Which Industries Are Served by Online Marketplaces for Technology?

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ABSTRACT

This study investigates a recent phenomenon in the market for technology: online marketplaces for technological inventions, which support the listing, search, and exchange of technological inventions by sellers and buyers. Focusing on three salient theoretical factors that affect markets for technology – search costs, ambiguity about the underlying knowledge and its applications, and expropriation concerns – our research systematically explores which industries are served by online marketplaces. We exploit the fact that the magnitude of these factors varies across industries and identify key features of online marketplaces that may address these factors. Our proprietary dataset covers 12 online marketplaces for technology and spans over 140 industries. The results indicate that online marketplaces are more likely to serve an industry with (a) a higher cost of searching for technologies in that industry, (b) greater ambiguity about the underlying technology's potential applications across industries, and (c) greater ability to protect inventions from expropriation.

Keywords: Market for Technology, Online Markets, Search Costs, Ambiguity, Appropriation

1. Introduction

Markets for ideas and technologies have grown dramatically over recent decades and are receiving increasing attention from both scholars and practitioners (Agrawal, Cockburn, & Zhang, 2015b; Arora, Fosfuri, & Gambardella, 2001; Rivette & Kline, 2000). The result is a large body of work investigating a broad range of issues important for the market for technology. These issues include factors driving inventors' participation in these markets (e.g., Bercovitz & Feldman, 2007; Ceccagnoli & Jiang, 2013; Conti, Gambardella, & Novelli, 2013; Fosfuri, 2006), the way in which the exchange is organized (e.g., Arora, Fosfuri, & Rønde, 2013; Laursen & Salter, 2006; Leone & Reichstein, 2012), and institutions supporting the market for technology (Lamoreaux & Sokoloff, 2003; Zhang & Li, 2010).

In this paper, we study an institution that has emerged recently in the market for technology: online technology marketplaces. These marketplaces use information technology and the Internet to facilitate the listing, search, and exchange of inventions between inventors and technology owners or sellers on one hand and prospective licensees or technology buyers on the other (Bakos, 1997; Brynjolfsson & Saunders, 2009; Dushnitsky & Klueter, 2011). For over a decade, a number of marketplaces have operated successfully, connecting tens of thousands of technology sellers and buyers (e.g., Yanagisawa & Guellec, 2009) and being used by prominent organizations such as NASA, Du Pont, and major academic research institutions (Lakhani, Lifshitz-Assaf, & Tushman, 2012; Leone & Reichstein, 2012). Anecdotal evidence suggests that online marketplaces have the potential to expand the reach of markets for technology between sellers and buyers, similar to online marketplaces for consumer goods (e.g., Amazon or eBay), physical products, or real estate (e.g., Craigslist or Zillow) (Brynjolfsson, Hu, & Simester, 2011; Brynjolfsson & Saunders, 2009; Dushnitsky & Klueter, 2011; Palomeras, 2007). However, while a growing number of firms participate in such online marketplaces (Agrawal et al., 2015b), we still know little about which industries are actually served by online technology markets in the first place.

The purpose of this paper is to address this gap by investigating which industries are served by online technology marketplaces. That is, we ask: In what industries do online marketplaces exist? Do they extend to technologies from the biotechnology and semiconductor industries as well as the transportation and construction industries? By analogy to online real estate marketplaces (like Zillow.com), we explore whether the marketplaces cater to properties in Boston and San Diego as well as other metropolitan areas like Pittsburgh and Philadelphia. This question is important, as studies in the market for technology typically focus on only a few industries (e.g., pharmaceuticals, chemicals) in which markets for technology are most prevalent (e.g., Fosfuri, 2006; Nishimura & Okada, 2014). Yet, we know little about the presence of a market for technology in dozens of other industries (e.g., transportation, construction).

The focal point of the paper is to explain which industries are served by online markets to begin with rather than to focus on consummated transactions between sellers and buyers within a marketplace (implicitly conditioned on the existence of a marketplace). Returning to the real estate analogy, consider the popular marketplace, Zillow.com. We focus on the metropolitan areas covered by Zillow, independent of which properties are ultimately sold. This initial search and identification of sellers and buyers – a stage which precedes the actual bilateral negotiations or deal-making between a pair of participants – has been shown as one of the most crucial but challenging stages in the market for technology, (Agrawal et al., 2015b).

In particular, we examine industry characteristics that impede prospective sellers and buyers from identifying each other, and study the potential of online markets for technology to alleviate these frictions. Our theoretical arguments pivot on three salient factors that affect markets for technology: search costs, ambiguity with respect to the underlying technology and its potential applications, and concerns regarding appropriation (Akerlof, 1970; Coase, 1960; Klevorick, Levin, Nelson, & Winter, 1995; Stigler, 1961; Teece, 1986). The frictions associated with these factors may prevent sellers and buyers from identifying each other and, in the extreme case, may altogether preclude participation in the market for technology (Arora et al., 2001; Teece, 1986). We exploit the fact that the magnitude of these frictions varies across industries and identify key features of online marketplaces that may address these frictions. This approach allows us to conjecture as to which industries can benefit from being served by online marketplaces and to empirically demonstrate what industries online marketplaces do – or do not – serve. Table 1 summarizes our key arguments.

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We posit that industries characterized by high geographic dispersion and firm fragmentation impose high search costs on industry participants. In those industries, an institution such as an Internet-based online marketplace can likely offer valuable services to facilitate interaction and identification among prospective sellers and buyers of technology (Forman, Ghose, & Goldfarb, 2009; Lamoreaux & Sokoloff, 2003). Similarly, in industries with high ambiguity about the underlying technological knowledge and its potential applications, sellers and buyers may face challenges in sharing, communicating, and evaluating technological inventions. Online marketplaces mitigate ambiguity and direct buyers' and sellers' attention by offering a codified representation of all the listed technologies in a highly standardized manner. Online technology marketplaces therefore enable the assessment of a focal invention's applicability, and facilitate its valuation by benchmarking it to the many other listed inventions. However, not all industries with high search costs and knowledge ambiguity will see the emergence of online marketplaces. Rather, the advent of such an institution is shaped by its ability to protect inventors' intellectual property (Teece, 1986). Because inventions that are disclosed, codified, and aggregated online can be at risk of imitation, we expect online markets to serve industries in which inventions cannot be easily expropriated, namely, industries that are characterized by strong appropriation regimes.

We test our predictions using a hand-collected sample of 12 online technology marketplaces that connected inventors and technology sellers with technology buyers in 2008. These marketplaces address specific industries and facilitate the listing, search, and exchange (i.e., licensing, sale, etc.) of innovative technologies between globally distributed parties. In the aggregate, the online technology marketplaces in our sample serve over 100 different industries in agriculture, manufacturing, and information technology. Importantly, the cross-section of industries in our data allows us to observe notable variation in search costs, knowledge ambiguity, and appropriation concerns across industries. We can therefore investigate the impact of these industry characteristics on the presence of online markets for technology for a given industry. Our findings suggest that online-based marketplaces are not ubiquitous as one might expect. We observe systematic variation in the number of online marketplaces across industries, and that the variation is explained by the predicted critical factors (i.e., search costs, knowledge ambiguity, and appropriation). These findings illuminate the unique role of information technology in the market for technology and suggest the potential for the expansion of the market for technology through online markets.

Finally, qualitative data and interviews with managers using online technology marketplaces further substantiate the implication of our investigation. The interviews reveal that transactions in the market for technology often originate online, where the parties initially identified each other, and proceed in interaction and negotiations that are consummated offline (Arora, 1996; Hagiu & Yoffie, 2013). This finding suggests that online marketplaces have considerable potential to address frictions between sellers and buyers and serve as an important starting point for industry participants to identify each other. This aspect is not much different from the real estate context, where online listings facilitate the identification of opportunities and offline interaction remains important for subsequent actions such as inspection, due diligence, and potential haggling before a property ultimately changes hands.

Our study is among the first to systematically examine multiple online markets for technologies that mold the interactions among sellers and buyers prior to consummation of a deal. Importantly, it expands the perspective on markets for technology to dozens of industries that have received little attention. Studying online markets for technology provides new insights into which industry characteristics lead to coverage of such markets by online technology marketplaces. In doing so, it sheds light on the initial stage of the market for technology, where prospective sellers and buyers initially search for, identify, and interact with each other. More broadly, the study explains the unique characteristics of online marketplaces and the role of information technology in shaping the market for technology in the face of search costs, knowledge ambiguity, and appropriation concerns between sellers and buyers. We elaborate on the implications of these findings in the discussion section.

2. Theory and hypotheses

2.1. The market for technology

Prior work indicates that inventions can be codified and "disembodied" from the original inventor so that development and commercialization are not limited to the inventing person or company (Conti et al., 2013). Accordingly, a market for technology may emerge in which participants with new technologies interact with participants who can commercialize the technologies and exchange inventions for a price (Arora et al., 2001).

Although the market for technology is growing rapidly (Arora & Gambardella, 2010), we know little about either the extent to which it supports gainful innovation or the specific pattern of its emergence across industries. Prior work has investigated a host of factors that influence the way prospective sellers and buyers identify each other and interact in the market for technology (Agrawal et al., 2015b; Arora et al., 2001; Gans & Stern, 2003). This study focuses on three of the most salient frictions this literature identifies, which relate to (a) the cost of searching for quality inventions across different geographies and companies, (b) the challenge of communicating and assessing technologies when ambiguity exists about the underlying knowledge and its potential applications, and (c) the difficulty of appropriating the value of an invention (Akerlof, 1970; Coase, 1960; Levin et al., 1987; Teece, 1986). Absent a mechanism to address these frictions, they can substantially affect the process by which sellers and buyers notice and identify each other and in the extreme case may distort the market for technology altogether (Agrawal et al., 2015b). Indeed, anecdotal evidence suggests that many viable technologies can remain "locked" or underused within firms (BTG, 1998; Danneels, 2007; Giuri et al., 2007; Rivette & Kline, 2000).

Researchers have identified institutions that address the aforementioned frictions in the market for technology, including patent lawyers (Lamoreaux & Sokoloff, 2003), accounting and financial accounting service firms (Zhang & Li, 2010), government agencies (Arora et al., 2001; Yusuf, 2008), and regional organizations (McEvily & Zaheer, 1999). We follow this stream of literature and study the recent emergence of a new institution: online markets for technology. These marketplaces may facilitate the functioning of a working market for technology, allowing us to systematically investigate which industries could benefit from such online marketplaces and the industry characteristics associated with the emergence of an active online marketplace for ideas.

2.2. Online markets for technology

Recent research suggest that a growing number of firms today use online marketplaces to mitigate frictions in the market for technology (Agrawal et al., 2015b). Following Bakos (1998), we stipulate that online marketplaces serve as virtual markets that facilitate the listing of, search for, and exchange of inventions. These are two-sided markets that support matching and efficient distribution of information in a timely manner (Dushnitsky & Klueter, 2011; Gans & Stern, 2010). A marketplace connects and promotes transactions between two pools of participants (Parker & Van Alstyne, 2005). It accommodates inventors (henceforth sellers) who list their inventions in the marketplace and potential licensees or investors (henceforth buyers) who can search the listed information online and engage with the sellers. Online knowledge marketplaces are independent from buyers and sellers and provide an online platform (e.g., a website) through which participants can communicate, find a match, and potentially initiate a transaction. Such marketplaces have appeared in many other settings, such as the real estate market (Zillow.com) and the labor market (Monster.com) (Brynjolfsson & Saunders, 2009).

The marketplaces we study tend to facilitate trade in a type of invention wherein the intellectual property is at least partially embedded in a legal right such as a patent. A unique feature of these institutions is that they are virtual – that is, the initial interactions among market participants take place through a dedicated interface on the Internet. One of the most prominent marketplaces in this category is yet2.com, which was launched in 1999. A few online markets draw inventions predominantly from universities or public research institutes (e.g., Flintbox and iBridgenetwork), while others receive the majority of inventions from the private sector (e.g., Tynax and yet2.com). Table 2 provides an overview over the marketplaces we examine and offers some background as to their mission and functionality.

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Online technology markets allow us to observe active markets for technology across a broad range of industries. To the extent that understanding the process by which prospective sellers and buyers take notice of and identify each other is crucial for the market for technology (Agrawal et al., 2015b), the study of online marketplaces can illuminate such dynamics in many different sectors. Moreover, our hypotheses focus on the unique features of an online marketplace and how these features address the frictions in the market for technology. We expect online markets to emerge in those industries in which their potential to address frictions is greater. The next sections develop hypotheses regarding the impact of industry characteristics associated with market frictions (i.e., search costs, ambiguity, and appropriation) and how they affect the likelihood that the industry will be served by online marketplaces.

2.3. Search costs

Search costs refer to the costs of identifying and finding transaction partners and may profoundly affect buyers and sellers in the market for technology (Stigler, 1961). Online markets may address these frictions and therefore could be particularly well suited to industries in which search costs are high.

Seminal work describes the roots of search costs, noting that a single firm cannot possess all relevant information since information about opportunities and potential partners is dispersed among industry actors and geographic locations (Stigler, 1961). In particular, search costs consist of two key elements: (a) the cost of "discover[ing] who it is that one wishes to deal with and. inform[ing] people that one wishes to deal with" (Coase, 1960:7), and (b) the foregone payoffs associated with the time and resources spent searching and screening potential transaction partners (Bakos, 1997). In the context of new technological opportunities, these costs may be substantial and the participants may either forego economic activity altogether or accept sub-optimal matches (March & Simon, 1958). Indeed, prior research highlights that the basic identification of sellers and buyers poses a major hurdle in the market for technology and the problem is exacerbated when sellers/buyers are not in geographic proximity (Agrawal et al., 2015b; Sorenson & Stuart, 2001).

Arora and colleagues (2001) emphasize that search costs may vary across industries. An important characteristic of an industry is how sellers and buyers of knowledge are dispersed around the globe. The adverse effect of geographical distance is twofold. First, firms commonly find that physical distance hinders them from being informed about technological inventions originating in distant locations (Sorenson & Stuart, 2001). For example, the role of clusters in effective knowledge sharing is typically attributed to firms' abilities to co-locate and benefit from knowledge spillovers (Jaffe, 1986).[1] Second, crossing large distances usually implies not only that one has to traverse a vast geographical space, but also that one encounters unfamiliar local contexts (e.g., a country with unique characteristics or culture) (Castellani, Jimenez, & Zanfei, 2013; Kranenburg, Hagedoorn, & Lorenz-Orlean, 2014). It follows that an industry, in which actors are dispersed across countries increases the cost of searching for new technologies.

An online marketplace can alleviate the search costs associated with geographic dispersion and may unlock the potential to connect distant parties. Online marketplaces are characterized by open networks and connectivity, which allow participants to observe and communicate with distant and diverse constituencies (Amit & Zott, 2001; Bakos, 1997; Garicano & Kaplan, 2001). These characteristics imply that online marketplaces have broad reach. That is, they can cater to a large number of participants because the marginal cost of adding a seller or buyer is low (Brews & Tucci, 2004). Thus, online markets ease the

[1] Note that knowledge flows remain geographically bounded even in the presence of well-known central knowledge repositories, such as a patent office directory (Jaffe, Trajtenberg, & Henderson, 1993).

identification of other participants in the market for technology, and such benefit increases the more severe the search costs in an industry.

Online markets are not constrained by geographical boundaries and can connect a large number of participants with access to Internet infrastructure (Amit & Zott, 2001). This ability to connect suggests that online markets for technology may offer important benefits to industries in which actors are dispersed around the globe. For example, online markets require inventors to list their technologies through uniform representations of information, using standardized templates for every technology. Such a common data structure, paired with the use of a common language, speeds the search process, enhances the scope of the search, and substantially reduces the cost of transmitting and exchanging information across geographic boundaries (Brews & Tucci, 2004). Indeed, recent work suggests that the use of web-based technology platforms alleviates the cost of search across geographic distance (Afuah & Tucci, 2012; Agrawal, Catalini, & Goldfarb, 2015a), and the use of online communication facilitates access to scientific repositories (Agrawal & Goldfarb, 2008).

Drawing on these arguments, we conjecture that online markets are well positioned to decrease search costs stemming from the geographic distance between technology sellers and buyers. We therefore expect that online markets emerge in industries where frictions due to geographical dispersion are most salient.

Hypothesis 1a: An industry where search costs are high, such as an industry characterized by high levels of geographic dispersion, is more likely to be served by online marketplaces.

Search costs may arise from factors other than geographic dispersion. They may also be associated with the number of firms in an industry such that highly fragmented industries – that is, industries characterized by many firms – experience higher search costs. Fragmentation can exacerbate search costs because emerging knowledge may be characterized by uncertainty regarding (a) the feasibility of a technology (i.e., will it work?), (b) the technology's viability (i.e., is there a market for it?), and (c) other uses for the technology (i.e., what other, potentially better, applications might the technology have?) (Cassimon, De Backer, Engelen, Van Wouwe, & Yordanov, 2011). This uncertainty suggests that the search process faces two hurdles. First, a firm has to search for a technology among a fragmented group of peers. Second, the observed applications may not be a good fit for the firm and may distract from identifying the best use.[2]

Industry fragmentation likely increases the two key elements of search costs: (a) the cost of searching across multiple prospective partners (Coase, 1960), and (b) the opportunity cost owing to foregone time and resources spent searching (Bakos, 1997). Simply put, in the presence of multiple firms generating knowledge, remaining informed about all possible technological opportunities can be challenging. Opportunity cost rises because fragmented knowledge requires more time and resources for making comparisons. Thus the more fragmented an industry, the more effort is needed to sift through multiple firms and the various potentially less relevant technologies and related applications they pursue (Basalla, 1988). The bio-pharmaceutical industry provides an example, as technological change is predominantly driven by a multitude of science-based startups (Arora & Gambardella, 1994; Cohen & Levin, 1989). Established firms incur considerable costs in attempting to stay updated about technological change, and often they resort to establishing units dedicated to searching for and evaluating new technologies (Dushnitsky & Lenox, 2005; Monteiro & Birkinshaw, 2016).

As with geographic dispersion, online markets can mitigate the search costs in those industries where the knowledge base is fragmented. The marketplaces are easily scalable, may encompass a plethora of participants, and consequently offer a timely and cost-effective

[2] One can think of the search for a knowledge asset as a search for a unique asset for which few buyers or sellers exist in the market (like, for example, unique paintings or baseball cards) (Stigler, 1961). While Stigler indicated that for such unique goods search costs will be high (as there is not really a market owing to a low number of participants), we predict that the fragmentation of actors may lead to higher search costs since potential sellers and buyers are confronted with a plurality of possibilities and can predict little as to which technology will be ultimately useful.

way to search potential different partners (Brews & Tucci, 2004). They are therefore particularly suited to addressing search challenges in fragmented industries (Evans & Wurster, 1999). The business media echo this observation: "The problem that people have when looking for technology is they can't spend hours . . . . IP exchanges that offer attractive search tools for the user . . . are more likely to attract potential licensees" (Tactics, 2008). Thus we expect online markets to emerge in industries with fragmented actors.

In addition, online marketplaces are inclusive and cater to a wide range of potential buyers and sellers. This feature can help identify potential new technology-application combinations, as sellers/buyers get exposed to a broad range of novel partners (Jeppesen & Lakhani, 2010). The sheer number of participants increases the likelihood of an invention's exposure to potential buyers from distant domains. Robert Hirsch, managing director of Licensing and DuPont Ventures, explained the important role of online markets for DuPont, saying: "We use yet2.com to help find licensees that we wouldn't normally know how to get to" (Wood & Scott, 2004:20). Consider, by analogy, the emergence of the long-tail phenomenon owing to online retailing. Online retail marketplaces such as Amazon have enabled sellers and buyers of specialty products – which were previously underserved – to come together and engage in valuable exchanges (Brynjolfsson et al., 2011; Brynjolfsson, Hu, & Smith, 2006). The result has been an overall expansion in the size of transactions within the book and music industries. In a similar vein, online marketplaces are not only associated with a quantitative decrease in the cost of search, but can also lead to a qualitative change in the type of connections. The latter feature is particular salient in industries where knowledge is fragmented.

In summary, we expect that highly fragmented industries are ripe for the emergence of new institutions that mitigate search costs.

Hypothesis 1b: An industry where search costs are high, such as an industry characterized by high levels of industry-fragmentation, is more likely to be served by online marketplaces.

While the market for technology facilitates the identification of sellers and buyers by mitigating search costs, participants in the market still face difficulties in communicating and sharing information about their underlying technological knowledge and its benefits across a wide range of potential applications. We next explore these frictions and how online markets may address them.

2.4. Knowledge ambiguity

Ambiguity regarding the technological value of an invention and its possible applications can also hinder the market for technology. The level of technological ambiguity varies across industries (Klevorick et al., 1995), and this cross-industry variation affects the ability to contract and trade in innovative technologies (Anand & Khanna, 2000). Specifically, ambiguity with respect to the underlying knowledge impedes the effective interpretation and communication of the knowledge. Prior work notes that sellers and buyers in the market for technology do not easily recognize the value of technological inventions that are characterized by a high level of ambiguity (Rosenberg, 1996; Simonin, 1999). We consider two forces driving such ambiguity. First, ambiguity regarding the underlying technological knowledge may result from multiple and diverging technological trajectories. Second, ambiguity can stem from the unknown potential of applications with which a technology can be ultimately associated. However, both of these challenges may be alleviated by online marketplaces.

Ambiguity regarding technological trajectories

The rapid pace of technological change contributes to the level of ambiguity within a given industry. In particular, the emergence of multiple technological paths at the scientific frontier will subsequently lead to technological change. Ultimately, a few of the technologies will prove useful and will result in productivity gains for the focal industry (Hicks & Hegde, 2005). The Solow Residual (also called multifactor productivity) captures such productivity gains, which are attributed to technological innovation rather than to growth in labor or capital inputs (Powell & Snellman, 2004). Prior research suggests that high levels of multifactor productivity exist in industries where technological frontiers are pushed forward and are associated with large-scale technological change (Griliches & Lichtenberg, 1984; Solow, 1957; Terleckyj, 1980). Such a high level of industry multifactor productivity is characteristic of an industry that is continuously experiencing new technological trajectories (Schilling & Steensma, 2001), while the onslaught of multiple technology trajectories is also indicative of a potential increase in ambiguity in that industry.[3]

The ensuing ambiguity affects the market for technology, because emerging technologies often depart from existing industry solutions and lead to many new technological trajectories (Hicks & Hegde, 2005). At the extreme, the constant influx of emerging technologies will render existing solutions obsolete and cast doubt on the viability of future technological trajectories. The problem is exacerbated by marketplace participants' lack of a clear benchmark or dominant design that could be used as a reference point to assess a focal technological invention (Anderson & Tushman, 1990). The result is an increase in the level of ambiguity with respect to the features inherent to the underlying technologies. Hence, ambiguity with respect to the features of the technology owing to multiple technological paths will increase the challenges of technology sellers and buyers to effectively communicate and evaluate technological inventions in the first place (Madhavan & Prescott, 1995).

Online markets are well positioned to address these challenges. First, technology owners who participate in an online market for technology have an opportunity to clearly

[3] While it is clear that productivity gains observed through multifactor productivity may stem from substantial incremental demand for existing technologies, high levels of multifactor productivity likely require more radical technological improvements stemming from new emerging technological trajectories.

communicate their technology to external parties. Online markets require disclosure and codification from each technology seller in the form of a standardized description of the invention, which is to be listed on a marketplace. Detailed disclosure reduces challenges stemming from ambiguity about the technology because (a) the codification process of listed inventions clarifies important technological information and (b) the codification is done in a consistent and standardized manner through standard entry templates. Most importantly, codification results in the technology seller's clear articulation of an invention's fundamental standalone features. A quote from yet2.com, a prominent marketplace in our sample, exemplifies these benefits: "Because patent abstracts are designed to protect an idea from infringement, they obscure the technology, making it difficult for potential buyers to imagine relevant applications. Conversely, yet2.com features functional abstracts written in plain English to communicate the potential … benefits of the technology." (Yet2.com, 2008) Hence, the articulation and codification of technological inventions ultimately reduce frictions associated with knowledge ambiguity.

Second, online markets accumulate and aggregate information across a broad range of listings in an industry (Evans & Wurster, 1999). The aggregate information about a wide range of technologies implies that participants in an online marketplace can go beyond assessing the technological feasibility and potential applications of a single invention. Rather, participants can compare and contrast each listing with a multitude of alternatives. In other words, online marketplaces facilitate comparison and benchmarking of different technological inventions. In a similar vein, the assessment of new and ambiguous technologies is easier when inventions can be compared to alternatives (Grégoire & Shepherd, 2012). Thus, by aggregating information across multiple inventions, online marketplaces facilitate relevant comparisons and mitigate ambiguity with respect to the multiple technological trajectories.

It follows that the aggregation of codified information is a hallmark of online marketplaces, as it equips market participants with templates and the ability to make comparisons. Accordingly, we expect online marketplaces to provide unique benefits in industries experiencing high ambiguity owing to the presence of multiple technological trajectories. We therefore propose:

Hypothesis 2a: An industry where ambiguity about technological trajectories is high, such as one characterized by a high level of multifactor productivity, is more likely to be served by online marketplaces.

Ambiguity regarding potential applications

Ambiguity may arise not only with respect to the identity of the technology trajectory that will ultimately prevail, but also regarding the potential applications of that winning technology. Simply put, the new technology may have applications that go well beyond those of the previous technology. Whether that is the case, and what the additional applications might be, remains unclear during the days of technological ferment. This insight dates back to Penrose (1959:76), who emphasized that "at any given time, the known productive services inherent in a resource do not exhaust the full potential of the resource." This perspective suggests that technologies may have not one application but possibly many.[4] Frictions in the market for technology emerge because a given technology has to be linked to potential applications, yet the links may be unknown to both the inventor and external parties. Indeed, discovering alternative applications for a focal technology is far from a trivial undertaking (Danneels, 2007; Rivette & Kline, 2000). The result is ambiguity regarding the feasible applications for the technology. Such ambiguity imposes limitations on the market for technology, since many potential technology applications may not be uncovered.

[4] A case in point is DuPont's Teflon (polytetrafluoroethylene). The technology has distinct technological properties (e.g., heat resistance and a low coefficient of fricton). Teflon's market applications span a broad range of industries including automobiles (for paint), housing, cookware, and photovoltaic energy products.

The extent of these frictions may vary across industries. An industry with strong linkages to other industries faces a particular challenge because the knowledge underlying a technological invention is context-specific: that is, the knowledge usually resides within a given firm and industry and tends to be associated with its existing organizational and industrial processes and applications (Winter, 1987). This "local" context clouds the ability to see all the different applications for a particular technology, and the challenge is exacerbated in settings where potential applications lie outside the focal industry (Dushnitsky & Klueter, 2016; Kogut & Zander, 1992). It stands to reason that industries that link intensively to products and technologies from other industries are particularly prone to ambiguity regarding the technology's possible applications.

Online marketplaces mitigate the challenge of application ambiguity. An important prerequisite to exploring the full range of applications for a technology lies in understanding the underlying characteristics and functionality of a technology and de-linking the technology from its existing applications and organizational context (Danneels, 2002; Grégoire & Shepherd, 2012). This result is achieved through the codification process of online markets by technology owners, who need to emphasize fundamental standalone features independent of the technology's existing application (Conti et al., 2013; Danneels, 2007). De-linking technological solutions from applications in online markets has noteworthy implications.

First, de-linking simplifies the representation of technological inventions and demonstrates their value beyond their firm-specific applications, likely facilitating the discovery of alternative applications for a technology (Dushnitsky & Klueter, 2016). Second, online markets rely on external partners to develop technological inventions. By definition, external partners are less encumbered by existing commercial routines or embedded competencies for a focal technology, and are therefore effective in facilitating novel linkages between a technology and its applications. Robert Hirsch (Wood, 2002) explained the advantage of online markets like yet2.com to address previously unconsidered application domains for DuPont: “But it's quite unlike process licensing, where we know who the potential customers are. It requires a very different marketing approach. Often … potential customers are from industries we would never normally have considered."

In summary, online markets for technology can systematically facilitate the identification of new technology-application combinations by market participants. We expect that the advantages of such processes are most notable in industries where ambiguity about potential applications is widespread, either within or beyond industry boundaries – namely, in those industries that exhibit substantial product and technology linkages with other industries. We therefore propose:

Hypothesis 2b: An industry where ambiguity about the possible applications for a technological invention is high, such as one characterized by strong linkages with other industries, is more likely to be served by online marketplaces.

Finally, ambiguity also exists regarding the extent to which the new technology will affect industry profitability. Put differently, the magnitude of value creation and value capture is also unknown from the outset. How much will a given firm gain by applying the new rather than the old technology? Indeed, experts often differ in their evaluations of organizations within those industries. Experts covering an industry characterized by strong knowledge ambiguity may find it difficult to agree on and assign specific values for focal organizations (Madhavan & Prescott, 1995; Rindova, Ferrier, & Wiltbank, 2010). Substantial disagreement among experts suggests a divergence of views and has been attributed to the challenge of evaluating knowledge-based assets (e.g., Humphery-Jenner, 2013; Martin, Gözübüyük, & Becerra, 2013; Rindova et al., 2010). Put differently, industries in which experts form divergent expectations (e.g., financial analysts’ expectations about future performance) are likely to be characterized by high levels of knowledge ambiguity.

In accordance with our prior arguments, we expect that the articulation and codification processes that are integral to the working of online markets will mitigate ambiguity. It follows that online marketplaces for technology will be particularly valuable in industries where experts vary in their assessment of existing organizations' values. We therefore propose:

Hypothesis 2c: An industry where ambiguity about the underlying technological inventions is high, such as one characterized by high levels of dispersion in expert opinions, is more likely to be served by online marketplaces.

The unique features of online markets may alleviate search costs and ambiguity frictions, thus facilitating the identification, communication and interaction among prospective sellers and buyers. However, that facilitation may deter technology owners from participating on online marketplaces owing to the risk of expropriation.

2.5. Appropriation

A critical challenge in the innovation process has to do with technology owners' limited ability to appropriate the returns from their invention. Formally, the economic properties of inventions make them a public good (Arrow, 1962): a potential buyer or licensee cannot easily be prevented from using an invention once it has been revealed. This appropriation problem limits an inventor's ability to fully capture the value of the invention, since revealing the invention to prospective licensees may lead to imitation. The limited protection of property rights over inventions often poses a critical challenge, as it implies that an invention can be easily exploited and replicated without the owner's permission (Arrow, 1962).

The appropriation problem is of particular concern in some industries. In other industries, conditions such as the prevailing legal environment may provide strong protection to inventors and thus circumvent imitation (Levin et al., 1987). The likelihood of imitation is affected by the intellectual property right (IPR) regime (Teece, 1986). For example, a patent is a well-recognized means of IPR protection that gives inventors legal rights over their inventions. Recall that a patent is often the "unit" that is traded in the online marketplaces we study. The efficacy of patents in appropriating value varies across industries: in industries with a strong IPR regime, patent holders face fewer concerns related to appropriation. Indeed, in the presence of weak patent protection, the market for technology sees less participation (Giarratana & Mariani, 2014).

While online marketplaces attenuate the frictions of search costs and information asymmetries, in so doing they may magnify the appropriation problem for technology sellers. Recall that online marketplaces mitigate search costs and ambiguity by including a broad range of industry participants and presenting them with rich codified descriptions of the listed inventions. Because of this practice, however, online markets may put inventors at a disadvantage since the higher level of codification may facilitate imitation. The problem is compounded because the people who browse the marketplace remain anonymous and can imitate a listed invention without the inventor's awareness. Anecdotal evidence suggests that the issue of expropriation is affecting online marketplaces: "technology descriptions listed in our database become part of the public domain. Only you can determine what you are willing to disclose to the public about your technology" (Yet2.com, 2008).

It follows that technology sellers participating in online marketplaces are sensitive to expropriation by prospective buyers: the greater the likelihood that potential buyers and licensees will exploit disclosed information, the greater the risk that the inventors will appropriate little or none of the value from their invention (Anton & Yao, 1995, 2005; Gans & Stern, 2003). The willingness of technology owners to participate and list their inventions in an online marketplace will therefore be shaped by the IPR regime in that industry. It will be low under a weak IPR regime and high in a strong IPR regime. Accordingly, we conjecture that a marketplace is more likely to serve an industry when it can attract the participation of high-quality technology sellers.

Hypothesis 3: An industry where the threat of appropriation is low, such as an industry characterized by a strong intellectual property protection regime, is more likely to be served by online marketplaces.

3. Methods

We study how search costs, knowledge ambiguity, and appropriation regimes inform which industries are served by a range of online technology markets. Our sample included marketplaces that allow independent parties to trade technological inventions for commercial purposes. We focused on all industries listed as part of the North American Industry Classification System (NAICS) in agriculture, industrial manufacturing, and information technology services. To test our hypotheses, we employed multiple data sources, including Compustat (public firms R&D data), the Carnegie Mellon University (CMU) survey, IBES (analyst earnings forecasts) and CRSP (stock prices).

3.1. Sample construction

Online marketplaces. We identified 12 leading online marketplaces that in 2008 were actively connecting inventors or technology sellers with potential technology buyers or licensees. These marketplaces addressed specific industries and facilitated the trade (i.e., licensing, sale, etc.) of innovative technologies between numerous globally distributed parties.

We followed an extensive three-stage search procedure to identify the marketplaces. First, we queried numerous databases (e.g., ABI Inform, Google, Lexis Nexis, Proquest) for information published in the business media during the period 1999–2008. The queries consisted of variations of the following keywords: (online, electronic, Internet), (marketplace, market, platform, exchange), and (innovation, invention, technology, knowledge). This search generated an initial list of online marketplaces, some of which had already received scholarly attention, such as yet.2com (e.g. Palomeras, 2007).[5] To avoid inclusion of low-quality or limited-transaction volume marketplaces, we excluded websites that were not mentioned as online marketplaces in a major credible business source (e.g., we excluded invention promotion scam sites).[6] A marketplace entered our sample only if it was mentioned at least once in an article covered by Lexis Nexis, Proquest, or ABI Inform. In addition, we read all news articles to further ascertain marketplace quality. In total, eight websites did not meet the requirements of our quality filters and were excluded from the analysis.[7]

Next, to enter our sample, a marketplace had to meet the theoretical features of an online marketplace. Specifically, it had to serve as a two-sided market. Accordingly, we excluded "one-sided" university websites aimed at technology transfer of inventions from a single institution (e.g., technology licensing offices of MIT and Harvard), as well as websites dedicated to the commercialization of government agencies' inventions (e.g., the US Department of Defense).

Finally, we required that each online market categorize its listings by assigning systematic sectors or identifiers to technologies listed on the marketplace. As a result, three more online marketplaces were dropped from our sample (Techtransferonline, NewIdeatrade, Spark-IP). The final sample consisted of 12 online technology marketplaces active in 2008 (see Table 2).

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[5] As an example of the characteristics of online knowledge marketplaces, we looked closely at the inventions listed on yet2.com as of 2008. We identified 1,450 inventions, of which 65% had associated patents or patent applications.

[6] The reason for coverage in a newspaper was to ensure that we do not include invention promotion scam sites such as http://newInventions.com. The US government explicitly warns technology sellers against using such patent websites (see http://www.uspto.gov/patents-getting-started/using-legal-services/scam-prevention).

[7] Excluded marketplaces for which we could not find a newspaper article included those like http://www.ideabuyer.com/, for which we could not adequately assess the quality when we engaged in the sampling effort.

Sample observations. Our analysis covered all industries listed at the NAICS 4-digit level within the agriculture (NAICS 1*xxx*), manufacturing (NAICS 3*xxx*), and information and business services (NAICS 5x*xx*)[8] sectors. A total of 161 distinct industries were included at the 4-digit level of NAICS. We considered these industries to have the potential of being served by online marketplaces. A few 4-digit NAICS were dropped due to limited data for our independent variables. Specifically, 13 NAICS industries were eliminated because they were not populated by a sufficient number of publicly listed companies during our study period of 2002–2007.[9] The final sample consisted of 148 industries.

3.2. Measures

Dependent variable: The dependent variable *Industry Coverage* is a count measure, capturing the number of online markets that served a focal 4-digit NAICS industry in 2008. The construction of the variable entailed several steps: (a) identifying the sectors served by online marketplaces, (b) matching them to NACIS industry codes, and (c) generating the measure. We expand below.

Online markets classify technology listings into different categories or keywords reflecting industry sectors. We collected these industry sectors listed on each online marketplace and mapped them onto NAICS codes as of 2008. The reason for using industry codes based on the NAICS schema is twofold. First, the NAICS codes provide a greater level of granularity than Standard Industry Classification (SIC) codes. Second, the scheme has been specifically designed to reflect the structural transformation due to the "new economy" (Landefeld & Fraumeni, 2001).

[8] Excluding Finance and Insurance and Real Estate. We use the 4-digit NAICS code as the construction of several of our independent variables was limited to the 4-digit level. We explain these constraints below.
[9] We excluded industries with two or fewer public firms (e.g., potato farming). In an additional robustness analysis, we show that industries with only a few public firms are not driving the results.

Two independent researchers matched the marketplaces' sectors to NAICS codes. Each sector could be assigned to multiple NAICS codes. As an example, the iBridgenetwork sector "dental" was matched to NAICS 339114 (Dental Equipment and Supplies Manufacturing), NAICS 339116 (Dental laboratories), and NAICS 325620 (Toilet Preparation Manufacturing).[10] However, it was not matched to NAICS 335999 (Ultrasonic Cleaning Equipment), which explicitly excludes any dental equipment.[11] As a further quality control, we compared the NAICS assignment in different marketplaces to verify that classifications were consistent. For example, the sector "dental" also appears in the Ideaconnection and Flintbox marketplaces. Inter-coder agreement was high (80%), and unclear matches were discussed among the researchers until mutual agreement was achieved.

The variable *Industry Coverage* is the number of online markets serving a focal 4-digit NAICS industry. Given that our sample contains 12 marketplaces, *Industry Coverage* is a count measure ranging from 0 (not served by any online market) to 12 (served by all online markets).[12]

Independent variables: All independent variables were constructed using information in years prior to observing the categories used to construct the dependent variable *Industry Coverage* in 2008.

Search costs: We captured search costs that characterize an industry by examining the distribution of potential technology sellers and technology buyers as proxied by fragmentation and geographic dispersion in that industry. For industry fragmentation, we

[10] Includes dental floss manufacturing.
[11] Ultrasonic cleaning equipment (except dental, medical) manufacturing.
[12] In many cases, the keywords found on the online marketplace allowed us to distinguish the industries on a 4-digit NAICS level. A more refined categorization proved infeasible. As an example, while we could distinguish beverage manufacturing as an industry NAICS, it was harder to identify in the categories beer vs. wine vs. distilleries or soft drinks (subcategories of that industry). However, replicating our analysis by using 5-digit NAICS codes confirmed our results.

calculated the Herfindahl index based on Compustat/Compustat Global R&D expense data from 2002–2007 considering 20,122 firms:

$$H = \sum_{i=1}^{N} s_i^2$$

where H is the concentration of firms, s_i is the market share of firm i in the industry, and N is the number of firms in a given industry per year. We averaged the annual concentration score for each industry between 2002 and 2007 to create a single industry concentration score. The variable *Industry Fragmentation* equals one minus the Herfindahl concentration. A large value for *Industry Fragmentation* indicates a highly fragmented industry in terms of R&D spending.

In a similar vein, we constructed *Geographic Dispersion* based on Compustat sales data, which covered 96 countries. Again, we use the same Herfindahl index-based approach, where s_i represents the market share in terms of revenue of a country i in an industry. Higher values suggest more country fragmentation of activities within an industry.

Ambiguity: Following our theoretical arguments we captured ambiguity through multifactor productivity, industry linkages and the dispersion in forecasts by industry experts.

Multifactor productivity: We captured the level of ambiguity with respect to emerging technological trajectories using an industry measure of multifactor productivity. The measure is commonly employed in economics and strategy literature as a proxy for technological change and an indicator of multiple technological paths (Griliches & Lichtenberg, 1984; Schilling & Steensma, 2001). Multifactor productivity values are calculated annually by the US Bureau of Labor Statistics. Specifically, for each industry, the BLS calculates the output per unit of labor, capital, and other measurable inputs (Harper, Khandrika, Kinoshita, & Rosenthal, 2010). Our *Multifactor Productivity* variable is the mean multifactor productivity for each 4-digit NAICS code during the 2002–2007 period.

Industry linkages: We captured the linkages to other industries (our proxy for ambiguity with respect to potential applications) by calculating the average correlation of a focal industry to all other industries using direct input/output tables. Following prior work, we proxied for the strengths of inter-industry linkages between a given industry and how its outputs are used by other industries using inter-industry flows of products and services. Higher correlations between industries indicate strong inter-industry linkages and potential for synergies (e.g., Villalonga, 2004). We employed input/output tables that are available through the US Bureau of Economic Analysis (BEA). For each industry, we calculated the correlation across industries and took the average value: the higher the value, the higher (on average) the linkages of a focal industry with other industries. Owing to missing data, we were able to construct this variable for only 116 industries.

Expert Forecast Dispersion: We directly proxied the level of knowledge ambiguity in an industry using the dispersion in expert assessments. To that end, we collected expert analysts' forecasts from the IBES database. The data covered all publicly listed firms in US and non-US stock exchanges for 2002–2007 (e.g., Humphery-Jenner, 2013; Madhavan & Prescott, 1995; Rindova et al., 2010). We excluded observations for penny stocks (<1%) and extreme outliers from our analysis (e.g., Feldman, Gilson, & Villalonga, 2013). We were able to match about 4.3 million analyst estimates to a firm identifier (i.e., a firm's industry NAICS code from Compustat and its stock price from CRSP). Consistent with prior studies, we required at least three analyst estimates per forecast period of a firm, and calculated the analyst dispersion for each firm forecast period (e.g., Martin et al., 2013). To facilitate comparison across firms, we divided the dispersion in forecasted stock prices by the firm's stock price at the end of the forecast period. Finally, we created the industry average, *Forecast Dispersion*, by taking the mean value of forecast dispersion across all firms within a 4-digit NAICS code (e.g., Madhavan & Prescott, 1995).[13]

Appropriation: We used the Carnegie Mellon University (CMU) Survey of Research and Development (Cohen, Nelson, & Walsh, 2000) to construct a proxy of industry appropriation regime. The CMU survey explores the effectiveness of various mechanisms in protecting profits due to invention. The variable *CMU Patenting* captures the relative importance of patenting as a way to protect intellectual property. It uses the item for the mean percentage of product innovations for which patenting was considered to be an effective mechanism in protecting intellectual property within an industry (e.g. Dushnitsky & Lenox, 2005). The higher the value of *CMU Patenting*, the stronger the appropriation regime within the industry. Owing to missing data, we were able to construct this variable for 101 industries.

Controls: We controlled for a number of industry characteristics that might further determine the prevalence of online markets. First, we controlled for an industry's *R&D Intensity* as a proxy for the general emphasis of technology within an industry (e.g., Klevorick et al., 1995): the greater the R&D in a focal industry, the greater the potential for online markets to serve that industry. The variable *R&D Intensity* is defined as average R&D spending over total revenue from 2002 to 2007, using Compustat data. In a similar vein, we also controlled explicitly for "high technology" industries using a classification from the US Bureau of Labor Statistics Monthly Labor Review (Hecker, 2005). BLS classifies industries as "high technology" by taking into consideration whether employment in technology-oriented occupations accounted for a proportion of that industry's total employment that is double that of the overall economy average. *High Technology* is an indicator variable that takes the value of 1 if an industry is so classified by BLS.

[13] For readability of the regression analysis, we multiplied the Forecast Dispersion variable by 100.

We also controlled for the average *Number of Firms* as reported in Compustat between 2002 and 2007, as more public firms may attract coverage by online markets. Moreover, we controlled for an industry's overall performance through its average *Return on Assets (RoA)* in years 2002–2007, as higher profitability may make the industry more attractive for online marketplaces. Further, we controlled for the importance of commercialization capabilities in an industry using a proxy of industry commercialization intensity, which is calculated as the average ratio of selling, general and administrative expenses relative to total revenues from 2002–2007 in an industry (Rothaermel, 2001; Teece, 1986).

3.3. Empirical specification

The dependent variable *Industry Coverage* is a non-negative count variable. Accordingly, we estimated a negative binomial model, which is similar to a Poisson model but relaxes the assumption of having a mean equal to the standard deviation.[14] All results reported are with robust standard errors.

4. Results

4.1. Hypotheses testing

Table 3 depicts descriptive statistics and a bivariate correlation matrix. On average, an industry (as defined by a 4-digit NAICS code) is served by 3.22 online marketplaces. Specifically, of the 148 industries, 41 are not served by a single marketplace while the remaining 109 are served by one or more marketplaces. With respect to the correlation matrix, we found no evidence that multicollinearity is a concern. The mean VIF for the final models is below 2.6 and individual VIFs are below 4.4, below the recommended cutoff levels

[14] The test of the over-dispersion parameter alpha fails to reject the null hypothesis that alpha equals zero. Hence, the negative binomial model is preferred to the Poisson regression model.

(Cohen, Cohen, West, & Aiken, 2003). Table 4 provides an overview of the top and bottom covered industries by the online markets for technology and provides further insights as to the patterns of our independent variables.

--------------Insert TABLES 3 and 4 about here. --------------

Table 6 reports regression analysis results. Model 1 reports the base specification with only control variables. We do not observe *High Tech* industries served by a larger number of online marketplaces, but this result can be partially explained by the effect of *R&D Intensity* on the coverage by online marketplaces. We also find that the *Number of Firms* and the industry's *Return on Assets* are associated with *Industry Coverage*. An industry's *SG&A Intensity* is not significantly associated with the likelihood of that industry being served by online marketplaces.

Model 2 introduces the effect of search costs due to *Geographic Dispersion*. The coefficient is positive and statistically significant. Consistent with Hypothesis 1a, the findings suggest that online markets serve those industries that experience the greatest need to search for novel technologies all across the globe. In a similar vein, Model 3 reports a positive and statistically significant coefficient for *Industry Fragmentation.* In line with Hypothesis 1b, the results indicate industry fragmentation is associated with the number of online marketplaces servicing it, in that the need to search for technologies across numerous firms is associated with the emergence of online marketplaces. In Model 4, both search cost variables are entered simultaneously and remain significant. To interpret the effect sizes of the relevant estimated coefficients, we estimate the response marginal effect of our variables of interest keeping all other variables at the mean values (Table 5). First, we predict the number of online marketplaces covered for *Geographic Dispersion*. The results indicate that when *Geographic Dispersion* increases by one standard deviation from its mean, *Industry*

Coverage increases by 51% (an extra 1.3 online marketplace covering the industry). In a similar vein, a change of one standard deviation around the mean of *Industry Fragmentation* increases *Industry Coverage* by 48%.

--------------Insert TABLE 5 about here. --------------

Next, we test the predictions regarding knowledge ambiguity (Hypotheses 2a, 2b, and 2c) through Models 5–9. We have complete data for 116 industries. Model 5 introduces *Multifactor Productivity,* which proxies for ambiguity due to the rapid technological change and multiple trajectories. The coefficient is positive but not statistically significant and the marginal effect *Multifactor Productivity* with a change of one standard deviation around its mean only shows an increase of 4% in industry coverage (Table 5). These findings suggest no support for Hypothesis 2a.

We introduce the second ambiguity variable, *Industry Linkages*, which captures the ambiguity regarding possible applications for technologies within an industry. Model 6 demonstrates that the coefficient of *Industry Linkages* is significant and positive. Finally, Model 7 highlights that *Forecast Dispersion*, our direct proxy for knowledge ambiguity by experts covering the industry, is positive and highly statistically significant, consistent with Hypothesis 2c. Model 8 shows that *Industry Linkages* and *Forecast Dispersion* continue to have a positive and significant effect on *Industry Coverage* when all prior independent variables are controlled for. The marginal effects of *Industry Linkages* and *Forecast Dispersion* are also meaningful. A change of one standard deviation from the mean of *Forecast Dispersion* increases *Industry Coverage* by 25% (about one extra online marketplace covers the industry) and a change of one standard deviation from the mean of *Industry Linkages* increases *Industry Coverage* by 23%.

Finally, we investigate the impact of an industry's appropriation regime. Because CMU survey data are not available for all 4-digit NAICS codes, the analysis is run on a subsample of 101 industries. Model 9 reports the effect of *CMU Patenting*, our proxy for the IPR regime in a given industry. The coefficient is positive and statistically significant, indicating that industries where patent protection is strong are served by more online markets. The result is consistent with the view that strong IP protection (e.g., patents) induces firms to participate in a technology marketplace and reveal their technologies because they face a lower risk of imitation. The marginal effect for *CMU Patenting* is also meaningful. A change of one standard deviation of *CMU Patenting* from the mean increases the number of online marketplaces serving the focal industry by 27%. Model 10 includes a full specification with all independent variables. We find results very consistent with our prior findings.[15]

--------------Insert TABLE 6 about here. --------------

4.2. Robustness tests

We conducted several checks to establish the robustness of our findings. First, we focused on the industrial manufacturing sector where technological innovation may be most important, and where the bulk of the data sits. Specifically, Model 11 in Table 5 replicates our analysis for the manufacturing sector (83 industries in total) and shows effects very similar to the results in the main analysis. We further examined whether our results are sensitive to industries with few publicly active firms. Limiting our sample to industries with at least 15 or more firms in the Compustat/IBES database continued to support our results.

4.3. Supplemental analysis: listed technological inventions

Next, we used an alternative dependent variable for our analysis focusing on the actual listings or posting by technology sellers on the online marketplaces. We used various

[15] Only Industry Fragmentation has a slightly weaker effect in this model (coefficient 4.39 at $p<0.11$). Using the dispersion based on sales and not R&D expenses yields similar results and continues to support our predictions.

Internet archives (e.g., Waybackmachine, Google Search) to retrieve a snapshot in 2008 or 2009 as to how many technologies were listed on an online market in a given industry category. This approach goes beyond examining which industries online markets serve and captures the number of active technology listings on an online marketplace for a given industry. For three marketplaces (iBridgenetwork, Pharmatransfer, and Pharmalicensing), we were unable to retrieve an exact snapshot between 2008 and 2009, which limits our analysis to nine marketplaces.[16] Given the strong heterogeneity in the numbers of technologies listed on each marketplace, we conducted the analysis on the industry market level so that, for example, our initial sample is 1,332 (9 marketplaces times 148 industries minus a few industries with missing data). We include market fixed effects in the analysis. Table 6 shows the regression results when our analysis is replicated using the number of listed inventions in an industry on a marketplace as dependent variable.[17] Models 12–22 in Table 7 replicate our analysis from Table 6 using technologies listed in an industry on each marketplace as a dependent variable. The results are very similar to the main results reported in Table 6, reaffirming our general conclusions with respect to the support of the hypotheses.

-----Insert TABLE 7 about here-----

4.4. Qualitative insights– Online markets for technology

To further investigate the role of online marketplaces, we asked each marketplace for information regarding transactions that ultimately materialize through the help of their markets. We received responses from seven marketplaces in 2015 and 2016 and conducted four follow-up interviews to determine whether the listing of an invention ultimately leads to realized transactions between sellers and buyers of technology. All responding marketplaces

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[16] We took the earliest possible comprehensive snapshot between 2008 and 2009.

[17] A disadvantage of this approach is that the counts reported through our analysis likely inflate the number of technologies listed because we aggregate the marketplace on the 4-digit NAICS code level and some categories may be classified to the same NAICS code. Since we are simply interested in which industries are ultimately covered by an online marketplace, we report only the results examining the number of listings as supplemental analysis.

emphasized that the disclosure of realized transactions is not necessarily in the interest of the market participants and, hence, is very challenging to track. For example, one interviewee (Tynax) indicated that “there is not much data published about patent transactions, because it is usually done under non disclosure agreements with all parties, including the broker. Therefore, limited information can be disclosed.” In a similar vein, it was revealed that “both inventors and licensors rarely disclose information and [very few] details regarding deal flow and values are available.” An important reason for the secrecy was revealed in an interview with Ideaconnection, which highlighted that when searching for patents, licensees “do not want other firms to know about their search. This is why they use the services of the marketplaces in the first place.” Other important reasons to conceal realized transactions included concerns that the pricing details of a transaction could adversely affect subsequent negotiations about the underlying technology or the reluctance of licensees to reveal a change in their strategy (through the acquisition of a patent). A concern of licensors was that engaging in a licensing deal fosters speculations regarding the financial health of the licensor. Indeed, patent sales in many cases (as, for example, by Kodak in 2012 and Nortel 2011) are often associated with poor financial conditions on the part of the companies.

Finally, many marketplaces emphasized that the online marketplace is only a starting point in deal-making between sellers and buyers: “Buying and selling patents takes a long time… [as] there is a lot of due diligence done on a patent before it is bought…. Ultimately, buying and selling patents requires a lot of offline brokering. The platform is a starting point and a marketing tool. It attracts buyers and starts a discussion between buyers and sellers.”

This observation corroborates research on markets for technology and confirms that deals may only materialize after a substantial number of interactions between the parties and that, in some cases, these interactions need to happen even after deals have been consummated (Arora, 1996). In summary, all responding marketplaces emphasized that deals materialize with the help of the marketplaces, while at the same time they acknowledged obstacles and limitations in ultimately tracking such realized transactions. Hence, online marketplaces for technology are best characterized as an extension to the market for the technology process, in which sellers and buyers need to become aware of each other and communicate effectively, but in which transactions are ultimately consumed offline.

5. Discussion

The rise of online marketplaces is an important phenomenon, as economic exchange increasingly happens online (Amit & Zott, 2001; Brynjolfsson & Saunders, 2009). Specifically, we investigate online technology marketplaces as a recently arrived institution in the market for technology. The popularity of such marketplaces has increased among firms (Agrawal et al., 2015b), and we examine whether it is equally strong across the different industries. Specifically, we study which industries are served by online marketplaces. Our conjecture is that online marketplaces serve prospective sellers and buyers in those settings where recognizing each other, and communicating effectively, is a difficult task.

We find that through their reach, codification, and aggregation, online markets may alleviate important frictions in the market for technology. These frictions include search costs and knowledge ambiguity about the underlying characteristics of the inventions when compared to other emerging technological trajectories, as well as the technology's potential application paths. At the same time, we outline how these features also make online markets for technology more prone to the risk of expropriation, so that they most likely serve industries that enjoy strong protection of intellectual property. More broadly, our findings illuminate the unique role of information technology in shaping the listing of, search for, and identification of technologies online, and showcase a novel path through which technology buyers and sellers may connect in the market for technology.

While our interest is predominantly phenomenological, studying online marketplaces also allows us to expand the general understanding of markets for technology. Namely, through the use of online markets, we can go beyond the much-studied high-technology industries (e.g., semiconductors, biotechnology, or telecommunications) and consider differences across a wider array of industries. Our qualitative insights reveal that online marketplaces play a particularly important role in the market for technology during the initial step, where prospective sellers and buyers initially identify each other. Subsequent stages in the market for technology, such as negotiations and deal-making between the participants (Agrawal et al., 2015b), may still happen offline. These insights suggest a complementary role of online markets for technology for existing technology transactions.

The study has a number of limitations, which provide ample opportunities for future research. First, we observed the industries online markets serve by studying the listing of technologies and the industries with which they are affiliated. However, we have no data regarding which transactions ultimately occur within each of those marketplaces. We have provided qualitative evidence from the marketplace to better understand why we may not be able to systematically observe realized transactions. As in prior research (Hagiu & Yoffie, 2013), the marketplaces indicated that actual deals, even if originated through an online market, may still be consummated offline in a bilateral agreement between a buyer and a seller. Therefore, the mechanisms studied facilitate the listing of, search for, and identification of technological inventions but do not address the actual execution of deals (e.g., through licensing) or the outcomes associated with them, such as the learning between the partners or commercialization success. Future research could extend our study by exploring the inventions that are ultimately exchanged and the intermediating role online marketplaces play in concluding successful deals. In a similar vein, future research should also explore the extent to which online marketplaces effectively facilitate the listing and search for technological inventions, and, hence, connect potential technology sellers (e.g., inventors) and prospective technology buyers (e.g., licensees). Such a study may need to go beyond examining specific industries to look at the potential for drawing linkages between industries and how firms may re-deploy technologies in new industries (applications), which could lead to a rapid expansion of the market for ideas (Dushnitsky & Klueter, 2016).

Second, our study offers the opportunity for replication with finer-grained proxies. The current set of variables builds on publicly available data and is therefore limited to public firms in the 148 industries in our sample. It includes information from over 24,000 public firms located in 96 countries. However, we recognize that these firms represent only a subset of all firms that might (or already do) participate in online technology marketplaces. Future studies should employ more fine-grained industry proxies for industry search costs. In a similar vein, it would be important to consider alternative ways to capture knowledge ambiguity. For example, our non-finding for multifactor productivity may simply reflect the need for a measure that more precisely identifies productivity improvements due to multiple new technological trajectories versus incremental improvements along a single pre-determined trajectory.

Another important line of extension is for researchers to more precisely explain to what extent online marketplaces for technology differ from offline markets for technology. Answering this question would require a more explicit explanation of how online markets may facilitate the consummation of deals that could not happen offline (e.g., by linking a technology to a previously unknown application). Such studies should also elaborate on our qualitative insights into how online markets precede bilateral (offline) negotiations and consummation of deals (potentially offline). Researchers should also pay attention to what type of potential online markets for technology cater to. Following our theoretical arguments, it is easy to imagine that connections in online markets may stem from an increase in activity between existing sellers and buyers (e.g., owing to reduced search costs). Alternatively, new connections may also come through links with previously unexplored industries or from previously uninvolved partners in the innovation value chain (e.g., as ambiguity regarding the technology's features is reduced). Investigating both types of connections and the role of online market places in expanding them could be an important way to refine the study for future research.

6. Conclusion

The literature presently offers rich evidence regarding existing institutions in selected industries (Arora et al., 2001; Hargadon & Sutton, 1997; Howells, 2006), usually those within a narrow subset of high-technology sectors (McEvily & Zaheer, 1999; Sahaym, Steensma, & Barden, 2010; Zhang & Li, 2010). To the best of our knowledge, this study is the first to investigate whether this new institution – online technology marketplaces – manifests in broad cross-industry coverage.

Our analysis pivots on three salient theoretical factors – search costs, knowledge ambiguity, and possible expropriation – that are known to affect the market for technology and vary across industries. It reveals that marketplaces are more likely to serve an industry with (a) higher costs of searching for technologies in that industry, (b) greater levels of ambiguity characterizing technological inventions and their potential applications, and (c) a greater ability to protect inventions from expropriation. The findings are consistent with the idea that the unique features of online markets (i.e., reach, codification, and aggregation) address the aforementioned frictions inherent to the market for technology. Hence, our findings advance the understanding of online technology marketplaces in particular and markets for technology in general.

Table 1

The unique features and implications of online marketplaces.

Key Argument	Supporting Anecdote	Related Work
H1a & 1b: Reduced costs of search. Online marketplaces enable (a) speedy search of potential parties, and are (b) easily scalable to include a large number of previously neglected parties domestically as well as across the globe.	"The problem that people have when looking for technology is they can't spend hours . . . IP exchanges that offer attractive search tools for the user . . . are more likely to attract potential licensees"(Tactics, 2008). "We use yet2.com to help find licensees that we wouldn't normally know how to get to."	Online platforms facilitate speedy access to external parties (e.g. Afuah & Tucci, 2012). Online platform facilitate access to previously neglected parties (e.g., Brynjolfsson, Hu, & Simester, 2011; Brynjolfsson, Hu, & Smith, 2006).
H2a & 2b & 2c: Reduced ambiguity regarding the underlying technological knowledge and its possible applications. Participation in an online marketplace requires (a) codification of the features of the focal technology, as well as (b) articulating its functionality and potential applications. Moreover, (c) the features and functionality of each and every technology are reported using a marketplace's standardized platforms which (d) facilitates comparisons across technologies, hence supporting identification and valuation of the focal technology and making linkages to alternative applications for the technology.	"Because patent abstracts are designed to protect an idea from infringement, they obscure the technology, making it difficult for potential buyers to imagine relevant applications. Conversely, yet2.com features functional abstracts written in plain English to communicate the potential applications and benefits of the technology." "But it's quite unlike process licensing, where we know who the potential customers are. It requires a very different marketing approach. Often … potential customers are from industries we would never normally have considered."	Outsiders find it difficult to observe the features of a technology developed by another firm. Codification of technology's features enables outsides to understand its functionality, especially as it goes beyond current firm-specific applications (Brews & Tucci, 2004; Zollo & Winter, 2002; Conti et al., 2013; Danneels, 2007). Online markets aggregate information in a standardized manner across a large number of technology listings (Evans & Wurster, 1999). Aggregated standardized information enables comparison and benchmarking, which is instrumental in facilitating assessment of new technologies (Grégoire & Shepherd, 2012).
H3: Increase risk of expropriation. The fact a marketplace requires codification of focal technology's features may facilitate imitation. The concern is exacerbated by the fact that the listing is publically posted online. Importantly, the concern is uniquely different from the common bilateral interactions that take place offline; party A discloses technology to party B, and can to monitor whether B has proceeded to imitate it. In contrast, when party A posts its technology online, it has (a) little knowledge of who inspected it, and (b) limited ability to monitor whether each and every one of them proceeded to imitate the technology.	"[T]echnology descriptions listed in our database become part of the public domain. Only you can determine what you are willing to disclose to the public about your technology" (yet2.com, 2008). "There should not be any disclosures that would allow someone to misappropriate your idea. If you have such concerns . . . you might want to consider [whether to] reveal your product or business idea in full detail" (RaiseCapital.com, 2008).	Disclosure of a focal technology feature is necessary to attract prospective buyers or licensers, but can also result in imitation (Arrow, 1962). The legal regime of intellectual protection varies across industries (e.g., Teece, 1986; Levin et al., 1987), and that, in turn, affects parties' willingness to participate in the market for technology (e.g., Anand & Khanna, 2000; Giarratana & Mariani (2014).

Table 2: Online technology marketplaces (2008–2009).

Online Market Website	Founded Country Focus	Description of Online Marketplaces (2008–2009)[a] Sources: Websites and press releases found on marketplace websites (2008–2009)	**Inventions Listers (2008-09)**	**Market-place 2016**
Flintbox www.flintbox.com	2004 Canada Universities	Flintbox provides a . . . platform for both research and industry to connect and build relationships. It is implemented at over fifty universities, government labs, and other research organizations (originated by University of British Columbia). It allows "direct access to innovation with a network of members and users from over one hundred countries around the world."	Inv: >3000 List: >50	active (acquired by Wellspring)
iBridgenetwork www.iBridgenetwork.com	2005 US Universities	A clearinghouse for innovation, featuring unique research materials posted by the participating universities and helping to facilitate the transfer of innovations. "Our objective is to drive transparency and access to university developed innovations that are available today as well as to field experts, ideas and information … researchers and those seeking innovations can easily search for and obtain the resources they need."	Inv: >5000 List: >100	active (acquired by Innovation Accelerator Foundation)
Ideaconnection www.ideaconnection.com	2007 US Broad	Ideaconnection is an idea exchange to post and view inventions, innovations, new products and patents. Predominantly it is used to share or sell ideas. Entrepreneurs can view and buy innovative business ideas, inventions, and solutions.	Inv: >2000 List: -	active (Focus on Tech Needs)
Inngot www.inngot.com	2007 UK Broad	Inngot is a patent listing and IP valuation service platform. "We think companies should be out there on the front foot utilising every asset they have, rather than leaving their knowledge and capabilities undiscovered, under-utilised and unvalued… [the marketplace] provides a consistent starting point for discussions" (Brassell, Inngot CEO).	Inv: ≈500 List: -	Active (Focus on Valuation)
Ocean Tomo www.icapoceantomo.com	2005 US Broad	Marketplace facilitates networking opportunities to support Ocean Tomo Auction and Conference. A forum to facilitate the open and public exchange of intellectual property.	Inv: ≈100 List: -	inactive online market
Patentauction www.patentauction.com	2004 Belgium Broad	Patent Auction.com is an online marketplace for innovative ideas protected by patent rights. The broad range of inventions for sale or license touches upon all fields of industry.… can freely browse through our entire database…. If you have questions…you can contact the inventor directly through this website.	Inv: >400 List: -	active

Patentcafe www.patentcafe.com and http://www.2xfr.com/	2004 US Broad	2XFR is PatentCafe's technology licensing exchange where licensees find appropriate technologies using a powerful "business terminology" taxonomy. 2XFR is the only technology transfer website where licensable technology is listed by manufacturing process, engineering risk and targeted market segment.	Inv: >200 List: -	inactive
Pharmalicensing www.pharmalicensing.com	2001 US Broad	Is the leading online global resource for open innovation, partnering, licensing and business development within the life science and biopharmaceutical industry… complements and enhances business development activity throughout the deal making process, from finding partners to making the deal. The marketplace allows promotion of business development activities to the global healthcare partnering community	Inv: >1000 List:	active (acquired by Utek then TechEx)
Pharma-Transfer www.pharma-transfer.com	2006 US Broad	Published nearly 20,000 unique opportunities from over 2,500 organisations spanning 100 countries. Pharma-Transfer creates a structured abstract that allows concise assessment and evaluation. Subscribers are corporate business developers, licensing executives or researchers.	Inv: - List: -	active (acquired by Utek then TechEx)
Taeus www.taeus.com	2004 US Broad	A free, self-service web portal for direct marketing and licensing of intellectual property (IP) … allows IP holders to list their technologies, bundle them into portfolios, manage their offerings, and monitor viewing statistics, at no charge. Buyers can browse and analyze patents and portfolios. Fortune 500 companies, universities, IP brokers, and other portals with their own websites can integrate with the TAEUS Patent Exchange.	Inv: >200 List: -	active (but inactive Online market)
Tynax www.tynax.com	2003 US Broad	Tynax operates a global online technology trading exchange currently featuring thousands of patents and technology assets for sale [to] provide unique, full-service brokering capabilities to buyers, sellers and other intermediaries. Tynax has a highly efficient process for matching buyers with sellers, connecting clients with potential partners.	Inv: >1000 (visible) List: -	active
yet2 www.yet2.com	2000 US Broad	yet2.com is focused on bringing buyers and sellers of technologies together so that all parties maximize the return on their investments. yet2.com offers companies and individuals the tools and expertise to acquire, sell, license, and leverage some of the world's most valuable intellectual assets.	Inv: >3000 List: >100	active (Focus on Tech Needs)

Table 3: Top and bottom industry coverage in manufacturing industries.

NAICS	Online Market Coverage	Geogr. Disper-sion	Frag-men-tation	Market Factor Product.	Industry Linkages.	Forecast Disper-sion	CMU Patent	NAICS Description
3254	Top	+	+	-	+	+	+	Pharmaceutical and Medicine Manufacturing
3256	Top	-	+	+	-	-	+	Soap, Cleaning Compound, and Toilet Preparation Manufacturing
3331	Top	+	+	+	-	-	+	Agriculture, Construction, and Mining Machinery Manufacturing
3333	Top	-	+	-	+	+	+	Commercial and Service Industry Machinery Manufacturing
3336	Top	+	+	-	-	+	+	Engine, Turbine, and Power Transmission Equipment Manu.
3341	Top	+	+	+	-	+	+	Computer and Peripheral Equipment Manufacturing
3342	Top	+	+	+	+	+	+	Communications Equipment Manufacturing
3345	Top	+	+	+	+	-	+	Navigational, Measuring, Electromedical, and Cont. Inst. Manu.
3346	Top	+	+	+	+	+	-	Manufacturing and Reproducing Magnetic and Optical Media
3391	Top	+	+	+	+	-	+	Medical Equipment and Supplies Manufacturing
3113	Bottom	+	+	+	-	-	-	Sugar and Confectionery Product Manufacturing
3116	Bottom	-	+	+	-	-	-	Animal Slaughtering and Processing
3119	Bottom	-	+	+	+	-	-	Other Food Manufacturing
3161	Bottom	+	-	-	-	-	+	Leather and Hide Tanning and Finishing
3162	Bottom	-	+	-	-	-	+	Footwear Manufacturing
3211	Bottom	-	-	-	+	+	+	Sawmills and Wood Preservation
3315	Bottom	+	-	-	+	+	-	Foundries
3326	Bottom	-	-	-	-	-	+	Spring and Wire Product Manufacturing
3369	Bottom	+	+	-	+	-	+	Other Transportation Equipment Manufacturing
3372	Bottom	-	+	-	+	-	+	Office Furniture (including Fixtures) Manufacturing

+ indicates value above the mean, - indicates value below the mean of the respective variable.

Table 4: Summary statistics and correlation table.

	n-148	1	2	3	4	5	6	7	8	9	10	11	12
1	Industry Coverage	1.00											
2	High Technology	0.53	1.00										
3	R&D Intensity	0.57	0.61	1.00									
4	Number of Firms	0.58	0.41	0.62	1.00								
5	Return on Assets	-0.05	0.02	-0.02	0.06	1.00							
6	SG&A Intensity	0.22	0.11	0.44	0.27	0.36	1.00						
7	Geographic Dispersion	0.32	0.01	0.03	0.34	-0.12	-0.19	1.00					
8	Industry Fragmentation	0.45	0.22	0.32	0.46	0.11	0.08	0.41	1.00				
9	Multifactor Productivity	0.13	0.10	0.17	0.16	-0.07	0.03	0.04	0.08	1.00			
10	Industry Linkages	0.12	-0.03	-0.02	-0.01	0.04	0.00	0.04	0.07	-0.13	1.00		
11	Forecast Dispersion	0.22	-0.07	0.00	0.05	-0.53	-0.31	0.22	0.03	0.05	0.05	1.00	
12	CMU Patenting	0.43	0.34	0.30	0.15	0.16	0.02	0.01	0.26	-0.09	0.24	0.03	1.00
	Mean	3.22	0.26	0.01	1.39	0.04	0.16	0.61	0.95	1.34	0.41	0.79	29.34
	Standard Deviation	2.99	0.44	0.02	1.44	0.04	0.10	0.20	0.05	1.74	0.00	0.40	8.84
	Minimum	0.00	0.00	0.00	0.05	-0.03	0.00	0.04	0.78	-2.07	0.40	0.12	12.08
	Maximum	12	1.00	0.10	5.56	0.12	0.75	0.89	1.00	5.37	0.42	2.60	44.55

Table 5: Key variables marginal effects.

Variable	Predicted Value (Industry Coverage)	Predicted Value (Industry Coverage at 1SD Above Mean)	Marginal Effect 1SD
Geographic Dispersion	2.69	4.06	51%
Industry Fragmentation	2.42	3.58	48%
Multifactor Productivity	3.13	3.24	4%
Industry Linkages	3.06	3.76	23%
Forecast Dispersion	3.16	3.95	25%
CMU Patent	3.31	4.20	27%

Table 6: Main regression (negative binomial) results - dependent variable: industry coverage.

DV: Industry Coverage	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11) Manuf.
High Technology	0.16	0.11	0.17	0.13	0.30*	0.32*	0.41*	0.41**	0.27*	0.40**	0.36**
	(0.17)	(0.15)	(0.15)	(0.13)	(0.15)	(0.16)	(0.16)	(0.15)	(0.13)	(0.14)	(0.12)
R&D Intensity	11.62*	13.60**	9.43*	11.67**	6.46	7.19	5.55	5.15	0.04	0.33	2.55
	(4.93)	(4.16)	(4.47)	(3.77)	(4.27)	(4.61)	(4.72)	(4.04)	(3.67)	(3.85)	(3.24)
Number of Firms	0.21**	0.11**	0.14**	0.07+	0.18**	0.18**	0.17**	0.08+	0.19**	0.11*	0.08**
	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
Return on Assets	4.05*	3.08	2.47	2.06	0.19	0.04	2.59	1.10	-2.50	-2.54	-2.86
	(2.02)	(1.92)	(1.94)	(1.77)	(2.05)	(2.14)	(2.22)	(2.06)	(2.02)	(1.95)	(1.83)
SG&A Intensity	-1.05	-0.34	-0.51	-0.07	-0.20	-0.25	0.24	0.92	0.75	1.54	1.68*
	(1.01)	(1.00)	(0.96)	(0.97)	(0.99)	(1.04)	(1.01)	(1.06)	(0.91)	(0.97)	(0.69)
Geographic Dispersion		2.26**		2.06**				1.07*		0.94*	1.08*
		(0.62)		(0.48)				(0.47)		(0.44)	(0.47)
Industry Fragmentation			6.99**	5.35*				5.05*		4.39	6.15**
			(2.52)	(2.32)				(2.44)		(2.61)	(2.34)
Multifactor Productivity					0.03			0.03		0.01	-0.00
					(0.03)			(0.03)		(0.02)	(0.02)
Industry Linkages						32.29**		24.34*		19.68*	22.60**
						(12.27)		(9.95)		(9.67)	(8.30)
Forecast Dispersion							0.51**	0.40**		0.30*	0.06
							(0.18)	(0.15)		(0.13)	(0.12)
CMU Patenting									0.03**	0.02**	0.02*
									(0.01)	(0.01)	(0.01)
Constant	0.53**	-0.94*	-6.05**	-5.78**	0.79**	-12.36*	0.20	-15.14**	0.21	-12.52**	-15.28**
	(0.18)	(0.43)	(2.28)	(2.18)	(0.16)	(4.83)	(0.33)	(4.54)	(0.23)	(4.74)	(3.57)
Log Likelihood	-316.78	-300.67	-309.69	-296.00	-251.90	-248.66	-248.22	-234.90	-210.52	-199.41	-159.38
Observations (Industries)	148	148	148	148	116	116	116	116	102	102	83

+ *p*<.10, * *p*<.05, ** *p*<.01, negative binomial regression estimates, robust standard errors in parenthesis

Table 7: Main regression (negative binomial) results – dependent variable: marketplace listings by industry.

DV: Number of	(12)	(13)	(14)	(15)	(17)	(18)	(16)	(19)	(20)	(21)	(22)

Listings											Manuf.
High Technology	0.00	0.08	0.01	0.07	0.27	0.32	0.43*	0.53*	0.19	0.51*	0.40*
	(0.18)	(0.23)	(0.22)	(0.23)	(0.22)	(0.23)	(0.20)	(0.25)	(0.18)	(0.22)	(0.19)
R&D Intensity	51.56**	52.87**	48.89**	53.68**	41.58**	42.28**	46.11**	43.91**	31.27**	35.08**	44.28**
	(6.42)	(9.66)	(9.72)	(11.42)	(8.34)	(8.23)	(10.37)	(10.98)	(6.92)	(7.58)	(8.71)
Number of Firms	0.48**	0.31**	0.34**	0.23**	0.51**	0.50**	0.50**	0.30**	0.47**	0.31**	0.28**
	(0.06)	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.08)
Return on Assets	10.78**	11.59**	6.38*	7.33**	3.26	1.50	8.93*	3.52	-2.25	1.73	0.69
	(2.67)	(3.08)	(2.58)	(2.85)	(2.54)	(2.90)	(4.45)	(5.22)	(2.85)	(2.53)	(2.13)
SG&A Intensity	-1.77	-0.39	-0.22	0.43	0.46	0.53	1.21	5.39*	0.41	5.66**	4.26**
	(1.21)	(2.12)	(1.87)	(2.16)	(1.69)	(1.60)	(1.78)	(2.10)	(1.13)	(1.90)	(1.60)
Geographic Dispersion		3.89**		3.31**				3.49**		3.40**	2.85**
		(0.98)		(0.89)				(0.85)		(1.05)	(1.09)
Industry Fragmentation			15.63**	10.84**				11.11**		11.57**	14.02*
			(3.85)	(3.42)				(3.30)		(3.35)	(5.45)
Multifactor Productivity					0.05			-0.01		-0.04	-0.04
					(0.04)			(0.04)		(0.05)	(0.05)
Industry Linkages						34.73**		40.32*		20.03*	15.29
						(10.78)		(15.70)		(9.96)	(9.51)
Forecast Dispersion							1.06**	0.98**		1.15**	0.83**
							(0.35)	(0.33)		(0.34)	(0.32)
CMU Patenting									0.06**	0.05**	0.04+
									(0.02)	(0.02)	(0.02)
Online Market Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Constant	0.68*	-1.75**	-14.04**	-11.60**	0.71*	-13.32**	-0.54+	-29.85**	-0.29	-23.40**	-22.59**
	(0.27)	(0.64)	(2.58)	(2.51)	(0.30)	(4.55)	(0.32)	(7.66)	(0.47)	(6.66)	(8.23)
Log Likelihood	-2782.21	-2758.22	-2752.41	-2736.04	-2540.09	-2538.47	-2534.49	-2490.22	-2393.96	-2302.03	-2127.37
Online Market-Industry Combinations	1332	1332	1332	1332	1044	1044	1044	1044	918	918	747

+ *p*<.10, * *p*<.05, ** *p*<.01, negative binomial regression estimates, clustered standard errors by markets in parentheses.

REFERENCES

Afuah, A., & Tucci, C. L. 2012. Crowdsourcing As a Solution to Distant Search. ***Academy of Management Review***, 37(3): 355-375.

Agrawal, A., Catalini, C., & Goldfarb, A. 2015a. Crowdfunding: Geography, social networks, and the timing of investment decisions. ***Journal of Economics & Management Strategy***, 24(2): 253-274.

Agrawal, A., Cockburn, I., & Zhang, L. 2015b. Deals not done: Sources of failure in the market for ideas. ***Strategic Management Journal***, 36(7): 976-986.

Agrawal, A., & Goldfarb, A. 2008. Restructuring Research: Communication Costs and the Democratization of University Innovation. ***The American Economic Review***, 98(4): 1578-1590.

Akerlof, G. A. 1970. The market for lemons: quality uncertainty and the market mechanism. ***Quarterly Journal of Economics***, 89(3): 488-500.

Amit, R., & Zott, C. 2001. Value creation in e-business. ***Strategic Management Journal***, 22(6-7): 493-520.

Anand, B. N., & Khanna, T. 2000. The structure of licensing contracts. ***The Journal of Industrial Economics***, 48(1): 103-135.

Anderson, P., & Tushman, M. L. 1990. Technological discontinuities and dominant designs: a cyclical model of technological change. ***Administrative Science Quarterly***, 35(4): 604-633.

Anton, J., & Yao, D. 1995. Start-ups, spin-offs, and internal projects. ***Journal of Law, Economics, and Organization***, 11(2): 362-378.

Anton, J., & Yao, D. 2005. Markets for partially contractible knowledge: bootstrapping versus bundling. ***Journal of the European Economic Association***, 3(2-3): 745-754.

Arora, A. 1996. Contracting for tacit knowledge: the provision of technical services in technology licensing contracts. ***Journal of Development Economics***, 50(2): 233-256.

Arora, A., Fosfuri, A., & Gambardella, A. 2001. ***Markets for technology: The economics of innovation and corporate strategy***. Cambridge: MIT Press.

Arora, A., Fosfuri, A., & Rønde, T. 2013. Managing licensing in a market for technology. ***Management Science***, 59(5): 1092-1106.

Arora, A., & Gambardella, A. 1994. The changing technology of technological change: general and abstract knowledge and the division of innovative labour. ***Research Policy***, 23(5): 523-532.

Arora, A., & Gambardella, A. 2010. Ideas for rent: an overview of markets for technology. ***Industrial and Corporate Change***, 19(3): 775-803.

Arrow, K. 1962. Economic welfare and the allocation of resources for invention. In R. R. Nelson (Ed.), ***The Rate and Direction of Inventive Activity: Economic and Social Factors***: 609-626. Princeton, NJ: Princeton University Press.

Bakos, J. Y. 1997. Reducing buyer search costs: Implications for electronic marketplaces. ***Management Science***, 43(12): 1676-1692.

Bakos, Y. 1998. The emerging role of electronic marketplaces on the Internet. ***Communications of the Acm***, 41(8): 35-42.

Basalla, G. 1988. ***The evolution of technology***: Cambridge Univ Press.

Bercovitz, J. E., & Feldman, M. P. 2007. Fishing upstream: Firm innovation strategy and university research alliances. ***Research Policy***, 36(7): 930-948.

Brews, P. J., & Tucci, C. L. 2004. Exploring the structural effects of internetworking. ***Strategic Management Journal***, 25(5): 429-451.

Brynjolfsson, E., Hu, Y. J., & Simester, D. 2011. Goodbye pareto principle, hello long tail: The effect of search costs on the concentration of product sales. ***Management Science***, 57(8): 1373-1386.

Brynjolfsson, E., Hu, Y. J., & Smith, M. 2006. From Niches to Riches: Anatomy of the Long Tail. ***Sloan Management Review***, 47(4): 67-71.

Brynjolfsson, E., & Saunders, A. 2009. ***Wired for innovation: how information technology is reshaping the economy***. Boston: MIT Press.

BTG. 1998. British Technology Group: IPR Market Benchmark Study

Cassimon, D., De Backer, M., Engelen, P.-J., Van Wouwe, M., & Yordanov, V. 2011. Incorporating technical risk in compound real option models to value a pharmaceutical R&D licensing opportunity. ***Research Policy***, 40(9): 1200-1216.

Castellani, D., Jimenez, A., & Zanfei, A. 2013. How remote are R&D labs? Distance factors and international innovative activities. ***Journal of International Business Studies***, 44(7): 649-675.

Ceccagnoli, M., & Jiang, L. 2013. The cost of integrating external technologies: Supply and demand drivers of value creation in the markets for technology. ***Strategic Management Journal***, 34(4): 404-425.

Coase, R. 1960. The problem of social cost. ***The journal of Law and Economics***, 3(1): 1.

Cohen, J., Cohen, P., West, S., & Aiken, L. 2003. ***Applied multiple regression/correlation analysis for the behavioral sciences*** (3rd ed.). NJ: Lawrence Erlbaum.

Cohen, W., & Levin, R. 1989. Empirical studies of innovation and market structure. ***Handbook of industrial organization***, 2: 1059-1107.

Cohen, W. M., Nelson, R. R., & Walsh, J. 2000. Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or not), ***NBER Working Paper Series***, Vol. 7552. Cambridge, MA.

Conti, R., Gambardella, A., & Novelli, E. 2013. Research on Markets for Inventions and Implications for R&D Allocation Strategies. ***Academy of Management Annals***, 7(1): 715-772.

Danneels, E. 2002. The dynamics of product innovation and firm competences. ***Strategic Management Journal***, 23(12): 1095-1121.

Danneels, E. 2007. The process of technological competence leveraging. ***Strategic Management Journal***, 28(5): 511.

Dushnitsky, G., & Klueter, T. 2011. Is there an eBay for ideas? Insights from online knowledge marketplaces. ***European Management Review***, 8(1): 17-32.

Dushnitsky, G., & Klueter, T. 2016. Linking Technologies to Applications–Insights from Online Markets for Technology, ***Resource Redeployment and Corporate Strategy***, Vol. 35: 285-317: Emerald Group Publishing Limited.

Dushnitsky, G., & Lenox, M. 2005. When do firms undertake R&D by investing in new ventures? ***Strategic Management Journal***, 26(10): 947–965.

Evans, P., & Wurster, T. S. 1999. Getting real about virtual commerce. ***Harvard Business Review***, 77: 84-98.

Feldman, E. R., Gilson, S. C., & Villalonga, B. 2013. Do analysts add value when they most can? Evidence from corporate spin-offs. ***Strategic Management Journal***.

Forman, C., Ghose, A., & Goldfarb, A. 2009. Competition between local and electronic markets: How the benefit of buying online depends on where you live. ***Management Science***, 55(1): 47-57.

Fosfuri, A. 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. ***Strategic Management Journal***, 27(12): 1141.

Gans, J., & Stern, S. 2010. Is there a market for ideas? ***Industrial and Corporate Change***, 19(3): 805-837.

Gans, J. S., & Stern, S. 2003. The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. ***Research Policy***, 32(2): 333-350.

Garicano, L., & Kaplan, S. N. 2001. The Effects of Business-to-business E-commerce on Transaction Costs. ***The Journal of Industrial Economics***, 49(4): 463-485.

Giarratana, M. S., & Mariani, M. 2014. The relationship between knowledge sourcing and fear of imitation. ***Strategic Management Journal***, 35(8): 1144-1163.

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., Garcia-Fontes, W., Geuna, A., Gonzales, R., & Harhoff, D. 2007. Inventors and invention processes in Europe: Results from the PatVal-EU survey. ***Research Policy***, 36(8): 1107-1127.

Grégoire, D. A., & Shepherd, D. A. 2012. Technology-market combinations and the identification of entrepreneurial opportunities: An investigation of the opportunity-individual nexus. ***Academy of Management Journal***, 55(4): 753-785.

Griliches, Z., & Lichtenberg, F. 1984. Interindustry Technology Flows and Productivity Growth: A Re-examination. ***The Review of Economics and Statistics***, 66(2): 324-329.

Hagiu, A., & Yoffie, D. B. 2013. The New Patent Intermediaries: Platforms, Defensive Aggregators, and Super-Aggregators. ***The Journal of Economic Perspectives***, 27(1): 45-65.

Hargadon, A., & Sutton, R. I. 1997. Technology brokering and innovation in a product development firm. ***Administrative Science Quarterly***, 42: 716-749.

Harper, M. J., Khandrika, B., Kinoshita, R., & Rosenthal, S. 2010. Nonmanufacturing industry contributions to multifactor productivity, 1987-2006. ***Monthly Labor Review***, 133(6).

Hecker, D. E. 2005. High-technology employment: a NAICS-based update. ***Monthly Labor Review***: 57.

Hicks, D., & Hegde, D. 2005. Highly innovative small firms in the markets for technology. ***Research Policy***, 34(5): 703-716.

Howells, J. 2006. Intermediation and the role of intermediaries in innovation. ***Research policy***, 35(5): 715-728.

Humphery-Jenner, M. 2013. Takeover defenses, innovation, and value creation: Evidence from acquisition decisions. ***Strategic Management Journal***.

Jaffe, A. 1986. Technological opportunity and spillovers of R&D: evidence from firms' patents, profits, and market value. ***American Economic Review***, 76(5): 985-1001.

Jaffe, A. B., Trajtenberg, M., & Henderson, R. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. ***the Quarterly journal of Economics***: 577-598.

Jeppesen, L., & Lakhani, K. 2010. Marginality and problem-solving effectiveness in broadcast search. ***Organization Science***, 21(5): 1016-1033.

Klevorick, A. K., Levin, R. C., Nelson, R. R., & Winter, S. G. 1995. On the sources and significance of interindustry differences in technological opportunities. ***Research Policy***, 24(2): 185-205.

Kogut, B., & Zander, U. 1992. Knowledge of the firm, combinative capabilities and the replication of technology. ***Organization Science***, 3(3): 383-397.

Kranenburg, H., Hagedoorn, J., & Lorenz-Orlean, S. 2014. Distance Costs and The Degree of Inter-Partner Involvement in International Relational-Based Technology Alliances. ***Global Strategy Journal***, 4(4): 280-291.

Lakhani, K., Lifshitz-Assaf, H., & Tushman, M. 2012. Open innovation and organizational boundaries: the impact of task decomposition and knowledge distribution on the locus of innovation. ***Harvard Business School Working Paper***.

Lamoreaux, N., & Sokoloff, K. 2003. Intermediaries in the US Market for Technology, 1870-1920. ***Finance, Intermediaries, and Economic Development***: 209-246.

Landefeld, J., & Fraumeni, B. 2001. Measuring the new economy. ***Survey of Current Business***, 81(3): 23-40.

Laursen, K., & Salter, A. 2006. Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. ***Strategic Management Journal***, 27(2): 131-150.

Leone, M. I., & Reichstein, T. 2012. Licensing-in fosters rapid invention! the effect of the grant-back clause and technological unfamiliarity. ***Strategic Management Journal***, 33(8): 965-985.

Levin, R., Klevorick, A., Nelson, R., Winter, S., Gilbert, R., & Griliches, Z. 1987. Appropriating the returns from industrial research and development. ***Brookings papers on economic activity***, 1987(3): 783-831.

Madhavan, R., & Prescott, J. E. 1995. Market value impact of joint ventures: The effect of industry information-processing load. ***Academy of Management Journal***, 38(3): 900-915.

March, J., & Simon, H. 1958. ***Organizations***. New York: John Wiley.

Martin, G., Gözübüyük, R., & Becerra, M. 2013. Interlocks and firm performance: The role of uncertainty in the directorate interlock-performance relationship. ***Strategic Management Journal***.

McEvily, B., & Zaheer, A. 1999. Bridging ties: a source of firm heterogeneity in competitive capabilities. ***Strategic Management Journal***, 20(12): 1133-1156.

Monteiro, L. F., & Birkinshaw, J. 2016. The external knowledge sourcing process in multinational corporations. ***Strategic Management Journal***, forthcoming.

Nishimura, J., & Okada, Y. 2014. R&D portfolios and pharmaceutical licensing. ***Research Policy***.

Palomeras, N. 2007. An analysis of pure-revenue technology licensing. ***Journal of Economics & Management Strategy***, 16(4): 971-994.

Parker, G. G., & Van Alstyne, M. W. 2005. Two-Sided Network Effects: A Theory of Information Product Design. ***Management Science***, 51(10): 1494-1504.

Penrose, E. 1959. ***The Theory of the Growth of the Firm***. Oxford: Oxford University Press.

Powell, W. W., & Snellman, K. 2004. The knowledge economy. ***Annual review of sociology***: 199-220.

Rindova, V., Ferrier, W. J., & Wiltbank, R. 2010. Value from gestalt: how sequences of competitive actions create advantage for firms in nascent markets. ***Strategic Management Journal***, 31(13): 1474-1497.

Rivette, K., & Kline, D. 2000. Discovering new value in intellectual property. ***Harvard Business Review***, 78(1): 54-146.

Rosenberg, N. 1996. Uncertainty and technological change, ***Mosaic of Economic Growth***. Stanford, CA: Stanford University Press.

Rothaermel, F. T. 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. ***Strategic Management Journal***, 22(6-7): 687-699.

Sahaym, A., Steensma, H., & Barden, J. 2010. The influence of R&D investment on the use of corporate venture capital: An industry-level analysis. ***Journal of Business Venturing***, 25(4): 376-388.

Schilling, M. A., & Steensma, H. K. 2001. The use of modular organizational forms: an industry-level analysis. ***Academy of Management Journal***, 44(6): 1149-1168.

Simonin, B. L. 1999. Ambiguity and the process of knowledge transfer in strategic alliances. ***Strategic Management Journal***, 20(7): 595-623.

Solow, R. 1957. Technical change and the aggregate production function. ***The Review of Economics and Statistics***, 39(3): 312-320.

Sorenson, O., & Stuart, T. E. 2001. Syndication networks and the spatial distribution of venture capital investments. ***American Journal of Sociology***, 106(6): 1546-1588.

Stigler, G. 1961. The economics of information. ***The Journal of Political Economy***, 69(3): 213-225.

Tactics, T. T. 2008. The promise and pitfalls of using an IP exchange, Vol. 2008.

Teece, D. J. 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. ***Research Policy***, 15(6): 285-305.

Terleckyj, N. E. 1980. What Do R & D Numbers Tell Us about Technological Change? ***The American Economic Review***, 70(2): 55-61.

Villalonga, B. 2004. Diversification discount or premium? New evidence from the business information tracking series. ***The Journal of Finance***, 59(2): 479-506.

Winter, S. G. 1987. Knowledge and competence as strategic assets. In D. J. Teece (Ed.), ***The competitive challenge: strategies for industrial innovation and renewal***: 159-184. Cambridge, MA: Ballinger.

Wood, A. 2002. Unlocking the value of intellectual property. ***Chemical Week***, 164(48): 25-26.

Wood, A., & Scott, A. 2004. Licensing Activity is on the Rise. ***Chemical Week***, 166(10): 20.

Yanagisawa, T., & Guellec, D. 2009. The emerging patent marketplace: OECD Publishing.

Yet2.com. 2008. The Mission of the Marketplace, Vol. 2008.

Yusuf, S. 2008. Intermediating knowledge exchange between universities and businesses. ***Research Policy***, 37(8): 1167-1174.

Zhang, Y., & Li, H. 2010. Innovation search of new ventures in a technology cluster: the role of ties with service intermediaries. ***Strategic Management Journal***, 31(1): 88-109.