FACTOR MARKET RIVALRY AND INTER-INDUSTRY COMPETITIVE DYNAMICS

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Most competitive dynamics studies classify rivals based on some level of product commonality, and symmetry in terms of firm profile such as size, operational scope, and strategic group. By contrast, this study redirects attention to competitive engagements in factor markets, where firms are often blindsided by atypical competitors. Using ten years of data on infringement lawsuits, the study reveals how firms that operate in distinctly different product markets attack each other in overlapping factor markets. The study also shows how resource positions, and long- and short-term inter-firm partnerships affect firms' proclivity to attack and their vulnerability to attacks. Results suggest that greater attention to factor market rivalry might expand the conceptual scope of competitive dynamics theory, thus allowing scholars to better appreciate and for companies to better anticipate attacks along firms' entire value chains. Lastly, to add another layer of rigor to the empirical study, we assessed our predictions with a mathematical model, thus enhancing the validity and robustness of our theory and findings.

Keywords:

Competitive dynamics, factor market rivalry, patent litigation, value chain

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Competitive dynamics research tends to study engagements by focusing on firms that share a certain level of commonality—often related to product offerings, technological domains, and, thus, competitive contexts. Following industrial-organizational (IO) economic frameworks (cf. Chen and Miller, 2012; Porter, 1980), researchers have predominantly taken a product-market view, focusing on fairly homogenous firms from the same industry (Chen, 1996). Thus, prevailing competitive dynamics research classifies firms as rivals when they proffer substitutable offerings to similar buyers in comparable markets—e.g., Coke vs. Pepsi, Ford vs. Toyota, P&G vs. Unilever, etc. (cf. Chen and Miller, 2012; Ketchen, Snow, and Hoover, 2004).

Such scholarly effort has contributed greatly to our understanding of rivalry. However, if rivalrous behavior is *not* limited to similar firms – i.e. that compete over customers in the same or related product markets – but in fact, entails competitors from different industries, then what are the implications for competitive dynamics research and theory? We anticipate several implications because—at least under the current view of competition—it is not trivial to anticipate and explain why firms from different industries and strategic groups can still contest each other (Markman, Gianiodis, and Buchholtz, 2009; Ndofor, Sirmon, and He, 2011). Thus, continuing to rely on a restricted definition of rivalrous behavior hinders the theoretical advancement in the literature (Chen and Miller, 2012).

By addressing this question, we seek to make two main contributions. First, we extend theory by clarifying why and how even very different firms—in terms of size, strategic groups, and customer base—can still act as rivals (e.g., a small, biotech startup competing with a multinational, telecommunication firm) (Markman et al., 2009). Hence, we employ a factor market rivalry perspective, which broadens the scope of competitive dynamics to explicitly

include engagements between dissimilar, and thus unexpected combatants (Chen and Miller, 2015). By relaxing industry designations as a boundary condition to study competitive interactions, we can examine friction points that are often overlooked. This helps to reduce firms' "blind spots", which can be the source of intensifying rivalry (Zajac and Bazerman, 1991).

Second, we add nuance to the factor market rivalry perspective by highlighting how two important firm-level factors – resource portfolio composition and inter-firm partnerships – affect a firm's vulnerability to attacks and its proclivity to attack competitors in factor markets (Markman et al., 2009). This is an important distinction; by emphasizing adversarial engagements that research often overlooks, scholars can apply a more complete model of competitive dynamics (Chen and Miller, 2015). For example, while the link between resource acquisition and competitive advantage is not new (cf. Peteraf, 1993), to date competitive dynamics research has neither sufficiently theorized nor empirically tested how rivalry represents a means to secure resource positions (Carmeli and Markman, 2011). In the next section we briefly describe the factor market rivalry perspective of competitive dynamics, which includes definitions, constructs and assumptions related to factor market interactions.

THE FACTOR MARKET RIVALRY PERSPECTIVE

Attending to the distinctions between factor market and product market perspectives of rivalry can unearth certain conceptual and methodological limitations (cf. Ketchen et al., 2004). These limitations continue to hinder theory development; for example, there is a tendency to conceptualize rivalry as dyadic interactions, rather than multi-firm engagements, which likely ignores the importance of external stakeholders such as allies and partners (Chen and Miller, 2015). Also, the assumption of homogeneity—i.e., whereby similar firms confront each other on the basis of similar offerings—underspecifies the blurring of industry boundaries and the

convergence of markets and sectors (Pouder and St John, 1996; Zaheer, Gulati, and Nohria, 2000). The concern is that when competitive dynamics research focuses too narrowly on hostile interactions among similar firms, it overlooks adversarial relationships among unrelated firms that contest each other in factor markets (Ndofor et al., 2011; Sirmon, Gove, and Hitt, 2008).

The heretofore reliance on a product-market perspective of rivalry—with limited attention to factor market rivalrous behavior—is understandable; product markets are a most salient location with well- measured outcomes such as product proliferation, market share, and market entry/exits, just to name a few (Chen, 1996; Ferrier et al., 1999; Ketchen et al., 2004). Yet, like others, we also worry that this focus, coupled with reliance upon cross-sectional designs and an implicit assumption of equilibrium, is de-contextualizing, and thus under specifying rivalry (Kim and Tsai, 2012; Sirmon et al., 2008). For example, by tagging events based on the dates covered by available data, earlier competitive actions are labeled as "attacks" and subsequent actions as "responses" or "counterattacks." Often this problem of how and when to classify actions as attacks or responses is an unavoidable limitation, but it may have profound consequences in event studies that parameterize rivalry within a narrow window of only days or months (Yu and Cannella, 2007). Indeed, action-response studies show that only about 12% of attacks elicit a reaction, thus revealing substantial ambiguity as to which actions are genuine "attacks," "counterattacks," or "non-attacks," and which firms are correctly identified as "targets"¹ (e.g. Tsai, Su and Chen, 2011). Naturally, this empirical imprecision often hinders theory development, which we argue can be addressed, in part, by applying factor market rivalry logic.

Magnifying these constraints—and the impetus of our study—is that the erosion of market boundaries and the rivalrous behavior that follows, is intimately tied to access to resources in factor markets (Peteraf, 1993). Prior research has shown how 'resource substitution' erodes

resource positions, thus lowering barriers to entry (cf., Peteraf and Bergen, 2003); such studies show that heterogeneous resources with substitutable functionality impact rivalry beyond industry boundaries. Just as product substitutes provide an early warning of possible rivalry, substitutable resources forewarn of possible rivalry in factor markets (Markman et al., 2009). Further, control of identical resources can elicit rivalry by firms that operate in unrelated product markets (Shane, 2001). This is especially prevalent if contested resources can be deployed within and across industry value chains (Le Breton-Miller and Miller, 2015). The implication; even generic resources can trigger rivalry between firms that operate in distinct product markets.

To illustrate how even highly homogenous resources can lead firms to very different types of customers, markets, and industries, and to engage *unusual rivals*, we draw from the patent strategy literature (e.g. Somaya, 2012). For example, Motorola Solutions a telecommunications equipment multinational has at various times been subject to several patent litigations with a highly atypical set of firms, such as in the case of Oxford Gene Technology, a genetics research solutions. This is but one example that challenges the homogeneity view espoused by prevailing competitive dynamics theory; the example also demonstrates possible *"blind spots"* that emerge from classifying rivals solely based on shared buyers, suppliers, or strategic intentions.

By contrast, we argue that factor market rivalry is prevalent across different value chains, involving a variety of resource types, including those linked to IP-domains and other more traditional factors. For example, while Big Pharma firms aggressively compete to defend valuable IP that support patent-protected products with industry rivals, they are also subject to competitive engagements by engineering firms, government agencies, and academia for the brightest minds in mathematics and software development (McBride, 2013). Rivalry over human capital is well documented (e.g. Gardner, 2005); however, as human capital becomes more

versatile and mobile, it is likely to become more predictive of rivalry. Thus, the factor market rivalry perspective may reveal *blind spots* that the product market perspective has overlooked.

THEORY AND HYPOTHESES

Following factor market rivalry logic, we investigate hostile engagements at the resource level. As shown in Figures 1a and 1b, we build logic supporting the importance of three main antecedents to factor market rivalry: a firm's (1) resource portfolio (2) inter-firm partnerships delineated into long-term alliances and short-term agreements—and (3) the extent of product market uncommonality (i.e. non-overlap). We examine these three factors because, as recent research shows, these are the strongest predictors of competitive engagements within technology markets; they also capture the influence of pertinent stakeholders across a firm's value chain (e.g. Chen and Miller, 2015). Because rivalry embodies defensive and offensive positions (i.e. vulnerabilities from and proclivity to attack) resulting in hostile engagements, our predictions acknowledge this duality explicitly. In particular, examining both types allows us to test a more dynamic model of factor market rivalry.

Insert Figure 1a and Figure 1b About Here

Resource Portfolio

Resource advantage theories explicitly describe how resources are inherently asymmetric and thus, are the impetus for adversarial engagements. This suggests a duality inherent in an asymmetric resource position; the firm holding the superior position can exploit the asymmetry, while the firm with an inferior position is more vulnerable to attack (Miller, 2003). In fact, scholars concede that certain resources—proprietary processes, skills, knowledge, and competencies that are exceedingly too costly to imitate, substitute, or buy—can elicit ferocious rivalry, even competitive wars (Chen and Miller, 2012; Peteraf, 1993). This is especially true

because value is often created from resource portfolios (Sirmon, Hitt, and Ireland, 2007). Further, and consistent with resource dependence theory (RDT) (cf., Hillman, Withers, and Collins, 2009), the contestability of the resource position increases as its value increases; not surprisingly, firms that have robust structuring, bundling and leveraging capabilities derive greater value from their portfolios (Ndofor et al., 2011; Sirmon, Gove, and Hitt, 2008).

Prevailing research acknowledges that varied resource-capability mixes explain how firms compete differently, and how their competitive actions change across time and market contexts (Chen and Miller, 2012). For example, Le Breton-Miller and Miller (2015) highlight how competitor behavior varies according to the relative size, and functionality of rivals' resource portfolio. Interestingly, a large resource portfolio may create a paradoxical condition; first, more resources provide greater slack and excess capacity allowing firms to lodge more competitive attacks, thus making them potentially more aggressive players (Ferrier, 2001; Miller, 2003). At the same time, however, firms that own larger resource portfolios may attract more and a varied set of adversaries, especially if the latter seek access to or disrupt the former's asset base (Christensen, Suarez, and Utterback, 1998; Markman et al., 2009). Factor market rivalry and RDT are inextricably linked to a firm's resource positions; however, less appreciated is how resource portfolio size relates to competitor aggressiveness and vulnerability to competitive attacks. In fact, theory suggests that resource size and value encourages increased contestability (Hillman et al., 2009; Livengood and Reger, 2010).

Further, increases in resource size and value provide competing firms a strong incentive to attack rivals, especially when the resources can be leveraged across the value chain (Carmeli and Markman, 2011; Lieberman and Asaba, 2006; Markman et al., 2009). To illustrate, eBay's dominance in the online auction market is more about its proprietary resources that gave it first-

mover advantage, which led to economies of scale effects, rather than the overall quality of its generic products. By creating and imposing a resource barrier through unique "bundling" (Ndofor et al., 2011), eBay was able to earn extended, abnormal returns from its resource portfolio (Peteraf, 1993)². Likewise, as firms, like eBay, leverage their resource portfolio to enter into diverse markets, they are subject to more and varied insurgencies (Chatain, 2014). The lesson is clear; just as large resource positions enhance a firm's competitive repertoire, they also can make the firm more susceptible to attack, even from what looks on the surface weaker rivals (Sirmon et al., 2008). Thus, resource portfolios can be a point of intense inter-firm rivalry, suggesting that the possession of larger resource portfolios are related to both increased vulnerability to attacks and proclivity to attack:

HYPOTHESIS 1a: All else being equal, the accumulation of large resource portfolios is positively related to vulnerability to attacks.

HYPOTHESIS 1b: All else being equal, the accumulation of large resource portfolios is positively related to a higher proclivity to attack.

Inter-firm Partnerships

Research shows that firms seek diverse interfirm partnerships in order to manage dependence (Barringer and Harrison, 2000), lower costs (Hennart, 1998), and/or achieve a more favorable competitive position (Lavie, 2006). Such partnerships range from complex *long-term* alliances—such as equity alliances or joint ventures—to less binding, *short-term* agreements—such as licensing, marketing, or manufacturing contracts. Long-term alliances seek synergy by sharing complementary resources (i.e. know-how, assets), which accelerate research processes, reduce development costs, and improve resource quality (Eisenhardt and Schoonhoven, 1996). By contrast, short-term agreements provide access to specialized service providers—standalone distribution or manufacturing channels—and essentially reflect a more modular inter-firm

exchange aimed at enhancing performance (White, 2005). The strategic alliance literature has produced rich findings (cf. Ireland, Hitt, and Vaidyanath, 2002), yet even the most recent research review articles show that our understanding of how different partnership types might correlate with rivalry in factor markets is quite incomplete (Chen and Miller, 2015). For example, inter-firm partnerships influence access to complementary assets, create path dependence within alliance networks, and thus can provide the ammunition for factor market rivalry (Gulati, Lavie, and Singh, 2009; Lavie, 2006). Given that these partnerships fulfill different aims, we suspect that their influence on competitive behavior in factor markets differs as well. With this in mind, below we seek to advance research in this area by explaining why long-term alliances are associated with reduced factor market rivalry, whereas short-term agreements are associated with increased factor market rivalry.

Long-term Alliances. In diverse industries, but particularly knowledge-intensive ones where resource endowments are especially critical (e.g. information technology, biotechnology, etc.), firms often derive some advantage through inter-firm partnerships (Lavie, 2006). Firms strategic engage to limit risk, and to access complementary assets (Barringer and Harrison, 2000). Long-term alliances, for instance, improve firms' positions by providing access to partner competencies and expertise (Eisenhardt and Schoonhoven, 1996). Thus, firms seek to align their existing "bundle" of resources or capabilities with complementary partners' assets to attain superior positions (Ireland et al., 2002).

One mechanism to achieve alignment is via equity alliances, which rely on long-term orientation, incentive co-alignment, and mutual accountability to reduce shirking, free riding, or opportunism (Hennart, 1988). Because incentive alignment, transparent governance, and a shared history elicit more inter-firm collaboration and trust for long-term alliances as compared to ones

that hinge on short-term transactions, the former tend to bolster inter-firm ties and reciprocal commitments (Lavie, 2006). In turn, these long-term alliances foster inter-firm trust, confidence, and signal inter-firm cohesion to inside partners and to outsiders (Gulati et al., 2009). Recent research suggests how alliance partners form quasi-coalitions, which according to mutual forbearance principles deter outsiders' attacks who wish to avoid retaliations from affiliated firms (Chen and Miller, 2012).

Although all interfirm partnerships are susceptible to *hidden* opportunistic behavior, research suggests that open inter-partner rivalry involving long-term partners is actually diminished (Rothaermel, 2001). These partners are motivated to preserve their beneficial relationship because inter-partner rivalry would not only destabilize and even dissolve existing alliances, but also escalate the costs of sunken capital and delay project completion, especially when other firms take sides (Lenox, Rockart, and Lewin, 2007). Further, path dependencies within alliance networks make long-term alliances quite robust, even under conditions of asymmetric power between partners (Dyer and Singh, 1998; Gnyawali and Madhaven, 2001). These inertial forces create strong disincentives to initiate competitive attacks that may undermine prior commitments (Gulati et al., 2009). Thus, while these alliances are not without risk and many dissolve without fully accomplishing their primary objectives, vulnerability to attacks and risk of rivalry related to long-term alliances are somewhat limited (White, 2005). Put differently, just as firms that operate in multi-contact markets tend to forbear, alliances often create a microcosm that motivates firms to forbear as well. The end result is a 'mutual equilibrium' that discourages explicit rivalry while fostering tacit live-and-let-live understanding that stabilizes competitive relationships (Le Breton-Miller and Miller, 2015). Therefore, we predict:

HYPOTHESIS 2a: All else being equal, long-term inter-firm alliances are negatively related to vulnerability to attacks.

HYPOTHESIS 2b: All else being equal, long-term inter-firm alliances are negatively related to firm proclivity to attack.

Short-term Agreements. As noted, short-term agreements are more transactional in nature; they are highly transitory, and thus less complex, obligating, and 'transactionally' costly to establish, change, or terminate (Gulati et al., 2009). Short-term agreements are characterized by a stricter demarcation of joint activities and resource sharing, which render partners' shirking and non-complying behaviors more transparent and less impactful (Lavie, 2006). In fact, firms employ these inter-firm agreements to plug holes in their resource portfolios (Sirmon et al., 2007); not surprisingly, the narrow scope of these agreements rarely provides sufficient incentives for parties to defend each other when competitive attacks ensue. Thus, transactional arrangements produce neither strong inter-firm ties nor cohesion that are a basis to deter hostility from outsiders (Le Breton-Miller and Miller, 2015; White, 2005); when rivalry arises and conflicts protract, parties often find it simpler to opt out of their short-term agreements rather than stand by their partners (Lavie, 2007). Although short-term agreements can accelerate market entry or penetration (Zachary et al., 2015), they do not provide a strong shielding mechanism against competitive attacks (Ireland et al., 2002). Rather, for rivals contemplating attacks the perception that a target firm (or network of firms) is not supported by its partners, suggest some level of vulnerability (Kilduff, Elfenbein, and Staw, 2010; Markman et al., 2009).

Contrary to long-term agreements that support mutual forbearance, the limited scope and duration of short-term agreements provide more incentive for parties to act opportunistically, launching aggressive attacks against diverse rivals—including partners (Khanna, Gulati, and Nohria, 1998). In the absence of peer pressure to enforce deterrence or the time to cement mutual trust, short-term agreements provide high levels of autonomy for partners to take self-serving action (Rothaermel, 2001). In addition, firms that face these types of attacks generally do not

have the time to develop a joint, competitive response, making them especially vulnerable (Ferrier et al., 2001). Similarly, this inability to coordinate jointly orchestrated competitive actions, make it unlikely that firms bound by short-term agreements will initiate aggressive competitive attacks (Kilduff et al., 2010). Thus, unlike long-term alliances where partner cohesion tends to suppress rivalrous initiatives inside and deter hostility from the outside, partners in short-term agreements tend to enjoy greater autonomy but are also more exposed to rivalrous actions. We predict, therefore, that firms are especially susceptible to this dual aggression-vulnerability related to participation in short-term agreements. Thus:

HYPOTHESIS 3a: All else being equal, short-term inter-firm agreements are positively related to firm vulnerability to attacks.

HYPOTHESIS 3b: All else being equal, short-term inter-firm agreements are positively related to firm proclivity to attack.

Cross-Industry Competitive Engagement

The fact that identical resources can form very different products is not new (e.g., Kodak's chemicals and Canon's optics yielded almost identical images); yet as noted above, competitive dynamics research has not fully addressed both the empirical and conceptual implications of contexts entailing firms that rely on *similar* resources but produce very *different* products (e.g. Markman et al., 2009). For example, discoveries in nanotechnology are used to design tennis racquets, improve ski's glide, produce self-cleaning agents, prevent arsenic contamination, or develop vaccines and therapeutic drug delivery. Nanotechnology represents just one example of how inventions based on a single resource or bundled resources can attract a varied set of competitive assumptions (Hseih, Tsai, and Chen, 2015). Indeed, research has shown that many types of resources – human, intellectual and social capital, just to name a few – can provoke competitive engagement between unfamiliar combatants (Chastain, 2014; Gardner, 2005;

Ketchen et al., 2004). This is especially true because resources such as human capital demonstrate resource versatility and mobility across many firm and industry contexts (Markman et al, 2009). Given this heterogeneity, it is not surprising that firms deploying these types of resource and/or participating in factor markets subject to these conditions are more likely to launch preemptive attacks, while simultaneously subject to greater vulnerability of attack.

We argue that the competitor heterogeneity is less predictable - combatants are driven by different assumptions, motivations and capabilities, and are thus conditioned to expect varied responses and outcomes – which may lead to more rivalrous behavior, especially in factor markets (cf. Chen and Miller, 2015; Chen et al., 2007). In fact, theory suggests factor market competition is a prelude to and outcome of asymmetric advantages (e.g. Miller, 2003). Thus, firms have strong incentives to attack across industry boundaries, and likewise firms are more vulnerable to these "cross-industry" attacks because they may be less aware of the threat and/or unable to adequately respond to an unfamiliar competitor (Chastain, 2014).

Such is the case in a prominent factor market of the modern economy – the market for intellectually protected innovation. For example patent thicket theory³ holds that when patents either 'overcrowd' a technology (Beard and Kaserman, 2002; Shapiro, 2001) or have diverse applications, the risk of hostile infringement intensifies. Analogous to a minefield, when numerous interrelated patents protect diverse technologies or processes, the owner of strong patents could take several actions – impede further technological developments, block downstream production, or delay product-market activity such as sales – thus jeopardizing rival firms' returns on R&D investments. This creates significant vulnerability for all parties and their vulnerabilities are intensified when products, services, and processes infringe on patents issued

even years after these offerings were or sold in the market (Somaya, 2003). When this scenario holds, avoiding confrontation is quite unrealistic.

The cumulative nature of bundling resource portfolios – such as intellectual and human capital supporting R&D (Sirmon et al., 2007) – may render the option of innovating around entrenched resource positions substantially more expensive, ex post (Schilling, 1998). This suggests that advantages derived from cumulative investments (e.g. in R&D capabilities) may become a liability in factor markets; in fact, recent research details how competition over control of intellectual capital can result in escalating rivalry (Hseih et al., 2015; Somaya, 2012). In the biomedical industry, for instance, there are about 300,000 patents that can be subject to infringement⁴. As a result, it is virtually impossible to know with certainty, ex ante, whether an innovation will infringe on existing patents or jeopardize current market offerings (The Economist, 2010). Patents are just one type of contestable resource (i.e. intellectual capital); yet, firms compete over other contestable forms of capital – human, social, political etc. – which makes them increasingly vulnerable to "cross-industry" attacks.

In sum, given asymmetric motivations (Chen et al., 2007) firms may act more aggressively towards *cross-industry rivals* in factor markets than they would with *industry rivals* in product markets (Markman et al., 2009). This may increase the likelihood of preemptive attacks as the norms of competitive engagement are tested (Livengood and Reger, 2010); the result is greater proclivity to conduct cross-industry attacks and thus more vulnerability to these types of competitive actions, (Ferrier, 2001). Therefore, we predict:

HYPOTHESIS 4*a*: All else being equal, factor market rivalry is positively related to vulnerability to attacks by cross-industry rivals, i.e. no overlap in product markets.

HYPOTHESIS 4b: All else being equal, factor market rivalry is positively related with the proclivity to attack cross-industry rivals, i.e. no overlap in product markets.

DATA AND METHODS

We investigate factor market rivalry in the technological domain traditionally related to firms competing in the biotechnology industry. The sample was drawn from the 2003 Thomson BioWorld database, which profiles more than 1800 biotechnology firms. This list was then crossreferenced to the Hoover's database of biotechnology firms, consisting of 728 firms. The result was a sample of 482 firms whose primary business is related to the discovery and commercialization of biotechnology products and services (SIC: 2833-2836; 8731-8733 or NAICS: 541710). We parsed the sample further to eliminate firms that were (a) recently acquired, in the process of merging, and/or did not supply financial and other key data (i.e. privately-held firms). This resulted in a final sample of 228 public firms. Due to inconsistent reporting of company data across time (1993-2003), our usable sample was made of 174 firms for which we had full and complete data⁵. We bounded our sample to firms in the biotechnology industry because they are especially reliant on patents-valuable, rare, inimitable, and costly to substitute resources—than firms in other industries (e.g. Lerner, 1995). Past research has shown that for a variety of reasons (e.g. mobility of scientific personnel), biotechnology firms are less likely to rely on trade secrecy, and more likely to protect discoveries through patents (Somaya, 2003). In addition, biotechnology firms' dependence on patents to protect their intellectual property (IP) makes them quite likely to litigate to defend these critical resources.

To provide triangulation and avoid common method bias, data were collected from and cross-validated using six different sources: (1) annual reports (e.g. 10Ks) from 1993-2002; (2) the 2003 Thomson BioWorld database; (3) Bioexchange.com, a portal for information on the biotechnology industry; (4) LexisNexis Academic and Library database; (5) firms' websites; and (6) the U.S. Patent and Trademark Office (USPTO). For example, we collected litigation data,

partnerships, and licensing, joint venture, and marketing agreements of each firm using five of the six sources outlined above. Likewise, patent data were first collected from the USPTO website, and then validated using each firm's 10K reports and their websites. Financial data were the only variables that came from a single source—firms'10K reports. Data for all variables were collected for years 1993-2003. We chose this timeframe because it broadly captures the progression of the Human Genome Project (HGP), closely associated with the biotechnology industry (McElheny, 2010). The HGP's primary goal was to determine the sequence of chemical base pairs, which make up DNA, and identify and map the approximately 20,000-25,000 genes of the human genome. Unless otherwise noted, to capture rivalry patterns over an extended period of time we used yearly averages for each variable to reduce the effects of random shocks.

Dependent Variables

The investigation of patent litigation motivates scholarship from diverse disciplines—e.g., legal studies, management, finance and economics, to name a few – in part, because it provides a robust context for examining firm-level competitive dynamics (Galasso and Schankerman, 2010; Lerner, 1995; Merges and Nelson, 1990; Somaya, 2012). Unlike many action-response studies, patent litigation incorporates clear aggressive and defensive competitive behavior between identifiable combatants and defenders (Somaya, 2003; Tsai, Su and Chen, 2011). In addition, patent litigation proceedings have specific time markers, which provide "natural" boundaries for empirical examination. Thus, patent litigation offers a robust, unambiguous context for empirically testing the factor market perspective (Markman et al., 2009).

We model patents as three-dimensional objects, where every dimension has an independent capacity to mitigate or exacerbate rivalry—the number of patents, the industrial space a patent occupies, and the technology transfer ability of each patent form the canvas on which we sketch

out our view of rivalry. We used two proxies to measure *factor market rivalry*: The number of litigations in which a firm was (1) named as a defendant and (2) brought legal action as a plaintiff relating to patent infringement. In order to accurately account for each case of litigation, we referenced the initial legal action and then detailed any subsequent action. We used this approach because patent-based litigations often are the result of a series of legal actions, which over time get "packed" into one action as it goes through the discovery and motion stages towards eventual trial and appeal, or settlement. For example, in 1998 Affymetrix filed suit against Incyte relating to three patents. In 1999, Incyte counter-sued related to two of their patents. In turn, Affymetrix filed suit to invalidate the two Incyte patents and added another patent to their original suit (i.e. in application stage at the time of the original suit). To simplify court proceedings, the three suits were combined into one file under one jurisdiction⁶. Under this scenario, we counted three legal actions as this approach more accurately depicts the rivalrous nature of each firm and is consistent with past research (Somaya, 2003).

In order to maintain accurate data, we first reviewed the firm's (1993-2002) annual reports in the *Legal Proceedings* section, as well as the *Business Risks* and *Intellectual Property* sections for all legal actions. By starting with annual reports, we determined only a firm's *material* legal actions. For example, we included patent interference actions (i.e. so called quasi-judicial procedural actions), for firms that reported them as material to the survival of their business (Lerner, 1995). We then validated this information with four additional data sources: the 2003 Thomson BioWorld database; Bioexchange.com; LexisNexis Academic and Library database; and firms' website. The multiple sources provided additional information related to each case including parties involved and if (and how) the action was settled. Since both the plaintiff and defendant litigations distributions are skewed, we took the natural log for both these variables.

Predictor Variables

Resource Portfolios. Consistent with past research, we operationalized *resource portfolios* as the number of a firms' patents (Lerner, 1995; Ndofor et al., 2011; Somaya, 2003). Firms' patent portfolio data were first collected from USPTO website, and then validated using each firm's 10K reports and their individual websites. Patent data were collected for the years 1993-2003. We also collected data on patent citations and claims, but these variables were highly correlated with the number of patent, thus these more qualitative measures were excluded from the analyses. To address distribution skewness, we took the natural log the variable.

Long-term Alliances. To increase measurement credibility, we test two types of long-term alliances: research partnerships and joint ventures. Data on the number of research partnerships were collected for years 1993-2003 on each partner. We first reviewed the firm's annual reports under *Business*, which includes a description of each corporate partner. We then validated this information with four additional data sources: the 2003 Thomson BioWorld database; Bioexchange.com; LexisNexis Academic and Library database; and firms' website. As with litigation data, the multiple sources provided additional detail including year initiated and alliance duration.

A joint venture (JV) is a separate legal entity in which other firms hold ownership interests under provisions that are specified by a legal agreement. Although JVs are not expected to last indefinitely, their prevalence is rising (Ireland et al., 2002). For example, as R&D and innovation in the biotech industry increase and as more firms adopt open innovation models (cf. Gianiodis, Ellis, and Secchi, 2010), JVs provide firms with opportunities to rapidly expand into new markets, create economies of scale, reduce risks, compress learning of new technologies, and facilitate effective resource sharing. Similar to research partnerships, JVs connect firms around

common goal and opportunities. In general, JVs are legally complex (Hennart, 1998); disentangling them and the IP that they generate is equally complex, and this complexity acts as a buffer to potential patent-based litigation. We operationalized JVs as any agreement between two firms, in which a new entity was created through joint ownership (i.e. equity sharing). Generally, joint ventures provide each partner with access to all IP created from the venture, or all IP licensed to and by the new entity (Lavie, 2007).

Short-term Agreements. Unlike long-term agreements, short-term agreements are highly transactional and more easily terminated. We used two types of inter-firm transactions as proxies for short-term agreements: licensing and marketing agreements. Licensing agreements were operationalized as the number of both in-licensing and out-licensing of patent-based technology including exclusive, non-exclusive (i.e. technology transfers) and cross-licensing agreements (i.e. patent swaps). Marketing agreements provide outsourcing and distribution links, and they were operationalized as any agreement that allowed a third-party access to offerings based on patented technology for the purpose of bringing them to market.

We collected data for years 1993-2003 for each type of transactional agreement by reviewing the firm's annual reports under *Business*, specifically the *Corporate Collaborator* and *Intellectual Property* sections, which includes a description of each corporate agreement. We then validated this information with four additional data sources: The 2003 Thomson BioWorld database; Bioexchange.com; LexisNexis Academic and Library database; and firms' website.

Non-traditional Rivals. To test the extent to which biotechnology firms compete with nontraditional rivals – firms with resource similarity, but product un-commonality – we assessed for inconsistency in SIC and NAICS designations of parties to a patent-related lawsuit. First, we compared parties only on the basis of primary SIC/NAICS designations and then we compared

parties on the basis of primary *and* secondary designations. In both cases we coded these variables as 1 when parties share the same designations and 0 when they did not. This dichotomous indicator signifies whether or not a firm serves the same product market (Peteraf and Bergen, 2003). We tested these variables in the regressions and obtained similar results. Henceforth, then, we present the findings using the latter variable as it provides a more conservative test of the predictions for hypotheses 4a and 4b. For ease and clarity, these variables are labeled 'plaintiffs' SIC' and 'defendants' SIC' (1 = internal; 0 = external SIC/NAICS).

Control Variables

Consistent with existing research on patent litigation, we employed several variables to control for firm and environmental effects (cf. Somaya, 2012). The data for these control variables were drawn primarily from Thomson BioWorld database, LexisNexis and the USPTO patent databases. *R&D Expenditures* measure represents both absorptive capacity and future innovation capabilities, making it highly predictive of subsequent strategic action (Lenox et al., 2007). In addition, for many biotech firms, R&D represents the most important resource allocation decision, and thus acts as a strong proxy for current and future strategic choice. Since the *R&D expenditures* distribution is skewed, we took the natural log the variable. A firm's capital structure is an important component of its overall strategy, in particular its capacity to initiate and defend competitive actions (Chen and Miller, 2012). We measured a firm's capital/debt structure (*Leverage*) as the ratio of total liability to total assets. To address distribution skewness, we took the natural log the variable. A firm's competitive repertoire evolves over time and impacts its competitive framing (Markman and Waldron, 2014). Therefore, we control for *Firm Age* measured as the number of years since incorporation. We took the natural log the variable since the firm age distribution is skewed. As large firms have

more resources to incur the significant costs associated with patent litigation (Lerner, 1995), we controlled for *Firm Size* as measured by using a firm's annual assets during the previous year. Assets are a particularly stable measure of strength among public biotechnology firms. Since the firm size distribution is skewed, we took the natural log the variable. In addition, we considered two additional firm-level controls – profitability and revenues – but these were highly correlated with *Firm Size* and R & D and thus were dropped from the analyses. Lastly, we included a year dummy variable (*Year*) in order to control for year-specific sources of heterogeneity within an industry's external environment.

ANALYSES AND RESULTS

Employing an ordinary least squares (OLS) regression technique is not appropriate because our dependent variable is a count variable. Instead, we used negative binomial models to analyze the data; this method has been widely used in management research to overcome the overdispersion problem associated with count dependent variables (e.g. Haunschild and Beckman, 1998). Also, we lagged all the time-varying independent and control variables by one year in all the regression analyses in order to avoid potential simultaneity problems. We conducted a Heckman two-stage selection procedure to address the imperfections of our sampling technique; we limited our sample to those that are publicly traded, and thus private firms were excluded from our sample. Specifically, we modeled the likelihood of being a public firm in the first stage by regressing firm leverage, firm size, patent portfolio, alliance partnerships, licensing agreements, and firm assets on a dummy variable (1 = public, 0 = non-public). We then generated the inverse Mills ratio from the first stage and controlled for it in the second stage model for predicting patent litigation initiation and defense.

Table I summarizes the descriptive statistics and the correlation matrix of variables used in the analyses. On average, a biotech firm in our study was 16 years old, had 417 employees, incurred a net loss of \$36 million on revenues of \$72 million, allocated \$28.6 million for R&D, and had assets of \$209 million. Interestingly, from 1993 to 2003, our 174-biotech firms logged 364 lawsuits relating to more than 300 patents, 185 as defendants and 179 as plaintiffs. These companies obtained an average of 3.5 new patents yearly.

Insert Table I About Here

Table II summarizes the two hierarchical regressions on each of the two measures of factor market rivalry—the number of *defendant* and *plaintiff* lawsuits. To assess multicollinearity we estimated the variance inflation factors (VIFs) and found no variable with a VIF greater than 2.11, which is below the recommended ceiling of 10 (Tabachnick and Fidell, 1996).

A two-step approach in each regression allowed us to examine the significance and amount of additional variance accounted for by the independent predictors. The control variables—R&D expenditures, leverage, firm age, firm size, and the inverse Mills ratio—were entered as a block in step one. Respectively, these predictors in Model 1 explained 28% (F = 9.07; p < .01) of the variance in defendants' number of lawsuits and 15% (F = 4.28; p < .001) of plaintiffs' number of lawsuits in Model 3.

Insert Table II About Here

In the second block, we entered the predictor variables for models 2 and 4. Hypotheses 1a and 1b predicted positive relationships between the size of resource portfolios and patent-based rivalry. These predictions were partially supported—having a larger number of patents is associated with an increased proclivity to attack on the basis of patents (p < .05). Though having a larger patent portfolio was related to vulnerability to attacks, the relationship was insignificant.

Hypotheses 2a and 2b predicted an inverse relationship between long-term agreements and rivalry. Again, we found partial support for these predictions. Having many research partnerships is associated with lower vulnerability from an attack (p < .01) and proclivity (p < .01) to attack using patent litigation. A firm's portfolio of joint ventures were, however, not significant.

Hypotheses 3a and 3b predicted that short-term agreements, such as licensing and marketing agreements, were significantly and positively related to both vulnerability from and proclivity to attack via patent litigation. We found strong support for these predictions as both licensing agreements and marketing agreements were significant (p < .01 and p < .05 respectively) for both defendant and plaintiff litigations; thus hypotheses 3a and 3b were supported.

Most importantly, hypotheses 4a and 4b, which predicted that factor market rivalry entails firms from different product markets, received partial support. Incumbents in the biotech industry are vulnerable to being blindsided by industry outsiders (p < .05), but their own proclivity to launch cross-industry attacks (i.e. blindsiding industry outsiders) is not greater than their proclivity to attack industry incumbents. All in all, the inclusion of these predictors to the equations explained an additional 17% (F = 8.11; p < .01) of the variance in defendants' number of lawsuits and 15% (F = 3.89; p < .001) of the variance in plaintiffs' number of lawsuits, to a total of 43% and 30% of the variance respectively.

Post-hoc Analyses

To ensure robust results, we conducted three important post hoc analyses. First, since we only used a one-year lag for our predictor variables in the above analyses, we also experimented with two and three-year lags for our predictor variables and patent litigation to see whether or not a lasting effect exists. We found that all patterns remained consistent, with slightly weaker effects for both short-term and long-term agreements compared with the results in Table II; this

indicates that the influence of both types of agreements diminish over time.

In addition, we verified our statistical results using other estimate techniques. We chose the negative binomial regression model in our main analysis; however, this technique can also lead to biased estimates. To address this potential weakness, we re-estimated our models using firm-level fixed-effects Poisson estimates (Cameron and Trivedi, 1998). In addition, we ran a series of OLS models on the logged dependent variables. The results of these additional tests were almost identical to what is reported in Table II.

Lastly, we subject our theory and empirical findings to a mathematical model that focuses on the rivalrous behaviour of two patent portfolio holders, firms *i* and *j*, as they battle for the ownership of patented technologies that are to be used in developing a process innovation. Briefly, upon perceived infringement of *i*'s technology by *j*, the two rivals can either try to amicably settle the matter, or they can opt for rivalry via litigation. Their choice of strategy is affected by: a) how many patents each firm has, b) how far apart their technologies are in terms of SIC/NAICS classification codes and c) on how they can use long-term or short-term agreements to mitigate rivalry. The number of patents affects the magnitude of a potential infringement and the associated losses. The distance between the technologies is an indicator of substitutability and can also lead to blind spots. Lastly, long-term agreements are perceived as necessitating a greater joint pooling of resources compared to short-term ones.

The reasoning of the models is captured in simple terms in Figure 2. It portrays the parameter space under which a settlement is possible (and the space where litigation prevails) in terms of two variables: i) patent portfolio size and ii) the shape of the agreement between the two firms i.e. long-term or not. Moreover, the curvature of this figure is affected by how far apart the technologies of the two firms are in terms of SIC/NAICS classification codes. The resulting

concave curve implies that greater patent portfolios are associated with more rivalry, and longterm agreements with less. Furthermore, as an increase in the technological distance (in terms of SIC/NAICS codes) results in a limited shift of the curve the effect of technological distance is lukewarm. In Appendix I, the complete model is fully explained.

DISCUSSION AND IMPLICATIONS

We began this study by attempting to redirect scholarly attention from competitive dynamics based upon product market commonality and firm symmetry, to competitive engagements between cross-industry rivals – resource similarity, but product-market uncommonality – in factor markets. We argue that rivalry is not limited to clusters of homogeneous firms that share product markets or draw from the same resource pools; rather, it also entails competitive engagements between heterogeneous firms from different industries that seek access to nonsubstitutable resources. This paper begins to answer the call for additional theory development and empirical validation of competitive dynamics across value chains - both firm and industry involving a broader set of stakeholders within more diverse contexts (Chen and Miller, 2015). Although research on the link between resources and competitive dynamics is not new (Capron and Chastain, 2008; Markman et al., 2009; Sirmon et al., 2008), our findings suggest that to better predict rivalry, research needs to cast a wider net (cf. Chen and Miller, 2012). In particular, this study highlights the importance of cross-industry rivalry and inter-firm partnerships in intensifying (i.e. short-term agreements) or muting (i.e. long-term alliances) competitive engagements in factor markets. Additionally, this study confirms the presence of factor market rivalry; incumbents within the biotech industry were vulnerable to attack by nonindustry rivals solely on the basis of a contestable resource (Markman et al., 2009). For the

purpose of added clarity and ease, below we first describe the findings in normative terms and then explain the contribution to competitive dynamics.

Resource Portfolio and Patent Litigation

Consistent with patent thicket theory, firms with a large IP portfolio are significantly more litigious (Shapiro, 2001). One explanation for this finding is that holding many patents enhances a firm's learning capabilities– they are savvier and more proactive about their IP having learned to both develop and protect patentable technologies (Somaya, 2012). By contrast, firms with fewer patents have not developed or acquired these capabilities (cf. Teece, 2014). This finding is also consistent with Chen's (1996, 2007) *awareness-motivation-capability* treatise; larger firms are generally *aware* of events in their task environment, are *motivated* to maintain their dominant position in factor markets, but most importantly have the *capability* to engage a varied and complex set of competitors. This finding supports our thesis; firms that accumulate large resource positions are likely to be proactive and demonstrate aggressive competitive behavior in factor markets.

Interestingly, we did not find support for the prediction that firms with larger resource portfolios are more vulnerable to rivalry. Perhaps the presence of a large patent portfolio acts as a deterrent to aggressive factor market behavior by rivals; firms with larger patent portfolios are in a strong position to retaliate (Lanjouw and Schankerman, 2004). In addition, these firms develop competencies that allow them to protect their resources, such as accessing complementary assets (Rothaermel, 2001), thus motivating others to seek non-rivalrous tactics. Our study's design and data do not provide clear explanation for either of these explanations, and as such it should be viewed with caution. Future research should integrate this logic from the

alliance literature and include variables that better approximate complementary assets, dynamic capabilities and patent-based litigation in factor markets.

Long-term Alliances and Patent Litigation

Consistent with mutual forbearance theory (Golden and Ma, 2003) and the relational view of interconnected firms (Dyer and Singh, 1998), firms that enter into long-term alliances are less vulnerable to attacks and have lower proclivity to attack others. In the case of research partnerships within the biotech industry, it seems that long-term alliances provide interdependence that entices even rivals to acquiesce, and suppress opportunistic behavior (Lavie). These findings were expected because when rivals join in partnership they have an inherent incentive to withhold aggressive interactions and exercise forbearance. The lesson here is that, over and above firm size, market or technological space in which competitors coalesce, long-term alliances are a shielding force that reduces rivalry.

Theory also predicts that joint ventures would reduce rivalry (e.g. Gulati et al., 2009); however, this prediction was not supported. Firms that enter joint venture agreements do not experience any significant relief from factor market rivalry. Given the importance biotech firms place on R&D capabilities, inter-firm research agreements may be a better vehicle than joint ventures to build trust between alliance partners (Lavie, 2007). In the context of extant literature on the benefits of joint ventures, this (lack of) finding is intriguing, but it must await future research. In particular, future research should employ more fine-grained approaches, including variable related to joint venture adoption, governance, and duration (Hennart, 1988).

Short-term Agreements and Patent Litigation

Licensing agreements can prevent inventor holdup or other threats to efficiency within innovation systems (i.e. help to resolve the patent thicket problem) by providing legal access and

protection from lawsuits (cf., Beard and Kaserman, 2002). Parties to cross-licensing agreements reduce the risk of accidental infringement and legal claims, which discourages competing firms to invent around existing patents. In fact, the risk of IP-based attacks is so serious that a new market niche has emerged; firms' entire value proposition is to provide patent risk management services, defensive buying, acquisition syndication, and patent intelligence (e.g., RPX Corp, cf. Hagiu and Yoffie, 2013). With reduced risk of infringement, firms can focus their R&D efforts to improve upon, rather than allocating resources toward rivalry or to merely bypass or duplicate, existing knowledge (Somaya, 2012). In economic terms, reducing competition and eliminating the need to invent around prior discoveries heightens the marginal productivity of R&D investment. In addition, licensing agreements reduce transaction costs and market entry because in the absence of licensing, each firm would have to perform costly patent searches and negotiations to obtain the same level of protection achieved with simple licensing agreements.

With these expected benefits, why are licensing agreements consistently related to increased patent-based rivalry—both for defendants and plaintiffs? One explanation for this finding is that even when licensing reduces rivalry between parties to an agreement, such agreements do not benefit uninvolved third party competitors. In fact, there is reason to believe that as far as excluded parties are concerned, licensing agreements actually raise the barrier to entry and increase excluded parties' incentive to attack (cf. Ferrier et al., 1999). In other words, cross-licensing is akin to the standards *lock out* described by Schilling (1998); for every licensing agreement made by two parties, additional parties are left out. This, of course, increases the incentives for third-party competitors to attack, and thus, increases the vulnerability of IP holders. Although this explanation begs for further empirical scrutiny, it points out the weakness of dyad research, which normally ignores the actions of third-party stakeholders or rivals (Chen

and Miller, 2015). In the absence of duopolistic markets, discounting the effects of third party actions hinders theory building, and may lead to incomplete descriptions.

In contrast to forbearance theory, firms that sign many marketing agreements tend to both endure and lodge more patent-related lawsuits. The rationale used is that publicity, broad exposure, and declined sales due to product substitutes bring inter-firm friction and motivate retaliatory actions. The lesson here is that although marketing agreements yield broad product reach and speed to market they also relate to factor market rivalry; many patent-based lawsuits use product injunction add-ons to delay product launch or to force offerings off the market.

Cross-Industry Rivalry and Patent Litigation

Strategy research has traditionally used the principle of equifinality to note that rivals use different factors to produce identical offerings (cf. Gresov and Drazin, 1997; Payne, 2006). Our study suggests that equifinality also applies in factor markets: identical resources attract rivals who operate in different industries and unrelated product markets (Shane, 2001). The implication to rivalry is twofold. First, identical resources act as friction points, eliciting rivalry among firms operating in different product markets. Second, rivalry over resource positions can disrupt incumbents, which hints that the element of surprise is probably strongest when target firms adhere to normative industry precincts (Markman and Waldron, 2014). The finding that firms are vulnerable to attacks by industry outsiders, but do not have the inclination to initiate such attacks challenges traditional paradigms that adhere to arbitrary industry designations (e.g. SIC or NAICS codes); rivalry *does not* only occur between firms who share buyers, sellers and strategic intentions. Furthermore, a cross-industry attack can result in disproportionate costs to the combatants, but only when these firms are positioned close enough to share value related to the contended factor. This final point is especially salient because it opens the possibility of more

volatile competitive behavior than what was previously modeled in terms of firm heterogeneity—in terms of size, resource endowments, and strategic intentions. We elaborate on this and the other findings and their implication to theory in the next section.

Contribution to Factor Market Rivalry

Our study broadens the definition of competitor identification and rivalry by directing attention to rivalry over core resources. This extends traditional classifications and schemas employed in the strategic management and inter-firm rivalry literatures (e.g. strategic groups). Focusing on factor market rivalry that consists of unusual rivals, or industry outsiders, reveals "blind spots" that afflict the product market-based research stream (Zajac and Bazerman, 1991). This, we hope, will inform both theory and practice. Current theory remains underdeveloped in understanding asymmetric competitive positions, often linked to factor market actions (Miller, 2003). Our study on patent-based rivalry relaxes the assumptions of symmetry and it also draws attention to rivalrous actions along earlier sections of firms' value chain. For practice, factor market rivalry extends earlier work (e.g. Peteraf and Bergen, 2003). It broadens competitor identification frameworks, which extol the virtues of overcoming the natural tendency of scholars to focus upon product markets, and ignore factor market engagements or other activities along a firm's value chain. This will help scholars and managers to better understand firms' vulnerability to indirect and unexpected competitors, identify early warning signs of competitive encroachment, and how firms should address challenges at the origins of the competitive process. This is critical given the ongoing convergence of, heretofore, disparate domains such as IT and entertainment, telephony and communications, just to name a few.

Limitations

As with all studies, this one has limitations. In particular, the use of a single industry and resource type can hinder generalizability. Given the early stage of theory and empirical research in this area, this limitation was to be expected as single-industry and single-resource research adds precision. Despite the specificity regarding biotechnology and patents, our literature review and interviews with managers suggest that parameterizing factor market rivalry extends theory and practice. It expands the view of rivalry, helping scholars and managers to overcome the natural myopia that stems from industry-centric views of competition (Peteraf and Bergen, 2003). Still, future research should determine whether these findings are specific to biotechnology and patents or if they can be generalized to other industries and other core resources. In particular, researchers should follow recent work that has explored competitive actions in strategic factor markets over other resources such as human, social, financial, and other forms of capital (cf. Carmeli and Markman, 2011; Chatain, 2014; Hseih et al., 2015; Ndofor et al., 2011; Walter, Heinrichs, and Walter, 2014). In addition, our research focused on attack volume (i.e. a count of patent-based litigation), without investigating other elements of an attack such as magnitude, duration, complexity, and unpredictability (Ferrier, 2001). Due to data constraints we operationalized factor market rivalry as the number of engagements; future research should investigate multiple measures related to the attack, especially the financial impact to the attacking (plaintiff) and defending (defendant) firms.

CONCLUSIONS

Rivalry comes in many forms and on from many fronts; it even entails heterogeneous firms from unrelated industries seeking advantage on multiple dimensions. In this study, we tested a model that links factor market and product market actions to better define rivalry to

accommodate cross-industry rivalry. In particular, it identified an unconventional class of rivals based upon resource advantage and resource dependence logic. Because rivalry is fundamentally about firms determined to capture irreconcilable domains, future research should identify other

points of conflict, and explicate the conditions, determinants and outcomes of rivalrous behavior.

Notwithstanding earlier work, to move inter-firm rivalry and competitive dynamics theory

forward, it is necessary to examine engagements at the resource level. Thus, our intention was to

complement existing competitive dynamics theory by exploring conditions and determinants of

factor-based rivalry.

NOTES:

¹ For example, is a cut in airfare prices at United Airlines an act of operational necessity or bona fide attack, and if the latter, who is the target? Is it Delta, American, Southwest, JetBlue Airlines, others?

² Many attribute Wal-Mart's success to *cost leadership*, but like the eBay example, resourcebased rivalry argues that achieving price advantage in product markets hinges on bundles of resources—namely, operations and proprietary logistics—rather than mindlessly cutting prices.

³ Shapiro (2001) describes a *patent thicket* as "a dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology".

⁴ Subsequent to the Oxford litigation, Motorola first split itself into two separate companies – Motorola Mobility, first acquired by Google in 2011 and then purchased by Lenovo in 2014, and Motorola Solutions, a publicly-traded firm listed on the NYSE (MSI).

⁵ Based on searches for patent description/specification containing the word "bio, medical, or biomedical" in the U.S. Patent and Trademark Office database.

⁶ Though rivalry can also be captured by the dollar amount awarded by lawsuits, in reality, court data reveal that of the 3,075 patent lawsuits filed in 2004, almost 97% of the lawsuits were settled before reaching a trial, plus the settlement amount is frequently undisclosed.

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Figure 1a: Research Model of Predictors of Defensive-Vulnerability to Attack



DEFENSIVE

** Hypothesis supported

* Hypothesis partially supported

Figure 1b: Research Model of Predictors of Offensive-Proclivity to Attack



OFFENSIVE

** Hypothesis supported

* Hypothesis partially supported

Figure 2: A Graph of the Equilibrium Strategies



The vertical axis represents the nature of agreements. As values move from zero to one the agreement gradually shifts from a short-term to a long-term one. The horizontal axis accounts for how much bigger *i*'s patent portfolio is compared to *j*'s. A value of one indicates that both firms have identical portfolios, and a value of two indicates that *i*'s portfolio is twice the size of to *j*'s.

	Mean	S.D	D Correlation												
			1	2	3	4	5	6	7	8	9	10	11	12	13
1. Plaintiffs' Cases	2.08	.62													
2. Defends' Cases	2.27	.75	.48												
3. R&D	9.41	1.23	.22	.28											
4. Leverage	.497	.278	.46	.39	.27										
5. Firm Age	1.21	.47	.48	.22	.68	.37									
6. Firm Assets	10.89	1.48	.33	.47	.79	.41	.74								
7. Inverse Mills Ratio	.44	.22	.03	04	.33	.09	.29	.42							
8. Resource Portfolio	.70	1.09	.31	.04	.49	.13	.55	.43	.36						
9. Research Partnerships	1.94	1.27	.24	.10	.41	.19	.27	.48	07	.48					
10. Joint Ventures	.04	.08	.16	.17	.09	.34	.17	.11	11	.09	.18				
11. License Agreements	1.00	.88	.30	.24	.34	.23	.22	.43	.02	.28	.39	.20			
12. Marketing Agreements	.15	.19	.30	.30	14	03	07	.02	.04	.06	.12	02	.04		
13. Plaint. SIC	.52	.50	24	33	.13	.33	.02	.06	.03	.02	03	06	04	35	
14. Defend. SIC	.46	.50	27	33	.06	.42	03	04	11	13	16	16	01	43	.65

 Table I: Means, Standard Deviations, and Correlation Matrix

Number of firms = 174. Correlations above .30 are significant at p < 0.01. Year dummy variables are not reported.

Variables	Defendants' #	# of Cases (log)	Plaintiffs' # of Cases (log)			
	Model 1	Model 2	Model 3	Model 4		
R&D Expenditures	-0.19	-0.03	16	06		
Leverage	0.20*	0.17	.27*	.22*		
Firm Age	0.44**	0.52**	.33**	.42**		
Firm Size (Assets)	0.59**	0.56**	.24**	.27**		
Inverse Mills Ratio	0.05	0.45	0.07	0.61		
Resource (Patent) Portfolio		-0.09		0.31*		
Research Partnerships		-0.54***		-0.46***		
Joint Venture Agreements		0.15		0.13		
Licensing Agreements		0.38**		0.51**		
Marketing Agreements		0.23*		0.26*		
Plaintiffs' SIC (int.=1; ext.=0)		-0.23*				
Defendants' SIC (int.=1; ext.=0)				-0.11		
Adj. R ²	.28	.43	.15	.30		
Δ R ²		.17**		.15**		
F	8.77**	7.91**	4.11***	3.83***		

Table II: Number of Lawsuits Litigated as Defendants and as Plaintiffs^a

^a Values are standardized regression coefficients (N = 174). The Year dummy control is included, but not reported.

* p < .05 level. ** p < .01 level. *** p < .001 level.

APPENDIX I: Mathematical Model On The Rivalrous Behaviour of Two Firms

We now examine how bundles of intellectual property rights (e.g. patent portfolios) affect our theoretical analysis and hypotheses, providing the unifying logic for our empirical model. At close inspection these bundles of patented technologies are a non-homogeneous ensemble of property rights, which often have little stand-alone value. Consequently, most scholars simply consider them as a strategy tool whose purpose is to use economies of scale to barricade a firm's main assets. With this Porterian view as our starting point, we chose to treat such portfolios holistically. We view them as three-dimensional objects, where every dimension has an independent capacity to mitigate or exacerbate rivalry. Accordingly, the number of patents, the industrial space a patent occupies, and the technology transfer ability of each patent form the canvas on which we sketch out our view of rivalry.

Thinking in three dimensions is challenging, especially when these dimensions are interwoven, because results can lead to a dual reading. Starting with the first dimension – the number of patents - we postulate that a thicket of patents is rivalry inducing. However, one cannot discard without further study the following chain of events: the emergence of a conflict forces a firm into acquiring patents. In terms of the second dimension, if the firms use technologies that stand far apart in terms of industrial space, then firms can be faced with blind spots. Hence, the possibility of being caught into an unexpected conflict is real. At the same time though, the further apart the two technologies are the less substitutable the final products become, which reduces the rivalling firms' incentive to fight. Thus, the interplay between the two effects is not immediately evident. In fact, this logic seems to indicate a non-linear relationship, in which case more than one argument can provide a plausible explanation to reality. The third dimension drives the model further into a grey area. Transferring patents through licensing agreements is here argued to affect rivalry. However, at the same time it also affects the other two dimensions of the model because it influences the number of patents the firm has at its disposal. Such perspective endogeneity can bias our perception of rivalry.

To overcome this conundrum, in order to uncover hidden causalities between the model's parameters (and in helping to undercover any additional nuances) we frame a mathematical model that accounts for conflicts over intangible ideas. The model uncovers a conceptual boundary. Our analytical understanding of conflicts between rival firms is shaped by competition over prises, or quantity; Bertrand and Cournot competition respectively. These models are good in analysing conflicts over a final product, or an input of production. However, they are not able to address a conflict over intangible inputs of production that are characterised by nonexcludability and a very small marginal cost of production. Biotechnology patents are such inputs, because once the principle behind the technology is known the marginal cost of production is effectively close to zero and until the conflict over ownership is resolved no firm can exclude the other from using the idea that is embodied in the patent. Thus, under Cournot competition the firms can produce unlimited amounts at will, or in case of Bertrand competition nothing at all; because the equilibrium price will drop down to naught forcing the firms to abstain from entering the market and innovating in the first place. In short, in both cases, by construction, we end up with equilibrium solutions that do not make sense. To address this shortfall we develop a model of rivalry where firms have amassed a panoply of patent portfolios that they can use in mitigating or exacerbating rivalry. In accordance with our theory these patent portfolios sketch out the firms' production and inevitably drive the results.

Accordingly, we subject our theory to a mathematical model that focuses on the rivalrous behaviour of two firms *i* and *j* as they battle for the ownership of patented technologies that are to be used in developing a process innovation. The conflict we have in mind is the following. Firm *i* owns a technology that it perceives to have been copied by *j*, inasmuch as *j* uses a similar technology in adding technological sophistication to its product.² Upon infringement firm *i* has a choice. It can either do nothing (**Strategy N**), or it can file an infringement suit at a court of law. After filing the case *i* can either wait until it is adjudicated (**Strategy L**), or it can pursue an out of court settlement (**Strategy S**). A settlement is indicative of an amicus agreement that puts an end to the conflict, contrasting litigation that is the epitome of rivalry.

Settlements can take myriad forms such as licensing/cross-licensing of technologies, market sharing, joint technological development etc. For simplicity, and in accordance with our theory, a settlement is framed in the form of a licensing agreement for the said technology, where agreements can be long-term or short-term. Specifically, the licensing agreement marks down how i and j compete against each other, where a long-term agreement effectively implies that i and j agree on staying out of each other's market. At the other side of the spectrum, a short-term agreement allows competition to ensue on the merits of each firm's technology.

By construction this mathematical exercise adopts the view that rivalry between *i* and *j* provides the breeding ground for long- and short-term agreements, reversing the causality of our verbal argument, which postulated that agreements shape rivalry. The reason for this reversal is to avoid a tautology. The tautology in this occasion is the simple fact that amicus solutions preclude rivalry. Therefore, we endeavor to illustrate that even when the causality is reversed the final argument remains intact. In a nutshell, we stride to prove an oxymoron: *rivalry leads to forbearance*.

Furthermore, since we study infringement *ex post*, our results (indicating when rivalry prevails over an amicus agreement) map j's incentives/proclivity for a conflict in view of i's characteristics. In this sense, the model equally captures i's vulnerability to rivalry stemming from j's decision to infringe. With this in mind let us now delve into the model's variables and parameters.

In accordance with our theory, the infringing technology need not be embedded in a product of similar functionality with the one encompassing the original technology. In fact, the two firms/products can occupy the same market or adjacent markets. If *i* and *j* share the same market then their technologies are substitutes, becoming less substitutable the farther apart they are in terms of SIC/ NAICS coding. Henceforth we use $x \in (0,1)$ in denoting substitutability, where a higher *x* is indicative of greater substitutability.

For our purpose, the two firms differ only in size, where size is not an output indicator, being instead indicative of a firm's patent portfolio. The underlying assumption is that firms that have amassed large portfolios are more prolific in their R&D. In fact, patent portfolios act as a testimony to their innovative abilities and technological sophistication. In the absence of a conflict (**Strategy B**) *i* and *j* have a patent portfolio of s_i and s_j respectively, where s_i is $\sigma > 0$ times the size of s_j , which we normalize to one. In other words, $s_i = \sigma s_j$, $s_j = 1$ where s_i and s_j are indicative of *i* and *j*'s technological sophistication. It should be noted that when σ is less than one *i* is smaller than *j* and vise versa.

We should note that in this static model it does not make sense to argue for an inversion of the chain of events, where in view of the opponent the firm opts to built up a portfolio. The

² The model does not focus on verbatim infringement as it can only lead to one outcome, litigation.

reason is the hiatus of 2-3 years between the invention of a technology and the ensuing patent. Plus, as uncertainty surrounds both R&D and patent prosecution, the form that the resulting portfolio takes and its capacity to be used in averting rivalry cannot be known in advance.

Firms i and j compete over technology intensive products whose main functions are perceived to be to some extent indistinguishable by consumers, who are homogeneous having a utility that is a function of price and the degree of technological sophistication that differentiates a product from its substitute. Demand is dependent on prices and technological diversification. Allowing the market to be competitive, prices show limited variation. Therefore, i and j charge the same price, which we use as a numeraire. Subsequently, working in the context of a simple differentiated model (see Dixit, 1977), the effect of each firm's price cancels out the other, allowing the differences in the technological sophistication between products to be the main driving force of demand.

With this in mind, for **Strategy B** the demand that *i* and *j* face is, $q_i^B = m + s_i - s_j^x$ and $q_j^B = m + s_j - s_i^x$ respectively. In the above equations *m* captures fixed demand, $x \in (0,1)$ is indicative of the degree of substitutability between the firms' technologies, and $s_i - s_j^x$, $s_j - s_i^x$ pinpoint how differences in technological sophistication (and the ensuing substitutability) affect demand. Notice that if *x* is close to zero $(x \to 0)$ and the two technologies are not substitutable, $q_i^B = m + s_i$ and $q_j^B = m + s_j$, in which case the rival's technology does not affect the firm. By contrast, if *x* is close to one $(x \to 1)$ then $q_i^B = m + s_i - s_j$ and $q_j^B = m + s_j - s_i$. In this occasion, the rival's technology diminishes demand in a one to one basis.

Considering that the marginal cost of production for most technologies is low, demand and profits must largely coincide. Thus, the profits of *i* and *j* are respectively derived as,

(1)
$$\pi_i^B = m + s_i - s_j^x$$
, $\pi_j^B = m + s_j - s_i^x$, where $s_i = \sigma$, $s_j = 1$.

Upon infringement, if *i* decides on taking no action we have **Strategy N**. In this case *j* appropriates *i*'s full patent portfolio (σ) which it uses in a product of enhanced technological sophistication. The assumption of comprehensive infringement does not on its own shape the final results. It only simplifies the mathematical expressions.³ An alternative interpretation for this assumption is that σ is the subset of *i*'s patent portfolio that encompasses the infringing patents. For **Strategy N** the profits of *i* and *j* are respectively derived as,

(2)
$$\pi_i^N = m + s_i - s_j^x$$
, $\pi_j^N = m + s_j - s_i^x$, where $s_i = \sigma$, $s_j = 1 + \sigma$.

Using equations (1)-(2) we can derive *i*'s losses from infringement, which are given by $l = \pi_i^B - \pi_i^N$. Substituting π_i^B and π_i^N into *l*, *i*'s losses from infringement are, $[(1 + \sigma)^x - 1]x^{-1}$. Note that as $x \to 1$ and the two products become more substitutable $l \to \sigma$, while if $x \to 0$ then $l \to 0$. To put it simply, if the two products are not substitutes, infringement results in no loss of profits for *i*. However, as *x* increases the loss of profits increases to a maximum of σ .

The above framework, treating infringement as being immediately discovered, does not account for the blind spots that our theory describes. However, the farther appart (in terms of x) i and j are the greater the blind spots. This logic suggest that as x becomes smaller it is

³ A more realistic assumption that views infringement to involve a partial copying of the technology will add an extra variable to the discussion without affecting the models results and intuition.

increasingly harder to spot infringement, and the longer infringement stays unditected the greater the losses for *i*. With this in mind we hereafter frame losses as $l^* = x^{-1}(\pi_i^B - \pi_i^N)$. Note that when $x \to 1$ (i.e the two products become more substitutable) $l^* \to l$. By contrast, if $x \to 0$ (and the products are described by very different SIC/ NAICS codes) since infringement is undetected for longer it increases *i*'s losses from infringement.

Focusing on the subgame, upon filing the case i can choose **Strategy L**, or it can pursue **Strategy S**. We frame **Strategy S** as follows. After detecting infringement the firm must decide on a short-term or long-term agreement. In this case the agreement does not focus on i getting back its infringed technology (**Strategy L** accounts for this) instead it focuses on mitigating competition/rivalry. To this end the profits of i and j from following **Strategy S** are respectively derived as,

(3)
$$\pi_i^S = m + s_i - (1 - \alpha)s_j^x$$
, $\pi_j^S = m + s_j - (1 - \alpha)s_i^x$, where $s_i = \sigma$, $s_j = 1 + \sigma$.

In (3) $\alpha \in [0,1]$ captures the aforesaid long/short term agreement. For example, if $\alpha = 1$, in which case we have a long-term agreement, equation (3) becomes $\pi_i^S = m + s_i$, $\pi_j^S = m + s_j$ and *i* and *j* face no rivalry from each other, in which case they can appropriate monopoly profits. By contrast, if $\alpha \to 0$ we have a very short-term agreement. In fact, for the extreme case where $\alpha = 0$ infringement continues in which case the firms' profits are given by equation (2).

We now frame **Strategy L**. Specifically, if after filing the case i wants to pursue litigation then the firms' profits from litigation are,

(4)
$$\pi_i^L = \mu(\pi_i^N + l^*) + (1 - \mu)\pi_i^N$$
, and $\pi_j^L = \mu(\pi_j^N - l^*) + (1 - \mu)\pi_j^N$.

In (4), $\mu(\pi_i^N + l^*)$ denotes *i*'s profits from winning the court case with probability $\mu \in [0,1]$. These should be equal to the π_i^N profits that accrue to *i* when infringement takes place, plus the losses l^* that it foregoes. On the other hand, if *i* loses its case, with probability $(1 - \mu)$, then it can only get π_i^N . Equation (4) draws a similar picture for the infringer, who has to return the l^* profits it appropriated if it loses the case, while if it wins it can legally get the π_j^N profits from infringement.⁴

Before finding the equilibrium solution let us recapitulate on how the main parameters affect the model. The greater *i*'s patent portfolio is the greater the losses from infringement become. Thus, we should expect that a greater σ should be associated with more litigation. This finding verifies the logic behind H1. The same should be true for μ , because an increase in the probability of winning the case inevitably increases the gains from litigation. On the other hand, as α increases we see greater gains stemming from a settlement. Hence, a greater α should lead to more amicus solutions and less attacks (i.e. litigation). This finding verifies the associated logic behind H2 and H3. Lastly, the effect of x is harder to predict. On the one hand if the firms are located far apart then, as their corresponding technologies are less substitutable, we shouldn't expect *i* to incur heavy losses from infringement. On the other hand, this effect is

⁴ In order to simplify the analysis, and in keeping within the borders described by our theory, we do not include in equation (4) the cost of litigation. Considering that greater patent portfolios endow the plaintiff with a lower litigation cost (Lanjouw and Schankerman 2004), such an inclusion would only shift the balance in favor of litigation.

counterbalanced by the blind spots effect that allows infringement to remain undetected for a longer period, increasing l^* . Therefore, our prior is that H4 should find lukewarm support.

We now derive the equilibrium solution starting from the subgame, where we compare the profits stemming from **Strategy L** with the ones from **S**. Accordingly, using equations (3)-(4), settlement dominates litigation for firm i if,

(5)
$$\alpha > \mu (1 - (1 + \sigma)^{-x}) x^{-1}$$

while for *j* **S** dominates **L** if $\alpha > -\mu(1 - (1 + \sigma)^{-x})x^{-1}$. In other words, for all values of α , *j* prefers to settle.

For the main game we do not need to focus on *j* because the decision to litigate (or not) is taken by firm *i* only. Comparing the profits from strategies **L** and **N** (using equations 2 and 4) for *i*, we find that as long as $\sigma > 0$ **L** is the dominant strategy. In the same fashion, by comparing the profits from strategies **S** and **N** (using equations 3 and 4) we find that, as long as $\alpha > 0$, **S** is the dominant strategy for *i*.

To sum up, the mathematical model indicates that: a) upon infringement the choice between conflict (**Strategy L**) and agreement (**Strategy S**) solemnly rests on firm *i* (as *j* always prefer to settle the case), and furthermore, b) *i's* choice is morphed by equation (5). As expected, (5) is positively affected by σ and μ , while the effect *x* is ambiguous. In fact, it turns out that, as long as $(1 + \sigma)^x > 1 + x \log(1 + \sigma)$ holds,⁵ equation (5) is negatively affected by *x*; leading to more litigation. These results are depicted in Figure 2 that plots equation (5) for $\alpha \in [0,1]$, $\sigma \in [0,1.5]$, $\mu = .5$ and x = 0.9. The upper part of the graph captures the area (in terms of α , σ) where **Strategy S** is the dominant strategy, while the lower part depicts the area where **Strategy L** is dominant. An increase in μ and/or a drop in *x* shifts the curve upwards, increasing the area under which litigation is the dominant strategy.

⁵ In this stylized mathematical model the equation always holds