on firms' balance sheets—representing novel and useful inventions. It has been assumed that having patents positively affects firms' financial performance when the inventions underlying patents are commercialized within firms' products (or are used to generate royalties). Under the greater umbrella of technology strategy, firms that choose to protect their inventions from imitation legally, albeit temporarily, through patenting may recover only a portion of their outlays directly—as some filed patents may be redundant (thickets)—and the rest of their expenditures may be recouped indirectly as protection against imitation by outsiders. Do firms need to persist in their patenting activity in order to realize the greatest advantage from filing patents?

Persistence is a strategic factor that can recognize the heterogeneity of firms' patenting activities and distinguish those groups of firms that engage in above-average types of patenting activities over time. Persistence patterns in patenting are important because of the time required for commercialized inventions to impact firms' profitability and become valuable balance sheet assets. Persistence assumes continuity of activity and the importance of persistence in explaining sustained financial performance has been much debated (McGahan and Porter, 1999; 2005; Ruefli and Wiggins, 2003; 2005).

Two effects are operative due to persistence—differentiation and infrastructural effects—since patenting activities offer beneficial external (market-oriented) and internal (organizational learning) advantages. If patents provide non-fungible competitive advantages, successful patents that are commercialized should have *differentiation* effects on firms' performance that positively reflect their relative competitive advantage as well as *infrastructural* effects that positively affect firms' organizational capabilities. Briefly, the rewards of differentiation may be reflected in a period of temporary relative profitability—reflecting the novelty contributed by using firms' inventions. Such differentiation may reflect a firm's greater willingness to explore exotic combinations of scientific knowledge that are reflected in their patents' content or it may simply reflect the novelty benefits of reaching customers first. The performance measure that reflects differentiation effects herein is returns on sales (firm's profit margin percentages).

Infrastructural effects arise from firms' accumulated experience in performing regular patenting activities. They are expected to create longer-duration organizational learning benefits. Such infrastructural effects may subsequently improve a firm's relative success in doing in-house R&D, thereby creating an experience-curve synergy that can become an organizational resource. That benefit, in turn, conveys relative competitive advantage that will be reflected favorably in firms' returns on assets, albeit as patents that are intangible assets which cannot be marked to market over time.

Technology strategies are varied. Some firms may patent a lot (and often) to cover many bases vis-à-vis research output goals. Others may build patent thickets around their most-critical inventions to deter imitation by close competitors. Risk takers may even undertake relatively radical technological syntheses in the hopes that these search activities may be rewarded (Harrigan, Di Guardo, Marku, *et al*, 2016).

Taken together, the differentiation and infrastructural effects from patenting may explain variations in firms' relative financial performance. But, to date, no study has decomposed the relative impact of diverse types of patenting activities upon firms' performance in order to test such linkages. The benefits of persistent patenting activities are expected to impact firms' returns on sales first (if their inventions can indeed *differentiate* the products or services being provided). Returns on assets will subsequently be affected as patent stocks generate continuing returns via commercialization or royalties. The cumulative *infrastructure* effect that creates an organizational-learning asset assumes that firms will fund R&D at a similar rate year over year. A contrary finding, *e.g.,* that persistence in patenting activities is not helpful to financial performance, would have substantial resource allocation implications for technology strategy, such as taking licenses from outside inventors instead of funding in-house research efforts heavily over time.

a) Differentiation Effects

Differentiation effects from patenting affect a firm's reputation as a technology leader. As such, persistence effects may be biased to favor larger firms that can sustain ongoing research and development efforts over time. Larger firms can cross-subsidize the unprofitable pursuit of dead-end technological leads, and convert patented inventions into funding engines for subsequent rounds of scientific inquiry that will occur over time (Madsen and Leiblein, 2015; McGahan and Porter, 1997).

As assets, the benefits of patenting are manifested in firms' intellectual capital. Patents convey the exclusionary rights to commercialize discoveries that may be considered to be a reward for investing in past research activities. Pecuniary benefits may also be enjoyed by collecting royalty income from users who license their inventions (which makes patents valuable as assets to monetize, even if the smaller firms owning them cannot afford to commercialize their inventions internally).

Since persistence effects carry reputational advantages for those firms that may be identified as technological leaders (Roberts and Dowling, 2002), firms that show evidence of salient above-average patenting activity over time are typically those that can command pricing premiums while their inventions are novel (Roberts, 1999). With time, such reputational effects may even create competitive advantage that translates into the ability to command premium prices by virtue of being perceived to be technological leaders (Ghemawat, 1986; Porter, 1980). However, competitors that commercialize me-too patents to imitate others inventions may erode the relative power of first-mover differentiation effects faster than does the next wave of technological innovation that would otherwise make firms' inventions obsolete, so novel patent content is particularly salient to the ability to sustain high margins.

Hypothesis 1: Persistently higher-than-average patenting activity will create differentiation effects that positively affect firms' returns on sales over time.

b) Infrastructural Effects

Firms' accumulated experience from persistence in performing regular patenting activities every year may create an *infrastructural* effect that will be reflected in positive returns on firms' assets. Infrastructural effects can be fragile because losing key researchers who change employers [*mobility losses*] may mitigate an organization's strength (Ganco, Ziedonis, and Agarwal, 2015). Sometimes mobility losses can be countered via external stimuli, *e.g.,* insights gained by provocative exposure to external stimuli, such as integrating acquisitions successfully with ongoing operations (Ahuja and Katila, 2001; Kim and Steensma, 2017; Puranamand Srikanth, 2007; Sears and Hoetker, 2014), successful collaborations with academic researchers (Kaiser, Kongsted, Laursen, *et al*, 2018) or working with stimulating third-party partners (Sampson, 2005; Stuart, 2000)—as each of these catalysts could enhance organizational learning and improve patenting activity's impact upon firms' returns on assets. In addition to the organizational learning that likely occurs in-house among a firm's scientists and engineers when pursuing patenting activities, learning may be helped by continual access to outside knowledge that can be assimilated successfully to create organizational assets.

Hypothesis 2: Persistently higher-than-average patenting activity will create infrastructural effects that positively affect firms' returns on assets over time.

c) Characterizing Patenting Activity

Patenting is not a costless activity since research efforts may be funded for years without realizing tangible benefits to offset its costs (Arora, Belenzon, and Patacconi, 2018). Moreover, it can be difficult to detect the direct effects of each patent upon firms' financial performance— especially where firms exhibit discontinuous patenting patterns over the years (*e.g.,* where there may be wide swings in their annual counts of awarded patents or other fluctuations within annual patterns of patenting efforts). For these reasons, analysis of patenting activity is typically focused upon consideration of aggregated annual patterns which we propose to study longitudinally.

d) Patenting magnitude and thickets

Choosing which indicators of patenting activity to analyze is difficult. There have been no formal tests to date of whether annually filing large *numbers of patents* helps firms with financial performance. The performance linkage is a conundrum. Patents receiving many forward citations from subsequent users ("blockbusters") are typically considered to be most impactful (Brinn, Fleming, and Hannaka, *et al*., 2003), but originating firms do not benefit financially when outsiders build upon their reported inventions unless originators collect licensing fees. It may be a fortunate public policy outcome when highly-cited patents are built upon by subsequent users, but forward citations do not necessarily improve originating firms' financial performance (Harrigan and Fang, 2019).

When patent applications are granted, originators receive a temporary monopoly on exploiting their unique intellectual property. When patent applications are filed, they are in the public domain and technical details revealed therein may attract imitation attempts by potential competitors. Since information must be disclosed when a patent is granted, would-be competitors sometimes try to replicate the efficacy of the newly-patented invention by changing some aspect of its formulation in their application. To prevent competitors from easily patenting variations of the originator's invention, originating firms could create a protective fence or thicket by patenting a cluster of related inventions containing such variations (and refuse to license any of these variations to would-be competitors) in order to slow down the success of competitive imitation since outsiders would then face a dense web of overlapping intellectual property rights that prevented easy commercialization of rival products (Shapiro, 2001).

"Patent fences" have been used by some firms to extend the duration of competitive advantage that patents conferred (Sternitzke, 2013). Within emerging industries, innovator firms have sometimes filed many patents early on to create protective thickets as technology evolved, and then sorted out subsequent claims via cross-licensing arrangements later as industry structures became better established (Sanderson and Simons, 2014).

To thwart easy imitation, inventing firms that possess adequate wherewithal to patent layers of interrelated inventions around their core invention

smaytry to protect their inventions against easy copying by closing off predictable ways of inventing around their patents. In doing so, many of the protective patents that they file will be redundant. Indeed, Clarivate Analytics (owner of the Derwent Innovation database) typically shows gestalts of patents pertaining to a central invention as part of its business-user offerings and most of the patents within such invention families are uncited since they reflect parallel routes that are also protected against unauthorized use.

Must patents be cited in order to be valuable? Although the fees required to file patents may have deterred the filing of some types of low-quality patents (de Rassenfosse and Jaffe, 2018), one could argue that filing many patent applications annually may be defensive patenting—an activity that is sometimes associated with creating patent thickets where their intent may beto forestall imitation (Hegde, Mowery, and Graham, 2009; Noel and Schankerman, 2013).

To approximate the effects of creating potential patent thickets, we examined the proportion of firms' annually-filed patents that were *not* cited by subsequent users (assuming that the most-efficacious patents that were protected inside the thicket of parallel patents would be the ones that would eventually be built upon by subsequent users and cited by patent examiners).

Our use of redundant patenting is controversial because it assumes that patents that are not subsequently cited can nevertheless contribute positively to a potential thicket strategy. It may be that low-quality firms are producing valueless inventions instead. A low-quality firm may be filing valueless patent applications year after year which could bias downward estimates of the effects of patent thickets upon financial performance.

Furthermore, it is not clear that uncited patents which create thickets will improve firms' financial performance. Defensive patent thickets have decreased the market value of some firms (Entezarkheir, 2017) and created negative, irrecoverable costs for others because many of the parallel patents within such thickets are redundant. Gambardella, Harhoff and Verspagen (2017) concluded that the frequent replenishing of firms' portfolios by filing multiple, related patents created value—even though the related patents within the thicket were less likely to be individually-cited by subsequent inventors due to their redundancy. Torrisi, Gambardella, Giuri, *et al.* (2016) found that a substantial share of firms' patents were, in fact, not used internally and did not generate royalties. These unused patents were used for blocking, preventing imitation, or defensive purposes, among others. Their findings suggested that having uncited patents created value for firms—most likely by forming protective thickets. Therefore we expected that above-average annual numbers of uncited patents could serve as patent thickets that enhanced *differentiation* effects by prolonging the relative duration of unchallenged competition. The longer that their inventions were not copied, the more valuable they would be as assets for the originating firm so long as they protected its core inventions from imitation.

Hypothesis 3: Persistently patenting large numbers of redundant patents, e.g., patent thickets, will impede competitive imitation and positively affect firms' returns on sales and returns on assets over time.

e) Patenting frequency and novelty of patent antecedents

It is not yet clear that patenting frequently has improved firms' financial performance and there have been no formal tests, to date, of whether firms that patented annually performed better than firms that patented intermittently. High patterns of annual patenting are expected to be associated with firms that funded larger R&D efforts, since the fees for filing patents are high. Firms having larger research efforts would better be able to afford to make regular patent filings, and persistence in patenting would enhance firms' organizational *infrastructure* effects via learning advantages. Presumably annual patenting would be done to amass a portfolio of patents pre-emptively or defensively to protect firms' inventions from imitation and forestall hold-up from third-parties. *Patenting frequency* was examined independently from consideration of patent content herein to address this aspect of patenting activity.

It is also not clear whether developing relatively more-radical inventions improved firms' performance. Kaplan and Vekili (2015) concluded that broader combinations of knowledge created greater economic value, but they found that patentable inventions were more likely to originate from local search. Creating inventions that utilized relatively radical antecedents typically required relatively more money and time to develop since they involve search afar, so developing such patentable inventions could depress firms' financial returns until they have been successfully monetized. In their study of backward citation content, Harrigan and Di Guardo (2017) found that relatively-radical inventions provided only temporary financial benefits to the firms that patented them. A regular diet of additional radical inventions was needed in order to maintain customers' willingness to pay higher prices. Their conclusion was consistent with Roberts (1999) who found that those firms which repeatedly commercialized breakthrough innovations enjoyed sustained profitability.

Differentiation effects are presumably enhanced by novelty, which is often identified by examining the antecedents cited within focal patent applications (Dahlin and Behrens, 2005; Schoenmakers and Duyster, 2010). Novel patent content could arise from exposure

to exotic knowledge origins or from how such knowledge was subsequently synthesized into new devices (Verhoeven, Bakker, and Veugelers, 2016). Patent novelty has sometimes been operationalized using antecedent scores, such as the originality index of Hall, Jaffe, and Trajtenberg (2001)—which is a Herfindahl-type of diversion index—or by using Harrigan, Di Guardo, Marku, *et al*.'s (2016) *V-score* distance measure—which is a centrality comparison between the focal patent's technology streams and those of backward-cited patents that it may have built upon. Both approaches to estimating relative patent novelty analyze information about patent antecedents as were indicated by backward citations that were contained in patent examiner reports.

Hypothesis 4: Persistently patenting inventions whose antecedents reflect significant deviation from firms' local-search technological streams, will increase the perceived differentiation of their products and positively affect firms' returns on sales and returns on assets over time.

III. Research Methodology

To distinguish whether persistence in patenting activity affected firms' financial performance, longitudinal variables were constructed to test whether those firms that persisted in (a) patenting frequently, (b) in large numbers, (c) using patent thickets often, or (d) routinely commercializing relatively radical inventions, had different financial performance from the others within their industry cohort. Persistence variables were created by comparing the values of firms' annual patenting activity variables against those of their industry's annual averages for each of the variables under consideration. Except for patenting frequency (which was a binary variable indicating activity for each year), firms were classified as being above or below their industry average for each type of activity examined over the years under study. In this case, two decades of patenting activity patterns were used to create persistence variables.

Table 1 summarizes base-case variable construction. Binary persistence variables identified "above-average" patenting activity in firms that (a) patented more frequently over time (compared with others within their industry), (b) produced above-average numbers of patents in most of the years examined, (c) repeatedly cross-subsidized potential patent thickets over time (as indicated by above-average numbers of non-cited and presumably valueless patents), and/ or (d) commercialized above-average radical inventions year after year (relative to the antecedent indices of industry competitors). Control variables included annual values for firms' sales growth, leverage, and the logarithm of their annual total assets or revenues, respectively.

Table 1

Variable Name	Construction
Patenting Frequency	Yearly indicator of whether focal firm filed patents (or not)
Persistence of Frequency	1, if focal firm filed patents in 50% or more of years when patents were filed by industry competitors, else 0
Number of Patents	Yearly count of number of patent applications filed
Persistence of Magnitude	1, if focal firm filed more annual patent applications than industry average for years under study, else 0
Patent Thickets	Count of firm's patents filed in $year_t$ that had received no forward citations
Persistence of Thickets	1, if focal firm had an above-average number of patents with no forward citations in $year_t$, else 0
Radical Patent Content	Firm's annual mean backward *V-score,* a distance measure to indicate relative antecedent originality, for portfolio of patents filed in $year_t$, (See Harrigan, *et al.,* 2016)
Persistence of Radical Content	1, if focal firm's annual mean backward *V-score*for that year's patent portfolio was above comparable industry average backward *V-score*, else 0

Models of patenting activity tested specifications containing base-case terms, persistence terms (typically representing the *above-average* group of firms for each type of variable), and interaction terms (*i.e.,* persistence variables times base-case variables). Where variable coefficients were significant, the interaction terms affected the slope of the base-case variable's coefficient while the persistence terms affected the value of the intercept coefficient.

a) Industry Samples

In order to understand how firms differed in their patenting success factors, we tested data from a longitudinal sample of 321 electronics firms that comprised an unbalanced industry panel overa span of twenty years. Patent count, code, and citation data was taken from U.S. patent examiners' reports using the *Derwent* classification scheme available through *Web of Science* (Clarivate Analytics, 2019). Financial data was taken from *BvD Osiris* (Bureau van Dijk Electronic Publishing, 2016), a database containing financial information about globally listed public companies. Only U.S. patents were used to characterize patenting activity.

Firms' patenting activity from 1992 through 2012 was used to create the independent variables, including the aforementioned persistence classifications and the interaction terms; financial results for the dependent variables were tested through 2014 in order to incorporate a two-year lag between the relationship between independent patenting activity variables and dependent financial performance variables. The two-year lag was chosen to conserve on degrees of freedom in order to capture the time that would transpire between filing patent applications to protect firms' inventions, commercializing them, and realizing their potential effects upon firms' financial performance. Results may be different if a longer lag time were assumed.

Firms included in the electronics industry panel made electronic components, electronic-storage devices, communications equipment, and/ or computing equipment. They provided related software for their electronics products.

Table 2 presents descriptive statistics for the samples. Because there was substantial heterogeneity in the numbers of patents variable, the outliers were winsorized at 0.5% and also at 1.0%. Relationships were unchanged when observations with outliers were trimmed in this fashion. The sample tested herein had the traits shown in Table 2.

Table 2: Descriptive Statistics for Electronics Sample

Variable Name	Observations	Mean	Standard Deviation	Minimum	Maximum
Return on Assets	4,760	-0.456	21.844	-99.620	86.830
Return on Sales	4,735	7.211	20.881	-98.180	100.000
Frequency of Patenting	5,124	0.460	0.500	0.000	1.000
Number of Patents	5,124	40.499	179.673	0.000	3221.000
Patent Thicket	5,124	0.107	0.309	0.000	1.000
Radical Patent Content	5,124	22.438	26.778	0.000	374.003
Sales Growth	4,848	0.551	5.415	-1.000	190.792
Leverage	4,984	0.703	15.959	0.000	1111.825
LogAssets	4,954	5.188	1.685	-88.690	15.630
LogSales	5,030	5.115	0.921	0.602	7.687

b) Model Specification

Panel data models with random effects and cross-terms were used to illustrate the effects of the patenting activity measures on firms' return on assets and return on sales, respectively. Random effects assisted in controlling unobserved heterogeneity—factors such as firms' internal and external environment factors that changed over time and could be explained by the independent variables. Moreover, random effects assumed that firms' engagement in patenting activities could change from year to year. For tests of patenting frequency with results shown in Table 3, the return on assets model was specified as

$$ROA_{it} = \beta_1 Frequency\ of\ Patenting_{it-2} + \beta_2 Above\text{-}Average\ Patenting\ Frequency_{it-2} + \beta_3 Cross\ Term\ for\ Frequency\ of\ Patenting_{it-2} + \beta_4 SalesGrowth_t + \beta_5 Leverage + B_6 LogSales_{it} + (\alpha + u_i) + \varepsilon_{it}$$

$$u_i \sim N(u, \sigma_u^2),\ where$$

$$Cross\ Term\ for\ Frequency\ of\ Patenting_{it} = Frequency\ of\ Patenting_{it} \times Above\text{-}Average\ Patenting\ Frequency_{it}$$

The constant term of the model consisted of two parts. Because we used a random effects model, there are *K* (the number of companies) regressors, including a constant. The first part α is the weighted average of all of the regressors' constants, and the second part u_i is the heterogeneity of the i^{th} company which is a random variable. These two terms together reflected that each firm had a different individual-specific "constant" with random effect over time. In turn, the intercept term shown in the results tables was the weighted average of all of the companies' intercepts (weighted by the number of observations).Base-case coefficients are interpreted as pertaining to the below-average group of competitors (as defined in building the persistence variables).When the persistence term, *Above-Average Patenting Frequency*$_{it-2}$= 0 (*i.e.,* when considering only the below-average group), the model became:

$$ROA_{it} = \beta_1 Frequency\ of\ Patenting_{it-2} + \beta_4 SalesGrowth_t + \beta_5 Leverage + B_6 LogSales_{it} + (\alpha + u_i) + \varepsilon_{it}$$

When persistence and interaction terms were added to the base-case model, the persistence variable for firms that were categorized as having above-average *Frequency of Patenting*$_{it-2}$was set to "1."Thus inclusion of the binary persistence variable modified the model as follows. When *Above-Average Patenting Frequency*$_{it-2}$ = 1 ,*i.e.,* when considering only the impact of that group of firms which patented for an above-average number of the years during a time span, *i.e.,* for 50 percent, or more of the years in a tested span, the model became:

$$ROA_{it} = \beta_2 Above\text{-}Average\ Patenting\ Frequency_{it-2} + (\beta_1 + \beta_3) Frequency\ of\ Patenting_{it-2} + \beta_4 SalesGrowth_t + \beta_5 Leverage + B_6 LogSales_{it} + (\alpha + u_i) + \varepsilon_{it}$$

For the return on sales models, the specifications and controls were the same—except that *Log Assets*$_{it}$ was used as the variable controlling for size instead of *Log Sales*$_{it}$ in order to avoid an identity. The same model structures were specified for frequency of patenting, the number of patents filed each year, the presence of potential patent thickets, and backward *V-scores* (indicating the breadth of a patent's antecedents that were novel to the focal patent's grant). Results are reported in Tables 3 through 6. When interpreting results in Table 3, for example, firms with below-average *Frequency of Patenting*$_{it-2}$ values represent the base case and their respective value for the persistence variable would be set to 0. Interaction terms in Models 2 and 4 in Table 3 would have an indirect effect on the base-case coefficient slope while the persistence variable would affect their intercept terms.

IV. Results

a) Frequency of Patenting

In Table 3, which tested how the activity of filing patents every year under study (or not) affected financial performance for electronics firms, the coefficients of the base case term, *Frequency*$_{t-2}$, were negative and significant in all four models tested. Frequent patenting appears to decrease relative profitability. The persistence term, representing those firms that patented in an *above-average* number of years from 1992 through 2012, was positive and significant only for Model 4 which tested the return on sales hypothesis. Frequent patenting brought novel products and processes to customers more frequently—which may have created a halo effect of relative differentiation for those firms engaging frequently in this activity. Results for Model 4 in Table 3 raised the intercept value for the above-average group of electronics firms, but results did not reverse the sign of the base-case slope for frequency of patenting since the coefficient of Model 4's interaction term was negative and not significant. Table 3 results may also hint that technological life-cycles were becoming relatively shorter for electronics firms than was the case for other industries (so patenting was becoming marginally less profitable), or results may suggest that annual patent filing does not positively improve the value of firms' infrastructural assets (which may be the case if no firms enjoyed relative competitive advantage over time in electronics).

Results in Table 3 suggest that frequent filing of patents undermined firms' relative profitability and these findings alone do not support the Hypotheses 2 suggestion that frequent patenting improves returns on assets since neither the persistence nor interaction term in Model 2 was significant. Nor do they suggest strong support for the differentiation argument of Hypothesis 1.

Table 3: Effect of Patenting Frequency on Financial Performance in Electronics, 1992-2014

	Return on Assets		Return on Sales	
	1	2	3	4
Intercept	-33.04	-33.08	3.494	1.138
	(5.525)	(5.479)	(1.943)	(2.120)
	***	***	*	NS
$Frequency_{t-2}$	-3.255	-3.732	-2.181	-1.927
	(0.739)	(1.025)	(0.790)	(0.961)
	***	***	***	**
Above-average $frequency_{t-2}$	--	0.520	--	5.564
		(1.912)		(2.184)
		NS		**
Interaction $Term_{t-2}$	--	0.834	--	-1.217
		(1.601)		(1.655)
		NS		NS
Sales Growth	-0.0143	-0.0153	-0.0667	-0.0663
	(0.0778)	(0.0779)	(0.0809)	(0.0807)
	NS	NS	NS	NS
Leverage	-19.18	-19.15	-8.329	-8.331
	(2.738)	(2.735)	(2.443)	(2.437)
	***	***	***	***
$LogSales_t$	7.743	7.683	--	--
	(1.020)	(1.056)		
	***	***		
$LogAssets_t$	--	--	1.220	1.200
			(0.235)	(0.222)
			***	***
Corrected R^2	0.1437	0.1431	0.0469	0.0551
Wald chi^2-Statistic	109.94	123.78	44.76	55.00
Prob> chi^2	0	0	0	0
Number of observations	4,358	4,358	4,281	4,281
Number of companies	321	321	310	310
*** =< 0.001 ** = 0.01 * = 0.05 † = 0.10				
All regressions use robust standard error. The number in parentheses is the z-statistic value.				

Table 4: Effect of Patent Thickets on Financial Performance in Electronics, 1992-2014

	Return on Assets		Return on Sales	
	1	2	3	4
Intercept	-36.74	-36.34	2.209	1.346
	(5.670)	(5.670)	(1.845)	(1.804)
	***	***	NS	NS
Thickets of patents$_{t-2}$	-6.192	-5.593	-1.248	-1.565
	(1.187)	(1.145)	(0.919)	(1.021)
	***	***	NS	NS
Above-average thicket$_{t-2}$	--	10.15	--	15.46
		(2.576)		(2.316)
		***		***
Interaction Term$_{t-2}$	--	-4.139	--	-0.871
		(3.155)		(2.342)
		NS		NS
Sales Growth	-0.0138	-0.0165	-0.0652	-0.0663
	(0.0740)	(0.0738)	(0.0791)	(0.0788)
	NS	NS	NS	NS
Leverage	-19.070	-19.060	-8.266	-8.255
	(2.781)	(2.779)	(2.388)	(2.389)
	***	***	***	***
LogSales$_t$	8.176	7.995	--	--
	(1.036)	(1.044)		
	***	***		
LogAssets$_t$	--	--	1.233	1.215
			(0.238)	(0.224)
			***	***
Corrected R^2	0.1354	0.1404	0.0467	0.0756
Wald chi^2-Statistic	106.95	132.99	42.46	101.48
Probability > chi^2	0	0	0	0
Number of observations	4,358	4,358	4,281	4,281
Number of companies	321	321	310	310
*** =< 0.001 ** = 0.01 * = 0.05 † = 0.10				
All regressions use robust standard error. The number in parentheses is z-statistic value				

b) Patent Thickets

Table 4 tests specifications suggesting that patent thickets were potentially formed by patenting frequently and in great quantities. The patent thicket variable is annual number of uncited patents, and it is negative since it represents a potentially-unrecovered cost. The base-case term was significant only for the returns on assets specifications (testing the infrastructural effects of patenting). The persistence terms, *Above-Average Patent Thickets*$_{t-2}$, were positive and significant in Models 2 and 4, increasing the intercept terms of firms in the above-average group by

over ten percentage points, but results did not reverse the signs of the base-case slopes for patent thickets since the coefficients of interaction terms in Models 2 and 4 were negative and not significant.

Results in Table 4 suggest that having large numbers of uncited patents did not improve the value creating potential of intangible patent assets that were carried on firms' balance sheets. Results showing high persistence terms alone do not support the Hypotheses 3 suggestion that creating potential patent thickets will protect firms' inventions from potential competitive imitation. Results in Models 2 and 4 do not support the infrastructural nor differentiation arguments.

c) Number of Patents Filed Annually

Table 5 tests how the effects of filing many patents every year affected financial performance for electronics firms. In addition to tests specifying the base-case variable (*i.e.,* annual number of patents filed) with the corresponding persistence and interaction terms, there are models that test specifications combining the effects of filing many patent applications with persistence terms for the assumed formation of patent thickets. The six models tested in Table 5 are "reversed term"—which means that variables representing *Below-Average Magnitude*$_{t-2}$ and *Below-Average Patent Thickets*$_{t-2}$were specified as persistence terms in order to avoid collinearity problems that were present within unevenly-sized persistence groupings when testing those respective patterns.

Table 5: Effect of Patenting Magnitude and Thickets on Financial Performance in Electronics, 1992 2014

	Return on Assets			Return on Sales		
	1	2	3	4	5	6
Intercept	-34.060	-28.760	-30.030	2.272	16.020	16.520
	(5.627)	(6.663)	(6.627)	(1.818)	(2.445)	(2.644)
	***	***	***	NS	***	***
Number of patents$_{t-2}$	-0.0066	-0.00636	-0.00542	-0.00325	-0.00356	-0.00364
	(0.00275)	(0.00243)	(0.00213)	(0.00110)	(0.000931)	(0.000911)
	**	***	**	***	***	***
Below-average magnitude$_{t-2}$	--	-5.797	--	--	-14.54	--
		(1.971)			(1.918)	
		***			***	
Below-average thicket$_{t-2}$	--	--	-5.051	--	--	-14.91
			(2.162)			(2.251)
			**			***
Interaction Term$_{t-2}$	--	-0.0856	-0.0551	--	-0.0586	-0.0198
		(0.0185)	(0.0131)		(0.0206)	(0.0156)
		***	***		***	NS
Sales Growth	-0.0112	-0.0131	-0.0111	-0.0642	-0.0659	-0.0649
	(0.0755)	(0.0755)	(0.0755)	(0.0791)	(0.0799)	(0.0794)
	NS	NS	NS	NS	NS	NS
Leverage	-19.12	-19.24	-19.49	-8.304	-8.387	-8.401
	(2.776)	(2.770)	(2.803)	(2.400)	(2.421)	(2.429)
	***	***	***	***	***	***
LogSales$_t$	7.589	7.734	7.867	--	--	--
	(1.020)	(1.063)	(1.053)			
	***	***	***			
LogAssets$_t$	--	--	--	1.221	1.22	1.213

				(0.227)	(0.227)	(0.221)
				***	***	***
Corrected R^2	0.1307	0.1435	0.1363	0.0443	0.0832	0.0708
Wald chi^2-Statistic	96.98	156.1	142.87	48.14	134.91	125.74
Probability > chi^2	0	0	0	0	0	0
Number of observations	4,358	4,358	4,358	4,281	4,281	4,281
Number of companies	321	321	321	310	310	310
*** =< 0.001 ** = 0.01 * = 0.05 † = 0.10						
Regressions use robust standard error. Number in parentheses is z- statistic value						

In a "reversed term" specification, interpretation of the coefficient signs for persistence variables and interaction terms are reversed. Thus while the base-case coefficients of the $Magnitude_{t-2}$variable were negative and significant in all models (suggesting that filing many patent applications decreases firms' relative profitability), the coefficients of the persistence and interaction variables in Models 2 and 5 reflect those electronics firms that patented relatively *few* patents each year while the persistence terms in Models 3 and 6 reflect those electronics firms that showed citation evidence for their patents.

Results in Table 5 of the reversed-term models show that coefficient terms were negative and significant for the persistence and interaction variables, which may be interpreted as *increasing* the intercept terms and base-case slopes for that group of firms that filed an *above-average* annual number of patents in Models 2 and 5. Persistent firms' intercepts increased for those specifications. The negative and significant coefficients for the interaction terms (which are the product of annual patent magnitude times the respective binary persistence term) may be interpreted as increasing the slope for that group of firms that filed an *above-average* annual number of patents *(i.e.,* because the structures of the model was "reversed," it reverses the sign of the base-case coefficient when adding the intercept term's coefficient value to that of the base case-variable). Results in Table 5 indicate that the slopes of the above-average groups of firms became positive. Thus results support Hypotheses 1 and 2 by suggesting that higher-than average patenting activity increases the differentiation and infrastructural effects that improve firms' returns on sales and assets, respectively.

A similar approach was used to combine the effects of patent magnitude with persistence terms suggesting formation of thickets from uncited patents. In Models 3 and 6 of Table 5, the reversed-term model used a binary persistence term representing the group of firms that was *less* likely to have potential patent thickets annually. Using the reversed-term interpretation, results in Model 3 indicated that firms which continually filed many patent applications and built patent fences over time performed better on returns on assets because of greater protection of their inventions from rapid imitation, which supports Hypothesis 3. In table 5, the R^2 values are higher for the return on assets models, suggesting that the positive effects of filing many patent applications annually produced a longer-lived asset that benefited firm performance.

d) Antecedent patents indicating relatively radical content

In Table 6, which tested how the effects of producing patents with relatively exotic antecedents annually affected financial performance for electronics firms, the base-case coefficients of the *Backward V-score*$_{t-2}$variable were negative and significant only in models of returns on assets. When annual persistence terms representing *Above-average Backward V-scores*$_{t-2}$, *Above-Average Patent Thickets*$_{t-2}$, and *Above-Average Magnitude*$_{t-2}$, respectively, were tested jointly with the base-case *Backward V-score*$_{t-2}$variable, their coefficients were positive and significant only for the returns on sales models. The coefficients of the corresponding interaction terms were positive and significant only for the returns on assets models, respectively.

Table 6: Effects of Patent Backward *V-scores* on Financial Performance in Electronics, 1992-2014

	Return on Assets				Return on Sales			
	1	2	3	4	5	6	7	8
Intercept	-33.630	-33.170	-33.110	-32.720	2.224	-0.120	1.475	1.172
	(5.588)	(5.582)	(5.637)	(5.660)	(1.833)	(1.961)	(1.786)	(1.766)
	***	***	***	***	NS	NS	NS	NS
Mean Backward V-score$_{t-2}$	-0.0224	-0.0464	-0.0278	-0.0299	-0.00275	-0.0192	-0.00554	-0.00646
	(0.0126)	(0.0155)	(0.0128)	(0.0130)	(0.0125)	(0.0169)	(0.0127)	(0.0129)
	*	***	**	**	NS	NS	NS	NS
Above-average Backward V-score$_{t-2}$	--	0.839	--	--	--	6.009	--	--
		(1.517)				(1.949)		
		NS				***		
Above-average thicket$_{t-2}$	--	--	-1.412	--	--	--	12.180	--
			(3.230)				(3.793)	
			NS				***	
Above-average magnitude$_{t-2}$	--	--	--	0.288	--	--	--	12.75
				(3.187)				(2.923)
				NS				***
Interaction Term$_{t-2}$	--	0.0505	0.16	0.143	--	0.0270	0.0462	0.0386
		(0.0239)	(0.0469)	(0.0474)		(0.0250)	(0.0874)	(0.0612)
		**	***	***		NS	NS	NS

Table 6: Continued

	Return on Assets				Return on Sales			
	1	2	3	4	5	6	7	8
Sales Growth	-0.0117	-0.0125	-0.0135	-0.0134	-0.0637	-0.0634	-0.0646	-0.0642
	(0.0758)	(0.0761)	(0.0757)	(0.0759)	(0.0791)	(0.0794)	(0.0791)	(0.0792)
	NS	NS	NS	NS	NS	NS	NS	NS
Leverage	-19.000	-19.010	-19.040	-19.140	-8.254	-8.231	-8.249	-8.293
	(2.768)	(2.758)	(2.771)	(2.778)	(2.393)	(2.397)	(2.392)	(2.401)
	***	***	***	***	***	***	***	***
LogSales$_t$	7.553	7.365	7.423	7.323	--	--	--	--
	(1.025)	(1.061)	(1.044)	(1.051)				
	***	***	***	***				
LogAssets$_t$	--	--	--	--	1.213	1.181	1.193	1.184
Corrected R^2					(0.221)	(0.201)	(0.206)	(0.198)
Wald chi^2-Statistic					***	***	***	***
	0.1371	0.1373	0.1383	0.1404	0.0536	0.0688	0.0785	0.0913
	95.89	122.45	123.1	137.69	44.78	68.67	94.36	112.85

Probability > chi^2	0	0	0	0	0	0	0	0
Number of observations	4,358	4,358	4,358	4,358	4,281	4,281	4,281	4,281
Number of companies	321	321	321	321	310	310	310	310
*** =< 0.001 ** = 0.01 * = 0.05 † = 0.10								
All regressions use robust standard error. Number in parentheses is z-statistic								

Base-case results suggested that exploring novel technological streams to synthesize novel inventions did not improve the value-creating potential of intangible patent assets that were carried on firms' balance sheets. When base case results were considered alone, having radical patent antecedents did not help firms' financial performance, but the coefficients of the interaction terms of return on assets Models 2, 3, and 4 in Table 6 were positive, significant, and reversed the slopes of the corresponding base-case *Backward V-scores*$_{t-2}$coefficients.Thus results suggest that higher-than-average radical content in patents' antecedents had an indirect positive effect on returns on assets, which supports Hypothesis 4. Patenting inventions whose antecedents reflected significant deviation from local-search invention processes created valuable assets for firms, which is consistent with Hypothesis 4.

The persistence terms that interacted with the base-case *Backward V-scores*$_{t-2}$variable in Table 6—*i.e.,Above-average Backward V-scores*$_{t-2}$, *Above-Average Patent Thickets*$_{t-2}$, and *Above-Average Magnitude*$_{t-2}$—were not significant for models of returns on assets, but each of them, respectively, was positive and significant in models of returns on sales—increasing the intercept terms of those firms in the above-average group by over ten percentage points in cases of *Above-Average Patent Thickets*$_{t-2}$, and *Above-Average Magnitude*$_{t-2}$.

Since the costs of developing radical inventions depressed financial returns (unless they could be commercialized successfully to recover sunk costs), base-case variable coefficients were frequently negative, but interaction effects frequently reversed the sign of base-case variable coefficients. Radical content in patent antecedents was an important discriminator of some electronic firms' financial performance. Firms that persistently filed patents having higher-than-average radical antecedents enjoyed higher financial performance than did firms whose patents more frequently incorporated incremental technological antecedents. For electronics firms, filing patents for many relatively radical inventions was a winning technology strategy—particularly after 2004 when the consumer products part of the industry faced rapidly-increasing demand and consumers eagerly embraced products that synthesized relatively novel technological attributes to enhance the variety of platforms enjoying access to digital content.

V. Discussion of Results

We expected that persistence measures—operationalized by above-average annual patenting activity and reflecting longer-term competitive behaviors—would have stronger relationships with firms' financial performance than simple activity measures—such as base-case patenting frequency, patent counts or other variables—would indicate. We decomposed the relative effects of patenting activity over time upon firms' financial performance by specifying models that included such persistence (and interaction) terms. We expected that persistent patenting activity would yield greater relative success as manifested in subsequently-higher operating margins that were used to justify the allocation of more funding to research activities over time.

In assessing contributions to profitability, we interpreted results for electronics firms having above-average patenting frequency as a higher intercept when predicting returns on sales, but showed no changes to their slopes unless the corresponding interaction term was also significant. The combined effects of above-average numbers of annual patent filings and the respective interaction terms increased the slope of returns on sales as well as assets. Electronics firms showed positive benefits from patenting heavily. Since many of their patents filed were not cited by subsequent patents, we inferred that persistence in that pattern represented efforts to protect intellectual property through overlapping claims that constituted a thicket. Electronics firms showed positive financial benefits over time for what we termed persistent patent thickets, thereby increasing their intercepts and slopes in tests of returns on sales and assets. The combinations of above-average numbers of patent filings of inventions having radical antecedents also increased intercepts and slopes when predicting financial performance—even where many of such patents were not cited.

Such findings could imply that certain types of patenting activities were best pursued by larger firms having scale economy advantages that could afford to field research divisions and file large numbers of patent applications annually. Since many small firms could not afford to fund the type of sustained research effort that involves persistent patenting over time, such an implication would be consistent with the scenario of innovative, smaller firms being acquired by larger ones to exploit their one-off, breakthrough discoveries.

Controls for firm size were included in specifications when testing the effects of patenting activity on financial performance; size controls were always positive and highly significant, even though sample size attenuated over time from 1992 through 2014 through attrition.

Cooper, Knott and Yang (2019) argue that larger firms get a bigger bang for their R&D buck (perhaps in a stepwise function or something more significant than a simple scale economy effect). It may be that the thicket and magnitude effects found in our results were especially strong for a small subset of large firms in the electronics sample. These bigger firms would likely have filed large numbers of patents each year and relatively few of these patents would have been cited by subsequent inventors if firms also consciously patented variations of their key discoveries to fend off easy imitation.

Results suggest that persistence in pursuing particular aspects of patenting provided superior financial performance. Changes in the trajectory of twenty years of persistent activity were sought to account for a potentially long lag time before patenting would affect firms' financial performance. Although persistence in filing patents annually was positive and significant in the samples, the negative and significant signs of the base-case patenting-activity terms suggested that patenting may have become a fungible competitive effect, *i.e.,* frequent patenting activity may have raised the ticket of admission to compete in the electronics industry without improving firms' financial returns. Persistently filing of many patent applications, creating patent thickets, and having patents with radical technological antecedents improved firms' returns. Thus, patenting activity provides both *infrastructural* and *differentiation* benefits that enhance firms' short-term competitive strategies and reinforce the longer-term benefits of organizational learning processes pertaining to technology development. The predictive effects of the persistence variables were stronger than simple patent counts or other types of activity variables. Therefore we suggest that using measures of annual persistence in analyzing the effects of a particular patenting activity may produce a more reliable characterization of the benefits to firms' patenting activity asit relates toyearly variance in firms' performance.

a) Limitations

More information about the effects of patenting activity differences was found when persistence variables were added to specifications than was shown in the coefficients of base-case, patenting-activity. Associated cross terms frequently reversed the signs of the base-case variable coefficients. We interpreted this outcome as evidence that using persistence terms produced better net predictors of the effects of patenting activity upon financial performance than did using the base-case variables alone.

Our study suggests that evidence of persistence in pursuing a particular type of patenting activity may be a better longitudinal predictor of the effects of patenting upon firms' performance than discrete activity measures. Results may be biased because patenting can be a risky strategy for smaller firms to pursue—since disclosures made during patent filings must be fiercely defended from appropriation without compensation—than it may be for larger firms that can defend their right to exploit patents. Larger, surviving firms may be over-represented in results reported herein.

Patent-thicket variables were identified by using the lack of forward citation counts. Consistent with Gambardella, Harhoff and Verspagen (2017) and Torrisi, Gambardella, Giuri, *et al.* (2016), these redundant patents received no citations from subsequent users. Annual production of large numbers of redundant patents were used to identify firms with apparent patent thickets. Evidence of beneficial effects from inferred patent thickets was more frequently associated with the *differentiation* effects of patenting strategy in our results as thickets would impede imitation initially and subsequently may extend the duration of enjoying higher returns.

Firms' diversification profiles were not included as controls in our specifications. Although firms' diversification strategies were heterogeneous in electronics and these differences in strategy choices were sometimes reflected in their patenting activities, Harrigan, Di Guardo, and Cowgill (2017) found a negative relationship in tests of the relationship between firms' relative diversification and creation of relatively radical technological antecedents. Briefly, narrowly-diversified firms had higher mean *Backward V-scores* while the scores of highly-diversified firms more frequently reflected incremental differences in their technological antecedents. Accordingly, diversification was not included as a control variable.

VI. Conclusions

Variables reflecting that some firms within an industry followed persistent patterns of patenting activity over time were useful in identifying how firms' technology strategies varied and how industry conditions may have affected firms' abilities to use particular patenting activities persistently. Results suggesting that filing redundant patents that received no citations from subsequent researchers was costly and argues against pursuing such practices. However, results suggesting that those redundant patents may, in fact, serve as barriers to inventing around key inventions would reverse such resource allocation guidelines. We found that persistently creating what we termed "patent thickets" may provide an effective means of collecting temporary rents for some firms. The above-average

patent thickets grouping variable was positive in most models where it was included, especially for specifications of returns on sales—suggesting that these redundant patents indirectly enhanced differentiation effects. Results not reported herein indicated that persistent use of such patent thickets was more effective as a means to protect competitive advantage within some industry contexts than others—especially if the other industries contained elements of hyper competition. We conclude that future evaluation of the benefits of patenting should consider the respective persistence effects of patenting activity, as all firms within an industry do not benefit equally from patenting and some industries will be less hospitable to long-lived strategic trajectories than are others.

Since patenting was not a costless activity (and technological disclosures in patent filings could be appropriated by savvy competitors), evidence that particular patterns of patenting activity were associated with superior financial performance could be a useful result for resource allocation decisions. Results offer insights concerning which patenting activities provided best advantage to firms' performance over. They also argue for the importance of being persistent in pursing patenting activities as part of firms' technology strategies, even if financial returns are not immediately obvious.

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