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Carlos J. Serrano
Rosemarie Ziedonis

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ABSTRACT

Entrepreneurial firms are important sources of patented inventions. Yet little is known about what happens to patents "released" to the market when startups fail. This study provides a first look at the frequency and speed with which patents originating from failed startups are redeployed to new owners, and whether the value of patents is tied to the original venture and team. The evidence is based on 1,766 U.S. patents issued to 285 venture capital-backed startups that disband between 1988 and 2008 in three innovation-intensive sectors: medical devices, semiconductors, and software. At odds with the view that the resale market for patented inventions is illiquid, we find that most patents from these startups are sold, are sold quickly, and remain "alive" through renewal fee payment long after the startups are shuttered. The patents tend to be purchased by other operating companies in the same sector and retain value beyond the original venture and team. We do find, however, that the patents and people sometimes move jointly to a new organization following the dissolution of the original venture, and explore the conditions under which such co-movement is more likely. The study provides new evidence on a phenomenon—of active markets for buying and selling patents—underexplored in the literature and consequential for both entrepreneurial and established firms.

Carlos J. Serrano
Department of Economics
Universitat Pompeu Fabra
Ramon Trias Fargas, 25-27
08005 Barcelona,
Spain
and Barcelona GSE
carlos.serrano@upf.edu

Rosemarie Ziedonis
Questrom School of Business
Boston University
595 Commonwealth Avenue
Boston, MA 02215
and NBER
rmz@bu.edu

"…the economic problem of society is mainly one of rapid adaptation to changes in the particular circumstances of time and place" – Hayek (1945: 524)

1. Introduction

Entrepreneurial firms are important sources of new technologies and patented inventions. Kortum and Lerner (2000) show, for example, that venture capital-backed startups produce three times more patents per investment dollar than established corporations. Although some startups are spectacular successes, many fail in their commercial pursuits and are disbanded (Arora and Nandkumar 2011; Hall and Woodward 2010). To illustrate, Kerr, Nanda, and Rhodes-Kropf (2014) report that 55 percent of all startups that received venture capital (VC) between 1985 and 2009 were terminated at a loss. While prior studies show that disbanded startups are important sources of human capital and learning spillovers for others (Knott and Posen 2005; Hoetker and Agarwal 2007; Kacperczyk and Marx 2017), little is known about the frequency and speed with which the legal rights to their patented inventions are redeployed to new owners.

It is widely assumed, often implicitly, that the resale market for patents is *inconsequential* for failed startups and innovative activity that follows in their wake. Relative to tangible assets such as real estate and equipment, patent rights are notoriously challenging to value and sell (Arora et al. 2004; Lemley and Shapiro 2005; Gans and Stern 2010). Even if the inventions cover technologies that are viable on the market, follow-on use and development can be impaired without access to the original organization and private knowledge of the team (Nelson and Winter 1982; Hoetker and Agarwal 2007). In the extreme, patent assets could be non-redeployable in the classic sense of Williamson (1988): rendered worthless to third parties when startups fail and teams disband. In this scenario, the rights should either lapse into the public domain post-exit—potentially removing legal

barriers to others for follow-on use—or remain tied to the human capital through asset purchase or co-movement to a new organization.

Anecdotal evidence suggests, however, that patents sometimes retain value for reasons imperfectly tied to the original project and team. In 2005, for example, Commerce One, a software startup with patents covering protocols used in electronic commerce, sold its patents at bankruptcy for $15.5 million to JGR Acquisitions, a Texas-based company acting on behalf of Novell Corporation. Novell, an established firm in the industry, reportedly purchased the patents for defensive reasons to reduce the risk and disruption of potential lawsuits had others purchased the rights and enforced them (Markoff 2005). More recently, LinkedIn, the social networking company, purchased 900 patents to strengthen and diversify its portfolio of legal rights. Doing so enabled LinkedIn to rapidly expand its portfolio size from only 36 patents in 2012 to almost 2,000 by mid-2016, reportedly bolstering its bargaining position with other corporate patent owners (Harrington et al. 2017).[1] Although these anecdotes raise the possibility that the market for buying and selling patents is potentially consequential both for failed ventures and surviving companies, empirical evidence remains limited.

This study sheds new light on the market for patented inventions by exploring what happens to patents "released" to the market when startups fail. Do the assets tend to retain value beyond the original venture and team? If so, which patents sell, how quickly, and who buys them?

To investigate these questions, we track 1,766 U.S. patents originating from 285 venture capital-backed startups that disband between 1988 and 2008 in three innovation-oriented sectors: medical

[1] According to Harrington et al. (2017), LinkedIn purchased the patents in small bundles (or "packages") from patent brokers and directly from owners. After reviewing 800 packages with 25,000 patents, the company bought 900 patents in 13 deals. When purchasing, LinkedIn reportedly prioritized patents likely to be infringed by 11 corporations viewed as "high risk" in extracting licensing fees from the company or restricting its freedom to operate in the industry. The case study did not mention a need for access to the original inventors or team in capturing value from the purchase. For additional discussion on the strategic value of patent portfolios for use in licensing negotiations and litigation settlement, see Grindley and Teece (1997), Cohen et al. (2000), Hall and Ziedonis (2001), Somaya (2003) and Galasso et al. (2013).

devices, semiconductors, and computer software. VC-backed companies tend to rely on patents to protect their inventions (Kortum and Lerner 2000; Graham et al. 2010) yet, as suggested earlier, they often fail in their commercialization attempts and cease operations (e.g., Hoetker and Agarwal 2007; Kerr et al. 2014). Selecting companies from the life sciences (medical devices) and information technology-related sectors (semiconductors, software) provides different vantage points for viewing patterns in the data. The sample is drawn from all VC-backed companies founded in these three sectors between 1987 and 1999, thus providing a decade-long period for observing dissolutions and patent sales if any. The failed startups in our sample raised $6.4 billion in equity financing pre-exit, averaging $22.4 million per company.

Hand-compiling and integrating multiple strands of data, we observe rich characteristics of the startups and their patents, which patents they sell when, as well as characteristics of the buyers. We also track environmental conditions in the broader resale market for patents using a "patent market liquidity" measure introduced in Hochberg et al. (2017) based on the thickness of patent trading activity in invention classes relevant for each company's portfolio of patents. As Gans and Stern (2010) discuss, thicker trading in the market should reduce search costs for both buyers and sellers, potentially increasing the likelihood of sale and accelerating the redeployment process. Similar to earlier work by Lamoureux and Sokoloff (2001, 2003) and Serrano (2010), we identify patent sales through transactions recorded in the US Patent and Trademark Office (USPTO) Patent Assignment dataset.[2] Finally, to capture the degree to which the value of patents originating from these firms remains tied to the human capital post-exit, we use LinkedIn profiles and patent records to discern if

[2] The scarcity of prior empirical research on patent sales could be due to the inherent "messiness" of the USTPO Patent Assignment records (e.g., see Serrano 2010). In 2015, the USPTO released the data in a format more amendable for large-scale study, thus opening up new opportunities for research. Graham et al. (2015) provide a useful overview of the data.

one or more of the inventors acquires the patents or moves as an employee to the purchasing organization.

To establish minimum thresholds in redeployment value, we follow convention in the innovation economics literature and determine whether maintenance fees are paid to keep the rights legally active (Pakes 1986; Schankerman and Pakes 1986).[3] Unfortunately, we lack direct evidence on the expected value at purchase since prices paid to acquire patents are typically treated as confidential information by transacting parties (Hagiu and Yoffie 2013). If patents are purchased at "fire sale" prices, however, the initial purchases could be followed by subsequent failure to pay the escalating fees later required to maintain the right. Finally, to deepen our understanding of the phenomenon and reflect upon the broader implications of our findings, we conducted 22 exploratory interviews, most of which were with intermediaries who service the patent resale market (i.e., as brokers, consultants, or attorneys) or supply capital to entrepreneurial firms as equity investors or lenders.[4]

The quantitative patterns revealed in our data are quite striking. Of the 1,766 patents issued to companies in our sample, almost 70% are sold. This share is highest for startups in the semiconductor devices sector, where 87% of the patented inventions are sold post-exit, followed by the software (74%) and medical devices (61%) sectors. The patents tend to sell quickly, within a year of the company's dissolution. In all sectors, the most common buyer is an operating company

[3] To keep a U.S. patent in force, the owner is required to pay maintenance fees of increasing amounts over the lifespan of the patent. For large entities, the current fee structure is $1,600 (due 3.5 years after the patent issues), $3,600 after 7.5 years, and $7,400 after 11.5 years as listed on the USPTO.gov website. Smaller entities pay reduced rates. Unless term extensions are granted for regulatory or procedural reasons, the maximum lifespan of a U.S. patent is twenty years from the filing date of the application.

[4] The interviews were semi-structured, conducted in person or by phone, and lasted one hour on average. Most of the interviews were conducted between 2014 and 2017. As reported in more systematic qualitative studies on patent markets (Benassi and Di Minin 2009; Brassell and King 2013; Hagiu and Yoffie 2013), many brokers and consultants we met had previously been employed in R&D, business development, or legal functions within large corporations.

in the same industry. Buyers typically keep the patents in force through 2014 or term expiration, which is suggestive of longer-term redeployment value.

Although many patent rights remain alive long after the startups shut down, they rarely follow the original inventors. Out of 1,203 patents that sell, less than 3% (31 patents) are purchased by one or more of the original inventors, ranging from 4% in medical devices to less than 1% in software. Among inventors with employment histories on LinkedIn, only 13% are subsequently employed by the organization that purchases the patents. This co-mobility percentage is slightly higher but still low, at 20%, as evidenced by name searches in patent invention records. These statistics suggest that, conditional on observing evidence of post-exit mobility, roughly 80% to 87% of the inventors in our sample move to organizations other than the entity that purchases the patents.

In summary, we find frequent and rapid sales of patent assets from failed startups to new owners and that the rights tend to remain alive long after the original venture is shuttered. We also find, however, that these patterns are not absolute. Some patents do not sell, some sell but not quickly, and some travel with the original inventors to a new organization. In a final set of analyses, we therefore explore sources of heterogeneity within the sample that might affect these outcome variables.

This study contributes to three streams of research that span the fields of strategic management and economics. A longstanding literature recognizes that patent rights are strategic assets for firms, whether as "isolating mechanisms" and "shields" against potential imitators (Rumelt 1984; Hall 1992; Teece 1986), as "bargaining chips" in negotiations with rivals (Teece and Grindley 1998; Cohen et al. 2000; Somaya 2003), or as quality signals that help secure funds from external resource providers (Hsu and Ziedonis 2013; Conti et al. 2013; Haeussler et al. 2014).[5] Within strategic management, our study adds to a growing call for empirical research on resource-based theory that

[5] We use the terms "assets" and "resources" synonymously throughout the paper.

moves beyond *whether* intangible assets such as patents are valuable toward a deeper understanding of *why* and *how* such assets confer value in product markets, strategic factor markets, or both (Priem and Butler 2001; Leiblein 2011). If patent assets are redeployable through factor markets in the event of failure, it could stimulate investments in unproven technologies earlier in the life cycle and potentially enable entrepreneurial firms to access debt sources of financing (de Rassenfosse and Fischer 2016; Hochberg et al. 2017). More broadly and consistent with resource-based theory (Barney 1986; Barney and Arikan 2001), inefficiencies and frictions in the market to acquire patent assets provide an opportune environment for strategic gain. The evidence in our study underscores the importance of future research on how established firms tap into this understudied factor market for intangible assets and the tradeoffs they face when doing so.

Relatedly, we contribute to a more targeted literature on asset redeployment. An extensive literature in economics examines the efficiency and speed with which tangible assets such as aircraft and equipment are redeployed to other entities when companies fail (e.g., Benmelech and Bergman 2008; Ramey and Shapiro 2001; Gavazza 2011). Far less is known about the conditions that affect the redeployability of *intangible* assets like patents. Within strategic management, a separate body of work examines factors that affect the redeployment of tangible and intangible assets *within* organizational boundaries (e.g., Anand and Singh 1997; Helfat and Eisenhart 2004; Lieberman et al. 2017). If, as our evidence suggests, established firms actively buy and sell patents through the secondary market, it could have important implications for the scale and scope of internal projects.

Finally, we contribute to a growing literature on markets for technology (e.g., Teece 1986; Arora et al. 2004; Gans and Stern 2010). It is well established in this literature that patent rights can facilitate the licensing and exchange of technological knowledge (e.g., Arora 1995; Gans et al. 2002, 2008; Agrawal et al. 2015). As discussed more fully in the section that follows, far less is

known about the buying and selling of patent rights as standalone assets. We bring new evidence to bear on this understudied exchange arena.

2. The Market for Patents: Background and Related Evidence

Although patents are widely used to measure the innovative capabilities of firms and to trace knowledge flows beyond their borders, they also are strategic assets that can be bought, sold, and traded.[6] A patent, if valid, confers a legal right to exclude others from making, using, or selling an invention for a limited period of time. Patent rights are often exchanged through technology licenses and transferred to new owners through corporate takeover markets (e.g., see Arora et al. 2004; Agrawal et al. 2015). Although less well studied, growing evidence suggests that patent rights also are redeployed through factor markets as standalone assets.

Patent sales can arise for many reasons. As Kerr et al. (2014) describe, it is often impossible for managers and investors to predict in advance whether a particular technology or new idea will be successful. This inherent uncertainty in the process of innovation naturally gives rise to failed attempts and abandoned projects. Even firms with promising projects can fail to survive the competition and be driven out of business (e.g., see Hoetker and Agarwal 2007; Wasserman 2012), potentially releasing patents at liquidation.[7] When the communications company Nortel went bankrupt in 2011, for example, the company recouped $4.5 billion through the sale of 6,000 patents (Hagiu and Yoffie 2013). Ma, Tong, and Wang (2017) further document that public US companies

[6] Hall et al. (2001), Murray and O'Mahony (2007) and Somaya (2012) review uses of patent-based statistics in innovation economics, organization studies, and strategic management. Prior research on the strategic value and use of patent assets includes Grindley and Teece (1998), Cohen et al. (2000), Hall and Ziedonis (2001), Shapiro (2001), Somaya (2003) and Graham et al. (2010). Several recent studies, which we draw upon in this section, provide in-depth coverage of patent markets and frictions within them. See especially Gans and Stern (2010), Lamoreaux et al. (2013), Hagiu and Yoffie (2013) and government reports by Brassell and King (2013) and the USFTC (2011, 2016).

[7] In a recent CB Insights survey, for example, founders of failed startups commonly attributed the source of failure to non-technological factors such as poor market timing and negative team dynamics (Griffith 2014).

in Chapter 11 proceedings often divest portions of their patent portfolios during the reorganization process.

A similar dynamic can result in "mismatches" between the original inventors and those best positioned to create and capture future value from patent rights and the inventions that they cover (Gans and Stern 2010; Akcigit et al. 2016). Lamoreaux and Sokoloff (2001, 2003) show, for example, that independent inventors in the nineteenth century often sold their patents to downstream companies better positioned to develop, market, and distribute products based on those inventions. The authors conclude that the ability to sell patents helped give rise to a class of specialized inventors, thus facilitating division of labor in early technology markets. In the first systematic analysis of modern markets for U.S. patents, Serrano (2006, 2010) documents that 13.5% of all U.S. patents issued between 1980 and 2001 changed owners, with higher rates for inventions produced by individuals and smaller firms. More recently, Akcigit et al. (2016) report that 20% of all U.S. patents issued between 1976 and 2006 transact through the secondary patent market, often to companies that own patent rights in related areas. In combination, this evidence suggests that patent sales are often driven by relative advantages in commercialization and other downstream activities.[8]

More controversial from a policy perspective, patent sales can also arise due to relative advantages in patent enforcement (Galasso et al. 2013; Hagiu and Yoffie 2013). As is well known, patent value is highly skewed and difficult to discern absent an uncertain and costly enforcement process (Harhoff et al. 1999; Lemley and Shapiro 2005). Bundling patents in larger portfolios of rights can reduce this valuation challenge and make it easier for firms to settle legal conflicts out-of-court (Teece and Grindley 1998; Somaya 2003; Lanjouw and Schankerman 2004; Galasso et al.

[8] Adding further credence to this view, a recent working paper by Kuhn (2017) finds that unexpected shocks that expand the scope of protection conferred by a patent increase the likelihood of future sale, especially for smaller firms.

2013). As illustrated by examples in the introduction, patent purchases can similarly serve as a form of self-insurance: acquiring the rights ensures that others will not own them. These strategic motives for portfolio-based trading and self-insurance are particularly prevalent in information technology (IT)-related sectors due in part to the wide array of rights typically embedded in IT products (e.g., see Cohen et al. 2000; Shapiro 2001; Ziedonis 2004).

Despite recent evidence that many patents change owners, the market for buying and selling patents is widely cast as friction-filled and inefficient. Patent rights are awarded for "non-obvious" and "novel" inventions. This uniqueness makes it inherently difficult to value patents and find comparable transactions. Patents also confer an exclusionary rather than an affirmatory right. In essence, they simply provide a right to sue others. This nature of the right means that value capture is intrinsically tied to the credibility of threats to exclude others through legal action (Lanjouw and Schankerman 2004; Lemley and Shapiro 2005). It also means that costly-to-discern details about the patents (e.g., the omission of prior art, poorly worded claims) can alter expectations of successful enforcement and thus value. As one broker we interviewed put it, "when you hire someone to inspect a house, you might learn things that shift the asking price by thousands of dollars. When you perform due diligence on a patent, it can shift the asking price from millions of dollars to zero." Except in isolated instances where patents are sold at open auction or the information is voluntarily made public, prices paid to acquire patents are not systematically reported (Teece 1998; Hagiu and Yoffie 2013), thus amplifying the valuation challenge.

Added complexities arise due to the specificity of patent assets. As suggested earlier, even though patent documents codify information about the inventions, downstream commercialization and use can be impaired without access to the private (or "tacit") knowledge embedded in the human capital of the inventive team (Nelson and Winter 1982; Teece 1998; Hoetker and Agarwal 2007). If value capture is strongly tied to human capital (i.e., if the assets are "human capital

specific"), patent rights may have limited value as standalone assets if separated from the originating team. Similarly, if value capture is tied to specific complementary assets and larger patent bundles owned by others (Gans and Stern 2010; Hagiu and Yoffie 2013), the resale market could be thinly traded.

Relative to the broader market for new technologies and ideas, patent markets are less prone to failure due to the classic Arrow Paradox problem, where sellers fail to reveal information due to risks of expropriation (e.g., see Teece 1986; Arora 1995). By definition, the assets offered for sale are all patent-protected. Prior studies suggest, however, that disclosure challenges continue to plague the secondary patent market, albeit in a different form. As Benassi and Di Minin (2009) report, established firms prefer to "close deals in the dark" so that inventors do not ask for "unrealistic compensation" for their patents (pp 78-79). Hagiu and Yoffie (2013) similarly report that the widespread use of third parties to broker patent transactions is partly due to this strategic concern among deep-pocketed buyers. In our interviews and unprompted, an executive at a large corporation underscored the importance of this point, while noting an additional value of anonymity as a potential buyer: "When we look to buy patents, we're often searching for rights that help us protect new products under development. We reveal our buying priorities to a few brokers that we trust, and they find and screen patents on our behalf." As noted in Benassi and Di Minin (2009) and Hagiu and Yoffie (2013) and much like real estate brokers, patent brokers are paid a commission on the deal.

Before turning to our empirics, it is important to acknowledge a recent shift in the structure of U.S. patent markets and to discuss insights from our interviews that have received less systematic coverage in the strategic management and innovation economics literatures. The structural shift is well described by Hagiu and Yoffie (2013). Although buying and selling activity in patent markets remains largely intermediated through a fragmented array of brokers, the past few decades have

given rise to large "aggregators" and "non-practicing entities" (NPEs) that buy and bundle patents on behalf of others but do not otherwise compete in product markets.[9] Intellectual Ventures is a prominent example. Founded by former executives from Microsoft Corporation, Intellectual Ventures (IV) spent over $2 billion between 2000 and 2012 to amass one of the world's largest portfolios of 35,000 patents, primarily covering software, semiconductor and mobile computing inventions (Hagiu and Yoffie 2013). As Hagiu and Yoffie (2013: 60) note, "[b]ecause of its size, Intellectual Ventures can single-handedly create liquidity in the market." Due to ongoing policy concern about patent sales to NPEs (USFTC 2011, 2016; US White House 2013), we investigate whether the buyers of patents originating from failed startups in our sample are NPEs or operating companies.[10]

Finally, qualitative insights from our interviews resonate with key points in Gans and Stern (2010) and Hagiu and Yoffie (2013) that: (a) trading frictions in the patent resale market are alive and real, (b) brokers play an important role as intermediaries in this market, and (c) anonymous "eBay"-type platforms for patent sales have largely failed to gain traction. In addition, we were struck by an apparent maturation in the market and the wide range of organizational and institutional innovations that seem to facilitate the redeployment of patent rights from failed startups to new owners. First, as documented in recent studies by de Rassenfosse and Fischer (2016) and Hochberg et al. (2017), many VC-backed startups pledge their patents as collateral to secure financial resources from lenders. In the event that the startups fail, the lenders have strong incentives to liquidate the assets to minimize their losses. Relatedly, a support tier of financial

[9] For more in-depth discussion, see Reitzig et al. (2007), Fischer and Henkel (2010), and the USFTC (2011, 2016).
[10] The main policy concern is that NPEs that threaten to enforce their patents (also referred to as "patent assertion entities") can extract "excessive" rents through litigation and holdup, thus potentially imposing an ex post tax on innovation. This concern is weighed against the possibility that these entities increase liquidity in the resale market for patents, which could enable innovation-oriented companies to recoup more returns from failed projects and stimulate ex ante investment incentives. Some NPEs such as United Patents and RPX serve a "clearinghouse" role and do not enforce their patents. See Hagiu and Yoffie (2013) and USFTC (2016) for more in-depth discussion.

intermediaries has emerged that helps mitigate the "ex ante valuation" problem for lenders, with some companies agreeing to purchase patents for an agreed-upon price should a creditor default on the loan (Brassell and King 2013). de Rassenfosse and Fischer (2016) provide survey evidence that lenders to growth-oriented startups (i.e., "venture lenders") consider the "salability" of patents when deciding to supply funding. In other recent work and consistent with observations in Hagiu and Yoffie (2013), Hochberg et al. (2017) document that trading activity in the market for U.S. patents has intensified during the decade of the 2000s, particularly for IT-related inventions. The authors further suggest that greater liquidity in the market stimulates lending to VC-backed companies, thus providing indirect evidence that expectations of patent sales "matter" to these external capital providers. Direct evidence on whether patents are redeployable as standalone assets in the worst-case-scenario that startups fail remains lacking, an empirical gap that we seek to help fill.

3. Sample, Data Sources, and Main Variables

What happens to patents "released" to the market when startups fail? Do the patents tend to retain value beyond the original venture and team? If so, which patents sell, how quickly, and who buys them? This section describes the data that we compile to inform these questions. Section 4 reports descriptive patterns that emerge from these data. In Section 5, we probe more deeply into underlying sources of variation by analyzing the likelihood and speed of sale in a regression framework.

3.1. Sample Construction and Data Sources

Although our research questions are straightforward, answering them requires the compilation and integration of disparate strands of data on (a) failed startups, (b) their patents, (c) whether and when those patents are sold, (d) the identities and characteristics of the purchasing organizations, (e) whether the new owners keep the rights "alive" through payment of maintenance fees, and (f) whether one or more of the original inventors travel with the patents post-exit through asset

purchase or co-movement to the purchasing organization. Guided by findings in prior research, we also compile information about patent-, firm-, and environmental-level factors that could affect the baseline likelihood or speed of sale. Table A-1 in the Appendix provides an overview of our main variables and data sources.

To identify disbanded startups at risk of selling patents, we start with the population of U.S. venture-capital backed startups reported in the Dow Jones' VentureSource database in three innovation-intensive sectors: medical devices, semiconductor devices, and software. We then select startups founded from 1987, the first year that VentureSource reports data comprehensively, to 1999. This cohort includes firms at risk of being affected by the collapse of the technology bubble in 2000 and allows a sufficiently long window to (a) identify companies that disband and (b) to trace subsequent sales and renewals of their patented inventions if any. To obtain more precise information on companies that go out of business and when they do so, we supplement the VentureSource data with information from Sand Hill Econometrics (Hall and Woodward 2010). We track the financing and patenting activities of each company through the year of dissolution or 2008, our last year of reliable exit-status data. To link startups to patents, we search the Delphion database for U.S. patents assigned all current and former names of each company as listed in VentureSource.

In total, we identify 285 VC-backed startups that go out of business by 2008 and own patents potentially "releasable" to the secondary market. The disbanded ventures include 116 medical device companies, 128 software companies, and 41 semiconductor companies. In combination, the companies own 1,766 patents in the year of exit. The average portfolio size is 6.2 patents.

3.2. Main Variables

Determining which patents sell when and who buys them is challenging, as is discerning whether the patents and the original inventors travel together post-exit. Below, we elaborate on the

information we compile about patent sales and renewals, buyer characteristics, and co-movement by patents and the original inventors.

3.2.a. On whether and when a patent is sold

To identify whether and when a patent is sold, we use patent ownership records in USPTO Patent Assignment Database. For each assignment record, we obtain the patent or patent numbers involved, the name of the seller (assignor), the name of the buyer (assignee), the type of transaction (conveyance), the date at which the private agreement between the parties was signed (execute date), and the date at which the transaction was recorded at the patent office (recorded date). The dataset covers the period 1983-2011.

As discussed in Serrano (2010) and Graham et al. (2015), USPTO patent assignments not only record patent sales but also include a wide array of unrelated transactions such as initial assignments of rights from inventors to their employers, corrections to previous assignments, the pledging of patents as collateral to secure loans, negative pledge agreements, and so forth. To track patent sales, we manually inspect each patent transaction record for the 1,766 patents in our sample and conservatively drop all assignments that appear not to be associated with an actual change in patent ownership made by the startup and subsequent patent owners. To elaborate, we drop assignments recorded at the patent application date, corrections, pledges of patents as collateral, and negative pledges. We also drop instances where the first assignment is of an unassigned patent since these transactions typically involve simple transfers of rights from inventors to the companies that employ them. We use information contained in the clean records to construct two variables:

- **Patent Sale$_j$**: a dummy variable equal to one if a patent is sold at least once after the startup goes out of business.
- **Speed of Sale$_j$**: conditional on a patent being sold, the number of years between when the startup goes out of business and when the patent is first sold as indicated by the "execute date" listed in the assignment record.

3.2.b. On buyer characteristics

For each patent sale transaction, we retrieve the name of buyer from the USPTO assignment records. Unfortunately, the names recorded in the USPTO patent assignment records are not standardized and do link to sources with more systematic business or economic data. To start, we therefore first standardize the names of all patent buyers using the names of firms that the USPTO assigns to entities to which patents are granted and the name of inventors reported in granted patents. These data enable us to identify purchases of patents by inventors originally affiliated with the failed startup (i.e., "inventor-purchases"). For buyers other than the original inventors, we standardize their names and manually search for information about them using a wide range of online sources and business directories.[11] Postal addresses listed for buyers in the USPTO assignment records facilitate this task. We use the information retrieved from these searches to categorize whether a buyer is an operating company, a "non-practicing entity" (NPE) or "patent assertion entity" (PAE), or another entity (e.g., a university or an individual not listed as an inventor on patents issued to the failed startup). We categorize an operating company as being in the same sector of the startup based on industry information from business directories, including SIC classifications when they are available.

Triangulating data from these multiple sources, we successfully match all patent buyers to industries, NPE-PAE, other, or inventors of patents issued to the failed venture. Setting aside non-operating companies (i.e., NPE, PAE, universities, and individuals), 92 percent of the patent buyers match to entities with USPTO assignee identifiers. For each patent sold, we use these data to construct several buyer-related variables, including:

[11]For each unique patent buyer, we conduct manual name searches on Google, Bloomberg.com, Yahoo.com, Manta.com, Hoovers, SICcode.com, Zoominfo.com, and Plainsite.org. PAEs often purchase patents through LLCs and subsidiaries. To categorize PAE purchases, we primarily rely on Plainsite.org, which maps LLC and subsidiary names to PAE organizations. If a buying entity is not categorized as a PAE on Plainsite.org but has an SIC code of 6794 ("patent owners and lessors"), we categorize the buyer as a non-practicing entity.

- **Inventor-purchase$_j$**: an indicator set to one if the patent buyer is an inventor (or company with ownership ties to the inventors) of one or more patents issued to the failed venture.
- **Same Sector$_j$:** an indicator set to one if the patent buyer is an operating company that primarily competes in the same sector as the startup.
- **NPE-purchase$_j$:** an indicator set to one if the patent buyer is either a "non-practicing entity" (NPE) or a "patent assertion entity" (PAE).

3.2.c. On co-movement by patents and inventors to a new organization

To investigate whether patents that sell move jointly with the original inventors to the organization that purchases the patents, we use both LinkedIn profiles and patent data. To do so, we first search for LinkedIn profiles using the inventor's name and/or the name of the failed startup.[12] Using a matching protocol available upon request, we are able to match 60 percent of the individuals listed as inventors of patents at failed startups in our sample to LinkedIn profiles and employment histories. We use these data to determine whether, after the startup fails, one or more of the original inventors is subsequently employed by the entity that buys the patents. Equally important, the employment histories enable us to observe instances where the inventors move to entities that do not purchase the patents.

Using an alternative approach employed in prior studies (e.g., Marx et al. 2009; Palomeras and Melero 2010), we also trace employment mobility using the inventor names reported in patent records. A critical concern of this approach is that the inventors in the focal patent may not patent again following the year the startup goes out of business even if other companies, including patenting companies, employ them (Ge et al. 2016; Frake 2017). Indeed, we find that it is quite common for inventors in our sample to stop patenting after the original venture disbands even though they continue working in the industry at other operating companies. A related concern is whether the potential future employers, including the patent's buyers, are patenting companies since

[12] LinkedIn.com is a business and employment-oriented social network service that presents self-reported employment and education profiles of individuals. As of 2017, LinkedIn had 500 million members in 200 countries. Interestingly, through triangulation with media stories and resumes posted elsewhere, we were able to identify employment profiles for individual inventors that opted not to reveal the name of the failed venture on his/her LinkedIn profile.

we cannot match the inventors to patents unless their future employers patent their inventions. These two possibilities are false negatives. There is also the possibility of false positives in that patent buyers could be granted "continuation" patents, which would list inventors on the original patent even if they are employed elsewhere.

Through use of patent records, we observe patenting activity for 40 percent of the inventors in years following the startup's failure. This patent-based "employment mobility" rate is higher than that reported in prior studies (e.g., Palomeras and Melero 2010)). This fact is not surprising since inventors are more likely to seek a new job when the original venture is out of business and the hiring firm can potentially draw upon the knowledge of the patented invention without competing directly with the startup company that originally developed the idea (Fosfuri Motta and Ronde 2001). The legal rights to exclude others from use of such inventions may, of course, remain alive as we explore in this study.

In combination, the LinkedIn and patent data provide different vantage points for viewing co-movement by patents and the original inventors following a startup's dissolution. Consistent with recent evidence reported in Frake (2017), we find that many inventors in our sample do not produce patented inventions at their future employers once the original venture disband. We therefore base our primary co-mobility measure on evidence gleaned from LinkedIn data as follows:

- **Co-mobility$_j$:** an indicator equal to one if the patent buyer eventually employs one or more of the inventors in the focal patent after the startup goes out of business as measured by LinkedIn employment profiles. The measure is conditioned on patent sales in which at least one of the inventors is matched to an employer after the startup goes out of business.

3.2.d. On whether patents that are sold are later renewed

Finally, a key question for our analysis is not just whether patents are sold but whether they are "kept alive" by the new owners through payment of maintenance fees. This information provides an indication that a minimum threshold of redeployment value has been met. It also is important when considering the broader implications of our findings. If the patent rights are sold and kept legally

alive and enforceable, the implications for follow-on use are quite different than if such rights are sold yet soon enter the public domain through failure by the new owners to pay the fees required for renewal. Following convention in the literature (Pakes 1986; Schankerman and Pakes 1986), we use renewal fee data from the USPTO to construct the following measure:

- **Renewed Patent$_j$:** is a dummy equal to one if renewal fees are paid to maintain the patent right at required intervals through 2014 or the expiration of the patent.

3.3. Other Factors that Could Affect the Likelihood or Speed of Sale

In our descriptive and econometric analyses, we explore how the likelihood and speed of sale co-varies with observable characteristics of the firms, their inventions, and environmental conditions in the broader resale market for patents. We summarize the main additional variables of interest and rationale for including them below.

As reported in Appendix Table A-1, the VentureSource data reveal numerous firm-level characteristics, including the *Sector, Founding Year*, *Exit Year*, and *Equity Funds Raised Pre-Exit.* We supplement these data with information on whether (a) the startup has used one or more of its patents as collateral to secure funds from a venture lender pre-exit, and (b) whether the startup is financed by a top-tier VC. The presence of venture lenders or top-tier VCs could be an indicator of companies that are higher quality and/or have higher-quality patents that secure the funding. An equally plausible explanation, which we are unable to tease apart, is that venture lenders and/or top-tier VCs play a role that facilitates the sale of patents when startups fail.

To identify whether a startup pledges its patents as collateral pre-exit, we examine whether any patents awarded to the firm are used in security interest agreements recorded the USPTO Patent Assignment database prior to the startup's failure. Specifically, *Had Patent Backed Loan$_i$* is set to one if one or more of the startup's patents are used to secure a loan prior to the year of exit.[13]

[13]Venture lenders have strong incentives to record with the USPTO secured interests in patents they accept as collateral when lending (Hochberg et al. 2017).

Separately, to identify companies backed by top-tier VCs, we match investor names in VentureSource to reputation scores computed by Lee, Pollock, and Jin ("LPJ" 2011). Computed annually for VCs active from 1990 through 2010, the LPJ scores range from zero, for fringe/new investors, to a maximum of 100, with a median value of 5.7 out of 100. Consistent with Gompers et al. (2010) and given high skew in VC reputation and skill levels, *Has Top-Tier VC$_i$* is set to one if a startup is financed by one or more VCs in the top 25th percentile of the annual LPJ score distribution.

Environment and portfolio-level factors also could affect the ability to redeploy patents originating from failed companies to other users and uses. The incomplete contracting literature suggests that asset reallocation through secondary markets hinges both on the number of potential buyers and the costs associated with finding them. When buyers are few and/or costly to locate, trading frictions can reduce the gains anticipated from the exchange and lower asset prices (e.g., Gavazza 2011). In thicker markets, however, matching between sellers and buyers is assumed to be more efficient, thus increasing the value likely to be retained in the event of an exchange.[14] Guided by these insights, we use a *Patent Market Liquidity* measure introduced in Hochberg et al. (2017) to track whether thicker trading in the secondary market for patents increases the likelihood of sale or accelerates the redeployment process. Compiled from annual buying and selling activity in invention classes relevant for a given firm's portfolio of patent, the measure represents the combined probability (averaged across invention classes and issue years) that a patent in startup *i*'s portfolio will be sold in the year *t*.

Even with favorable trading conditions, some patents and portfolios could be easier to sell than others. If a startup's patents are extensively cited by outside parties in follow-on inventions relative

[14]Benmelech and Bergman (2008, 2009) and Gavazza (2011) document that thicker trading (increased "liquidity") in the secondary market for tangible assets correlates with higher resale values. Gans and Stern (2010) map insights from economic theory on market thickness to transactions in technology-related markets.

to citations made by follow-on patents by the same startup (i.e., the share of self-cites is relatively low), recent studies suggest that the patents should be more redeployable in outside use. Put differently, portfolios of patents with a high share of self-cites are more likely to be "firm-specific" and thus more difficult to redeploy if the original venture fails. Consistent with Hochberg et al. (2017), we proxy the *Firm-specificity of Patent Assets* based on the share of citations a startup's patents receives within three years from follow-on patents issued to the focal company (i.e., the share of "self-cites").[15]

Finally, at the patent level, Serrano (2010) reports that patents that are more highly cited in other patented inventions are more likely to be sold, a finding that likely correlates the value or economic importance of the specific invention as documented in Hall et al. (2001) and elsewhere. Serrano (2010) further shows that the baseline likelihood of sale declines as patents age, suggesting that the assets depreciate over their life cycles. This latter finding is also intuitive since the legal rights are finite and typically last a maximum of twenty years. Separately, Hoetker and Agarwal (2007) show that more "original" patents (i.e., patents that span more technology classes) are more likely to be built upon in other patented inventions after companies fail. Although the authors do not examine the sales of patents post-failure, this patent-level characteristic could be indicative of inventions with a wider range of market applications that in turn are more likely to sell. We therefore construct a comparable measure of *Patent Originality* based on invention classes reported in the patent data as in Hall et al. (2001).

4. Descriptive Patterns

[15] The measure is similar in spirit to an internal-focus proxy used in Hoetker and Agarwal (2007)'s study of failed disk drive companies: the authors report a steeper decline in follow-on citations (invention use) following exits of companies with high self-citation shares in the pre-exit period. Marx et al. (2009) use a similar citations-based measure to gauge the firm-specificity of skills among employee-inventors. More recently, Hochberg et al. (2017) find that when the share of self-citations to a startup's patent portfolio is high, the company is less likely to attract debt sources of financing.

This section summarizes the descriptive evidence revealed in our data that informs our primary research questions. In Section 5, we explore patent-, firm-, and environmental-level factors that could underpin these statistics.

4.1. Do the patents sell?

To start, Table 1 Panel A reports observable characteristics of the 285 failed startups in our sample that do (n=191) and do not (n=94) sell one or more of their patents after the ventures fail and are disbanded. Although the ventures are comparable in age at the time of exit, those that succeed in selling patents post-exit look "higher quality" on multiple dimensions, which is not surprising. To elaborate, Table 1 Panel A shows that on average and relative to failed startups that do not sell patents, failed startups that sell patents post-failure raise more money prior to dissolution, have larger and more highly cited patent portfolios at exit, are more likely to be backed by top-tier VCs, and are more likely to have secured loans with their patents.

Panel B of Table 1 compares average characteristics of patents that do (n=1,203) and do not (n=563) sell after startups in our sample fail and are disbanded. On average, patents that sell tend to be more highly cited, more original, younger, and less firm-specific that patents that do not sell. Again, these descriptive statistics are intuitive and accord with evidence reported in recent studies on the salability of patents and their use in lending (e.g., Serrano 2010; Hochberg et al. 2017). More strikingly, Panel B of Table 1 further reveals that 81% of all patent sold are renewed to their maximum legal length of protection or the end of our sample period.

Table 2 takes a closer look at patent sales post-exit overall and by sector. Of the 1,766 patents in our sample, Panel A shows that 68 percent (1,203 patents) are sold to new owners after the startup exits. The proportion sold is highest in semiconductors (87 percent), followed by 74 percent in software and 61 percent in medical devices. Panel A further suggests that, conditional on being sold, most patents originating from failed startups in our sample are kept alive long after the

original venture is shuttered. Overall, the share of patents sold that are renewed to the maximum length of legal protection during our sample period is 81 percent. This share is high across all three sectors, ranging from 90% in semiconductors and software to 74% in medical devices.

Panel B of Table 2 shows that more than two-thirds of failed startups in our sample (67%) sell one or more of their patents post-failure. This share ranges from 80% for failed semiconductor ventures to 66% and 64% for failed companies in the medical device and software sectors respectively. When failed startups sell at least one patent, Panel B of Table 2 further reveals that the patents are typically sold in "bulk" within the same year but potentially to more than one buyer. On average, 95 percent of the patents sold transact during the first year of sale with limited variance across the sectors.

4.2. Do the patents sell quickly?

Another important factor when assessing the redeployability of patent assets is how quickly the rights are sold and transferred to new owners. In principle, lenders and investors must weigh the benefits of finding a potential buyer against the costs of searching and negotiating with such a buyer. Even if there is potential value, there are frictions that could potentially complicate the quick redeployment of the patent assets to the firms with the highest value. Patent assets could be sector specific when the best match for the patents are companies operating in the same sector of the failing firm. Patent assets could also be firm specific when redeployment value depends on having access to the human capital of the inventors in the patent. Moreover, thin markets and costly search can make it hard to find in a timely manner the buyer that best matches the characteristics of the patents of the failed startup. At the same time, patent assets deteriorate rapidly and retaining the teams of patent inventors from disbanding to facilitate redeployment can be costly. The sale and redeployment of displaced patent assets, therefore, faces a trade-off between the potential benefits

of finding a buyer that matches the characteristics of the patent against the costs, which not only include asset depreciation but may also require retaining key employees to facilitate redeployment.

In our sample, patents are sold quickly after the startup goes out of business. Figure 1A shows that the number of patents directly sold by startups substantially decreases following the startup's failure year, indicating that most patents are transferred immediately after the startup fails. In particular, of the 1,203 patents sold, 779 are transferred during the same year the startup goes out of business and 218 additional patents are sold by the end of the first year after exit. In total, 83 percent of the patents are sold within a year after the companies are disbanded.

A similar pattern emerges when we look at startups instead of patents. In Figure 1B, we show that most startups sell their first patent immediately after going out of business and the number of startups selling their first patent declines significantly in the years thereafter. Of the 191 startups that go out of business in our sample and sell a patent, 115 companies sell their first patent (or bundle of patents) in the year they fail, and 40 additional startups sell their first patent the first year after they are disbanded. These statistics imply that 81 percent of the startups in our sample that eventually sell patents do so within a year after they go out of business.

In sum, this evidence suggests that most patents from failed startups in our sample are sold, are sold within a year after the companies disband, and are kept alive and legally in force by the new owners.

4.2. Who buys the patents?

4.2.a. Patent sales by entity type and industry sector

Which types of entities tend to purchase patents from failed startups? The first Panel in Table 3 sheds light on this question and reports buyer characteristics based on each patent sold within our sample. As Panel A shows, the overwhelming majority of patents (89% overall) are purchased by operating companies, followed by NPEs (9.6%), and individuals that have no ties to NPEs (1.8%).

Consistent with prior evidence that NPE/PAE purchases are more common in IT-related sectors (e.g., USFTC 2011, 2016), we find that NPE/PAEs purchase around 20% of all patents sold by failed ventures in semiconductors and software but only 3% of patents originating from failed medical device companies.

Panel B of Table 3 shows the distribution of patent buyers by the sector of the startup. Again, operating companies remain the most common buyer of patents originating from failed startups across all sectors. Consistent with the evidence reported in Panel A, the sector-level analysis similarly shows reveals that NPE/PAEs purchase a smaller share of patents originating from failed medical devices ventures (3.0%) than is true for patents originating from failed software (17%) and semiconductor device (18%) startups.

In summary, Table 3 shows that most patents from failed startups in our sample are purchased by operating companies in the same sector. As a share of patents sold, NPE/PAE are more active purchasers of patents from failed ventures in the two IT sectors represented in our sample (semiconductor devices and software) relative to the non-IT sector of medical devices. Even within IT, however, the overwhelming majoring of patents are sold to operating companies in the same sector.

4.2.b. Patent sales to inventors and co-mobility of patents and inventors

Measuring whether patent assets are tied to the human capital of the inventors is challenging. We need information on whether patent buyers have access to the human capital of the patent inventors in the focal patent. To infer this, we consider whether (i) patent inventors reallocate to work for the patent buyer after the startup fails; or alternatively, (ii) the buyer is a patent inventor or a company with ownership ties to the inventors in the focal patent.

Table 4 reports the share of patents and startups that sell a patent to one or more of the original inventors overall and by sector. The table shows that the vast majority of patents are sold to <u>other</u>

entities. The proportion of patents sold to an original inventor in the focal patent is 2.6 percent, or 31 out of 1201 patents sold. Moreover, only 5.8 percent of the startups sell patents to an original inventor, representing 11 out of 191 startups. Medical devices companies developed by startups often have strong ties with the medical doctors that may have been involved in the design of the medical equipment (Chatterji and Fabrizio 2014). Even there, only 10.5 percent of the startups (8 in total) sell at least one patent to one or more of the original inventors, accounting for only 3.95 percent of the patents sold in the sector. In the other two sectors, sales to the original inventors are even rarer events. The share of startups that sell the patent ownership rights to an original inventor post-exit is 2.4% in Software and 3% in Semiconductors, representing only 0.7 and 1.2 percent of patent sales in these sectors, respectively.

Table 5 examines whether the patents and inventors from the original venture move jointly to a new organization post-exit based on employment histories inferred from the LinkedIn (Panel A) and patent database (Panel B) searches. In Panel A, 12.9 percent of the patents co-move with at least one inventor to the purchaser of the patent as evidenced by LinkedIn employment profiles. This co-movement percentage ranges from 17.8% in software to 11.8% and 8.9% in medical devices and semiconductors respectively. As Panel B in Table 5 reveals, these co-movement rates are higher when measured with patent data alone but reveal a similar pattern across the sectors.

5. Multivariate analysis

The descriptive patterns in Section 4 reveal that most patents from failed startups in our sample are sold, are sold quickly, and retain value beyond the original venture and team. It is equally true, however, that some patents in the sample are not sold, are sold slowly, and remain tied to the original inventors following the dissolution of the original venture.

In this section we therefore probe more deeply into the underlying sources of variation in the data by analyzing the likelihood and speed of sale and the co-mobility of patents and inventors in a

regression framework. To summarize from before, the three dependent variables in our analysis are defined as follows:

- **Patent Sale$_j$:** an indicator equal to one if a patent is sold at least once after the startup goes out of business.
- **Speed of Sale$_j$:** conditional on a patent being sold, the number of years between when the startup goes out of business and when the patent is first sold.
- **Co-mobility$_j$:** an indicator equal to one if the patent buyer eventually employs one or more of the inventors in the focal patent after the startup goes out of business as measured by LinkedIn employment profiles.[16]

The first and third dependent variables are binary measures equal to 1 or zero whereas the *Speed of sale* is a count (in years).

As discussed in Section 3, numerous characteristics of the firms, their patent portfolios and inventions, and environmental factors at the time of exit could affect the likelihood and speed with which patent assets from failed startups are redeployed to new owners. At the patent level, we rely on the patent number of patent citations received, the originality of the patent, and the age of the patent as of the year the startup goes out of business. At the firm level, we examine the presence of venture lenders—whether the startup has used one or more of its patents as collateral to secure funds from a venture lender pre-exit, and top-tier VCs—whether the startup is financed by a top-tier venture capitalist. As in Hochberg et al. (2017), we also compute whether a startup's portfolio of patents is "firm-specific" as evidenced by a high share of self-citations to the inventions in future patents. Finally, the variable *Patent market liquidity* captures the environmental conditions in the broader patent market relevant for the firm's inventions. In the regressions and to control for technology- or cohort-specific effects, we include fixed effects for the aggregate technology class corresponding to the NBER patent categories defined by Hall et al. (2001), the startup's founding

[16] This variable is defined for each patent sold in which at least one of the inventors is matched to an employer through LinkedIn employment profiles after the startup goes out of business.

year, the startup's sector, and the year the startup went out of business. Table 6 reports summary statistics for variables included in these regressions.

Tables 7-9 present the results of the likelihood that a patent sells, the speed of sale, and the co-mobility of patents and inventors, respectively. In all tables, Column 1 includes patent-level covariates. Column 2 adds the variables *Patent Market Liquidity* and *Firm-specificity of Patent Assets*. Columns 3 and 4 introduce the two intermediary-related variables, *Has Top-tier VC variable* and *Had Patent-backed Loan* sequentially in turn. All columns include controls for patent technology class, founding year, sector, and exit year.

5.1. Patent Sale

Table 7 presents OLS estimates of the likelihood that a patent is sold after a startup goes out of business.[17] Column 1 shows that patents that are more highly cited and more original are more likely to be sold, which is not surprising. We also find that the coefficient of patent age is negative and significant, indicating that patented inventions that are older are less likely to be sold than patents with similar characteristics but issued more recently to the startup. In line with Serrano (2010), this latter evidence suggests that patent value depreciates over time as the rights draw near to their maximum lifespans.

Column 2 of Table 7 adds two variables to capture the broader liquidity of the patent market for the inventions of the startup and the extent to which their portfolios of patent inventions are redeployable to alternative uses and buyers. We find that the coefficient of the variable *Patent Market Liquidity* is positive and significant, suggesting that the likelihood that a patent sells is positively associated with the broader liquidity of the patent market for the inventions of the startup as of the exit year. To interpret, a one-percentage point increase in patent market liquidity boosts the likelihood that a patent is sold by 5.9 percentage points. In contrast, the estimated coefficient of

[17] In robustness tests, we obtain similar results using a Probit model.

Firm-specificity of Patent Assets is negative and significant: the patents of startups with firm-specific patent assets have a lower likelihood of being sold on average than the patents of startups that are more redeployable to alternative uses even controlling for other sector, technology class, and entry/exit cohort-related factors. To elaborate, Column 2 of Table 7 suggests that a one standard deviation increase in the *Firm-specificity of Patent Assets* decreases by 2.5 percentage points the likelihood that a patent is sold.

Next, we examine the past presence of top-tier VC investors and venture lenders in the likelihood of a patent selling after a startup goes out of business. To do this, Column 3 and 4 add the variables *Had Top-tier VC* and *Had a Patent-backed Loan,* respectively. We find that the likelihood that a patent is sold is positively correlated with *Had Top-tier VC*, suggesting that the presence of a top-tier VC investor, whether in early or later round, is positively associated with the likelihood that a patent is sold. In particular, backing from a top-tier investor is associated with an increase of at least 5.9 percentage points in the likelihood that a patent is sold. The coefficient of *Had Patent-backed Loan* is also positive, significant, and of comparable magnitude to that of *Has Top-Tier VC*. Indeed, having had a patent-backed loan is associated with an increase of 6.7 percentage points in the likelihood of patent selling. The presence of venture lenders or top-tier VCs could be an indicator of companies that are higher quality and/or have higher-quality patents that secure the funding. An equally plausible explanation, which we are unable to tease apart, is that venture lenders and/or top-tier VCs play a role that facilitates patent sales when startups fail.

In combination, these results are consistent with the view that thicker trading activity in the resale market for patents increases the likelihood that patents from failed startups will be redeployed to new owners. This evidence further suggests that patents that are more extensively cited by external parties are more likely to be redeployed to new owners in the worst-case-scenario that

startups fail. Finally, startups with financial backing from top-tier venture capitalists and/or venture lenders have a higher baseline likelihood of selling patents when they fail.

5.2. Speed of Patent Sale.

Another important factor when assessing markets for buying and selling patents is how quickly patents are actually sold. In Table 8, we present the results of a duration analysis (Cox proportional hazard model) of the speed at which patents are sold after the startup goes out of business. The table follows the same format as of Table 7. Column 1 shows the results of regressing the number of years from the year the startup fails until a patent is sold on the number of patent citations received, patent originality, and patent age as of exit. Column 2 adds the variables patent market liquidity and firm-specificity of patent assets. Columns 3 and 4 add the dummy variables indicating the presence of top-tier investors and whether the startup has had a patent-backed loan. We find that highly cited and more original patents sell quickly as seen by the hazard of trade in Column 4. In contrast, the estimated coefficient of patent age does not have a discernable effect on how quickly a patent sells.

Consistent with the view that a more liquid patent market should facilitate finding buyers, we find that patent market liquidity is positively associated with the speed of sale. To interpret, the estimates suggest that a one-percentage point increase in *Patent Market Liquidity* raises the hazard of trade by 11%. Table 8 further shows that presence of top-tier investors and venture lenders is positively associated with the speed at which patents sell. To elaborate, having top-tier investors or a patent-backed loan increases the hazard of trade by 26.3% and 18.2%, respectively. As in Table 7, this positive "intermediary effect" remains large and significant even after we include controls for technology classes and patent-level characteristics, sector and cohort effects, and characteristics of the startups portfolio of patents (i.e., the share of self-cites and the thickness of trading in the secondary patent market related to the portfolio of patents).

5.3. Co-movement of patents and inventors

To examine the possible factors that shape whether patent inventors relocate to work for patent buyers following the sale of patents, Table 9 presents OLS estimates of the likelihood that an inventor in a patent relocates to work for a patent buyer after a startup goes out of business.[18] The table follows the same format as Tables 7 and 8. The estimated coefficients indicate that whether a patent is highly cited overall (i.e., valuable in general) fails to have a discernible effect on whether the inventions and people travel together in patent transactions. We do, however, find that co-movement is much higher for more original inventions even after controlling for other factors.

In Column 2 of Table 9, we examine whether co-movement of patents and inventors in patent transactions is more likely when the patents released to the market are more specific to the failed firm or when the broader patent market is more liquid. The estimated coefficient of firm-specificity is positive and significant, suggesting that having access to original inventors is particularly important for buyers when the patent assets are specific to the failed startup. To illustrate, a one standard deviation increase in the firm-specificity of patent assets is associated with a 5.5 percentage point increases in the likelihood that a patent buyer hires an inventor, as compared to the unconditional mean of 12.9. The coefficient of patent market liquidity is negative and of sizable magnitude but is not statistically significant at conventional levels.

In combination, the evidence in Columns 1 and 2 of Table 9 suggest that more original patents and patents that are more "specific" to the original venture are more likely to travel with the original inventive team to a new organization when startups fail.

Columns 3 and 4 of Table 9 explore whether the presence of top-tier investors and venture lenders is salient for the co-movement of patents and inventors in patent transaction. The estimated coefficient of *Has top-tier investors* is positive, significant, and sizable in magnitude. To illustrate,

[18] In robustness tests, we obtain similar results using a Probit model.

having a top-tier investor is positively associated with 8.1 percentage point increase in the likelihood of co-mobility of patents and inventors in patent transactions. In contrast, the coefficient of *Had a patent-backed loan* is negative and significant, suggesting that the presence of venture lenders is negatively associated with co-movement. The presence of top-tier investors could facilitate inventor mobility since their presence, including additional financial support, could potentially prevent the immediate disbanding of the key inventors while the investors search for potential buyers for the patent assets. An alternative explanation, which we cannot separately identify, is that top-tier VCs could be an indicator of companies that attract higher "quality" inventors. Venture lenders, unlike equity investors, focus their effort primarily on the sale of the assets to cover their outstanding loans rather than maximizing the upside value of the assets, which could involve matching both patents and inventors to potential buyers. Venture lenders could also choose to lend to startups with patents that are more "saleable" to outsiders in the event of failure, which could reduce the baseline likelihood that the patents and people travel together to a new organization in the worst-case-scenario that the startup fails.

6. Discussion and Conclusion

The process of innovation naturally gives rise to failed attempts and abandoned projects. Prior studies show that disbanded ventures are important sources of human capital and learning spillovers for others (Knott and Posen 2005; Hoetker and Agarwal 2007; Kacperczyk and Marx 2017). This study documents that failed startups also "release" legal rights to patented inventions that are often redeployed to new owners. Based on 1,766 U.S. patents awarded to 285 VC-backed companies that go out of business, we find that most patents originating from these companies are sold, are sold quickly, and are kept alive by the new owners long after the original company is shuttered. The assets tend to retain value beyond the original project and human capital of the team, and to be

purchased by another operating company in the same sector. These findings suggest that patent rights are far more redeployable as standalone assets than is widely assumed in the literature.

At the environmental level, we find that the likelihood and speed of sale is higher when the resale market for patent assets is more liquid. While prior studies in economics document this effect for tangible assets (e.g., Gavazza), our findings show that trading thickness in the secondary patent market is also salient for patent sales when startups fail. These findings add to recent evidence that the market for buying and selling patents is surprisingly active (e.g., Serrano 2010; Hagiu and Yoffie 2013; Akcigit et al. 2016) and is consequential for the financing of entrepreneurial firms (Hochberg et al. 2017).

Our evidence further reveals that the likelihood and speed of sale depend on patent-level characteristics and the presence of top-tier VCs and venture lenders. Although this latter effect could be driven by the selection by top-tier VCs and venture lenders of higher quality companies with more "sellable" patents, our qualitative evidence suggests that these intermediaries play a far more active role. Despite a large body of evidence in strategic management and economics on the services that financial intermediaries provide young companies on the road to success (e.g., Hsu 2004, 2006; Hellmann and Puri 2002), much less is known about the roles that these intermediaries play in less favorable conditions and the corresponding implications for entrepreneurs and their intangible assets. We hope that our study stimulates future research on these important topics.

Finally, we show that even though most patents from failed startups in our sample become unbundled from the human capital of the original inventive team post-exit, some patents and people move jointly to a new organization. Within our sample, the likelihood of co-mobility is higher for more original patents and inventions that are primarily cited by other inventions of the failed venture (i.e., patents with a high share of self-citations). Consistent with Hoetker and Agarwal (2007), this evidence could suggest that buyers find it particularly difficult to capture value from

original inventions specific to the failed company absent access to the private knowledge of the team. Our findings further suggest that the likelihood of co-movement by the people and patents is higher for failed companies with top-tier VCs but lower for those that use their patent rights to secure loans earlier in their life cycles. Future research could investigate the trade-offs individuals and entrepreneurs face when assigning patent control rights to lenders and how such trade-offs shape both the mode of exit and the potential separation of patent rights from the inventors in the event of failure.

If patents are redeployable to others when startups fail, as our evidence suggests, it could simultaneously stimulate investments in experimental projects earlier in the entrepreneurial life cycle and (in the event that the company fails) unleash assets that others can use for follow-on development or strategic gain. The market for patents is friction-filled and non-transparent, thus providing potential buyers an opportune environment for strategic gain. Future research on the choices and trade-offs buyers face when transacting in the secondary patent market is needed both overall and relative to other transfer channels. Future studies could also investigate the implications of patent-market transactions on the scale and scope of internal projects. If established firms are able to self-insure against legal risk by purchasing patents on their own or in combination with others, for example, the need to allocate internal R&D activity toward "defensive" patenting could be reduced. Similarly, firms with complementary bundles of IP or other downstream assets may be able to reinforce their sources of advantage through purchasing exclusionary rights through the patent resale market. We hope that the empirical evidence in this study ignites new research on this underexplored exchange arena.

References

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

Akcigit U, Celik MA, Greenwood J. 2016. Buy, keep, or sell: Economic growth and the market for ideas. *Econometrica* **84**(3): 943-984.

Anand J, Singh H. 1997. Asset redeployment, acquisitions, and corporate strategy in declining industries. *Strategic Management Journal, Summer Special Issue* 18(S1): 99-118.

Arora A. 1995. Licensing tacit knowledge: intellectual property rights and the market for know-how. *Economics of Innovation and New Technology* 4: 41-59.

Arora A, Fosfuri A, Gambardella A. 2004. *Markets for technology: The economics of innovation and technology licensing.* Cambridge MA: MIT Press.

Arora A, Nandkumar A. 2012. Insecure advantage? Markets for technology and the value of resources for entrepreneurial ventures. *Strategic Management Journal* 33: 231-251.

Barney JB. 1986. Strategic factor markets: expectations, luck, and business strategy. *Management Science* 32(10): 1231-1241.

Barney JB, Arikan AM. 2001. The resource-based view: origins and implications. In the *Handbook of Strategic Management*, Hitt MA, Freeman RE, Harrison JS (eds). Blackwell: Oxford, UK: 124-288.

Benmelech E, Bergman NK. 2008. Liquidation values and the credibility of financial contract renegotiation: Evidence from U.S. airlines. *Quarterly J. Econom.* **123**(4): 1635-1677.

Benmelech E, Bergman NK. 2009. Collateral pricing. *J. Financial Econom.* **91**(3): 339-360.

Berman B. 2014. The intangible investor. *Intellectual Asset Magazine*. **65** (May/June): 33.

Benassi M, Di Minin A. 2009. Playing in between: patent brokers in markets for technology. *R&D Management* 29: 68-86

Brassell M, King K. 2013. *Banking on IP? The role of intellectual property and intangible assets in facilitating business finance: Final Report*. Newport, UK: UK Intellectual Property Office.

Capron L, Dussauge P, Mitchell W. 1998. Resource redeployment following horizontal acquisitions in Europe and North America, 1988-1992. *Strategic Management Journal* 19(7): 631-661.

Chatterji AK, Fabrizio K. 2014. Using users: When does external knowledge enhance corporate product innovation? *Strategic Management Journal* 35(10): 1427-1445.

Cohen WM, Nelson RR, Walsh JP. 2000. Protecting their intellectual assets: Appropriability conditions and why U.S. manufacturing firms patent (or not). NBER working paper 7552.

Conti A, Thursby J, Thursby M. 2013. Patents as signals for startup financing. *J. Industrial Economics* 22(2): 592-622.

Dawson AB. 2016. Better than bankruptcy. *Rutgers University Law Review* 69: 137-194.

de Rassenfosse G, Fischer T. 2016. Venture debt financing: Determinants of the lending decision. *Strat. Entrepreneurship J*. **10**(3): 235-236.

Fischer T, Henkel J. 2010. Patent trolls on markets for technology: An empirical analysis of NPEs' patent acquisitions. *Research Policy* 41(9): 1519: 1533

Fortune A, Mitchell W. 2012. Unpacking firm exit at the firm and industry levels: The adaptation and selection of firm capabilities. *Strategic Management Journal* 33: 794-819.

Fosfuri A, Motta M, Ronda T. 2001. Foreign direct investment and spillovers through workers' mobility. *Journal of International Economics* 53(1): 205-222.

Frake J. 2017. Signals or shackles: how patents affect inventor mobility and entrepreneurship. University of Maryland working paper.

Galasso A, Schankerman M, Serrano CJ. 2013. Trading and enforcing patent rights. *Rand J. Economics* **44**(2): 275-312.

Gambon J. 2009. Failed takeoff leaves entrepreneurs with orphaned IP. *Boston Business Journal*, October 6th, available at: https://www.bizjournals.com/boston/

Gans JS, Hsu DH, Stern S. 2002. When does start-up innovation spur the gale of creative destruction? *Rand Journal of Economics* 33: 571-586.

Gans JS, Hsu DH, Stern S. 2008. The impact of uncertain intellectual property rights on the market for ideas:

evidence from patent grant delays. *Management Science* 54(5): 982-997.
Gans JS, Stern S. 2003. The product market and the market for 'ideas': commercialization strategies for technology entrepreneurs. *Research Policy* 32: 333-350.
Gans JS, Stern S. 2010. Is there a market for ideas? *Industrial and Corporate Change* 19(3): 805-837.
Gavazza A. 2011. The role of trading frictions in real asset markets. *Amer. Econom. Rev.* **101**(4):1106-1143.
Ge C, Huang KW, Png IPL. 2016. Engineer/scientist careers: Patents, online profiles and misclassification bias. *Strategic Management Journal* 37(1): 232-253.
Gompers PA, Kovner A, Lerner J, Scharfstein D. 2010. Performance persistence in entrepreneurship. *J. Financial Economics* 96: 18-32.
Graham SJH, Marco AC, Myers AF. 2015. Patent transactions in the marketplace: Lessons from the USPTO patent assignment database. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2489153
Graham S, Merges R, Samuelson P, Sichelman T. 2009. High technology entrepreneurs and the patent system: Results of the 2008 Berkeley Patent Survey. *Berkeley Technology Law Journal* 24: 1255-1327.
Griffith E. 2014. Why startups fail, according to their founders. *Forbes* 05 Sept, available at: http://fortune.com/2014/09/25/why-startups-fail-according-to-their-founders/
Grindley PC, Teece DJ. 1997. Managing intellectual capital: licensing and cross-licensing in semiconductors and electronics. *California Management Review* 39: 1-34.
Haeussler C, Harhoff D, Mueller E. 2014. How patenting informs VC investors—the case of biotechnology. *Research Policy* 43(8): 1649-1659.
Hagiu A, Yoffie DB. 2013. The new patent intermediaries. *J. Econom. Persp.* **27**(1): 45-66.
Hall BH, Jaffe A, Trajtenberg M. 2001. The NBER patent citation data file: Lessons, insights and methodological tools. NBER working paper #8498.
Hall BH, Lerner J. 2010. The financing of R&D and innovation. In BH Hall and N Rosenberg (eds.), *Elsevier Handbook of the Economics of Innovation.*
Hall BH, Ziedonis RH. 2001. The patent paradox revisited: An empirical study of patenting in the U.S. semiconductor industry, 1979-95. *Rand J. Econom.* **32**(1): 101-128.
Hall R. 1992. The strategic analysis of intangible resources. *Strategic Management Journal* 13: 135-144.
Hall RE, Woodward SE. 2010. The burden of the nondiversifiable risk of entrepreneurship. *American Economic Review* **100**(3): 1163-1194.
Harrington S, Keeley P, Richardson K, Oliver E. 2017. How and why LinkedIn learned to love patents. IPWatchdog (July 13), available at: http://www.ipwatchdog.com/2017/07/13/linkedins-patent-strategy/id=82863/
Hayek F. 1945. The use of knowledge in society. *American Economic Review* 35 (September): 519-530.
Helfat CE, Eisenhardt KM. 2004. Inter-temporal economies of scope, organizational modularity, and the dynamics of diversification. *Strategic Management Journal* 25(13): 1217-1232.
Hellmann T, Puri M. 2002. Venture capital and the professionalization of startup firms: Empirical evidence. Journal of Finance 57: 169-197.
Hochberg Y, Serrano CJ, Ziedonis RH. 2017. Patent collateral, investor commitment, and the market for venture lending. *Journal of Financial Economics*, forthcoming.
Hoetker G, Agarwal R. 2007. Death hurts, but it isn't fatal: The postexit diffusion of knowledge created by innovative companies. *Academy of Management Journal* 50(2): 446-467.
Hsu D. 2004. What do entrepreneurs pay for venture capital affiliation? *Journal of Finance* 59: 1805-1944.
Hsu D. 2006. Venture capitalists and cooperative startup commercialization strategy. *Management Science* 52: 204-219.
Hsu D, Ziedonis RH. 2013. Resources as dual sources of advantage: Implications for valuating entrepreneurial firm patents. *Strategic Management Journal* 34: 761-781.
Kacperczyk A, Marx M. 2017. Revisiting the small-firm effect on entrepreneurship: Evidence from firm dissolutions. *Organization Science*, forthcoming.
Kerr WR, Nanda R, Rhodes-Kropf M. 2014. Entrepreneurship as experimentation. *J. Economic Perspectives* **28**(3): 25-48.
Kortum S, Lerner J. 2000. Assessing the contribution of venture capital to innovation. *Rand J. Economics* **31**(4): 674-692.

Knott AM, Posen HR. 2005. Is failure good? *Strategic Management Journal* 26: 617-641.
Kuhn J. 2016. Property rights and frictions in the sale of patents. SSRN working paper available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2865293
Lamoreaux NR, Sokoloff K. 2001. Market trade in patents and the rise of a class of specialized inventors in the nineteenth-century United States. *American Economic Review* 91(2): 39-44.
Lamoreaux NR, Sokoloff K. 2003. Intermediaries in the U.S. market for technologies, 1870-1920. In *Finance, Intermediaries, and Economic Development.* eds. Engerman SL, Engerman P, Hoffman T, Rosenthal J-L, Sokoloff KL. New York: Cambridge University Press, 209-246.
Lamoreaux NR, Sokoloff KL, Sutthiphisal D. 2013. Patent alchemy: The market for technology in US history. *Business History Review* 87(1): 3-38.
Lanjouw JO, Schankerman M. 2004. Protecting intellectual property rights: Are small firms handicapped? *Journal of Law and Economics* 47: 45-74.
Lee PM, Pollock TG, Jin K. 2011. The contingent value of venture capitalist reputation. *Strategic Organization* 9: 33-69.
Lemley MA, Shapiro C. 2005. Probabilistic patents. *Journal of Economic Perspectives* 19(2): 75-98.
Lieberman MB, Lee GK, Folta TB. 2017. Entry, exit, and the potential for resource redeployment. *Strategic Management Journal* 38: 526-544.
Loizos C. 2011. Silicon Valley's undertaker: 'We're anticipating a major fallout', Private Equity Hub Silicon Valley (peHUB.com), August 10th. available at https://www.pehub.com/2011/08
Ma S, Tong T, Wang W. 2017. Selling innovation in bankruptcy. SSRN working paper available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2903003
Markoff, J. 2005. Secretive buyer of some e-commerce patents turns out to be Novell. *New York Times*, 02 May: B1.
Marx M, Strumsky D, Fleming L. 2009. Mobility, skills, and the Michigan non-compete experiment. *Management Science* 55, 875-889.
Murray F, O'Mahony S. 2007. Exploring the foundations of cumulative innovation: Implications for organization science. *Organization Science* 18(6): 1006-1021.
Nelson RR, Winter S. 1982. *An evolutionary theory of economic change.* Harvard University Press: Cambridge, MA.
Pakes A. 1986. Patents as options: Some estimates of the value of holding patent stocks. *Econometrica* 54: 755-784.
Palomeras N, Melero E. 2010. Markets for inventors: learning-by-hiring as a driver of mobility. *Management Science* 56(5): 881-895.
Penrose E. 1959. *The theory of the growth of the firm*. Oxford University Press: Oxford, UK.
Peteraf M. 1993. The cornerstones of competitive advantage: A resource based view. *Strategic Management Journa*l 14(3): 179-191.
Priem RL, Butler JE. 2001. Is the resource-based 'view' a useful perspective for strategic management research? *Academy of Management Review* 26(1): 22-40.
Ramey VA, Shapiro MD. 2001. Displaced capital: A study of aerospace plant closings. *Journal of Political Economy* 109(5): 968-992.
Reitzig M, Henkel J, Heath C. 2007. On sharks, trolls, and their patent prey: Unrealistic damage awards and firms' strategies of "being infringed". *Research Policy* 36: 134-154.
Rivette KG, Kline D. 2000. Discovering new value in intellectual property. *Harvard Business Review* 78: 54-66.
Rosenberg N. 1994. Economic experiments. In *Exploring the Black Box: Technology, Economics, and History.* Cambridge University Press.
Rumelt RP. 1984. Towards a strategic theory of the firm. In *Competitive Strategic Management*. Lamb B (ed). Prentice Hall: Englewood Cliffs, NH; 556-570.
Rumlet RP, Schendel D, Teece DJ. 1991. Strategic management and economics. *Strategic Management Journal* 12: 5-29.
Schankerman M, Pakes A. 1986. Estimates of the value of patent rights in European countries during the post-1950 period. *Economic Journal* 29: 1052-1076.

Serrano C. J. 2006. The Market for Intellectual Property: Evidence from the Transfer of Patents. PhD Thesis, University of Minnesota.
Serrano C. J. 2010. The dynamics of the transfer and renewal of patents. *RAND Journal of Economics* **41**(4): 686-708.
Shapiro C. 2001. Navigating the patent thickets: cross-licenses, patent pools, and standard-setting. In A. Jaffe, J. Lerner and S. Stern, eds., *Innovation Policy and the Economy*, Vol 1. Boston: MIT Press.
Somaya D. 2003. Strategic determinants of decisions not to settle patent litigation. *Strategic Management Journal* 24(1): 17-38.
Somaya D. 2012. Patent strategy and management: An integrative review and research agenda. *Journal of Management* 38(4): 1084-1114.
Teece DJ. 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy* 15: 171-180.
Teece DJ. 1998. Capturing value from knowledge assets: The new economy, markets for know-how, and intangible assets. *California Management Review* **40**(3): 55-79.
U.S. Federal Trade Commission (USFTC). 2011. The evolving IP marketplace: aligning patent notice and remedies with competition. Washington D.C. USFTC.
U.S. Federal Trade Commission (USFTC). 2016. Patent assertion entity activity: An FTC study. Washington D.C. USFTC.
U.S. White House. 2013. *Patent assertion and U.S. innovation.* Executive Office of the President. Washington D.C.: U.S. White House.
Wasserman N. 2012. *The Founder's Dilemmas: Anticipating and Avoiding the Pitfalls that can Sink a Startup.* Princeton NJ: Princeton University Press.
Wernerfelt B. 1984. A resource-based view of the firm. *Strategic Management Journal* 5:171-180.
Williamson OE. 1975. *Markets and Hierarchies: Analysis and Antitrust implications.* New York: Free Press.
Williamson OE. 1985. *The economic institutions of capitalism*. New York: Free Press.
Williamson O.E. 1988. Corporate finance and corporate governance. *Journal of Finance* **43**(3): 567-591.
Winter S. 1987. Knowledge and competence as strategic assets. In *The Competitive Challenge: Strategies for Industrial Innovation and Renewal.* Teece D (ed.) Balinger: Cambridge MA.
Ziedonis RH. 2004. Don't fence me in: Fragmented markets for technology and the patent acquisition strategies of firms. *Management Science* 50: 804-820.

TABLE 1: Summary statistics of startups that fail and are disbanded by 2008

	All Failed Startups	Failed startups that sell at least one patent	Failed startups that do not sell patents
Panel A. Startup level			
Equity Funds Raised Pre-Exit (million $)	22.40	25.51	16.08
Has Top-tier VC	0.66	0.71	0.55
Patent-backed loans	0.39	0.43	0.29
Patent Portfolio Size	6.20	7.36	3.84
Patent Portfolio Size, citation weighted	43.44	55.43	19.09
Founding Year	1995.06	1994.93	1995.32
Number of Years Active at Exit Year	7.12	7.24	6.89
Number of Startups	285	191	94
Panel B. Patent level			
Patent Citations Received	5.96	6.28	5.28
Patent Originality	0.57	0.58	0.54
Patent Age at Exit Year	4.99	4.85	5.27
Firm-specificity of patent assets	0.13	0.12	0.15
Patents Renewed up to their Maximum Legal Length or end of our sample period (%)	0.66	0.81	0.33
Number of patents	1766	1203	563

NOTE: Appendix I reports variable definitions and data sources.

TABLE 2: Patent Sales After Startups Fail

	All	Medical Devices	Semiconductor Devices	Software
Panel A. Patent Sales: Patent level				
Share of patents sold (%)	0.68	0.61	0.87	0.74
Share of patents sold that are renewed up to their maximum legal length or the end of our sample period (%)	0.81	0.74	0.90	0.90
Number of patents	1766	1079	281	406
Panel B. Patent sales: Startup level				
Share of startups that sell at least one patent (%)	0.67	0.66	0.80	0.64
Proportion of patents sold that are transacted for first time during first year that a startup sells a patent (%)	0.95	0.93	0.95	0.99
Number of startups	285	116	41	128

NOTE: Appendix I reports variable and data sources.

TABLE 3: Patent Buyers by Type and Industry of Patents Sold by Failed Startups

	All	Medical Devices	Semiconductor Devices	Software
Panel A. Type of Buyers				
Operating companies	0.89	0.95	0.82	0.80
Individuals (excluding NPEs)	0.02	0.02	0.00	0.03
NPEs	0.10	0.03	0.18	0.17
Panel B. Buyers' Industries				
Same Sector as Startup	0.80	0.89	0.75	0.64
Patent Owner and Lessors (NPEs)	0.10	0.03	0.18	0.17
Remaining Sectors	0.10	0.08	0.07	0.19

NOTE: Appendix I reports variable definitions and data sources. Patents sold to individuals that are patent inventors in the focal patent are classified as having the sector as the startup.

TABLE 4: Patent Sales to Patent Inventors

	All	Medical Devices	Semiconductor Devices	Software
Panel A. Inventor and Patent Level				
Share of inventors that eventually buy a patent sold	0.010	0.016	0.005	0.005
Share of patents sold to the patent's inventors	0.026	0.039	0.012	0.007
Panel B. Startup level				
Share of startups that sold at least one patent to a patent inventor	0.058	0.105	0.030	0.024

NOTE: Appendix I reports variable definitions and data sources.

TABLE 5: Co-mobility of Patents and Inventors After a Startup Goes out of Business

	All	Medical Devices	Semiconductor Devices	Software
Panel A. Patent Buyers Hiring Patent Inventors (LinkedIn Data)				
Patents sold in which at at least one inventor is eventually employed by the patent buyer in the transaction (%)	0.129	0.118	0.089	0.178
Share of Inventors in All Patents Sold that are eventually employed by patent buyers (%)	0.086	0.059	0.107	0.104
Proportion of Startups in which at least one inventor is eventually employed by the patent buyer	0.204	0.185	0.241	0.205
Panel B. Patent Buyers Hiring Patent Inventors (Patenting Data)				
Proportion of patents sold in which at least one inventor is eventually employed by the patent buyer in the transaction	0.204	0.203	0.236	0.181
Share of Inventors in All Patents Sold that are Eventually Employed by patent buyer	0.208	0.194	0.307	0.170
Proportion of Startups in which at least one inventor is eventually employed by a patent buyer	0.230	0.203	0.333	0.211

NOTE: Measures in Panel are conditional on having at least one patent inventor with LinkedIn employment profile.

TABLE 6: Summary Statistics and Correlation Matrices

	Mean	S.D.	Min	Max									
Panel A. Variables in Regression Analysis of Patent Sale and Speed of Sale (1719 observations)													
Patent Citations Received	6.080	8.124	0	98	1								
Patent Originality	0.574	0.277	0	1	0.062	1							
Patent Age at Startup Exit	4.993	2.282	0	19	0.185	0.063	1						
Patent Market Liquidity	0.053	0.012	0	0.077	0.002	0.063	-0.028	1					
Firm-specificity of Patent Assets	0.131	0.171	0	1	-0.064	0.091	0.219	0.215	1				
Has Top-Tier VC	0.742	0.438	0	1	0.113	0.015	0.037	0.075	0.113	1			
Had a Patent-backed Loan	0.506	0.500	0	1	0.109	0.006	0.078	0.001	0.104	0.218	1		
Exit Year	2003.2	3.361	1991	2008	0.037	0.168	0.397	0.252	0.339	0.045	0.058	1	
Founding Year	1995.1	3.175	1987	1999	0.063	0.125	-0.060	0.176	0.137	0.045	-0.100	0.639	1
Panel B. Variables in Regression Analysis of Co-mobility of Patents and Inventors (967 observations)													
Patent Citations Received	6.455	8.660	0	98	1								
Patent Originality	0.593	0.277	0	1	0.038	1							
Patent Age at Startup Exit	4.802	2.144	0	13	0.162	0.144	1						
Patent Market Liquidity	0.053	0.012	0	0.077	-0.043	0.073	0.019	1					
Firm-specificity of Patent Assets	0.125	0.159	0	1	-0.071	0.105	0.198	0.287	1				
Has Top-Tier VC	0.779	0.415	0	1	0.091	-0.014	0.115	-0.003	0.257	1			
Had a Patent-backed Loan	0.517	0.500	0	1	0.131	-0.026	0.115	-0.065	0.082	0.253	1		
Exit Year	2003.7	3.128	1991	2008	-0.024	0.242	0.492	0.195	0.287	0.072	0.007	1	
Founding Year	1995.7	2.690	1987	1999	0.036	0.145	0.005	0.046	0.070	0.002	-0.146	0.558	1

NOTE: Appendix I reports variable definitions and data sources.

TABLE 7: Decision to Sell a Patent

	1	2	3	4
Estimation Method	**OLS**	**OLS**	**OLS**	**OLS**
Dependent Variable	**Patent Sale**	**Patent Sale**	**Patent Sale**	**Patent Sale**
Patent Citations Received	0.004***	0.003**	0.003**	0.003*
	(0.001)	(0.001)	(0.001)	(0.001)
Patent Originality	0.091**	0.089**	0.085**	0.087**
	(0.043)	(0.043)	(0.043)	(0.043)
Patent Age at Startup Exit	-0.023***	-0.017***	-0.017***	-0.017***
	(0.006)	(0.006)	(0.006)	(0.006)
Patent Market Liquidity		5.922***	5.681***	5.326***
		(1.900)	(1.897)	(1.898)
Firm-specificity of Patent Assets		-0.115	-0.134*	-0.136*
		(0.076)	(0.076)	(0.076)
Has Top-Tier VC			0.061**	0.059**
			(0.028)	(0.027)
Had Patent-backed Loan				0.067***
				(0.025)
Patent Category Fixed Effects	YES	YES	YES	YES
Sector Fixed Effects	YES	YES	YES	YES
Exit Year Fixed Effects	YES	YES	YES	YES
Founding Year Fixed Effects	YES	YES	YES	YES
Sample	Utility Patents of Failed Startups by 2008	Utility Patents of Failed Startups by 2008	Utility Patents of Failed Startups by 2008	Utility Patents of Failed Startups by 2008
No. of Patents	1,719	1,719	1,719	1,719
Observations	1,719	1,719	1,719	1,719

NOTE: Appendix I reports variable definitions and data sources. The number of patents drops from 1,766 to 1.719 because the control variable Patent Category is only defined for utility patents; the remaining 47 observations correspond to design patents. Similar results were obtained if we expand by one category the number of categories in the variable Patent Category to include design patents.

TABLE 8: Speed of Patent Sale

	1	2	3	4
Estimation Method	**Cox Proportional Hazard Model**	**Cox Proportional Hazard Model**	**Cox Proportional Hazard Model**	**Cox Proportional Hazard Model**
	Hazard Ratio	**Hazard Ratio**	**Hazard Ratio**	**Hazard Ratio**
Patent Citations Received	1.010***	1.010**	1.008**	1.007*
	(0.004)	(0.004)	(0.004)	(0.004)
Patent Originality	1.271**	1.245*	1.233*	1.243*
	(0.152)	(0.150)	(0.149)	(0.150)
Patent Age at Startup Exit	0.960**	0.972*	0.970**	0.972
	(0.016)	(0.017)	(0.017)	(0.017)
Patent Market Liquidity		1.123**	1.113**	1.105*
		(0.059)	(0.059)	(0.058)
Firm-specificity of Patent Assets		0.855	0.801	0.801
		(0.188)	(0.178)	(0.179)
Has Top-Tier VC			1.317***	1.263***
			(0.104)	(0.102)
Had a Patent-backed Loan				1.182**
				(0.083)
Patent Category Fixed Effects	YES	YES	YES	YES
Sector Fixed Effects	YES	YES	YES	YES
Exit Year Fixed Effects	YES	YES	YES	YES
Founding Year Fixed Effects	YES	YES	YES	YES
Sample	Utility Patents Sold of Failed Startups	Utility Patents Sold of Failed Startups	Utility Patents Sold of Failed Startups	Utility Patents Sold of Failed Startups
No. of Patents	1,719	1,719	1,719	1,719
Observations	1,719	1,719	1,719	1,719

NOTE: Appendix I reports variable definitions and data sources. The number of patents drops from 1,766 to 1.719 because the control variable Patent Category is only defined for utility patents; the remaining 47 observations correspond to design patents. Similar results were obtained if we expand by one category the number of categories in the variable Patent Category to include design patents.

TABLE 9: Patent and Inventor Co-mobility

	1	2	3	4
Estimation Method	**OLS**	**OLS**	**OLS**	**OLS**
Dependent Variable	**Patent-Inventor Co-mobility**	**Patent-Inventor Co-mobility**	**Patent-Inventor Co-mobility**	**Patent-Inventor Co-mobility**
Patent Citations Received	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Patent Originality	0.117***	0.098**	0.097**	0.096**
	(0.040)	(0.040)	(0.040)	(0.040)
Patent Age at Startup Exit	0.006	0.004	0.004	0.003
	(0.006)	(0.006)	(0.006)	(0.006)
Patent Market Liquidity		-3.137	-2.974	-3.120
		(1.944)	(1.939)	(1.938)
Firm-specificity of Patent Assets		0.362***	0.326***	0.333***
		(0.083)	(0.084)	(0.084)
Has Top-Tier VC			0.071***	0.081***
			(0.027)	(0.028)
Had a Patent-backed Loan				-0.043*
				(0.023)
Patent Category Fixed Effects	YES	YES	YES	YES
Sector Fixed Effects	YES	YES	YES	YES
Exit Year Fixed Effects	YES	YES	YES	YES
Founding Year Fixed Effects	YES	YES	YES	YES
Sample	Utility Patents Sold of Failed Startups with at least one of the patent inventors with LinkedIn employment profile	Utility Patents Sold of Failed Startups with at least one of the patent inventors with LinkedIn employment profile	Utility Patents Sold of Failed Startups with at least one of the patent inventors with LinkedIn employment profile	Utility Patents Sold of Failed Startups with at least one of the patent inventors with LinkedIn employment profile
No. of Patents	967	967	967	967
Observations	967	967	967	967

NOTE: Appendix I reports variable definitions and data sources. The number of patents sold with at least one of the patent inventors with LinkedIn employment profile drops from 987 to 967 because the control variable Patent Category is only defined for utility patents; the remaining 20 observations correspond to design patents. Similar results were obtained if we expand by one category the categories in the variable Patent Category to include design patents.

Figure 1A: Histogram of the Number of Patents Sold for the First Time

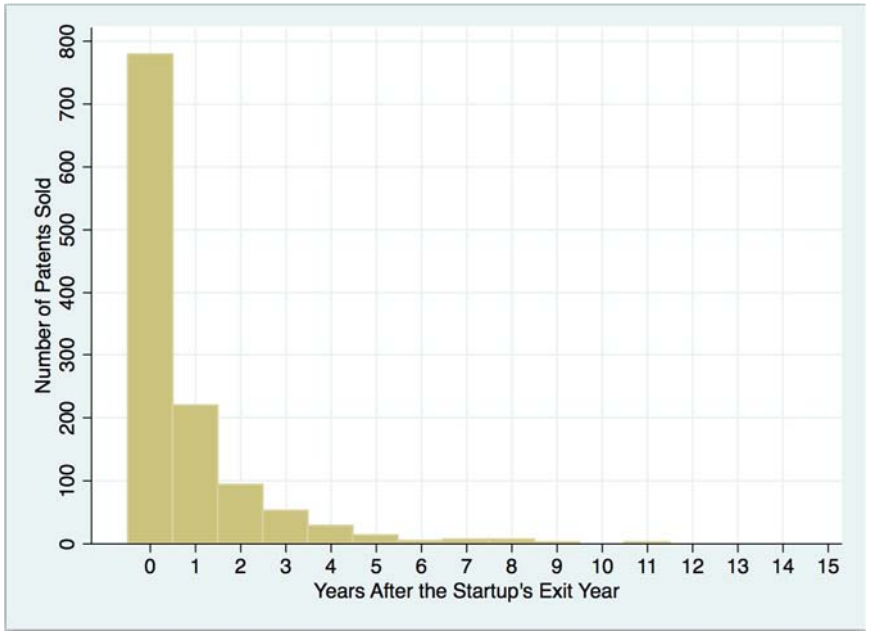
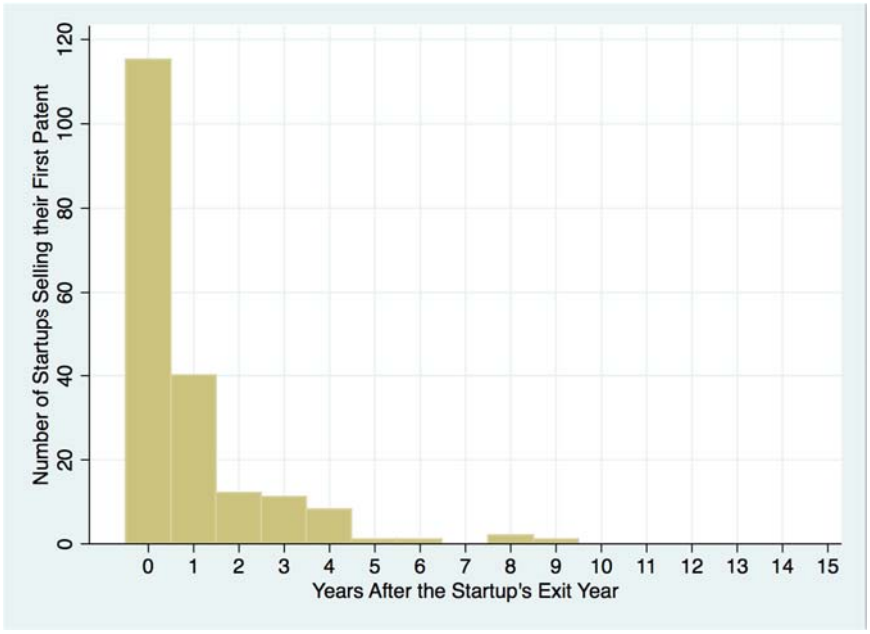


Figure 1B: Histogram of the Number of Startups Selling Their First Patent



APPENDIX

Table A-1. Main Variables and Data Sources

	Definition	Data Source
Main Variables		
PATENT SALE$_j$	Indicator set to 1 if a patent is involved at least once in a change of ownership after the startup goes out of business	USPTO Assignments Data
SPEED OF SALE$_j$	Conditional on a patent being sold, number of years between when the startup goes out of business and when the patent is first sold as indicated by the "execute date" listed in the assignment record	USPTO Assignments Data
CO-MOBILITY$_j$	Indicator set to 1 if the patent buyer eventually employs one of more of the inventors in the focal patent after the startup goes out of business as measured by LinkedIn employment profiles.	USPTO Assignment Data; LinkedIn
INVENTOR-PURCHASED$_j$	Indicator set to 1 if the patent buyer is an inventor (or a company with ownership ties to the inventors) of one or more patents issued to the failed venture	USPTO
SAME SECTOR$_j$	Indicator set to 1 if the patent buyer is an operating company that primarily competes in the same sector as the startup.	MANTA.com Google Searches
RENEWED PATENT$_j$	Indicator set to 1 if renewal fees are paid to maintain the patent right at required intervals through 2014 or the expiration of the patent	USPTO Maintenance Fees Data
Other Variables		
Patent Age at Startup Exit$_j$	Number of years between when the patent is applied for and when the startup goes out of business	USPTO
Patent Citations Received$_j$	Number of citations each patent receives 3-years post-grant	USPTO
Patent Originality$_j$	Corresponds to the Originality measure in Hall et al. (2001). By counting the number of citations a patent makes within each of the 3-digit patent classes, it is a proxy for the degree to which the patent draws upon a wide range of technology areas. In the few instances where no patents are cited, the variable is set to zero.	USPTO
Has Top-Tier VC$_i$	1 if the startup is backed by a VC in the top 25% of the annual LJP reputation score distribution.	LPJ2011
Had a Patent Backed Loan$_i$	1 if one or more of the startup's patents are used to secure a loan prior to the exit year (Hochberg et al. 2017)	USPTO Assignment Data
Patent Market Liquidity$_i$	Based on the Patent Market Liquidity measure in Hochberg et al. (2017). Startup *i*'s combined probability (averaged across patents in its portfolio as of year t) that patents issued in the prior 8 years in its sector are traded by the exit year	USPTO Reports[a]; Graham and Vishnubhakat (2013)[b]; RPX Corp
Firm-Specificity$_i$	Proxy for degree to which the value of startup *i*'s patents are "firm-specific"; measured as the share of patents citing startup *i*'s patents within three years that are made by the focal startup (i.e., are "self-cites"). In the few instances where no patents within a startup's portfolio are cited within three years, we set the variable to zero.	USPTO
Patent Portfolio Size (citation weighted)$_i$	Cumulative number of successful U.S. patent applications of startup *i* by the year the startup goes out of business, weighted by the number of citations each patent receives 3-years post-grant	Delphion; USPTO
Equity Funds Raised Pre-Exit$_i$	Millions of equity US$ raised in startup *i*'s by the year that the startup goes out of business	VentureSource
Founding Year$_i$	Year startup *i* was founded (1987-1999)	VentureSource
Sector$_i$	Startup *i*'s primary sector: medical devices, semiconductor devices, or software	VentureSource
Patent Category$_j$	Corresponds to NBER patent categories in Hall et al. (2001).	NBER; USPTO
Exit Year$_i$	Indicates the calendar year a startup goes out of business (1987-2008)	VentureSource; SandHillEconometrics

[a] The list of class-subclass combinations relevant for medical device inventions is available from the USPTO website at: http://www.uspto.gov/web/offices/ac/ido/oeip/taf/meddev.htm. A parallel list for semiconductor devices is at: http://www.uspto.gov/web/offices/ac/ido/oeip/taf/semicon.htm.

[b] The class-subclass list relevant for computer software invention, equivalently compiled by USPTO examiners, is reported in Graham and Vishnubhakat (2013) on page 75, footnote 7.