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A Date With Destiny: The Impact of Early Environment on Persistent Innovation Strategy[†]

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December 10, 2016

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Keywords: Organizational structure; innovation; firm evolution; mergers and acquisitions, firm heterogeneity.

INTRODUCTION

How does an organization's unique past shape its future? A key assumption in modern strategy is that firm differences are important precisely because they at once enable and constrain capabilities (Penrose, 1995). But we know little about how differences originate, evolve, and persist (Cockburn et al., 2000; Siggelkow, 2011). Within the study of innovation in particular, we know that firms often draw disproportionately on either internal and external sources for technological inputs (Cohen and Levinthal, 1990; Kogut and Zander, 1992), but why they may favor one channel versus the other is unclear (Arora et al., 2014; Pisano, 1990).

This study contributes to our understanding of the origins of firm heterogeneity by showing how the post-IPO environment influenced the divergent evolution of 1,211 technology firms, towards either a more internal or external innovation strategy. I propose a mechanism that may explain some of this divergence: Firms lack fully-developed routines and capabilities for technology sourcing at their initial public offering ("IPO"), and begin favoring whichever method is most efficient (either internal or external) given the prevailing environment. What is initially a temporary response then persists because IPOs involve intense firm-level transformation and high plasticity (Gavetti and Rivkin, 2007; Stuart and Sorenson, 2003), leading to structural changes which are less responsive to subsequent environmental stresses (Stinchcombe, 1965).

While prior work has identified the early part of a firm's history as a determinant of future heterogeneous capabilities (Boeker, 1989; Eisenhardt and Schoonhoven, 1990; Holbrook et al., 2000), we still lack a coherent theory on how, when, and why firms are thus constrained by the past. For example, there is evidence that firms cannot adapt after radically changed institutional environments (Kogut and Zander, 2000), but on the other hand, firms often change after the original founder leaves (Hannan et al., 1996). Similarly, while early work suggested that the link between founding and persistence operates through cognitive mechanisms (Boeker, 1989), more recent scholars argue that it is likely to involve multi-level interactions (Marquis and Tilcsik, 2013; Siggelkow, 2011), or through limiting the set of local optimization options (Levinthal,

1997). Just as importantly, the literature is virtually silent on which of these mechanisms are responsive to managerial intervention. Therefore, in this paper I look at just one specific temporal setting (the post-IPO window) and one possible conditioning factor (the economic environment), in order to focus the discussion and hopefully clarify and extend prior findings of this diverse literature.

The propositions that environmental conditions during developmental milestones may explain long-run firm heterogeneity is tested by exploiting a series of seven shocks between 1975 and 2008 which created unfavorable environments for the acquisition of external technology. I develop a novel dataset which details the ownership, financial, acquisition, and patenting history of all innovative firms that went public in this period, then measure the impact to firms that faced (worse) periods for M&A after IPO. Because the post-IPO period is one of rapid expansion(Bernstein, 2014), these shocks raised search and transaction costs for external technology at a time when firms would normally seek aggressive growth via acquisitions (Celikyurt and Sevilir, 2010). Conversely, because newly-public firms still need to find sources of growth, decreased acquisition opportunities should increase their effort and investment on internal development, given the relatively lower cost of internal research vs. acquisition of external technology (Stiglitz, 2000).

Importantly, innovation is characterized by lags between inputs and outputs, uncertainty, and imperfect appropriability (Arrow, 1962b; Cohen et al., 2000), and thus innovative firms are quite prone to path-dependency and inertial forces, which might make these early decisions hard to change later. Therefore I argue we should expect enduring differences in firms' future corporate strategy mix of business development/external acquisition vs. organic R&D, as a result of their early environment. In other words, the timing of IPO might partially explain why some firms end up being more "makers" or "buyers" of technology.

While this might seem a straightforward argument, its empirical study faces considerable identification problems. After all, firms not only decide to go public, they also pick the exact date of their IPO, thus self-selecting into the early economic environment they face (Ritter

and Welch, 2002). At the same time, firms may be inherently different pre-IPO, or even since founding–in other words, firms have "pre-histories," inherited from the histories of their founders (Helfat and Lieberman, 2002). For example most firms go public during IPO waves, when the financial markets are robust, yet other firms chose to go public during recessionary periods. In either case, potential self selection and endogeneity makes it difficult to identify the role played by the post-IPO environment on future firm characteristics.

I employ two strategies to mitigate these concerns. First, I develop a detailed dataset on key characteristics of the sample firms, including novel matched and hand-collected data on their pre- and post-IPO patent applications, inventors, and regulatory filings. The information contained in their SEC S-1 filings is particularly useful, as it discloses both their pre-IPO experience in acquisitions, but also their intentions to pursue acquisitions as part of their long-term strategy. After all, a key worry is that the heterogeneity we measure at maturity is the manifestation of early differences, rather then the outcome of exposure to different environments at IPO.

Second, private firms or those that IPO during recessions might nonetheless be different in unobservable ways, and may still self-select to IPO during more (less) munificent times for M&A. Therefore I employ a quasi-experimental setting which exploits unpredictability in the length of corporate event waves (Harford, 2005). I restrict the sample to firms that went public *and* which did so during the seven active IPO waves that ended suddenly. This allows me to focus on firms that went public into similar environments, but then faced different economic conditions *after* the IPO.[1] Thus, while firms self-select to go public during an active period, they do not know if they will enjoy a long period of robust economic activity as newly-minted public firms (I call this control group the "early" firm) or whether they will face unexpectedly dampened capital and M&A markets (the "late" firms).

My main results provide strong evidence of the long-run persistence of temporal shocks: Firms exposed to fewer acquisition opportunities just after an IPO (the "late" firms) engage in

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[1]As I explain in the *Empirical Methodology* section the only identifying assumption needed is that firms do not know *ex ante* if they are going public close to the end of a wave. Because wave lengths vary from nine months to 3.5 years and end unexpectedly, this is a reasonable assumption. Nonetheless, I exclude firms at the very beginning and end of waves, to mitigate the concern that some firms expect the end to be near.

up to 30% lower acquisition intensity even 25 years later. Conversely, late firms also demonstrate higher levels of internal research, as reflected by patent-level measures. I also find differences in top management teams. Late firms have more science PhDs and fewer MBAs, which is consistent with more internal research and less acquisition activity. These findings support the view that the mechanism at work may involve the adaptation of firms' whole set of activities. In other words, lack of early acquisition experience does not just decrease acquisition capabilities, but also seems to increase substitute activities. Interestingly, I find little difference in terms of financial performance between treated and control groups, suggesting that firms adapt quickly given their initial post-IPO environments.

Taken together, my findings partly bridge some of the tension between adaptation and selection theories of firm evolution (Hannan and Freeman, 1977; Levinthal, 1997), suggesting a brief period of adaptation after IPO followed by long-run inertia.

Theory and background

Adaptation and inertia in technology sourcing

Most firms are unable to efficiently generate all the technology they need (Arrow, 1962a), and therefore complement internal R&D ("make") with externally sourced technology ("buy") (Arora and Gambardella, 1994; Granstrand and Sjölander, 1990). In this sub-section, I highlight the inertial nature of these activities. Both *make* and *buy* should require tacit organizational know-how developed over time, as it is unlikely that firms can quickly become good at either activity.

With regards to *make*, it is well accepted that a firm's ability to perform internal research is closely related to complementary activities, takes time to accumulate, and that once mastered, it can provide competitive advantage (Cohen and Levinthal, 1990; Henderson and Cockburn, 1994). With regards to *buy*, however, the issue is not as obvious. While buying is sometimes characterized as a faster or more nimble way of acquiring resources (Higgins and Rodriguez, 2006; Karim and Mitchell, 2000; Puranam et al., 2006), successful buying and integration are

also notoriously tacit and hard to master processes (Haleblian and Finkelstein, 1999; Haspeslagh and Jemison, 1991).[2]

A recurring problem in studying the value-creation of acquisitions comes from the fact that some firms buy often and are good at it, while others simply pursue different channels for accessing new resources (Graebner et al., 2010; Laamanen and Keil, 2008). Thus, I point out that the ability to acquire well should itself be heterogeneous, cumulative and path-dependent. These *buy* capabilities likely reside at the organizational level, accumulate over time, and interact recursively with *make* capabilities to perform internal research (Cohen and Levinthal, 1990). For example, as noted in detailed studies of Lycos and Vanguard, these firms became good at acquiring after a period of trial-and-error (Gavetti and Rivkin, 2007; Siggelkow, 2002), which involved several organizational readjustments. Summarizing the foregoing discussion, *buy* is somewhat of a paradox in that it is an activity that when well-honed allows the firm to adapt, but is itself resistant to adaptation by virtue of its own inertial pressures. Google, for example, has sourced almost all of its new products from acquisitions, but it learned how to acquire well by doing it early, while it was still a malleable firm. As David Lawee, Google's Director of Acquisitions, put it in 2012:

> *"Integration is a really well-honed process now, I certainly wouldn't have said that four years ago. Four years ago we could get away with, You are smart, figure it out, because it was a smaller business"*[3]

This raises an interesting question, which motivates the present study: if technological *buy* capabilities must be learned, and in such regard are similar to *make* capabilities, what happens to firms that have fewer opportunities to buy during key formative stages? I propose that post-IPO firms have not yet developed either type of capability fully, and will begin growing via whichever method is most efficient given the prevailing environment. But since *make* and *buy* are at least partial substitutes (Arora et al., 2014), increasing reliance on one channel should

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[2]These challenges in integrating acquisitions buttress the widely-held view that acquisitions either do not create value (Hitt et al., 1996), or only do so given very specific contingencies (Ahuja and Katila, 2001).

[3]http://www.xconomy.com/san-francisco/2012/03/05/googles-rules-of-acquisition-how-to-be-an-android-not-an-aardvark/

result in decreasing reliance on the other. In other words, once a firm begins on a path to acquire often, it will not only get good at external sourcing, but it may also under-develop internal research capabilities. Thus, their initial vertical integration choices as public firms (with new resources and pressures) would be strongly conditioned by the environment, based on the prevailing market and technological considerations (Gans et al., 2002; Pisano, 1990).

These early choices should result in the persistent favoring of one or another set of capabilities through the path-dependency of technology and accumulation of capabilities, routines and structures (Nelson and Winter, 1982; Siggelkow, 2011). In turn, such divergence should amplify to make future choices less conditioned by the environment and more conditioned by accumulated experience and abilities. In other words, their early environment might arbitrarily determine a firm's future reliance on a *make* or *buy* mode of growth, and lead to heterogeneous strategies at the population level.

Much theory and evidence support the view that inertial pressures can perpetuate patterns that develop during critical periods of a firm's history. As firms become enmeshed in the complex interdependencies of both internal and external activities (Boeker, 1989; Kimberly, 1975), the idiosyncratic webs of specific investments *themselves* become both the firm's critical resources (Zingales, 2000), and the organizational "genes" that persist even as the organization grows and changes (Nelson and Winter, 1982). Interdependencies of this sort have been conceptualized under various constructs, such as interactions (Siggelkow and Rivkin, 2006) or "organizational activity patterns" (Romanelli and Tushman, 1986). In general, theoretical perspectives agree that the relationships among multiple dimensions of organizational activity: e.g., strategy, structure, political processes, norms, should be inertial by virtue of their intrinsic organization, above and beyond any deliberate managerial volition.

Consistent with such a view, many well-known firms such as Cisco Systems, Illinois Toolworks, Google, and Johnson & Johnson persistently gravitate towards the external channel. On the other hand, firms like Apple and IBM engage in considerably fewer acquisitions relative to their internal research efforts. Recent work has provided large-scale evidence that in fact

most firms heavily favor either internal or external technology, and that a firm's orientation is highly persistent and related to organizational structure. Arora et al. (2014), for example while agnostic about causality, strongly supports the view that firm-specific heterogeneity is related to the mutually reinforcing patterns of internal and external innovative activity.

But where do these divergent trajectories originate? There are many views on why events from the past influence a firm's present structure and conduct. Much work fits loosely under the umbrella of the *founding/founder effects* or *imprinting* literatures. For example, at the firm level, jobs and occupations, capabilities, and routines may reflect the conditions that were prevalent at their creation (Beckman and Burton, 2008). On the other hand, at the individual level, workers' early and prior experiences both enable and constrain the range of their choices in the long run, even after changes in employment (Azoulay et al., 2009).[4]

My study differs from the aforementioned streams by looking at a critical juncture that comes years after founding: the IPO. This setting lets me explore the interplay between adaptation and inertia during an interesting window when the firm is on the cusp of maturity, but also still changing. An important difference between an IPO and a founding setting is that the survival rate for firms post IPO is much higher that that of new ventures. For example, studies by the Federal Reserve of New York find that 80% of IPOs make it past their 7th anniversary (Peristiani and Hong, 2004), while the literature on entrepreneurship has documented survival rates of about 40% for new ventures (Headd, 2003). This means that firms going public are less sensitive to the population ecology mechanisms (e.g., liability of newness, resource constraints) often associated with imprinting theories (Stinchcombe, 1965), and thus less driven by culling effects and survival (which tend towards homogeneity, rather than explaining heterogeneity).

Summarizing the foregoing, my paper provides one explanation for the divergence along the internal/external divide in innovation strategy. As I more fully describe in the empirical section, I compare young, newly public firms faced with better (worse) opportunities to grow by acquisition just after their IPO. Then I observe them for several years and measure whether these initial conditions increased (decreased) the frequency of future *buy* decisions.

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[4]See Marquis and Tilcsik (2013) for a thorough review of the literature.

My setting allows us to better isolate a link between the economic environment and the evolution of the firm, just after crossing a major survival milestone and at a considerable distance from the founder's original "blueprints" (Hannan et al., 1996).

IPOs and plasticity

Given the empirical setting which focuses on IPOs as a critical point in the divergence of technological orientation, some discussion of certain relevant features of this period are warranted. IPOs change core features of the organization's processes and structures at many levels, rendering the firm more *plastic* (Gavetti and Rivkin, 2007). At one level, the ownership of the firm changes from concentrated to diluted, disrupting prior relational contracts, internal political structures, and incentive systems. More directly, going public often results in changes in management, as founder-CEO's give up some control, external professional managers come in, and early participants cash out (Stuart and Sorenson, 2003). As I describe in the next section, one possible observable of such changes would be the educational background of top managers. Specifically, I look at the number of MBAs and PhDs in positions of leadership. I argue the MBA managers would be more useful to an acquisitive firm, whereas PhDs would be more useful to a more research-oriented firm.

A growing body of work within the finance literature has also documented that firms become heavy acquirers just after going public.[5] An IPO eases liquidity constraints, increases legitimacy, and rewards growth. For example, Celikyurt and Sevilir (2010) found that pior to IPO, only 19% of firms had made any acquisitions, but that the figure jumped to 74% within 5 years of IPO. Relatedly, Arikan and McGahan (2010) find evidence supportive of the view that some (but not all) firms begin to engage in "programs of acquisitions" shortly after IPO, yet acknowledge that we still don't know what drives these patterns. My core argument is that not all firms respond to IPO in the same way, and that the environment may drive some of the divergence.

Finally, stricter reporting and regulation requirements, combined with pressure from investors seeking grow, might change the goals of the firm. For innovative firms, it has been

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[5]See Hovakimian and Hutton (2010) for a review of the literature.

argued that this would reduce the incentives to pursue more uncertain or longer-term projects in favor of projects with shorter horizons and less variance. Of particular relevancy to my paper, such pressure against internal development might have countervailing positive effect on the firm's search for external technologies. In line with this view, Bernstein (2014) not only found that IPOs increased M&A activity by 300% among patenting firms, but also that going public led to less basic research. His paper is closely related to my study, since we both look at how IPO increases acquisitions and decreases research. However, while prior evidence documented the mean effect for all firms that go public (comparing public to non-public) I go on to show that the effects of IPO are not uniform for all public firms.

INSERT FIGURES 1 AND 2 HERE

As I discuss in the next section, depending on a firm's position in the wave, these changes can move in opposite directions, and seem to be driven by the environmental conditions facing the firm after IPO. *Figure 1* shows a simple illustration of prior findings on the average impact of IPO on the ration of internal/external technology, while *Figure 2* shows my proposed decomposition of the response to IPO in response to different external conditions.

EMPIRICAL METHODOLOGY

This quasi-experimental study tests whether going public in the later half of an IPO cycle causes firms to engage in fewer technological acquisitions (Ahuja and Katila, 2001) but more original research, not just on the heels of the IPO, but also into maturity. In the next section I discuss the identification strategy, and how I am able to characterize two discrete types of exogenous economic environments (favorable/unfavorable for technological acquisitions).

Identification strategy

I classify firms as *early* or *late*, depending on whether they go public on the first or second half of an IPO wave. I then test for the impact of environmental conditions that make it less

efficient/desirable to access external technologies. I exploit two regularities that have been well-documented in the finance literature. First, IPOs come in waves which begin and end suddenly and unpredictably (Ritter and Welch, 2002). Second, the end of an IPO wave usually comes due to a macroeconomic shock that also brings about conditions unfavorable for acquisitions (Mitchell and Mulherin, 1996).[6] Thus, building on much work in the economics of information, I argue that periods of slow economic activity should result in increased search costs for firms seeking technological assets in the market for firms Arrow (1974); Stigler (1961).

While it is beyond the scope of my paper to weigh competing explanations for such persistent correlations, we can make two assertions: First, there is no reason to believe that firms can reliably predict the end an IPO wave or an M&A at the time of going public, since waves come to an end due to macroeconomic shocks. Second, and most important: for all the periods under observation, IPO activity (the criteria used to assign treatment and control groups) and technological acquisition activity (the mechanism I argue should drive the divergence), both essentially shut down at the same time. *Figure 3* plots the 1999-2000 wave, showing that IPO activity and volume of small technological acquisitions are highly co-temporal.

<div align="center">*INSERT FIGURE 3 HERE*</div>

The dark line represents the monthly volume of IPOs, while the shaded area below represents the volume of technological acquisitions completed by public firms under 5 years old. As more fully described in the *Data* section, technological acquisitions involve targets that hold at least one self-generated patent, and which are no more than 50% as large as the acquirer in terms of assets and patents held. All waves in the period of study follow the same pattern, consistent with the findings of a robust empirical literature showing that IPO and M&A waves are highly correlated with each other and to broader economic trends. For example, Lowry et al. (2010) focuses on IPOs, while (RhodesKropf et al., 2005) analyze merger waves and their correlation to broader macroeconomic patterns such as corporate valuations and GDP. A second relevant finding in the finance literature is that waves end unexpectedly. Brealey and Myers (2003),

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[6]See also Stiglitz (2000) for a discussion of how fluctuations in financial markets affect investment decisions, especially for R&D intensive firms

for example, call the existence of these "financial fashions" an important unsolved puzzle for corporate finance.

<p style="text-align:center;">*INSERT FIGURE 4 HERE*</p>

There are seven such waves between 1975 and 2009, resulting in seven treatment/control cohorts. *Figure 4* illustrates the temporal relationship between the dependent and independent variables. Acquisitions in future (DV) at top and position within IPO wave (IV) at bottom. I assign firms to treatment groups if their IPO was after the midpoint in their respective IPO wave. Conversely, firms that went public before the midpoint are coded as control. For ease of exposition, I refer to treated firms as $LATE$ firms for the remainder of the paper. I refer to control firms as $EARLY$.

The identification approach is important because firms pick the exact date of their IPO, so they choose the type of economic environment in which they go public (Ritter and Welch, 2002). Such self-selection makes it difficult to untangle the role played by the environment (versus unobserved heterogeneity) on future characteristics. My quasi-experimental design approximates randomization since firms do not know if they will enjoy a long or short wave (Harford, 2005). Consequently, at the moment of IPO, they do not know how close they are to the shock that brings about a dampened acquisitions market.

DATA

Information on IPOs comes from Jay Ritter at the University of Florida.[7] I use his data on IPO volume per month to demarcate the beginning and end of the IPO waves. I supplement his data on dates of incorporation for the firms with COMPUSTAT and BvD data (the corrections are minor). I also use his data on first day returns (underpricing) as controls in my regressions.

I construct an inventory of patents, inventors, firm structure, and M&A activity for almost all firms traded in major global stock exchanges. My paper combines data from several sources: (i) patent-level information from the EPOs PATSTAT database; (ii) ownership structure data from ORBIS by Bureau vanDjik (BvD); (iii) merger and acquisition data from Thomson Reuters

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[7]http://bear.warrington.ufl.edu/ritter/ipodata.htm

SDC Platinum and Zephyr by BvD; (iv) scientific publications data from Thomson's ISI Web of Knowledge; (v) S-1 Regulatory filings from the Securities and Exchange Commission (SEC); and (vi) accounting information from COMPUSTAT.

In order to mitigate the concern that firms have differential pre-IPO orientation in terms of internal vs. external technology strategy, a team of researchers read the full S-1 filings for over half of the sample. We were limited in the number of forms we could get online, but nonetheless collected 620 full forms from the SEC. Each form was read by two people, and coded for firms' prior M&A experience and mentions of whether acquisitions played a part of their pre or post IPO strategy. Details of the coding and methodology can be found on *Appendix C.*

The dataset also leverages the massive efforts of the European Patent Office (EPO), which has over several years developed the PATSTAT relational database.[8] This is a snapshot of the EPO master documentation database (DOCDB) with worldwide coverage, containing 20 tables including bibliographic data, citations and patent family links. Reassignment data from PATSTAT is also used to trace the complete history of every patent and ascertain whether it was kept by the original inventing firm or transferred. Thus, I am able to exploit the complete portfolio of patents held by and invented by firms as well as observe the entire history of each patent.

A major advantage of using PATSTAT over resources like the NBER or HBS patent databases (Hall et al., 2001; Li et al., 2011) lies in the fact that PATSTAT includes the global scope of all applications and priority family relationships. My study looks at the acquisition of technology which is often held by small private and/or foreign firms, and these legal entities are hard to find in competing patent databases. Small private firms often change names, and their pending applications can be granted to the acquiring firm, which destroys the evidence of who the original applicant was. This has hampered earlier efforts to trace the sources of external technology.[9]

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[8]https://www.epo.org/searching-for-patents/business/patstat.html

[9]For example, the patents behind Google's Picasa technology would seem to have been generated by Google, according to traditional databases. This is because Google appears as the first assignee both on the original patent and in the USPTO assignment database. However, the original applications for this technology were filed by Michael Herf, the entrepreneur and founder of Picasa, Inc., a company which Google bought and absorbed in 2006 prior to any of Herf's patents being granted. Such cases of IP transfer in the period between application and grant are actually rather frequent, as documented by Gans et al. (2008) in the context of licensing, and lead

Another important advantage of my data comes from using the Bureau vanDjik (BvD) database[10] to map firm structure for the sample firms. Many firms have complex corporate structures which makes it difficult to draw the boundaries of the firm. For example, within the same firm, some patents may be assigned to headquarters or to wholly-owned subsidiaries. That means that even with perfect matching of assignee to corporate entity, we may still miss the "real" owner of a patent. Johnson & Johnson, Inc., for example, has a very decentralized structure where wholly-owned subsidiaries retain title to patents. Such structures under-count the patent portfolios for many firms. Most importantly, it introduces more than just simple measurement error, since it has been shown that the decision to centralize or decentralize patent assignment is strongly correlated with firm structure and innovation strategy (Arora et al., 2014)

My final set matches all patents, applications, and reassignments between 1950 and 2014 for publicly traded US firms, their wholly owned subsidiaries, or their acquisition targets. This allows me to capture all pre-IPO patenting activity performed by firms, up to 25 years prior to the first IPO in the sample. I match firms to patents by starting with the raw match provided by BVD, and refining the data using a number of original routines. However, it is important to note that the raw data from BvD is still in the beta trial stage, and required considerable adjustment. In order to clarify ownership, I used the PATSTAT's legal event database to verify ownership of each patent. I found that BvD required corrections for about 35% for the whole sample, and as much as 70% for smaller firms, some of which are completely missed by BVD. Corporate ownership structure and transaction data consists of three parts: cross-sectional ownership information from BvD for 2013; M&A data from SDC Platinum and BvD's Zephyr product; and reassignment data from USPTO and PATSTAT.

INSERT TABLES 1 AND 2 HERE

Ultimately, the extensive matching of patents to firms is necessary to identify proper techno-logical acquisitions. The importance of a detailed inventory of patents for both acquirers and

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to underreporting the scope of external technology. Thus, in constructing my dataset, I paid particular attention to linking patent priority families to inventors, start-ups, and ultimate acquirers, (rather than treating patents as discrete quanta) to trace these hidden transfers.

[10]http://www.bvdinfo.com

targets has been emphasized by prior studies (Ahuja and Katila, 2001; Higgins and Rodriguez, 2006), and to date a majority of studies looking strictly at technological acquisitions have exploited small samples. Whereas firms might buy targets for a variety of reasons (e.g., market share, vertical integration, talent) my arguments about the balance between internal and external technology requires that we look only at acquisitions which can substitute for internal research. For similar reasons, I only look at targets which can be thought of as inputs. Clearly, a lateral merger among equals would be beyond of the scope of our discussion, and may change the firm in a number of ways not contemplated here. Thus, I limit targets to firms that are no larger than 50% the size of the acquirer, both in terms of patents and assets held. In all, my sample includes 5,835 acquisitions over the period 1985-2013.

RESULTS

IPO timing and technological orientation

Before presenting parametric tests, it is useful to look at a striking pattern in the raw data. *Figure 5* shows the stark difference in average external orientation between early and late firms. The graph shows a plot of the average share of external patents (that is, what portion of a firm's monthly flow of patents were sourced via a technological acquisition). On the vertical axis, we have the percentage share average for early and late firms. I equalize time periods so that we can look at all firms in relation to their IPO date, which takes a value of 0 on the horizontal axis.

INSERT FIGURE 5 HERE

This allows us to see how the trends in patenting for early and late firms compare both before and after going public. We can see that before IPO (value 0 on horizontal axis), both early and late firms have very similar shares, about ten percent. However, the dashed line shows that going public creates a sharp jump in the external ratio for early firms. On the other hand, the solid line shows how for late firms an IPO has a negligible effect on the firms' pre-existing trend in share of externally acquired patents.

Parametric evidence. I am interested in measuring the differences between treated firms, for whom the main explanatory binary variable $LATE$ takes the value of 1, and the control group, for whom $LATE$ takes a value of 0. The main prediction here is that we should expect to see late firms engage in fewer technological acquisitions in the long-run, and that these differences will due solely to the timing of their IPO. *Table 3* begins to explore the relationship between $LATE$ and the number of small technological acquisitions that each firm made by looking at the period between years 5 and 10 after IPO. In later tests I will explore for persistence, however here I concentrate on seeing how the relationships between $LATE$ and acquisitions respond to different controls.

On *Column 1* we see that firms on average make just over four such acquisitions.[11] Given that the dependent variable is a count of completed acquisitions, which likely exhibits overdispersion, I explore the treatment effect of going public on the second half of a wave by using variations of a negative binomial specification (Cameron and Trivedi, 2009). All specifications include controls for pre-IPO firm characteristics such as size, number of patents, and S-1 form information, as well as industry code dummies and individual wave dummies (so that we capture the within-wave, and within industry variation only).

Incidence ratios on *Column 1* show that $LATE$ firms acquire only 67.24% as many technological targets, relative to early firms. *Column 2* includes controls for pre-IPO patenting characteristics. I include measures for the average originality, generality, and non-patent references of the stock of patents held prior to IPO. These are measures that capture the quality of a firm's research. Including these controls further reduces the ratio of $LATE/EARLY$ to 60.79%, which goes against the possibility that the differences between early and $LATE$ are driven by differences in pre-IPO technological capabilities. *Column 3* shows a slight attenuation once we include firm-level characteristics such as assets, employees, and sales measured at maturity. This makes sense, as firms likely diverge in business and strategic orientations in addition to related to their acquisition activity

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[11]This is consistent with Celikyurt and Sevilir (2010), who report the number to be 4.3 acquisitions in the first 5 years post IPO.

INSERT TABLE 3 HERE

I also look at whether the *LATE* dummy predicts a firm's acquisition rate in the long run. Because firms generally become larger and more acquisitive with age, counts may be harder to interpret. Instead, I compare the ratio of *LATE* firms to early firms that are in the top quartile of M&A volume for each wave, and within a 5-year moving window that begins on the year of IPO. Looking at quartiles thus helps us see the impact of IPO timing in terms of how likely a firm is to be among the top acquirers for a cohort. In Table 4, *Column 1* shows the effect for firms up to five years post-IPO. Using a moving 5-year window, the magnitude of the negative coefficient on *LATE* decreases slightly as we move across *Columns 2-5*. Incidence ratios (IRR) are reported and range from 66.92% in years 1-5 to 74.44% in years 15-20. This shows that the differences between early and *LATE* firms remains quite steady over time, albeit with a slight trend toward convergence. In other words, *LATE* firms engage in about a third to a quarter fewer technological acquisitions over their life. Not surprisingly, the statistical significance begins to drop as the sample becomes smaller, thus, by *Column 5* we only have 171 firms and the standard errors are slightly larger. These results provide strong evidence of long-run persistence for the impact of *LATE* on future technological acquisitions. However, the slight attenuating of the impact does not support the view that differences amplify over time.

INSERT TABLE 4 HERE

Evidence of adaptation or selection

The foregoing results have shown that firms exposed to environments unfavorable for acquisitions just after their IPO are roughly 30% less likely to engage in this kind of deal even after they mature. However, the finding could mean different things. Since technological acquisitions are important for firms to access resources, it could mean that *LATE* firms are simply unlucky, at a disadvantage in terms of acquiring technology, and would exhibit lower performance and survival. This would be consistent with a population ecology view. Alternatively, and according to the arguments presented here, it could be that firms facing times of slim acquisition oppor-

tunities might compensate by developing better internal research capabilities. In the next three tables, I explore these two scenarios.

Differences in performance and survival. What is the impact of *LATE* on survival and performance? Interestingly, I find that there is no impact *per se* of the *LATE* dummy. In unreported results, a series of tests (using OLS, Negative binomial, and Probit) failed to find statistically significant correlations between *LATE* and measures for sales, sales growth, or return on assets at maturity. These findings do not support the view that "unlucky" firms were more likely to be selected out. Firms that go late might look and act very differently in terms of their patenting and acquisitions (as shown in the prior results), but this seems an adaptive response, since these differences do not impact their outcomes.

Differences in proxies for internal research. I explore the impact of *LATE* on patent-level proxies for more basic research. Originality, generality, and references to non-scientific literature (NPL) are widely accepted measures that reflect the degree to which a firm engages in more fundamental versus incremental research (Hall et al., 2005). Table 5 shows that *LATE* is associated with a significant increase in non-patent references (*NPL*). We see similar results for *generality* and *originality*. These regressions are OLS with a full gamut of controls for pre and post IPO characteristics. Note that whereas the association between acquisitions just after IPO and acquisitions later in life is relatively intuitive, and consistent with learning and resource accumulation theories, for us to find divergence in terms of type of research performed is strongly supportive of a more complicated adaptive view.

Put simply, it seems that firms which might appear "unlucky" at first (having gone public close to an economic slowdown), actually manage to compensate by developing better internal research capabilities. It is important to note that I do not measure capabilities, but rather measure proxies for research effort. However, to putting these findings on research effort together with the findings on performance suggests that the *LATE* firms have developed better research capabilities. Otherwise, it would be hard to explain their ability to be economically on par with early firms, while doing fewer technological acquisitions and spending more effort on research.

INSERT TABLES 5 AND 6 HERE

While the main tests in the paper split firms into early and late based on their position within a wave, the core argument is that the shock comes at the end of the wave. If this is the case, we should expect that the temporal "distance" from the end of each wave should be correlated with our variables of interest. To check, I run the exact same regressions as in *Table 5*, while replacing the *LATE* dummy with a count measure of how many months between a firm's IPO and the end of its wave. As *Table 6* shows, the results are very similar.

Mechanism

Differences in top management. I proceed by exploring potential mechanisms under-girding these patterns. Prior studied have shown that managers can be one locus of persistence in organizations. For example, seminal work in imprinting has shown founders bring organizational "blueprints" become part of the firm's core structure (Hannan et al., 1996), but that these effects may attenuate over time. More recently the focus has shifted to exploring whether top managers can be important factors in determining a firm's ability to change and adapt via sensing, seizing, and reconfiguring Helfat and Peteraf (2015) However there is not much known about how the environment shapes the firm's management post-founding, as the founder's influence fades. Thus, I explore whether IPO timing is also related to the composition of top management. The logic is that a firm should have consistent supporting structures for its sets of activities (Drazin and Van de Ven, 1985; Siggelkow, 2011), and that management is part of this structure. If firms develop external(internal) capabilities, then we should expect their management to reflect the firm's orientation. I explore the impact of *LATE* on the composition of top management at maturity. I measure top management for firms between 5 and 10 years of age as of 2013, and include the educational background of its managers as observed 2013. Data limitations prevent me from observing educational background across moving windows, as in the acquisition analysis.

I perform negative binomial regressions to look for differences in education of top manage-

ment. *Table 7* shows the impact of the *LATE* dummy on the characteristics of top management as of 2013. The dependent variable is a count of how many top managers had either an MBA (*Column 1*) or a PhD in a scientific field (*Column 2*). I measure top management for each firm during the window between 5 and 10 years post IPO. Coefficient estimates for negative binomial regressions are exponentiated and reported here as incidence ratios. For managers of a given type (MBA or PhD), incidence ratios reported can be interpreted as the ratio of: count of managers for early firms/count of managers for late firms. *Column 1* shows that *LATE* firms have only 33.4% as many MBA managers relative to early firms. On the other hand, *Column 2* shows that *LATE* firms have a 34.7% more managers with a science or engineering PhD relative to early firms.

<div align="center">*INSERT TABLE 7 HERE*</div>

Robustness tests. Despite the argument that firms cannot know their place within a wave *ex ante*, it is still possible that some omitted variable drives some firms to be quicker to go public within a wave, and that this is also correlated with future orientation. To mitigate this concern, I run Probit tests for selection on several observed characteristics of both the firms themselves (pre-IPO, including S-1 characteristics) and their patents (pre-IPO). As shown in Table 8, I find no difference in terms of non-patent citations (a standard measure of scientific orientation and basicness), originality, or generality. This suggests that firms in the sample were not systematically different between treatment and control groups.

In unreported specifications, I also check the robustness of my results by restricting the sample to exclude firms that went public in the first and last 2 months of a Wave, in order to mitigate concerns that firms have private information that allow them to predict the beginning or end of waves. Results are not much different for these specifications, however the standard errors are larger in some coefficients due to smaller sample sizes. I also systematically exclude individual waves from the analysis in all main specifications to ensure that no single wave is driving the results. This is largely a redundant test, since the specifications already capture within-wave variation through wave dummies. Removing individual waves has no effect.

INSERT TABLE 8 HERE

DISCUSSION

Theoretical Implications. Technological innovation is *prima facie* economically important (Schumpeter, 1942), it takes time to master (Arrow, 1962b), and it exhibits strong path-dependency (Cohen and Levinthal, 1989). Not surprisingly, it has been a key empirical setting for thinking about organizational evolution and capabilities. Within strategy, a core tension in innovation is the extent to which current capabilities allow a firm to compete, but may also hinder the exploration of future technological solutions (Christensen, 1997; Katila, 2002; Levitt and March, 1988). Firms buy external knowledge to complement their internal efforts while selling or licensing technology that cannot be optimally exploited internally (Arora and Gambardella, 1994; Granstrand and Sjölander, 1990). Much work in the innovation literature exploring these dynamics has focused on how attributes of the technology (e.g., appropriability and patentability), as well as institutional and market conditions, influence entrants' and incumbents' decision to compete through internal development or cooperate via acquisition (Arora et al., 2001; Cohen et al., 2000).

However, the transaction-oriented branch of the innovation literature has largely side-stepped issues of persistent firm differences. While firm differences are sometimes discussed in this literature, they are generally treated as orthogonal to the core arguments. For example some explicitly assume "memoryless" R&D investments and firms that can symmetrically increase or decrease their R&D bargaining power (Gans and Stern, 2000). Similarly within this vein Arora et al. (2001) acknowledge that *absorptive capacity*, *not invented here*, and similar firm-specific constructs *should* interact with markets for technology, though these are never included in their formal models. In other words, it is assumed that all firms come to the same decision (e.g., make or buy) given the same set of technological and market circumstances, and that having made a decision, firms do not face significant barriers to implementation.

In contrast to the transaction-oriented view, the resource-based view on innovation focuses on

the accumulation of firm-specific idiosyncratic experiences and capabilities over time (Penrose, 1995). For example, regular investments in R&D have been shown to increase firms' ability to access and integrate external knowledge (Cohen and Levinthal, 1990), and there is evidence that competencies arise through experience and reside in the hard-to-change organizational structure of the firm (Henderson and Cockburn, 1994). This is a type of "memory" effect, and we should expect that more mature firms would be less responsive to exogenous factors (e.g., nature of technology and institutional environment) in their make/buy calculus. In other words, these firms are subject to inertial pressures that limit their ability to adapt to the environment.

In this paper I have argued that innovative firms develop their technological orientation through a sequential process of transaction and resource accumulation mechanisms, and that the importance of these varies depending on the life stage of the firm. During times of change, such as IPO, transaction mechanisms orient the firm to the environment. After that, resource accumulation mechanisms maintain a degree of inertia. While recent theoretical arguments have identified the need for such cross-framework integration (Argyres, 2011), to my knowledge this is the first large-scale empirical study to undertake such an endeavor.

Beyond the field of innovation, the interdisciplinary implications of my paper are also significant. There are divergent views on what *founding* and *imprinting* literatures are, and my paper does not seek to map perfectly with any of them. Nonetheless, my results should contribute to many of these streams, by showing large-scale evidence consistent with the imprinting hypothesis, but occurring in a non-founding setting. Furthermore, within the context of imprinting and founding conditions, the inertial view has been brought to bear to argue that a one-shot luck of the draw at founding might determine survival or failure Stinchcombe (2000). However, expanding concepts like imprinting to include subsequent periods of alternating plasticity and ossification allows for a more nuanced view, where adaptation and inertia can take turns charting a firm's path. Such reconciliation can help us bridge some potentially false dichotomies across disciplines. After all, even Hannan and Freeman's population ecology manifesto (1977), often seen as the antithesis to strategic management's faith in managerial volition, admits that:

> *"a complete theory of organization and environment would have to consider both adaptation and selection, recognizing that they are complementary processes."*

Managerial Implications. My findings are also informative to managers, who must constantly "discriminate between what is and is not controllable" (Gavetti and Levinthal, 2004; Winter, 1987). In this regard, the present study is helpful in guiding organizational self-awareness. For example, firms that ramp up in times of depressed acquisition markets may have internal obstacles to overcome along the way of implementing an acquisition strategy, such as entrenched roles and compensation structures that reward internal development. These may not be responsive to a top-down decree to change strategy.

From the perspective of younger firms, my findings could inform decisions about IPO timing and how to nimbly respond to reversals in capital markets. For example, while I looked only at firms going public during waves, my findings could be useful for firms considering an IPO during a non-wave period. If a firm has particularly strong internal research opportunities, then an off-wave IPO may be desirable. Finally, IPOs are not the only process that can disrupt core features of the organization. Mergers and demergers, when large enough, might also make firms plastic. Therefore, firms undergoing such transformations may need to consider the economic environment as it may have unintended effects on the direction of a firm's growth after a transformative event.

CONCLUSION

This study has shown that the timing of IPO mattered for the population of firms that went public between 1975 and 2008. Firms that went late during waves in this period engaged in fewer technological acquisitions in the long run, and engaged in more internal research. The econometric tests sought to mitigate concerns about selection, and it is argued that the observed differences among late firms was due to their exposure to less opportunities to grow via technological acquisitions in the period after going public.

I thus provided strong evidence of how quickly firms might cement their technological orientation. Such brief but important sensitive periods call for future work into the conditions under

which inertia and adaptation interact. Theoretically, my paper draws on economics, finance, RBV and evolutionary theory, and thus highlights the value of drawing on literatures that do not often speak to each other. From an innovation perspective, my paper paper builds on recent work that has shown persistence heterogeneity in organization of R&D, and suggests a potential mechanism behind the empirical findings.

There are likely other punctuated windows that we should be looking at. Mergers and acquisitions in particular, can be transformative events, and future work should look at similar windows, for example succession after founder exit or bankruptcy. While it may be uncontroversial to suggest that past events would affect future performance and organization characteristics, there has been surprisingly little empirical evidence to document how and when such a thing actually occurs. Thus, my paper makes two novel contributions. First, by focusing on a window of time during which firms are still evolving, but which is removed from their actual founding, it isolates the role of the environment from potential confounds, such as founder effects. Second, it shows that the window after IPO is a very sensitive period during which firms adapt to the environment, and that once this short window closes, very strong inertia takes over. The impact is empirically shown by the stark difference among firms which experienced differences in exposure that amounted to, on average, about 18 months. This is a novel finding that should stimulate future work on the origins of firm heterogeneity.

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Table 1: Correlation matrix of relevant variables. Consistent with our hypothesis, LATE is negatively correlated with technological acquisitions

	tech acq	private acq	R&D	patents	wave	age	age IPO	assets	sales	LATE
tech acq	1.00									
private tech acq	0.66 (0.00)	1.00								
R&D	0.10 (0.00)	0.03 (0.00)	1.00							
patents	0.37 (0.00)	0.20 (0.00)	0.29 (0.00)	1.00						
wave number	-0.01 (0.19)	-0.04 (0.00)	0.28 (0.00)	-0.06 (0.00)	1.00					
age postIPO	0.06 (0.00)	0.01 (0.28)	-0.10 (0.00)	0.06 (0.00)	-0.45 (0.00)	1.00				
age at IPO	0.03 (0.00)	0.01 (0.21)	-0.01 (0.12)	0.02 (0.01)	-0.05 (0.00)	0.02 (0.00)	1.00			
assets	0.11 (0.00)	0.03 (0.00)	0.15 (0.00)	0.16 (0.00)	0.00 (0.66)	0.06 (0.00)	0.00 (0.82)	1.00		
sales	0.16 (0.00)	0.06 (0.00)	0.24 (0.00)	0.23 (0.00)	-0.03 (0.00)	0.12 (0.00)	-0.04 (0.00)	0.63 (0.00)	1.00	
LATE	-0.06 (0.00)	-0.09 (0.00)	-0.02 (0.01)	0.01 (0.00)	-0.20 (0.00)	0.05 (0.00)	-0.02 (0.01)	0.05 (0.00)	0.04 (0.00)	1.00
Observations	14568									

P-values in parentheses

Table 2: Descriptive statistics

	mean	sd	min	max
technological acquisitions	.950	1.140	0	30
private technological acquisitions	.935	.656	0	25
R&D expenditures ($mill)	.589	.988	0	7.83
wave number	3.995	1.470	1	7
age postIPO	13.023	5.838	6	34
age at IPO	5.811	4.065	1	15
assets	2,555	17477	0	691,063
sales	1,463	7866	0	352,369
LATE	.512	.499	0	1
Observations	14,498			

Note: Unit of observation is firm-year

Table 3: Impact of late-wave dummy on number of small tech acquisitions completed between years 5 and 10 post IPO. Incidence ratios on *Column 1* show that LATE firms acquire 67.24% as many targets vs early firms. *Column 2* controls for pre-IPO patenting.Including these controls further reduces the ratio to 60.79%, mitigating the possibility that the differences are driven by pre-IPO technological capabilities.   *Column 3* shows a slight attenuation once we include firm-level characteristics such as assets, employees, and sales measured at maturity.

	small deals	*small deals*	*small deals*
dummy for late in wave	-0.396	-0.498	-0.347
	(0.114)	(0.137)	(0.118)
mean value for DV	4.183	4.963	4.456
incidence ratio	0.672	0.608	0.707
	(0.076)	(0.084)	(0.087)
control pre-IPO NPL references	No	Yes	Yes
control pre-IPO originality	No	Yes	Yes
control pre-IPO generality	No	Yes	Yes
control pre-IPO firm characteristics	Yes	Yes	Yes
control post-IPO firm characteristics	No	No	Yes
NAICS Codes	Yes	Yes	Yes
individual wave dummies	Yes	Yes	Yes
Observations	907	633	633

Unit of observation is the firm.

Standard errors in parentheses are robust to arbitrary heteroskedasticity. Results are virtually unchanged using classical standard errors

Table 4: This table explores how differences in technological acquisitions between early and LATE firms persist over time. *Column 1* shows the effect for firms up to five years post-IPO. Using a moving 5-year window, the magnitude of the negative coefficient on LATE remains fairly constant on *Columns 2-5*. Incidence ratios (IRR) are reported and range from 66.92% in years 1-5 to 74.44% in years 15-20. In other words, LATE firms engage in about a third to a quarter fewer technological acquisitions over the study period. These results provide strong evidence of long-run persistence for the impact of LATE on future acquisitions.

	(1) top 4tile yrs 1-5	(2) top 4tile yrs 5-10	(3) top 4tile yrs 10-15	(4) top 4tile yrs 15-20	(5) top 4tile yrs 20+
LATE dummy	-0.402 (0.139)	-0.385 (0.151)	-0.335 (0.125)	-0.295 (0.117)	-0.326 (0.158)
incidence ratios	0.669 (0.093)	0.680 (0.097)	0.715 (0.097)	0.744 (0.123)	0.722 (0.186)
ln(age at IPO)	0.147 (0.189)	0.248 (0.233)	-0.018 (0.341)	-0.626 (0.350)	-0.526 (0.424)
ln(age)	-1.538 (0.588)	-2.561 (0.907)	-0.619 (1.541)	2.017 (1.473)	2.682 (1.679)
1st wave	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)	0.0000 (.)
2nd wave	-0.193 (0.507)	-0.180 (0.517)	-0.199 (0.585)	-0.200 (0.674)	-0.1706 (0.7120
3rd wave	0.536 (0.362)	0.383 (0.398)	0.680 (0.448)	0.950 (0.570)	1.074 (0.563)
4th wave	0.304 (0.383)	-0.146 (0.484)	0.554 (0.645)	1.448 (0.715)	
5th wave	0.024 (0.431)	-0.544 (0.565)	0.535 (0.839)	(0.888)	
6th wave	0.109 (0.514)	-0.771 (0.720)	0.518 (1.134)		
7th wave	0.217 (0.679)	-0.198 (0.862)			
pre IPO firm chars	Yes	Yes	Yes	Yes	Yes
post-IPO firm chars	Yes	Yes	Yes	Yes	Yes
NAICS	Yes	Yes	Yes	Yes	Yes
Observations	1211	806	646	325	171
r2	0.339	0.386	0.476	0.659	0.730

Unit of observation is firm. Standard errors are robust to arbitrary heteroskedasticity

Results are virtually unchanged using classical standard errors

Table 5: This table shows the relationship between LATE and patent generality (gen), originality (orig), and non-patent scientific references (NPL). *Columns 1-3* show a positive impact of LATE on all measures. *Columns 4-6* include additional controls for assets and R&D expenditures at time of IPO, as well as patent stock in 2013 and dummy for whether the firm survived. The additional controls marginally strengthen the coefficients and tighten up the estimated standard errors. This is consistent with the view that results are not driven by pre-IPO characteristics nor by survival or growth.

	(1) gen	(2) orig	(3) NPL	(4) gen	(5) orig	(6) NPL
LATE dummy	0.033	0.070	0.049	0.035	0.072	0.060
	(0.015)	(0.021)	(0.019)	(0.013)	(0.020)	(0.019)
DV mean value	0.427	0.614	0.306	0.427	0.614	0.306
(effect of LATE on DV)	(7.73%)	(11.4%)	(16.0%)	(8.20%)	(11.73%)	(19.61%)
ln(age at IPO)	-0.007	0.015	0.004	-0.002	0.023	0.013
	(0.017)	(0.020)	(0.022)	(0.018)	(0.020)	(0.021)
ln(assets)	-0.005	-0.015	-0.021	-0.003	-0.014	-0.018
	(0.008)	(0.014)	(0.011)	(0.008)	(0.016)	(0.012)
ln(R&D spend)	0.008	0.024	0.058	0.003	0.012	0.030
	(0.007)	(0.014)	(0.010)	(0.009)	(0.014)	(0.011)
R&D / sales	0.028	0.193	0.214	0.026	0.171	0.156
	(0.041)	(0.081)	(0.063)	(0.038)	(0.075)	(0.056)
ln(employees)	-0.028	-0.011	-0.040	-0.036	-0.010	-0.034
	(0.012)	(0.014)	(0.016)	(0.014)	(0.018)	(0.015)
ln(patents)	0.013	0.010	-0.009	0.030	0.022	0.000
	(0.006)	(0.008)	(0.008)	(0.010)	(0.017)	(0.013)
ln(sales)	-0.021	-0.057	-0.189	-0.011	-0.042	-0.164
	(0.023)	(0.035)	(0.033)	(0.027)	(0.043)	(0.036)
surviving in 2013				0.001	0.048	0.064
				(0.021)	(0.031)	(0.028)
ln(age 2013)				0.019	-0.001	0.022
				(0.011)	(0.016)	(0.018)
ln(assets at IPO)				-0.001	-0.008	-0.014
				(0.007)	(0.011)	(0.009)
ln(R&D spend at IPO)				0.015	0.021	0.038
				(0.007)	(0.011)	(0.008)
ln(patent stock 2013)				-0.026	-0.021	-0.021
				(0.009)	(0.018)	(0.015)
NAICS	Yes	Yes	Yes	Yes	Yes	Yes
year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	192,648	255,895	255,468	182,446	242,348	241,952
r2	0.111	0.068	0.079	0.119	0.071	0.084

Standard errors in parentheses clustered at firm level. OLS regressions.

For binary dependent variable in models 3 and 6, results are robust to Probit specification.

Table 6: This table shows the relationship between time to wave-end and patent generality (gen), originality (orig), and non-patent scientific references (NPL). These are the same specifications as Table 5, replacing the DV with the count of months between IPO and end of wave. All the results are similar to Table 5. However, interpreting the coefficients is less-straightforward. Given that the average wave lasts 18 months, one potential way to conceptualize the impact is to multiply the percentage (monthly effect) coefficients by 18. Importantly, this yields results that are very similar in magnitude as those shown in Table 5.

	(1) gen	(2) orig	(3) NPL	(4) gen	(5) orig	(6) NPL
distance	-0.001	-0.002	-0.002	-0.002	-0.003	-0.003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
DV mean value	0.427	0.614	0.306	0.427	0.614	0.306
(effect/month on DV)	(0.24%)	(0.33%)	(0.65%)	(0.47%)	(0.49%)	(1.0%)
ln(age at IPO)	-0.007	0.009	-0.002	0.002	0.024	0.017
	(0.018)	(0.021)	(0.025)	(0.018)	(0.020)	(0.021)
ln(assets)	-0.005	-0.012	-0.016	-0.004	-0.017	-0.021
	(0.008)	(0.015)	(0.012)	(0.008)	(0.017)	(0.013)
ln(R&D spend)	0.008	0.029	0.065	0.003	0.014	0.031
	(0.007)	(0.018)	(0.012)	(0.009)	(0.015)	(0.012)
R&D / sales	0.038	0.233	0.258	0.032	0.185	0.166
	(0.042)	(0.082)	(0.069)	(0.039)	(0.076)	(0.058)
ln(employees)	-0.027	-0.010	-0.041	-0.036	-0.009	-0.033
	(0.013)	(0.016)	(0.018)	(0.014)	(0.019)	(0.015)
ln(patents)	0.011	-0.002	-0.024	0.031	0.023	0.002
	(0.006)	(0.010)	(0.010)	(0.010)	(0.018)	(0.014)
ln(sales)	-0.020	-0.058	-0.192	-0.011	-0.040	-0.165
	(0.024)	(0.040)	(0.040)	(0.027)	(0.045)	(0.038)
ln(age)				0.019	-0.003	0.021
				(0.012)	(0.017)	(0.018)
ln(assets at IPO)				-0.001	-0.007	-0.013
				(0.007)	(0.011)	(0.009)
ln(R&D spend at IPO)				0.015	0.020	0.038
				(0.007)	(0.012)	(0.009)
ln(patent stock 2013)				-0.028	-0.023	-0.023
				(0.009)	(0.019)	(0.016)
surviving in 2013				0.003	0.053	0.069
				(0.021)	(0.033)	(0.030)
Observations	192646	255889	255462	182445	242343	241947
r2	0.110	0.061	0.074	0.119	0.069	0.084

Standard errors in parentheses clustered at firm level. OLS regressions.

For binary dependent variable in models 3 and 6, results are robust to Probit specification.

Table 7: This table shows the impact of the LATE dummy on the characteristics of top management. The dependent variable is a count of how many top managers had either an MBA (Column 1) or a PhD in a scientific field (Column 2), for firms between 5 and 10 years of age as of 2013. Data limitations prevent me from observing educational background across moving windows, as in the acquisition analysis. Coefficient estimates for negative binomial regressions are exponentiated and reported here as incidence ratios. For managers of a given type (MBA or PhD), incidence ratios reported can be interpreted as the ratio of (count of managers for early firms)/(count of managers for late firms). *Column 1* shows that LATE firms have only 33.4% as many MBA managers relative to early firms. On the other hand, *Column 2* shows that LATE firms have a 34.7% more managers with a science or engineering PhD relative to early firms.

	count of MBA mgrs (1)	*count of PhD mgr* . (2)
LATE dummy	0.333 (0.140)	
LATE dummy		1.347 (0.192)
control pre/post-IPO firm characteristics	Yes	Yes
IPC Codes	Yes	Yes
NAICS Codes	Yes	Yes
individual wave dummies	Yes	Yes
Observations	274	274

Unit of observation is the firm.

Exponentiated coefficients (incidence rate ratios).

Standard errors are robust to arbitrary heteroskedasticity

Results are virtually unchanged using classical standard errors

Table 8: Probit test for selection into treatment group: Do pre-IPO non-patent references, originality and generality measures predict dummy for late in wave? Despite the quasi-experimental setting, it is possible that some firms self-select to go early or LATE. This might driving the relationship between LATE firms and their differences in patenting and M&A. To mitigate this concern, I run Probit tests to see whether the type of research performed by the firms prior to IPO predicts the sorting into early or LATE. I use average originality, generality and non-patent citations for the stock of patents of firms pre-IPO. These are widely accepted proxies for quality of research, and if firms are less research intensive before IPO, it would make sense that they are more acquisitive and less research intensive after IPO. Pre-IPO firm characteristics include M&A experience and intention dummies from S-1 fillings. The table shows that none of the measures of research quality are significantly correlated with the LATE dummy. This suggests that firms' pre-IPO patenting was not systematically different between early and LATE firms.

| | . | *Prob(late=1)* | . |
	(1)	(2)	(3)
NPL share pre-IPO	-0.353		
	(0.532)		
firm-level average originaltiy pre-IPO		0.727	
		(0.571)	
firm-level average generality pre-IPO			0.617
			(0.425)
control pre-IPO firm characteristics	Yes	Yes	Yes
IPC Codes	Yes	Yes	Yes
NAICS Codes	Yes	Yes	Yes
individual wave dummies	Yes	Yes	Yes
Observations	368	302	291

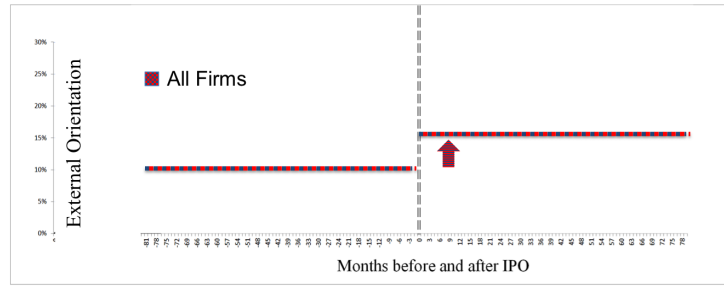Unit of observation is the firm.

Standard errors in parentheses.

Figure 1: This figure shows a stylized depiction of the shift in technological orientation documented in prior literature (e.g. (Bernstein, 2014).
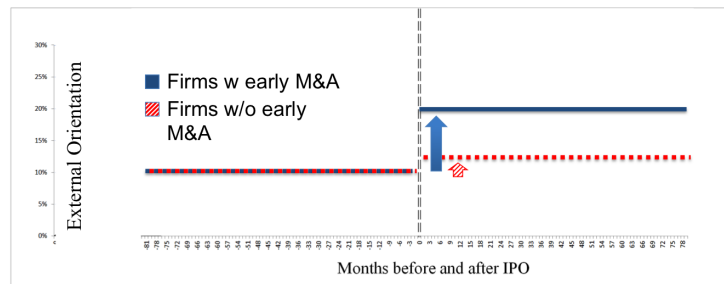

Figure 2: This figure shows a stylized depiction of the predicted differential shift in technological orientation: If firms late to the cycle have fewer options to acquire, they may compensate by investing in internal R%D, leading them down a different trajectory.
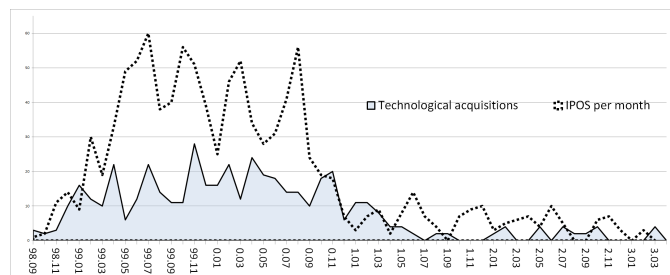

Figure 3: This figure illustrates the high degree of correlation between IPO waves and intensity of technological acquisitions, as observed during the 1999-2000 wave. Importantly, both IPO and acquisitions end sharply and almost at the same time. The horizontal axis shows months, and the vertical axis shows number of IPO and technological acquisitions.
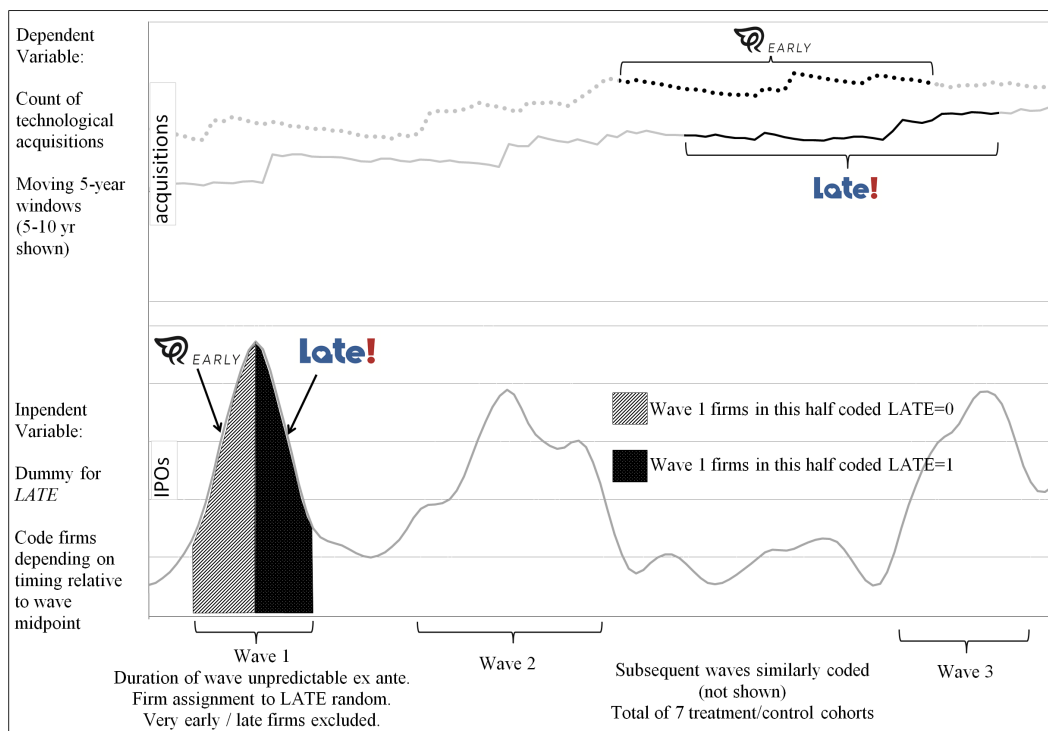
Figure 4: Hypothetical firms "Early" and "Late!" are coded $LATE{=}0$ (control) and $LATE{=}1$ (treatment) respectively, based on the timing of their IPO relative to midpoint wave. DV compares the count of technological acquisitions between treatment and control groups. The regressions look at moving 5-year windows at 0, 5, 10, 15, and 20 years post-IPO (shown here are the two different measurement windows for each firm in their years 5-10). We expect treated ($LATE$) firms to engage in fewer acquisitions in the long-run.
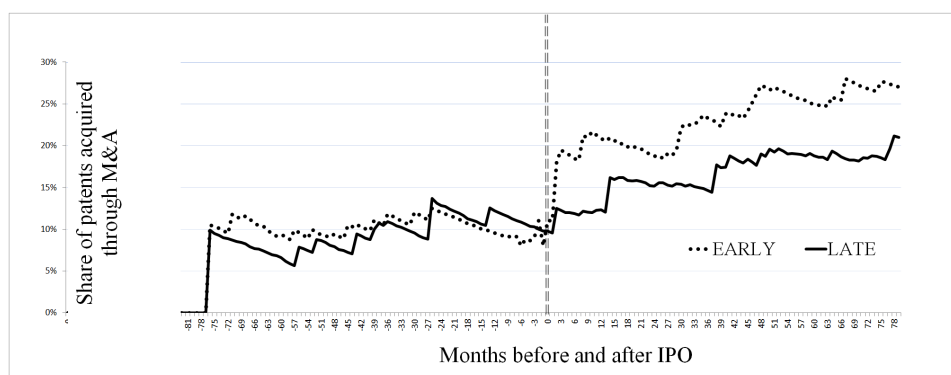

Figure 5: This chart shows the change in share of external patents held by all firms in the sample. We can see that on average, early firms increased their technological acquisitions sharply after IPO, whereas $LATE$ firms did not. Horizontal axis spans from 75 months prior to IPO to 77 months after IPO. The plots are jagged because the underlying data is a mix of monthly and yearly observations.

Coding Pre-IPO SEC Registration Forms

In this study we are interested in disentangling the role of the environment from the role of founder effects, or similar unobserved heterogeneity. Thus, we pay special attention one of the most consistent and reliable sources of information available that gives us a window into the characteristics of the pre-IPO firms: their registration forms. The Securities and Exchange Commission (SEC) stipulates that any firm undertaking an IPO in the United States must provide details about the issuing company, its financials, a statement of its intended use of IPO proceeds, and background information for its officers and board members.

This is most often via a registration statement *S-1* which that includes the firms prospectus.[12] However, firms with less than $25 million in revenues can use Form *SB-2*. We omit from our analysis the smallest offerings, raising less than $5 million, as these are almost never traded on major exchanges (due to high administration and compliance costs of exchanges like NASDAQ). These small offerings would use Form A. [13] For ease of exposition, we refer to all registration forms as *"S-1"*, as these are the most frequently used ones. This is consistent with prior literature.

1. Explicit M&A Experience (categorical variable):

We read S-1 filing for mentions that the company has previously acquired other technologies or companies. This type of information is usually in the *Company* or *Overview* section. We code this variable as *1* if we find explicit mentions of M&A, for example: "In [year] we acquired [company X]." Another possible place is the *Financials* section where they may report financial information related to an acquisition. We look for any mentions such as: "... expenses from acquisition of [company X]" or similar statements. We find that 32% of firms state having had M&A experience prior to IPO.

Examples:

"We do, however, expect that product revenues will increase in the near term as a result of our acquisition of [company X] on September 30, 2005"

"The acquisition of [company X] is consistent with our strategy to transition our revenues mix from contract research revenues to product sales and license revenues."

"22,745 shares of common stock issued or reserved for issuance in connection with the acquisition of [company X] that were held in escrow on that date, and 429 shares of common stock issuable upon the exercise of warrants at an exercise price of $21.06 per share held in escrow as of that date."

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[12]https://www.sec.gov/about/forms/forms-1.pdf
[13]See Certo et al. (2009) for an overview of IPO research in management and entrepreneurship.

2. Soft Intention to Acquire (categorical variable):

We look in the *Use of Proceeds* section. There is both a summary and a full description of what the IPO proceeds are anticipated to fund. We code this variable as *1* if the filling states that the firm "intends" or "may use" the proceeds to fund acquisitions of "complementary" or any other businesses/technologies. This is a frequent statement, and is used by most firms. It does not so much express an express intention or interest in acquiring, as much as it connotes being open to the possibility. We can interpret this as indication that firms that do not include such statement may be predisposed against acquisitions. In all, 69% of firms state this level of "open mindedness" about potential acquisitions.

Examples (bold added for emphasis):

- *"We intend to use the net proceeds from this offering for working capital and other general corporate purposes, including to finance our growth, develop new products, assert and defend our intellectual property rights, and fund capital expenditures. **In addition, we may choose to repay our loan facility with Silicon Valley Bank or expand our current business through the acquisitions of other businesses, products, or technologies.***

- *"We may also use a portion of the net proceeds to us to expand our current business through strategic alliances with, **or acquisitions of, other businesses, products, intellectual properties or technologies.** We currently have no agreements or commitments for any acquisitions at this time."*

3. Explicit Intention to Acquire as Part of Strategy (categorical variable):

This is the strongest indication of the firms intentions to acquire. We find that 25% of firms have made made a definitive and/or specific statement of their intention to acquire. In many cases a specific target or technology is mentioned.

Examples (bold added for emphasis):

- *"Selective Acquisition Strategy. **We selectively pursue the acquisition of proprietary aerospace component businesses** when we see a clear path to create value through the application of our three core value-driven operating strategies... We have established a dedicated acquisition effort to identify, approach and evaluate potential acquisition targets. We also have significant experience among our management team in executing acquisitions and integrating acquired operations, having successfully acquired and integrated fifteen businesses and/or product lives since our formation in 1993.*

- *"Pursue strategic acquisitions and alliances: We intend to selectively pursue acquisitions and alliances in the future that will provide us with new or complementary technologies, personnel with significant relevant experience, or increased market penetration. We are currently evaluating a number of possible acquisitions or strategic relationships and believe that our resources and experience make us an attractive acquiror or partner."*