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Acquisition of new technology firms – Pioneering advantages and disadvantages of sellers and buyers

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„Man kann nicht hoffen, die Welt zum Besseren zu wenden, wenn sich der Einzelne nicht zum Besseren wendet. Dazu sollte jeder von uns an seiner eigenen Vervollkommnung arbeiten und sich dessen bewußt werden, daß er die persönliche Verantwortung für alles trägt, was in dieser Welt geschieht, und daß es die direkte Pflicht eines jeden ist, sich dort nützlich zu machen, wo er sich am nützlichsten machen kann. “

Marie Curie

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List of abbreviations

Abbreviation	Description
AAR	Absolute abnormal return
AR	Abnormal return
CAAR	Cumulative absolute abnormal return
CAPM	Capital asset pricing model
CAR	Cumulative abnormal return
CDRH	Center for Devices and Radiological Health
CEO	Chief executive officer
CMS	Centers for Medicare & Medicaid Services
CPHM	Cox Proportional Hazard Model
DAX	German stock index
DV	Dependent variable
ELS	Excimer Laser System
EMT	EvaluateMedTech
FDA	Food and Drug Administration
FTSE MIB	Milano Indice di Borsa (Italian stock market index)
ICT	Information and Communication Technology
IP	Intellectual property
IV	Independent variable
J&J	Johnson & Johnson (company name)
Ln	Logarithmus naturalis
LZS	Excimer Laser System
M&A	Mergers and acquisitions
Medtech	Medical technology
MFT	Market for technology
NYSE	New York Stock Exchange
OLS	Ordinary least square
PMA	Premarket Approval
R&D	Research & Development
RoI	Return-on-Invest
S&OP	Sales and operations planning
SAR	Standardized abnormal return
SCAR	Standardized cumulative abnormal return
SMI	Swiss Market Index
Topix	Tokyo Stock Price Index
TVC	Time-varying covariate
US	United States of America
USD	U.S. Dollar
UV	Ultraviolet
VAD	Ventricular Assist Devices
WiFi	Wireless local area networking

Zusammenfassung

In der vorliegenden Arbeit befasse ich mich mit technologieorientieren Unternehmenskäufen am Beispiel der Medizintechnik. Die Medizintechnik ist nicht nur hoch innovativ und schnelllebig, sondern geprägt vom Zusammenspiel verschiedener Spieler: Kleine, oft junge Firmen besitzen hervorragende Voraussetzungen, fundamental neue Produkte und Technologien zu entwickeln; große, alt eingesessene Unternehmen hingegen bei der Vermarktung und Skalierung dieser Innovationen. Kommt es zu einem technologieorientierten Unternehmenskauf („Groß kauft Klein"), können beide Seiten wechselseitig profitieren.

Der erste Teil dieser Arbeit ist eine qualitative Studie, die den Kaufzeitpunkt solcher Übernahmen erforscht. *Wann* ein bestimmtes Übernahmeziel zugekauft wird, ist eine schwierige Entscheidung für das Großunternehmen als der künftige Besitzer der neuen Technologie: Einerseits reduziert Abwarten das Risiko die neue Technologie zu früh, nämlich *vor* seinem potenziellen Scheitern aufzukaufen. Langes Zögern andererseits birgt das Risko, dass Wettbewerber schneller sind, sich die Technologie zu eigen zu machen. Die Ergebnisse zeigen, dass Großunternehmen mit der Akquisition warten bis das Übernahmeziel das Produktrisiko entlang von spezifischen Meilensteinen im Innovationsprozess reduziert hat.

Der zweite Teil dieser Arbeit ist quantitativ und nimmt den Blickwinkel des Verkäufers ein – also den des kleinen, jungen Unternehmens, das das neue Produkt entwickelt hat. Im Mittelpunkt steht die Frage, ob es für den Verkäufer vorteilhaft ist, „Pionier" innerhalb eines neuen Produktsegments zu sein, wenn es sein Ziel ist, aufgekauft zu werden. Tatsächlich zeigen die Forschungsergebnisse, dass solche Pioniere mit höherer Wahrscheinlichkeit akquiriert werden. Allerdings müssen sie länger auf die Akquisition warten. Spiegelbildlich können sich direkte „Nachfolger" (mit einem vergleichbaren Produkt) die Vorarbeit der Pioniere zunutze machen und mit einer früheren Akquisition rechnen. Sie werden allerdings seltener aufgekauft.

Der dritte Teil dieser Arbeit ist ebenfalls quantitativ und nimmt den Blickwinkel des Käufers ein – also desjenigen Großunternehmens, das das kleine, junge Unternehmen übernimmt. Ich stelle die Frage, ob sich für Großunternehmen mit Blick auf ihren eigenen Börsenwert derartige Technologiezukäufe lohnen. Eine Event Study zeigt, dass der Käufer tatsächlich mit einer Sonderrendite rechnen darf – insbesondere, sofern er einen der Pioniere innerhalb eines neuen Produktsegments zukauft. Der Effekt ist allerdings auf den Tag der Akquisition beschränkt und damit nur sehr kurzzeitig beobachtbar.

Abstract

In my dissertation, I look at markets for technology in the medical device industry. This fast-paced, innovative industry is characterized by small new entrants, which excel in radical innovation, and big established incumbents, which excel in sales, marketing, and scaling up new products. Thus, markets for technology exist and create new opportunities for firms selling new product types and technologies.

In my first study, I qualitatively explore timing-related decisions behind technology acquisitions. The decision when to purchase a target firm with a novel product type is difficult for the prospective owner: on the one hand, the buying firm may want to wait with an acquisition in order to reduce the risk of the innovation failing (after the acquisition); on the other hand, if it waits too long, competitors might be faster and pre-empt the given buyer from getting access to the new product. In their decision *when* to acquire a target firm, I find that buyers of a new product technology wait for specific innovation milestones to be achieved. These milestones indicate the extent to which the targeted small new entrant has already de-risked its new product innovation.

In my second study, I take the viewpoint of the seller involved in such technology acquisitions, and ask whether it is beneficial for the small new entrant to reach the above mentioned milestones early if its goal is to be acquired. Indeed, quantitative findings suggest that pioneers (reaching these milestones earliest) have better odds of being acquired, but wait longer for acquisition to happen. In turn, later movers can free-ride on the pioneers' attempts in a way that aids earlier acquisition – however, later movers are less likely to be acquired at all.

In my third study, I take the viewpoint of the buyer involved in such technology acquisitions, and ask whether and how the acquirer of a small new entrant is rewarded by capital markets for this acquisition. The results of my event study suggest that purchasing a new entrant of a novel product type comes with short-term excess stock returns on the date of acquisition. Moreover, shareholders seem to reward the acquisition of one of the pioneering entrants in particular.

1. Introduction

1.1. Motivation

My dissertation considers a setting in which an innovative firm can not only sell its new high-tech product to end users and customers – instead, the innovating firm, as an entire company, can also be acquired by a big, established incumbent who acts as a corporate buyer in this case. The latter option, where a big, established incumbent acquires an innovative entrant on a so called market for technology (MFT), is a very common phenomenon in many high-tech industries such as pharmaceuticals (e.g., Higgins et al. 2006), telecommunications (e.g., Ransbotham and Mitra 2010), or ICT (e.g., Brueller et al. 2015).

Entrepreneurial outcomes in markets for technology are binary for both parties involved in the transaction, the small new entrant selling a new product type, as well as for the acquiring incumbent. Success in an MFT is binary for the small new entrant because the firm is either acquired for its innovation or not. Even if deal values might vary to a certain extent, outcomes in MFTs are more digital compared to product markets where numerous (end) customers need to be convinced in order to scale up the business for a new product. Similarly, success in an MFT is binary also for the acquiring incumbent: it implies to integrate one (and not the other) new technology into an existing product landscape; it means to preempt competitors from acquiring a certain technology (or being preempted by others); it allows to outsource the risk of a certain innovation failing during its early days to the small new entrant. Lastly, it has a strong impact on the buyer's capital market valuation because a new technology is added to the portfolio at a specific, singular point in time (rather than after a long-cycled period of internal development).

In this setting of binary outcomes, I argue that *timing* of acquisitions plays an essential role in at least two ways: First, timing is important when interpreted as a measure for the *pioneering position* of the acquired small new entrant. In explanation, new firms' timing of market entry helps to delineate first- and early-movers from later followers within the space of a new product segment. Second, timing is important if seen as a measure for the *risk associated with an acquired small new entrant* and its product. More precisely, it measures the elapsed time the new product of an acquired small new entrant has been exposed to the market

before getting acquired. Across all three of my studies, I provide evidence that this risk significantly decreases along standardized milestones of the innovation process and, thus, over time.

The above mentioned interpretation of (acquisition) timing leads to interesting and relevant questions. From the perspective of a small new entrant which sells its technology one might ask: when should a small new firm enter the market if it seeks to be acquired? Is it better to be one of the pioneers or among the direct followers? Complementary, from the perspective of an incumbent which acquires the technology one may ask: which of these small new entrants do incumbents select? When do they buy an entrant – right before or after its market entry? (How) will shareholders value the acquisition?

Several studies address the timing of acquisitions but they interpret timing differently and, thus, have yet left a gap to the questions raised in the above. To mention only some of them[1]: Carow et al. (2004) interpret acquisition timing as the timing of a certain deal relative to acquisition market waves (i.e., acquiring a new technology at the market peaks or market lows). Laamanen and Keil (2008) interpret acquisition timing as the frequency of acquisitions in which a given buyer performs its (multiple) acquisitions and how that translates into performance. Kusewitt (1985) investigates how the acquisition rate interferes with a proper integration and assimilation. Barkema and Schiyven (2008) interpret acquisition timing under the question when buyers unlock synergies over a longer time period in the aftermath of an acquisition. Authors like Ransbotham and Mitra (2010) or Brueller et al. (2015) interpret acquisition timing as target maturity and its relationship with the acquirer's performance in the aftermath of a deal.

The work of all these scholars as well as my own dissertation is connected with two assumptions: first, I look at the specific case of acquisitions. By definition, this is the case when a small new entrant (and its innovation) is entirely acquired by another firm. I want to highlight that there are also other forms of technology transfers, such as license agreements, joint ventures, or equity investments, and they are very popular in other high-tech settings like, for example, in biotechnology. However, I will focus on acquisitions because they are of particular importance in the chosen empirical setting of medical devices. Thus, my findings (as well as those of the literature stream around technology acquisitions) are not automatically generalizable or transferable to a setting where this is not the case.

[1] Compare Shi et al. (2012) for an in-depth literature review on temporal perspectives of M&A.

Second, I assume that both parties involved in a technology acquisition (i.e., buyer and seller) seek an acquisition and define it as a success. Why the buying incumbent aims at such an acquisition, is relatively intuitive: it might want to gain access to a new technology or prevent its peers from getting access. Why the self-selling small new entrant seeks such an acquisition, is less intuitive. Behavioral entrepreneurship suggests that motivation of entrepreneurs is complex (e.g. Lerner and Tirole 2002), and entrepreneurs often share a desire for independence or a strong locus of control (Shane et al., 2003). At a first glace, this seems to be in stark contrast to the rationale behind acquisitions which is that the selling firm hands over full control to the buying firm. I argue that entrepreneurs might accept a loss of independence (inherent in an acquisition) in a setting where they face certain constraints on the way to achieve the biggest market adoption of their new technology. I do this on the shoulders of scholars like Gans and Stern (2003) or Henkel et al. (2015) who underline the importance of incumbents' complementary assets in scaling up a new entrant's innovation. They come to a similar conclusion and state that "only the incumbent can commercialize an innovation, so the entrants' goal is to be acquired" (Henkel et al., 2015 p.296). This makes an acquisition desirable also for those entrepreneurs whose major goal is *not* to purely maximize the own individual welfare but rather to see the innovation being scaled-up and commercialized.

1.2. Research setting, objectives and questions

I chose the medical device space as the research setting for all studies of my dissertation because of three main reasons: first, the medical device environment is an excellent example of a vital market for technology. Second, it also allows to observe the points in time that different entrants come to market with a comparable new product. Third, the environment also allows to objectively measure the risk drops for a new product type *generally* and for a focal new entrant *specifically*.

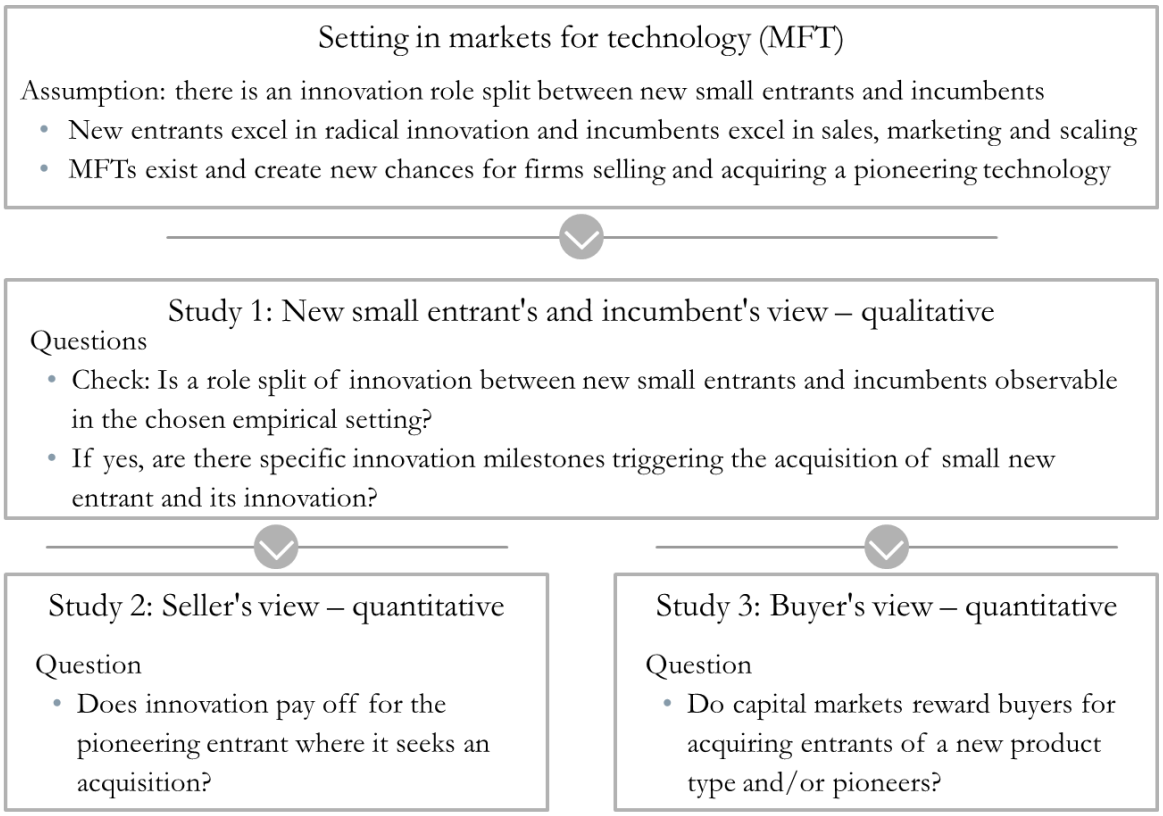
The convergent element across all three studies of my dissertation is to understand acquisition timing as a key decision behind any technology transfer in markets for technologies. In my first study, I start with a qualitative approach. The research objective here is to validate that the chosen empirical setting provides an innovation role split between small new entrants and incumbents which is necessary to observe technology acquisitions. More importantly, I explore *which* factors and milestones have an influence on timing-related decisions behind such acquisitions. The study is based on eight interviews, two panel discussions, two fireside talks, a keynote speech as well as two case studies. Concretely, the research question of my

first study is: are there specific innovation milestones triggering the acquisition of small new entrant and its newly developed product?

The research objective of the second study is to better understand how the *sell-side* of such technology acquisition is affected by the identified relationship between innovation milestone achievements and (the timing of) acquisitions. In a joint effort with Joachim Henkel (TUM) and Ariel Dora Stern (Harvard Business School), I take the perspective of a small new entrant which passes innovation milestones for a new product type and sells it to a big established firm. My research question here is: as a small new entrant, is it advantageous to be early to market with a new product? With regard to acquisition likelihood, I ask whether earlier market entry by a small new entrant is positively associated with its acquisition likelihood. With regard to acquisition timing, I ask to what extent the acquisition hazard of a small new entrant increases at points in time when the innovation risk essentially drops – this should be the case when the general technology risk, the general market risk, and ultimately the firm-specific technology risk decreases. Lastly, I ask if – conditional on an acquisition – pioneers have to wait longer for acquisition after market entry.

The research objective of my third study is complementary to my second study: I come from the *buy-side* of such technology acquisitions and take the perspective of the incumbent which acquires a small new entrant for its technology. I ask similar questions but from a different perspective: as an industry incumbent, is it advantageous to *acquire* an entrant which is *early* to market? I ask whether capital markets *generally* reward buyers for acquisitions of entrants which obtain a new product type. Moreover, I ask whether capital markets *specifically* reward buyers for acquisitions of one of the pioneering entrants within a given new product type. Methodologically, this chapter is based on a (quantitative) event study. An overview of all my research questions is provided by Figure 1.

Figure 1: Overview of research questions



1.3. Structure of the dissertation

My dissertation consists of three studies and is structured as outlined in the following. Chapter 2 focuses on the determinants for acquisition timing in the medical device space. I start with providing an overview of my (motivation for) qualitative research in the technology-acquisition space (2.2.1.), and with outlining why I choose the medical device industry as the empirical setting for my study (2.2.2.). I continue with briefly overlooking all different elements of my qualitative research (2.2.3.). Next, I discuss results and derive characteristic patterns of an innovation role split (2.3.1.) and acquisition timing (2.3.2.). Finally, I end with summing up findings and limitations, and I translate my findings into a forecast of necessary future research (2.4.).

Chapter 3 provides empirical evidence on pioneer (dis-)advantages from the seller's perspective in markets for technology. In joint work with Joachim Henkel and Ariel D. Stern, I given an introduction (3.1), provide the theoretical pillars of first-mover (dis-)advantages, and project them into a setting in which MFTs exist (3.2.). Next, I develop a conceptual framework and a (sub-)set of two streams of hypotheses (3.3.). In 3.4. and 3.5., I provide

context on the industry, the empirical setting, data, and methodology before the given hypotheses are tested in a quantitative study (3.6.). Lastly, I end with implications for acquisition literature and management (3.7.).

Chapter 4 comes with exploratory insights on the value of acquiring a pioneer in markets for technology. Similar to chapter 3, I start with theory around the valuation of new product innovation and (technology) acquisitions (4.2.1. and 4.2.2.); this also includes a discussion to which extent the acquisition of targets with a new product type may be associated with extra returns for the respective buyer. After a glance at the empirical setting (4.3.), I discuss the quantitative results of my event study (4.4.), before I conclude with general implications and limitations (4.5.).

In chapter 5, the main insights of all three studies are converged, and I discuss contributions for acquisition research and management. Also, I outline implications on future paths of research.

2.The timing of acquisitions in markets for technology

The present study explores timing-related decisions behind technology acquisitions. Such acquisitions occur whenever a small new firm is purchased by one of the large, established incumbents for its technology. Deciding when to buy a firm that developed a new technology is a difficult trade-off for the future owner. On the one hand, delaying an acquisition may reduce the risk of the innovation failing after acquisition; on the other hand, waiting too long may increase the risk of being pre-empted by a competitor or getting access to a novel product type too late. I conduct qualitative research based on eight interviews, two panel discussions, two fireside talks, a keynote speech, and two case studies. I choose the medical device space as a high-tech environment because there seems to be a complementary innovation role split between small new entrants and incumbents and, as a consequence, a lot of technology acquisitions happening. With regard to acquisition timing, I learn that potential buyers of a new product seem to watch out for specific innovation milestones which indicate that the targeted small new entrant has de-risked its new product innovation. In particular, *one* major milestone which indicates market access and a drop of technology risk seems to be a specific trigger point for (the timing of) acquisitions. This aspect of timing of acquisitions is new to M&A research which, so far, has been focused on explaining factors such as target firms' maturity, buyers' M&A routine, or M&A market waves. Thus, I suggest to perform further (quantitative) research on this phenomenon. In this regard, the U.S. medical device industry might be a particularly well suited setting because specific innovation milestones are objectively observable and comparable across firms.

2.1. Introduction

Scholars like Allain et al. (2016) have noted that the timing of technology transfer between small new entrants and big established incumbents is not only essential for companies' individual success, but also for social welfare. Considering that firms should own an innovation at a stage where they are most efficient, they state that small new entrants should cover the early-stage of new product innovation. In contrast, incumbents should take over in the final stage of product development, commercialization, and downstream activities (compare e.g., Arora et al. 2001 or Allain et al. 2016). If the transfer happens too early or too late this can increase costs of innovation, but it can also drive down the level of innovativeness of an entire

industry. Allain et al. (2016) concentrate on the competition among buyers as an explaining factor for the timing of such technology transfer[2].

In my study, I pick up the threads of Allain et al. (2016) looking at the timing of such technology transfers but I shift the research focus: I keep looking at determinants for the timing of such technology transfers, but from the perspective of the sell-side's achievement of a string of milestones along the innovation process rather than from the perspective of the buy-side's competition. Focusing on specific trigger points is interesting because these milestones may help a new market entrant to proof a significant risk reduction of its novel product. Technically, I look at technology acquisitions which are more relevant in the given setting of medical devices as opposed to license agreements.[3] Building on the work of previous scholars, I define such acquisitions as incumbents buying innovative entrants for their technology and capabilities (Doz, 1988, Granstrand and Sjölander, 1990, Ranft and Lord, 2002, and Graebner and Eisenhardt, 2010, cited by Stein, 2017).

I conduct qualitative research based on eight interviews, two panel discussions, two fireside talks, and a keynote speech. Also, I construct two descriptive case studies. I learn that the timing of technology acquisitions critically depends on the question whether a target firm is able to reduce the technology and market risk of its innovation. I conclude that the milestone indicating a reduction of technology risk is *the* major trigger point for (the timing of) acquisitions – followed by another milestone which indicates a drop of market risk. Also relevant is the capacity of a small new entrant to reach these trigger points early or even first, and thus to pave the way for a new product type. Moreover, I learn from participants that the U.S. medical device industry, in particular, is well suited for further quantitative studies since specific milestones for the reduction of technology and market risk are clearly measurable and observable.

Focusing on a series of specific innovation milestones as trigger points for acquisition timing is new and goes beyond the work of Allain et al. (2016) but also of other scholars who

[2] Technically, Allain et al. (2016) do research on license agreements, which are more common in the pharmaceutical industry and where the incumbent acquires "just" the right to use or commercialize the entrant's new technology instead of acquiring the entire firm.

[3] Regarding which vehicle to choose for a technology transfer, there are indications that technology acquisitions are even more relevant than license agreements in high-tech fields outside of pharma. For example, in the given setting of medical device technologies, cross-firm data of an innovation history of more than 35 years reveals that acquisitions appear seven times more often than license agreements. For other high-tech industries like telecommunication (Ransbotham and Mitra, 2010) or ICT (Brueller et al., 2015), the importance of technology acquisition is also highlighted. Shi et al. (2012) provide an overview of studies of technology acquisitions in various other industries.

have been focusing on determinants for acquisition timing – such as overall M&A market waves (Carow et al. 2004), target firms' maturity (Ransbotham and Mitra, 2010), or buyers' M&A routine (Brueller et al., 2015).

I structure the remainder of this chapter as follows: first, I explain my motivation for qualitative research in the technology-acquisition space, and I outline the rationale behind choosing the medical device industry as my empirical setting; also, I introduce my three-sided, qualitative research approach. Next, I discuss results and derive characteristic patterns of an innovation role split and acquisition timing. I conclude with a summary of findings, give an outlook on the following chapters presenting quantitative research, and point out the limitations of my research approach.

2.2.Methodology

2.2.1. Motivation for a qualitative pre-study

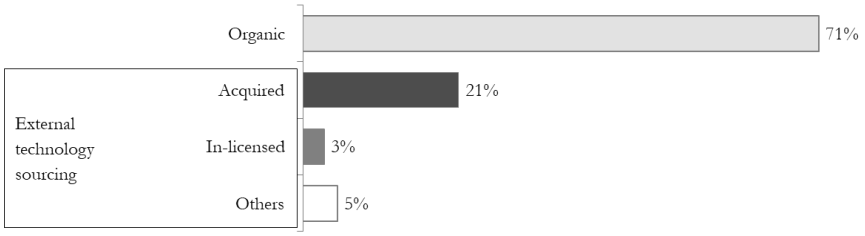
An essential precondition for empirical work is that researchers have a clear understanding of mechanisms, industry, and the broader environment that they choose for their quantitative work. By the given qualitative study, I try to identify concepts, patterns, and key parameters of the decision making behind technology acquisitions (in application of Punch, 1998). This includes not only acquisition variables such as target selection, deal value, date of acquisition, but also processes, governance, and stakeholders involved in an acquisition. An inductive research strategy can be a valuable starting point to create a theory based on real-world observations (compare e.g., Siggelkow, 2007). It is essential to understand the precise real-life context of the phenomenon which is subject to deeper empirical work (Yin, 2003) – i.e., industry environment, regulatory framework, or market entry barriers.

2.2.2. Empirical setting: Medical device industry

The medical device industry is very attractive for an empirical study of technology acquisitions: first, big and established firms such as Medtronic, Boston Scientific, Zimmer Biomet, Johnson & Johnson, Stryker, Philips, Siemens, or Olympus compete with innovative small new entrants across various medical specialties.

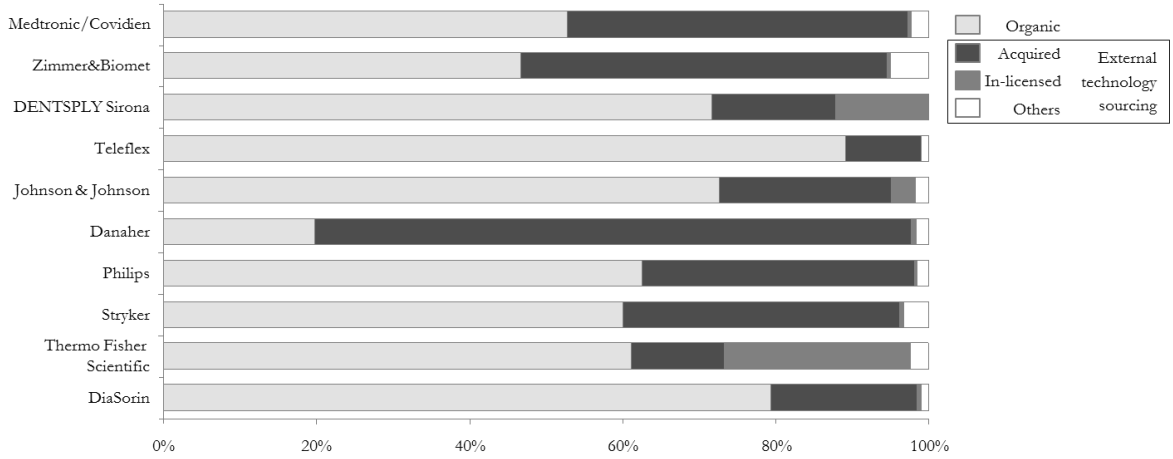
Second, there is a collaboration between big firms and small firms. Figure 2 shows that international medical device companies develop 71% of their product portfolio organically, while 29% are insourced as aggregated portfolio data suggest[4] [5] [6].

Figure 2: Source of innovation of medical device firms



The share of external technology sourcing is at an even higher share of more than 40% for some of the top 10 medical device companies[5] as reflected by Figure 3.

Figure 3: Source of innovation of top-10-medical-device firms



Both figures reveal that there seems to be a certain role split of the commercializing incumbent and the innovating new entrant, and a vital technology transfer is existent between both of these parties. Complementary to this observation is the fact that over 70% small new entrants with a new device type are acquired (details provided in chapter 3).

2.2.3. Approach: Three-sided, qualitative study

I apply a three-sided approach of qualitative research consisting of eight interviews, two panel discussions, two fireside talks, a keynote speech, and two descriptive case studies. Doing so,

[4] Analysis is based on portfolio data from Evaluate MedTech database. It included 961 medical device companies with regulatory approvals in the U.S., Europe, and Japan, and in the period between 1971 and 2017.
[5] By distinct counts of different device names.
[6] Others include distribution agreements and co-developments.

I incorporate multiple data sources into my qualitative research. Such an approach is commonly used in grounded theory and case study research (compare e.g. Merriam, 2009). Table 1 gives an overview of all three elements and provides details on participants, case study settings, and the selection rationale behind.

Table 1: Overview of qualitative research elements[7] [8] [9] [10]

Item	Method	Form	Role	Company focus	Position	Date (M/D/Y)	Time (min)	Topic/Field	Selection rationale
I01	Interview	Explorative	M&A advisor	Medtech (consulting)	Senior project leader	02/20/2017	30	Target selection, acquisition timing	Advised 5-10 acquisitions
I02	Interview	Semi-structured	Serial acquirer	Medtech (cardio.)	Head of business unit	02/20/2017	40	Target selection, acquisition timing	Company with 20-30 acquisitions over 5 years
I03	Interview	Semi-structured	Serial acquirer	Medtech (orthopedics)	Head of M&A	03/12/2017	40	Target selection, acquisition timing	Company with 20-30 acquisitions over 5 years
I04	Interview	Semi-structured	Serial acquirer	Medtech (imaging diagnostics)	Head of M&A	03/26/2017	40	Target selection, acquisition timing	Company with 5-10 acquisitions over 5 years
I05	Interview	Explorative	Acquired new entrant	Medtech (cardio-vascular)	Former founder, CEO	03/30/2017	40	Target selection, acquisition timing	Two product market entries
I06	Interview	Explorative	Regulator	Medtech	Director, medical services	06/21/2017	25	US/EU market entry regulation	>10 years of US/EU regulatory experience
I07	Interview	Explorative	New entrant	Medtech (cardio-vascular)	Founder, CEO	07/06/2017	30	Target selection, acquisition timing	One expected product market entry
I08	Interview	Explorative	Buyer	Medtech (imaging diagnostics)	Head of technology	07/26/2017	50	Target selection, acquisition timing	Company with 5-10 acquisitions over 5 years
K09	Keynote speech		New entrant	Biotech	Founder, CEO	02/03/2018	30	Creating a successful Medtech venture	One product market entry
P10	Panel discussion		Acquirers, entrants, investors	Medtech, biotech	Diverse	02/03/2018	60	Innovation in Medtech	Overview on innovation process
P11	Panel discussion		Investor	Medtech, biotech	Partner(s)	02/03/2018	60	Later-stage investments	More than 200 investments (collectively)
F12	Fireside talk		New entrant	Biotech	Founder, CEO	04/09/2018	45	First-mover advantages	One product market entry
F13	Fireside talk		Investor	Medtech, biotech	Partner	04/04/2018	45	Exit strategies, venture funding, proof of concept	100 - 200 investments
C14	Case study	Descriptive	Acquired new entrants	Cardiovascular				Acquisition timing	3 entrants, exemplary product code
C15	Case study	Descriptive	Acquired new entrants	Ophthalmic				Acquisition timing	4 entrants, exemplary product code

[7] Interviewees 4 and 8 have worked within the same firm, but took different roles at different times.
[8] Number of acquisitions (between 2011 and 2016) from Capital iQ (https://www.capitaliq.com)
[9] Number of investments from Thomson Venture Xpert (http://vx.thomsonib.com/)
[10] Any other information based on interview statements

I follow this multi-perspective approach in order to triangulate different views on the emerging research topic (Yin, 2003). In this attempt, I utilize different sorts of data including primary data from interviews (explorative and semi-structured) and panel discussions as well as secondary data from M&A- and product-data bases.

Interviews

I recruit three groups of stakeholders for my sample in order to get a comprehensive picture of technology acquisitions in medical devices. The first group is the buy-side (i.e., buying incumbents), the second group is the sell-side (i.e. small new entrants), and the third group is the industry environment (i.e., regulators). Interviews were conducted in English and German and in the time period between February, 20th 2017 and July, 26th 2017. Five of them were explorative interviews in order to generate new ideas and hypotheses. Three interviews were semi-structured in order to test my raising questions on the role split and timing of technology acquisitions. The questionnaire for semi-structured interviews is presented in Figure 4.

Figure 4: Questionnaire for semi-structured interviews

Questionnaire

Technology acquisitions in medical devices (medtech)

Background

- Research project on technology acquisitions in medical devices
- Chair for technology and innovation management at Technical University of Munich (TUM)
- Project is part of a broader research effort, with several projects in the field of technology acquisitions (ICT/AI etc.)
- What do we mean by "technology acquisitions in medech"? Large established medtech incumbents acquiring small technology-based medtech firms for their technology and capabilities – in focus:
  - Product-/device focus (NOT internal processing, supply chain etc.)
  - 100% acquisitions (NOT minority stake investments)
  - Decision-making *before/within* acquisition stage (NOT PMI-/integration phase)
- What are we keen to learn more about?
  - "Role split" between big companies vs. small/young companies in innovation process
  - (Different) types of technologies, products and devices concerned by M&A
  - Timing of technology M&A considering typical characteristics in medtech
- Current research in this field very explorative: Our approach
  - First step: Interviews with M&A heads and startups to catch practical views
  - Second step: Empirical analysis of large transaction/regulatory data set

Questions

1. **General Questions**
   a. *(Only if needed)* Could you briefly describe your role at XXX?
   b. Do you consider M&A as an alternative or substitute to internal R&D? Are some deals primarily to gain access to a certain technology (rather than to expand business geographically, to extend product portfolio etc.)? Is there any reasonable size-related threshold to distinguish technology acquisitions from any other acquisition type?
   c. How do "make-or-buy" decisions look like at your company? Ex-ante decision prior to new product development process? Or more driven by market opportunities?
   d. Does it happen that you have internal R&D that you know is competing with efforts by start-ups, and you acquire a start-up when the internal R&D is less successful?

2. **Innovation role split**
   a. In case you buy a technology, do you have a classification by which you categorize technologies acquired?
   b. From our experience in other high-tech industries, new product innovations and technology acquisitions can often be categorized into "performance" vs. "functionality", i.e.
      i. Performance-focused acquisitions: *Improve* 1+X product performance dimensions (= size, weight, reliability, speed, efficiency, error rate, throughput); medtech example: Buying new software fastening the cycle time of a diagnostic imaging device
      ii. Functionality-focused acquisitions: *Add* 1+X novel functionalities to a product (= add. technical feature, new materials, integrated solution); medtech example: Buying an IT solution to integrated/interlink all devices and instruments in the operating theatre

      What do you think? Is that applicable to your technology acquisitions in the past? Could you give us examples of clear-cut cases?
   c. Does this distinction – assuming it makes sense – correlate with the source of the innovation (in the sense of "users, doctors" vs. other founders)?
   d. Which of these/other technology types are more likely to be performed in-house? Which in-sourced by M&A? Where is the competitive edge of big/small firms especially in terms of user innovation etc.?
   e. (How) do you reflect this in allocating your M&A and R&D resources?
      i. Do you allocate M&A and R&D resources 100% similarly or differently regarding the above distinction? E.g.,
         1. 100% R&D budget → Improve a performance of exiting products
         2. 100% of M&A budget → Add new features/functionalities to products?
      ii. Or rather a contest between own R&D and start-up around same type of technology?

3. **Timing of technology acquisitions**
   a. Appreciating there is a lot of technology and market uncertainty around a new technology, how do you diminish these risks in your timing of an acquisition? Do you wait for certain thresholds to be successfully passed, e.g.,
      i. Regulatory approvals (mitigating technology risk)?
      ii. Reimbursement approvals (mitigating market risk)?

      Which one(s) from your experience is/are most important? (FDA/CE-mark, CMS approval …?)
   b. Referring to this, what is the most important reference point in timing of technology M&A? E.g.,
      i. Certain *life cycle stage* of a target company?
      ii. Certain *time period since or ahead of regulatory/market approval* of a target company?
   c. Is there somewhat an "optimal timing"?
   d. *(if applicable)* Timing of acquisitions dependent on technology type of acquisition?
      i. Same or different timing of performance-focused vs. functionality focused acquisitions? Why? (Considering ability to assess technological superiority, reimbursement mechanisms, speed of user/surgeon adoption etc.)
   e. Timing of technology acquisitions dependent on own R&D effort?

      Setting 1: Assume you buy a target "competing" with own R&D project
      i. Would you wait with M&A decision until own project has failed?
      ii. More broadly, is there any correlation between failure of own R&D project and timing of technology acquisitions?
      iii. What do you think about the following hypotheses?
         1. "If failed late, buy late-stage"?
         2. "If failed early, buy early-stage"?

      Setting 2: Assume you buy a target NOT comparable to any own R&D project
      iv. Does life cycle stage of underlying technology affect timing of M&A?
      v. What do you think about the following hypotheses?
         1. "If technology still in pre-dominant stage, buy early-stage"?
         2. "If technology in dominant/post-dominant stage, buy later-stage"?
   f. *(only if time allows)* Do other factors influence timing of technology acquisitions? E.g.,
      i. Domestic vs. international target company?
      ii. Founders' involvement into scientific research?
      iii. Competition on the buy-side and/or on the sell-side?

4. **Further suggestions**
   a. Questions we should ask, things we should study?
   b. Particular firms to look at?
   c. Certain people we should talk to?

I purposefully recruit participants heterogeneously in terms of the group of stakeholders they represent, but homogeneously in terms of their knowledge and experience in the relevant area: regarding participants from the buy-side, I talked to heads of M&A of incumbents

which, in total, completed more than 60 acquisitions over the last five years[11]. Regarding participants from the sell-side, every of the founders of small new entrants whom I joined for fireside talks or keynote speeches has launched at least one new product successfully. Regarding participants from the venture capital side, investors look back on a cumulative deal experience of 300 to 400 acquisitions. Regarding the regulatory participant, the director of medical services whom I interviewed at a big regulatory body has more than 20 years of experience of medical device approvals in Europe, but is also knowledgeable about the U.S. regulatory system. Analyzing interview results, I build on the approach of Gioia et al. (2013). I categorize answers along the dimensions of my questionnaire, and aggregate statements in three clusters: innovation role split between small new entrants and incumbents (2.3.1), acquisition timing (2.3.2), and additional findings (2.3.3). Opinions of all these people help me to develop a sharp, granular background for future quantitative work around technology acquisitions in medical devices.

Panel discussions, keynote speeches, and fireside talks

Beyond interviews with individuals, I participated in panel discussions, a keynote speech, and fireside talks. This approach is to test whether interviewees' insights can be validated by representatives of a greater population in the same field. Therefore, I joined five appointments in the greater Boston area, a top node for medical innovation, over the time period of February 3rd 2018 to April 5th 2018 and listened to various senior executives such as medical start-up CEOs, venture capital financiers, and serial acquirers.

Case studies

The two cases in the present study are descriptive and investigate the verbal statements around technology acquisitions within a real-life context. They help to elaborate findings from interviews (in adaption of e.g., Patton, 1990, Punch 1998, Yin 2003) when focusing, in particular, on the timing of technology acquisitions.

Concretely, I dive into the cases of small new entrants in the two spaces of 1.) Ventricular Assist Devices (VAD) and 2.) Excimer Laser Systems (ELS). I apply four systematic criteria to come up with this selection: first, I focus on the medical device industry in the United

[11] In 2011 to 2016

States because the regulatory environment allows to get a comprehensive picture of all successful new entrants of a certain product category. In this regard, I make use of the fact that for the U.S. market any new medical device product is registered and classified by a single institution, the Food and Drug Administration (FDA). Thus, the full landscape of new market entrants can be observed (compare e.g., Stern 2017). Second, I focus on so called PMA-approved devices. These devices represent implantable and/or life-sustaining devices such as ankle prostheses, catheters, or bone sonometers, and they are usually associated with high-technology innovations. Third, I focus on PMA product segments whose FDA approval statistics indicate a high level of activity of new, small entrants[12]. Fourth, I choose the two cases from different medical specialties in order to enhance the validity of outcomes – in explanation, case 1 is situated in the cardiovascular space, while case 2 is situated in the ophthalmic space.

2.3. Results

2.3.1. Innovation role split

The role of incumbents

Big firms seem to have a competitive advantage in commercializing new products and rolling them out rapidly across markets and geographies: "Look, we are a publicly traded company and we make our money on sales. So we have to be able to sell. We are doing little R&D. We are changing colors from blue to red, but there is very small and incremental change on our products." [interviewee 05 who cites a CEO of a big medical device firm]

A major share of R&D resources seems to be allocated to product improvements and portfolio maintenance rather than on radically new innovations. An advisor very familiar with the M&A and R&D strategy of large medtech firms highlights that "it already causes [incumbents] a lot of effort to maintain the existing product portfolio. There are various regulatory requirements out there and tons of different formats associated with it. So, [product] updates of the portfolio bind a major share of [incumbents'] time and R&D budget." [interview 01]

This idea is supported by the analysis of one of my interviewees working at a medical device incumbent. He looked into new product introductions in the U.S. market for orthopedic devices and compared the number of substantially new approvals of large international

[12] A small new entrant shall be a firm which is *new* to medical devices and *focused* on one product (family).

firms with their number of supplementary or incremental approvals[13]. As a result, he finds that large firms have tens or even hundreds times fewer new approvals than supplementary or incremental approvals. [interview 03] Knowing that supplementary approvals come with a third to a fifth of the costs of an original approval (compare FDA, 2003), incumbents seem to spend a higher share of R&D budgets on supplementary innovations and portfolio maintenance.

Consistent with this, capital markets seem to require big firms to go for less risky R&D projects with highly predictable outcomes and revenues. The same incumbent-related interviewee says "publicly listed companies face a huge pressure in terms of what comes out of their R&D budgets… [it forces these firms] to bring products to markets with a rather manageable [R&D] risk.." [interview 03]

The role of small new entrants

In reverse, small new entrants seem to have a competitive advantage over big firms in coming up with radical innovations. Small new entrants are less complex in terms of organization structures which allows time advantages in the development and approval process. An advisor familiar with the R&D strategy of incumbents and start-ups states that "start-ups are more agile in terms of how they generate idea and how they can run clinical trials. They obtain a higher flexibility in how they approach the regulatory approval process, and this helps them to come up with truly innovative stuff. Let's take stethoscopes as an example – these devices carry a relatively low risk, because they are non-invasive to the patient. Developing such a product, the start-up's approach would simply be to search for two doctors who were willing to apply it – instead, the incumbent's approach would take a different strategy that minimizes any risk that you could think of: they might not do it [i.e., running an in-field trial of the stethoscope], because their medical affair department has concerns since patient involvement is needed [even if the technology is non-invasive]." [interview 01]

Moreover, small new entrants are more likely to find unconventional new ways to convince users to apply a new technology (here: patients or hospital surgeons who trial new medical technologies). For example, one of the interviewees at a successful small new entrant reports how the management team relieved patients from any bureaucracy during the process

[13] These data are publicly available at the U.S. Food and Drug Administration (FDA).

of clinically trialing a new product: "so they [patients involved in the clinical trial] are involved in these, what we call 'recruitment centers'. On our website… one of the things we are doing is to support patients while on that endeavor, is to provide a series of different support services to those patients in the clinic. The service team for patients that is placed in our offices … can actually help patients with identifying when they want to go for a certain treatment. It was also providing anxious support actually … to get flights and accommodation …" [keynote speech 09]

Mutual incentives for an acquisition

In a high-tech industry such as U.S. medical devices, technology acquisitions can be the connector between these different roles and strengths of incumbents and small new entrants. They allow both parties to collaborate and to benefit from the strengths of the other party. Gans and Stern (2003) outline the benefits for both parties involved in a technology acquisition, the small new entrant and the incumbent: most importantly, an acquisition drives down the level of competition in the product market, and it prevents both parties from duplicating (R&D- and downstream-) resources. An example of such an acquisition is given by one of my buy-side interviewees who thinks back of an innovative start-up which they acquired several years ago: "The product [of the start-up] was a massive break-through. We acquired the firm for particularly this product." [interview 03]

For big incumbents, the incentive to acquire an innovative entrant is relatively easy to understand. In an industry where usually a few big players fight for segmental leadership it is crucial to get access to new technology: "Someone has to bring something through. If you bring something through, then –and there are not many things coming through– we will buy. Someone [any of the incumbents] will buy it. If it is not me, then another incumbent is going to buy it. And then we have to compete against it. So, then that is the bidding war." [interview 05] In these cases, it may also have an influence on the timing of such acquisitions that buyers, among each other, try to preempt the other side from getting access to a new technology.

For small new entrants, it needs a bit more elaboration to understand the incentive of becoming acquired. The result is similar though: technology acquisitions are also beneficial also for the self-selling venture because acquisitions are often more attractive than product markets. Most importantly, small new entrants seem to be dependent on the complementary assets of big firms in order to scale up their innovation. From the standpoint of a new market entrant whose product had recently received FDA approval, one of the participants argues

that "… [the collaboration between incumbents and small new entrants] is a win-win situation, because – in turn – it prevents us from duplicating resources necessary to reach all these customers." [fireside talk 12] So, at a stage where small new entrants usually do not have the resources to convince thousands or millions of end customers to buy their product, they "only" have to convince a *single* corporate buyer in the market for technologies – and buyers are often willing to pay attractive prices. In this regard, a venture capitalist among my participants judges from his investment experience that "[firm value to revenue] multiples of large cap companies may be somewhere in the 4-5 times… instead, some of the *smaller* companies (that have 20-30% growth profiles) get valued at up to 7, 8 or 10 times revenue. We absolutely see the hunger for growth. There is value arbitraged that both, we as investors, but also the entrepreneurs, can absolutely achieve, if we can capture companies that will be growing at those [double digit] rates and those companies will ultimately be acquired by the large incumbents." [speaker in panel discussion 11]

Moreover, the market for a specific technology often leaves room for more than one acquisition target. In case of promising new product types, there often is a run of incumbents for a limited amount of available acquisition targets. An M&A-experienced advisor among the interviewees refers to acquisitions in the specific context of new therapies against Hepatitis C: "Gilead acquired Pharmasset which, as an acquisition target, obtained the best and likely most valuable break-through technology. However, there were also start-ups with a similar technology. They were the second or third best – and all of them got acquired in billion-dollar deals." [interview 01].

2.3.2. Acquisition timing

Acquisition timing as an instrument to reduce technology risk

Acquisition timing can determine the amount of technological risk inherent in the entrant at the time of acquisition. That is particularly true in any case where (the reduction of) technological risk is clearly indicated by specific milestones along the innovation process.

In the context of U.S. medical devices, such a specific milestone indicating a drop of technology risk of a new product is the regulatory approval. The U.S. Food and Drug Administration (FDA) is the single institution to judge whether a new medical device is safe and effective – and so, whether the technology risk is sufficiently low. Only in case of an FDA approval, products are allowed to be marketed in the US. FDA is not only relevant for new product developments, but also for new product components, such as WiFi, Bluetooth, or

tracking functions[14]. Thus, *not* receiving FDA approval by itself represents a process risk which goes beyond the technological risk of a new product. The founder of an acquired small new entrant stresses that, once a firm has established a new FDA product code, this lowers the technology uncertainty also for potential followers: one of my interviewees recapitulates the strategy of a small new biotech entrant which got FDA approved soon after the first-mover had established the FDA product code. He says that the follower firm was thankful to the pioneering firm, because they could more or less go through the same FDA regulatory pathway which the first-mover firm had established shortly before [interview 01]. However, the approval process remains lengthy: "…once you get through [with an entirely new technology], then everybody else would have to go through this regulatory hurdle [the same approval process with similar clinical trials etc.]" [interview 05]

FDA approval does not only signal the reduction of product-related risk; it is also associated with the reduction of production- and process-risk of the corresponding manufacturing facilities. Looking back on his experience as a small new entrant getting FDA-approved with a new device type, one of the participants states "we are now being able to not only get a first approved product, but a first approved facility and go through" [keynote speech 09]

However, the *timeline* to get FDA-approved for a new product type is uncertain. The same interviewee continues to say "…the PMA process is highly variable. There is very little predictability to say which one it is going to be when the process starts… The average [i.e., time until PMA approval] is around 10 to 15 years. But the problem is the variances. So it does not help the person [i.e., the start-up] to come through." [interview 05]

Deciding on acquisition timing from a buyer's perspective, the FDA approval of the targeted firm seems to be a trigger point for incumbents to acquire this firm – indicating that the technology risk of a new product has dropped. One of the interviewees looks back on his experience becoming acquired by an incumbent and recaptures the position of the buy side: "we [as the acquiring incumbent] need to sell a product. We cannot pick that up because [before the target firm got FDA approval for its device] we are prohibited by law from selling the device. That is the FDA. You [as a small new entrant] have to have the regulatory approval, before you go to the market and sell it. … Once you got it through the FDA clearance we are looking to buy it on the other side" [interview 05]. In a similar way, a buy side-related

[14] Confirmed by one of the interviewees who works at a small new entrant on an additive feature for an existing product type in the cardiovascular space [interview 07].

interviewee states that "we acquire products that are fully developed. In very rare cases we acquire at an earlier stage" [interview 02].

Deciding on acquisition timing from a seller's perspective, small new entrants seem to take into account the strong signaling effect of FDA approval towards buyers. Concretely, it does not seem optimal for small new entrants to sell their technology long before the technical risk is reduced (and FDA approval is gained) – at least if they are confident about the success of a new technology. "We believe being acquired at this point in time [i.e., before FDA approval] would not pay us the price this technology is worth" [fireside talk 12]

Deciding on acquisition timing from an investor's perspective, the FDA approval seems to be a trigger point for venture capitalists to exit small new entrants. Any activity after the approval (i.e., commercializing and scaling up a new product innovation) requires massive capital and would be a duplication of the incumbents' sales and distribution channels. To avoid this inefficiency, many investors focus their capital spending on the phase prior to FDA approval. A founder of a new biotech entrant recalls his experience with financiers at times when his firm received FDA approval: "Ultimately, it's about the cost of capital. … You keep raising money to go do the clinical trials. You organize that way and the venture guys are fine with it. That's great, but most venture guys are going to want to exit around that time a portfolio firm receives FDA approval" [fireside talk 13]

Acquisition timing as an instrument to reduce market risk

Acquisition timing can determine the amount of market risk that a buyer faces when targeting a new technology. The reduction of a new technology's market risk is driven by two factors: one driving factor is the user adoption which is a steady process over time. Another driving factor is a specific event or trigger point which lead to a discrete jump of demand for a new technology.

These trigger points or "market shocks" can be observed in many high-tech industries. For example, governments may decide to accelerate the market adoption of certain new technologies by directives or subsidies (e.g., solar energy, electric vehicles). For the specific case of innovations in healthcare, reimbursement decisions of big insurance companies can positively affect the (speed of) market perception.

In the case of U.S. medical devices, such a "shock" that leads to a rapid reduction of market risk of new medical devices is the reimbursement decision of the U.S. Center for Medicare and Medicaid Services (CMS). CMS decides if a new reimbursement scheme is

created for a newly developed medical device; and thus, whether the corresponding treatment of millions of U.S. patients is sufficiently reimbursed.

Having reduced the technology risk of a new technology (by FDA approval) it is still a lengthy path to reduce the market risk (by CMS coverage). The former CEO of a small new entrant confirms that "as long as you do the same thing like 'A' you will get this reimbursement and the same rate like 'A'. If you go with a new product that is superior, then it is not the same product like 'A'. Now we have to request a new reimbursement. That takes a process of another two to five years. So you might get business much later." [interview 05] Similarly, incumbents face the same hurdles when scaling up a new product: "There are huge [reimbursement] obstacles to overcome when we launch a new product. For example, [insurance companies] massively challenge new products on their [increased] medical use. Nobody is going to pay an extra bill of $5,000 dollars, if the new product does 'a little better' or 'equally well' – in other words, if the new product is just a facelift of an existing device." [interview 02]

Thus, it takes especially small new entrants a lot of their resources to get paid for a new technology: "Speaking about reimbursement coverage in the U.S. [CMS]: "… You have to find a way to get paid [and to] write CMS guidelines… [A] major part of our current activities is to change reimbursement … and payers want to talk about outcomes and costs … [they] don't care about technology … [they] want to see it's better" [fireside talk 12]

Potential buyers seem to wait with acquisitions of a new technology until they have a positive indication for general user adoption and specific reimbursement decisions. One of the buy-side participants argues that "customers in our industry [healthcare] are quite conservative. The more it takes [surgeons] to adopt and to apply a new technology, the longer we [incumbent] wait to acquire a new technology … some of them we acquired after five to seven years of market exposure." [interview 04]

Consequently, if a given new technology requires users to adopt their behavior to a new functionality, this may postpone the incumbent's decision to acquire this technology: "Any technology that requires a massive change of processes and user behavior – they are discussed in many nuances in our investment committee." [interview 04] Vice versa, if a given new technology "only" improves the performance of an existing functionality, the incumbent's decision to acquire this technology comes faster: "the technology that we acquired in this particular case [a component that increases the performance of an existing device] was not associated with a massive change of users' behavior [surgeons]. Thus, the acquisition was

not a major subject for our investment committee; it was approved quite quickly." [interview 04] In a similar way argues another an incumbent's representative on the buy-side: "risk aversion often wins when (such) an acquisition target is proposed to our management board." [interview 08]

Accordingly, potential buyers expect a minimum amount of revenues prior to acquisition which they see as an indicator for both, increasing user and market adoption: "we [incumbent] always try to acquire an approved product rather than an early-stage-technology. Our board is not interested in companies of revenues of less than $10-20 million. This naturally requires a certain target maturity." [interview 04]

In summary, timing of acquisition seems to play an important role aiming to reduce both, technology risk (FDA) *and* market risk (CMS) associated with a novel product of the acquired firm. Recapitulating how they got acquired, the former CEO of a small firm summarizes the concerns of the former buy-side: "It is very rare that we look at ventures before FDA clearance. Our sweet spot for company acquisitions: as soon as you get it [i.e., FDA approval] and if the sales ramp looks good (relevant is the right trajectory) then we will ask our doctors, whether they would buy it. And if they would buy it, we are going to buy you [i.e., the start-up company]." [interviewee 05 quoting a potential buyer of his firm]

Case examples from the cardiovascular and ophthalmic space

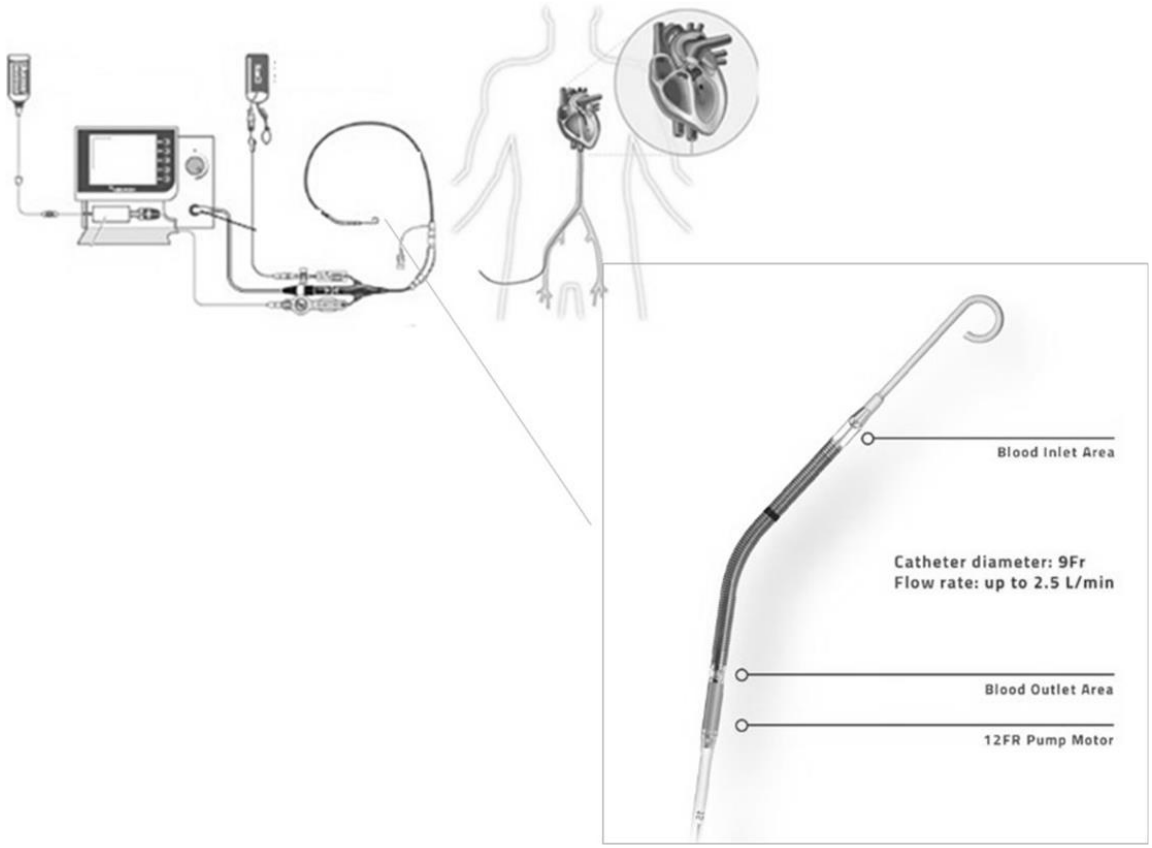
Regarding the timing of technology acquisitions, results from the two case studies are confirmative to the above mentioned, qualitative findings from interviews, panel discussions and fireside talks. In summary, it seems that the timing of acquisitions is related to the reduction of technology risk and market risk of a new product type

The first case example is situated in the cardiovascular device space and focuses on the FDA product category of so called Ventricular Assist Devices (VAD)[15]. Presented in Figure 5, VAD is a mechanical pump which offers significant medical benefits for heart disease patients while waiting for a heart transplant. Abiomed was the first company to be approved by FDA for its VAD technology in 1992; another small new entrant, Thoratec, followed shortly after (in 1994) within the same product code. Abiomed paved the way for VAD starting with clinical trials and ending at reimbursement stage. Afterwards, early followers like Thoratec were the first to merge with one of the industry incumbents in early 2001 and to

[15] FDA product code: DSQ

offer their innovation in the market for technology. The acquisition followed more than eight years after Thoratec gained FDA approval for its VAD technology.

Figure 5: Case study 1: Ventricular Assist Device (VAD)



Illustrations: Abiomed

A value that is in the same range like for a later follower, World Heart. The firm was FDA-approved for its VAD device in 1998 and acquired in 2007. None of the companies was acquired before the product category had been established by Abiomed gaining the first FDA approval for a VAD system. The innovation process of all three entrants is recaptured by Figure 6.[16]

The second case example is situated in the ophthalmic device space and focuses on the FDA product code of so called Excimer Laser System (ELS)[17]. Shown in Figure 7, the excimer laser is a large medical equipment which removes fine layers of surface with (almost)

[16] - Date of foundation from Bloomberg (https://www.bloomberg.com)
- Date of clinical trial end from PubMed (https://www.ncbi.nlm.nih.gov/pubmed/)
- Date of U.S. regulatory approval (PMA) from Evaluate MedTech database
- Date of U.S. reimbursement from Centers for Medicare and Medicaid Services (CMS)
- Date of acquisition from Capital iQ (https://www.capitaliq.com)

[17] FDA product code: LZS

no heating or change of the remaining layers of materials by emitting UV light. Therefore, it is ideally suited for various optical surgeries.

Figure 6: Small new entrants within the VAD space

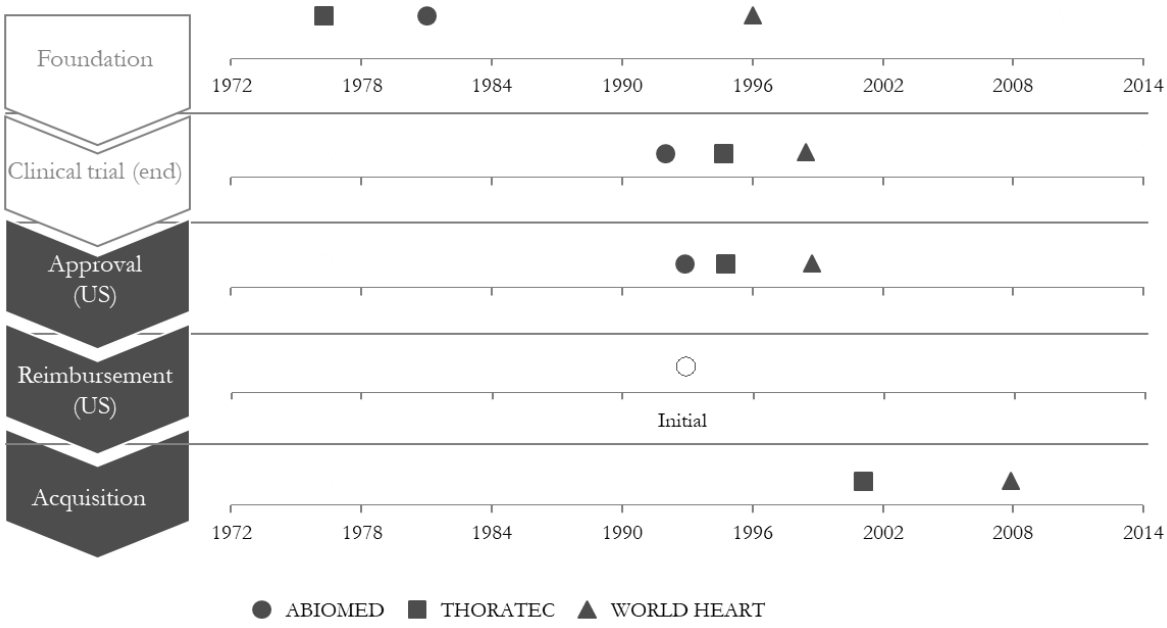


Figure 7: Case study 2: Excimer Laser System (ELS)

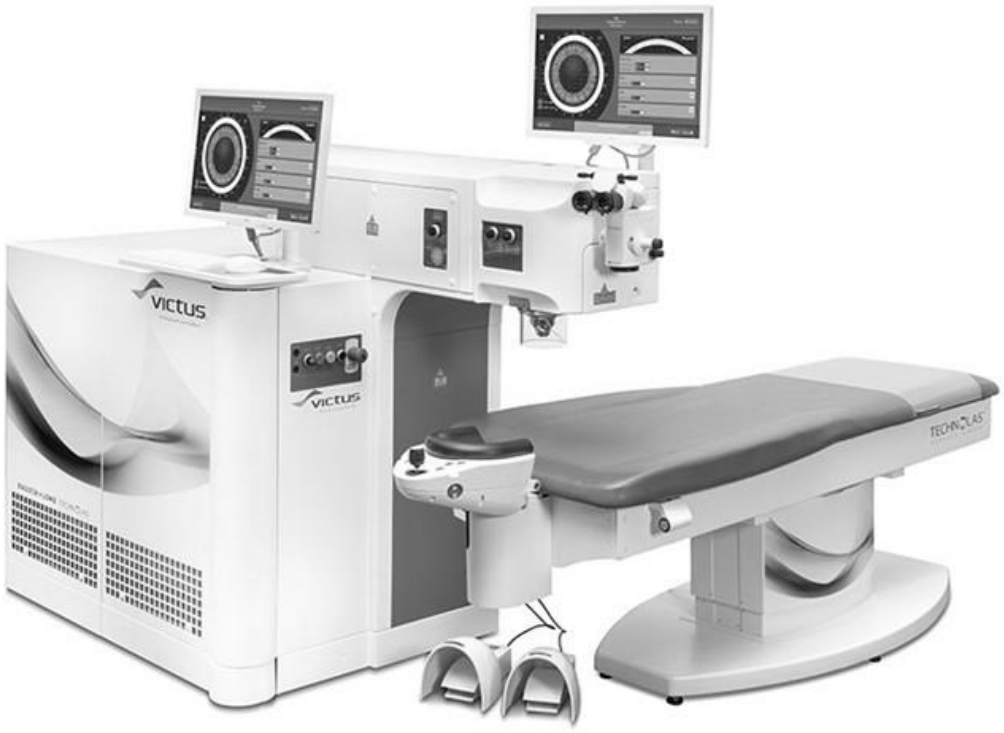
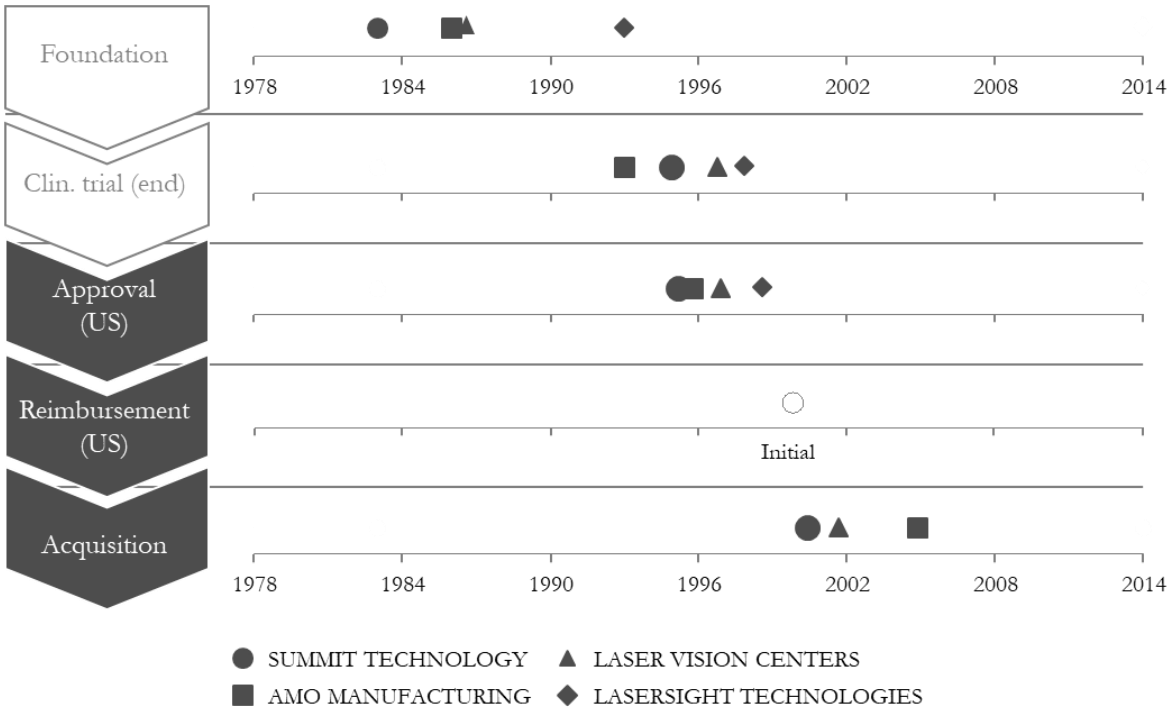


Illustration: Technolas Perfect Vision

Similar to the first case, a small new entrant (here: Summit Technology) pushed the new product category through all major milestones of the innovation process. Most importantly, Summit Technology was the first to reduce the technology risk of the entire ELS product category by its FDA approval in 1995. Moreover, none of the small new entrants in this segment was acquired before the technology risk (FDA) and market risk (reimbursement decision) had been reduced. The innovation path of all four entrants is presented in Figure 8.[18]

Figure 8: Small new entrants within the ELS space



Different from the first case example, the small new entrant which establishes the new FDA code in 1995 and pushed it through also other key milestones was also the first one to be acquired in 2000 – earlier than Laser Vision (2001) and Amo (2004). Consistent with the first case example, all of the acquired small new entrants sold their firm five to nine years after they had gained FDA approval.

[18] - Date of foundation from Bloomberg (https://www.bloomberg.com)
- Date of clinical trial end from PubMed (https://www.ncbi.nlm.nih.gov/pubmed/)
- Date of U.S. regulatory approval (PMA) from Evaluate MedTech database
- Date of U.S. reimbursement from Centers for Medicare and Medicaid Services (CMS)
- Date of acquisition from Capital iQ (https://www.capitaliq.com)

2.3.3. Additional findings

Some interesting side findings from the explorative and semi-structured interviews are presented in the following. They are not directly linked to the *timing* of technology acquisitions but they are likely to play an important role in the acquisition process.

Innovation strategy of small new entrants

Small new entrants obtain different options when they, ex-ante, have to decide on their innovation strategy – one of the interviewees distinguishes between trendsetters and fast followers: on the one hand, "there are trendsetters who establish new technologies and create new markets. They disrupt the existing [product landscape] – at this point in time, nobody knows whether the technology really works. On the other hand, there are fast followers. They follow a strategy which is 'the-second-mouse-gets-the-cheese'. They let the trendsetters do the work around product approval and user adoption and are fast to follow on his/her attempts." [interview 08]

Innovation contest between incumbents and small new entrants

Despite the fact that incumbents and small new entrants often seem to have different focuses and advantages along the innovation process, there can be overlaps in their R&D activities. This is the case when an incumbent and a small new entrant work on a similar R&D project at the same time. In such situations, the incumbent has a strong incentive to acquire the small new entrant (compare Henkel et al. 2015) – especially, if the target firm's technology is superior: "we [incumbent] develop new products internally if this is at the core of our technology. However, if we find a start-up in this field which clearly obtains a superior technology this start-up is very interesting for us [as a potential acquirer]." [interview 04]. In a similar way argues one of the big firm's participants whose internal R&D project on a particular product failed: "we [incumbent] had been doing a lot of own research in this particular product segment. It took us a long time and was not really successful. As a market leader in the overall field, we found ourselves soon in a position where we had to acquire this specific technology." [interview 02]

2.4. Conclusions

2.4.1. Summary and outlook

In summary, the medical device industry seems to be a typical example for a market for technology. I find that international medical device companies insource 29% of their product portfolio on average.[19] This indicates that there is a certain role split of innovation between incumbents and small new entrants: on the one hand, incumbents focus their internal R&D budgets on product facelifts and incremental improvements with a more predictable Return-on-Invest (RoI). Ideally, the RoI is easy to predict and to explain to capital markets at an early point in time. On the other hand, there are small new entrants focusing on more radical innovations. Such innovations often arise from unmet needs of patients and in the operating theatre. My interviews confirm that, in many cases, these new entrants are user-driven (surgeons, medical doctors) and much closer to actual demands than the incumbent. This makes it easier for them to come up with a disruptive innovation which is close to customers' needs (compare e.g., Chatterji, 2009).

Therefore, strong incentives exist for both incumbents *and* small new entrants to collaborate with each other: incumbents may need small new entrants because they need to complement their own (often incremental) R&D pipeline with more radical innovations. In turn, small new entrants are dependent on the sales and distribution channels of incumbents in order to scale up a new technology without an inefficient duplication of resources (a scenario that also financiers often want to avoid). These mutual interests cause a high acquisition activity in the medical device space, and also they are the necessary condition for research on technology acquisition.

An interesting field of research is the *timing* of acquisitions along the innovation process that small new entrants have to go through while they develop a new technology. The medical industry particularly in the U.S. is well suited for research because it allows to observe clear milestones along the innovation process and these milestones are comparable across firms. Interview statements suggest that achieving these milestones as an innovative young firm this has an effect on the acquisition likelihood and timing of this firm.

[19] Analysis is based on portfolio data from Evaluate MedTech database. It included 961 medical device companies with regulatory approvals in the U.S., Europe, and Japan, and in the period between 1971 and 2017.

The first and most important trigger point for acquisitions is the reduction of technological risk: For U.S. medical devices, this is the FDA approval which indicates that a new technology must be "safe and effective" at the time when it enters the U.S. market. The second trigger point for acquisitions is the reduction of market risk. For U.S. medical devices, this is indicated by the CMS's decision on reimbursement coverage which ensures that insurance companies and payers compensate for the treatment by a new device.

Both events, FDA and CMS, are trigger points for incumbents to acquire a small new entrant. Many of the interviewees highlight the importance of the FDA approval over CMS coverage. A potential explanation for this prioritization might, again, be the complementary profile of strengths of incumbents and small new entrants: incumbents have a competitive advantage in commercializing new products, while small new entrants are more efficient in generating substantially new technologies. Consequently, many buyers may at least want to wait until the targeted small new entrant has earned FDA approval and, thereby, proved that its technology was safe and had market access. In other words, if any sort of risk is acceptable, incumbents might rather accept market risk than technology risk because they can utilize their own relative strengths in marketing new products in order to neutralize this risk.

2.4.2. Limitations

Given the focus and size of my sample, this study faces two considerable boundaries. First and with regard to the scope of industry, the external validity of results is limited. I choose the U.S. medical industry as the empirical setting of this study because it bears the advantage that environmental factors (such as regulatory approvals, reimbursement decisions) are consistent and comparable across firms. However, these factors are different for other industries; this has to be taken into account when transferring the given findings to other industries.

Second and with regard to the sample size of 15 research items[20], internal validity is limited even if any attempt is taken to derive non-subjective results. For example, I choose participants for this study from various backgrounds (buy-side, sell-side, investors, regulatory bodies), I utilize different interview formats (classical interviews, panel discussions, fireside talks), and I triangulate verbal outcomes with two descriptive case studies. Therefore, quantitative research will is necessary to increase the objectivity of empirical results.

[20] 15 qualitative research items consist of eight interviews, two panel discussions, two fireside talks, and a keynote speech, as well as two descriptive case studies.

3. Pioneer (dis-)advantages in markets for technology[21]

This study sheds new light on first- and early-mover advantages. Research on this classic topic often assumes that each firm participates in the entirety of the innovation process and that all firms aim to monetize their innovations in product markets. However, a division of labor between innovative new entrants and industry incumbents, endowed with complementary assets, is common in many industries. Such settings are distinct because new entrants have the additional option to sell their innovations in a "market for technology" and may therefore seek acquisition rather than shepherding a product through the entire commercialization process. We argue that this binary outcome – i.e., success via acquisition – creates different opportunities and threats for new entrants and has important and novel implications for the question: is it advantageous to be early to market? Using data from the U.S. medical device industry, we find that pioneer (dis-)advantages in a market for technology setting are similar to those typically seen in product markets, but different in some important respects. In particular, pioneers must pave the way for a new product type in order to reduce the technological and market risks, where reducing technological risk is of paramount importance. As a reward, pioneers ultimately realize a higher likelihood of acquisition, but among acquired firms, early entrants wait longer to be acquired. To a certain extent, therefore, later movers can free ride on early-movers' efforts: although they are less likely to be acquired overall, acquisitions of later entrants happen more quickly.

3.1. Introduction

The question of when and how to enter a new market is central to a firm's innovation strategy. Scholars have identified a number of advantages and disadvantages to being a first-mover (Liebermann and Montgomery 1988 and 1998, Kerin et al. 1992, VanderWerf and Mahon 1997, Suarez and Lanzolla 2007). While this body of research has greatly improved our understanding of the (dis)advantages of early entry into new markets, existing scholarship often

[21] This chapter is based on a joint working paper with my co-authors Joachim Henkel (Technical University of Munich) and Ariel Dora Stern (Harvard Business School). As the first author of this paper, I initially came up with the idea to do research at the edge of First-Mover Advantages and Markets for Technology. Also, I drafted the first overall version of this paper. Moreover, I designed and conducted the quantitative analysis including an outline of the methodology, data collection, sampling, and regressions. Also, I negotiated with the data base providers in support of this study. In this regard, my special thanks go to EvaluateMedTech (EMT) which generously provided regulatory and product data for this chapter.

implicitly assumes that each firm participates in the entirety of the innovation process and that all firms aim to monetize their innovations in (emergent) product markets. Instead, in many cases, pioneering small entrants have an additional path for realizing returns on an innovation: a small firm can also sell its innovation to an established firm (Granstrand and Sjölander 1990, Gans and Stern 2003).

There may be gains from such a division of labor in the innovation process, with smaller firms playing a greater role in early-stage innovation, and larger firms specializing in later-stage activities (Arora et al. 2001). For example, early scholars such as Schumpeter (1912) have noted that pioneers (i.e. first or early-movers to enter a new product market) are often new and/or small entrants (i.e. firms not previously established in that industry) (Scherer 1980, Teece 1986, Christensen 1997). Importantly, incumbent firms are likely to already have expertise in activities such as sales, marketing, manufacturing scale-up, and distribution in final product markets (see e.g., Teece, 1986, Christensen, 1997). Indeed, intermediate "markets for technology" (MFTs) are common, and scholars have described them in industries ranging from pharmaceuticals and chemicals to semiconductors, software, and telecommunications (e.g., Arora et al. 2001, Angell 2004, Higgins and Rodriguez 2006, Warner et al. 2006, Ransbotham and Mitra 2010, Brueller et al. 2015, Henkel et al. 2015, Allain et al. 2016).

The primary contributions of this study to innovation strategy research is to outline a novel way of evaluating questions of early-mover advantage vs. disadvantage when the primary option to monetize an innovation lies in selling that innovation in an MFT rather than in a final product market. In doing so, we bridge the gap between the literature on first- and early-mover advantages and the literature on MFTs. Factors specific to the MFT context include information asymmetries between potential transaction partners, firm risk preferences, and the linkage of complementary resources. Additionally, the resolution of technological uncertainty should be more important in this context since acquisitions can (but need not) happen before the target's technology has reached product market maturity. Finally, in a setting where the originator transfers its innovation to an exclusive buyer by being acquired – a frequent situation, and the one we focus on[22] – the main outcome becomes binary: either the

[22] Besides acquisitions, the innovator firm can also sell unit licenses or distribution agreements of its technology to potential buyers. However, our empirical analyses focus on company acquisitions, which by far represent the majority of cases of MFT medical device transactions. Indeed, when cataloging different forms of collaboration between large and small medical device firms in the period from 1971 to 2017, we can trace 73% of all insourced

innovator firm experiences acquisition or it does not. We consider these factors in particular, since they are specific to our setting of interest. Other factors that have been shown to influence early entrant advantages in traditional product markets include advantageous market positioning, higher switching costs of customers, lock-in effects, cooperation with desirable partners, and higher technological and market uncertainty. All of these traditional factors continue to be relevant in our context, to the extent that an early-mover position in an MFT coincides with early entry in the corresponding product market.

Accordingly, we aim to understand pioneer (dis-)advantages in a context where an innovator firm seeks acquisition, and where potential buyers are equipped with superior resources for product market sales and other later-stage commercial activities. Specifically, we ask two questions: first, with respect to acquisitions, is it advantageous or disadvantageous for small new entrants to be pioneers in an MFT setting? Second, how does being a pioneer relate to the timing of such technology acquisitions? Since a small new entrant will typically lack the complementary assets required to successfully commercialize an innovation, it is likely that being acquired and being acquired earlier are desirable outcomes for such a firm. In our results section we provide empirical evidence that supports this reasoning.[23] Thus, given that 1) being acquired, 2) being acquired earlier, and 3) realizing a high price of acquisition are desirable outcomes for a small new entrant, studying these outcomes in an MFT setting can inform both a theoretical and empirical interpretation of the implications of early market entry as it relates to pioneer advantages and disadvantages in MFTs.

Our empirical setting is the U.S. medical device industry. We assemble a comprehensive dataset covering all high-risk medical devices that came to market over a roughly 25-year period. This context is particularly appropriate for a study of first-mover advantages, since the emergence of new, product-specific, (independently) regulator-defined product categories allows for a clear observation of entry order, and detailed administrative data facilitate precise identification of the date of market entry for each product. Combined with a newly-assembled dataset of medical device firm and product acquisitions, we are able to reconstruct detailed product histories and timelines for each device and innovator firm in the sample. Consistent with theoretical considerations regarding R&D-intensive settings, robust MFTs

technologies to a company acquisition, while only 11% correspond to technology licensing, and 16% to distribution agreements (analyses based on data from Evaluate MedTech).

[23] A comparison of acquisition prices with the comparatively small revenues of new entrants that are not acquired lends support to the view, although endogeneity issues prohibit a causal interpretation of this finding.

characterize the medical device industry, and the division of labor between innovative entrants and established companies manifests itself in frequent acquisitions of small firms by larger industry incumbents.[24]

We define small new entrants, based on two characteristics: they have fewer than five years of high-risk device experience in total, and a very small portfolio of previous products (no more than one).[25] We distinguish small new entrants by their entry timing, defining the "earliness" of entry based on elapsed time since the establishment of a product category. Thus, "early" market entry is defined relative to the establishment of a product type, rather than as a discrete function of entry order or an arbitrary cut-off. Using this variation allows us to learn from the empirical data, while building on hypotheses that are based on considerations about elapsed time since key events, rather than *ad hoc*, discrete cut-offs (which have the potential to be arbitrarily and/or incorrectly defined).

We find that for small new entrants, being a first or early-mover (a "pioneer") in a new product category is associated with a higher likelihood of acquisition, a desired outcome for such firms. Furthermore, survival analysis shows that the hazard of acquisition increases significantly at the specific point in time when the U.S. Food and Drug Administration (FDA) establishes a new product category for the type of device under consideration. This event signals a discrete and publicly observable reduction in the general technology risk of a new product type, and sends a positive signal to potential technology buyers regarding the product's technical viability. In other words, the event facilitates the technology transfer for this specific product type by a concrete reduction of uncertainty (compare Gans et al. 2008). Inherently, this milestone has to be achieved by one of the pioneers. Among acquired firms, we find that pioneers' acquisitions occur at a later stage of the firms' life cycle.[26] Considering alternative explanations for the later acquisitions of pioneers, we compare their acquisition prices to those of later entrants, but fail to find any evidence that small new entrants in this setting can expect higher exit prices in the case of later acquisitions.

[24] In the high-risk medical device context, over 70% of firms in our sample classified as small new entrants experienced acquisition during our period of observation. Publicly listed industry incumbents were responsible for nearly two thirds of all acquisitions (65%). In our data, 19% of all U.S. Food and Drug Administration (FDA) approvals in the product categories established between 1985 and 2010 are tied to small new entrants, and the share of new product categories established by these entrants is even larger (28%).

[25] Both criteria are assessed based on a firm-specific FDA track record.

[26] Conditional on acquisition, an OLS analysis confirms that first or early entry of a small new entrant is associated with a longer period of elapsed time between market entry and acquisition.

We conclude that pioneers' (dis-)advantages in an MFT setting differ from more traditional product market settings in important respects. The strongest increase in the acquisition hazard observed in our empirical models is linked to the establishment of the respective new product category (a so-called "product code") through a first-time product approval. This reflects the importance of resolving technological uncertainty for potential acquirers, an aspect largely irrelevant for first-movers in traditional product markets, who will have resolved technological uncertainty prior to market launch through product testing. A second key difference is due to the binary nature of the outcome – i.e., whether or not a small new entrant is acquired. MFTs reward early-movers through a higher likelihood of acquisition, but only after the early-movers have paved the way for a new product type and have reduced the general technological and market risk. Thus, early-movers need to wait longer to realize success in the form of acquisition. In contrast, later followers can "piggy back" on early entrants' investments in mitigating technological and market risk. As a result, acquisition of later entrants in our setting occurs *earlier* in a later entrant's product life cycle. However, later entrants are *less* likely than pioneers to be acquired. Potential reasons for this lower acquisition likelihood could be that the number of small new firms with mutually substitutive innovations may exceed the number of potential buyers, or that in-house development of the respective product by potential acquirers becomes more feasible (and therefore more likely) as more time elapses after the introduction of a new product type. Furthermore, later prospective buyers need to find their acquisition targets among the firms not yet acquired (often later movers). Thus, later movers may not need to convince prospective buyers that their offerings are superior to those of the firms acquired earlier; an acquirer may be content to buy a firm whose product is of comparable or even lower quality than that of the already acquired firms if it perceives presence in the new product category as strategically important. This is in stark contrast to the situation seen in traditional product markets, where, absent binding capacity constraints, all customers could buy from the pioneer.

We structure the remainder of this paper as follows: first, we provide theoretical background on first-mover (dis-)advantages and extend the theory for settings in which MFTs exist. We then develop a conceptual framework for pioneer acquisition and advance a set of related hypotheses. We then provide necessary background on the industry before presenting data and methodology. In the final sections, we test our hypotheses in a quantitative study using detailed data from the U.S. medical device industry and conclude with implications for innovation strategy research and insights for practitioners.

3.2. Markets for technology and pioneer advantages

This paper considers pioneer market entry in settings where a firm cannot only sell its innovation in a final product market (i.e. to end customers), but also in an MFT (i.e., to one of several large firms acting as acquirers). We outline the structural differences of both market types and revisit typically acknowledged (dis-)advantages of pioneering small new entrants, developed from insights in a product market setting. We extend the typical framework using arguments specific to an MFT setting.

3.2.1. Pioneer disadvantages

Previous scholars have identified different pioneer disadvantages in the context of product markets. Important source of such disadvantages are higher technological and market uncertainty (Warner et al. 2006). As seen in Jones et al. (2000), pioneering a truly new product type is often associated with "discontinuous technological change and characterized by a high[er] degree of technical uncertainty […]" (p. 261). We note that this argument is likely to be particularly relevant in the health care context, where it takes pioneers longer to demonstrate technical feasibility, product quality, safety, and effectiveness (Stern 2017). Further, pioneer entrants face higher market uncertainty than followers in regards to the rate and extent of (potential) user adoption, preferences, and readiness. In an experimental study, Zhou and Nakamoto (2007) show that when buyers are less familiar with a product category, they will "prefer a product with enhanced features [i.e. improvements of existing products] to one with unique features [i.e. pioneering products]" (p. 53). Such preferences will further raise the bar for adoption of products developed by first- and early-movers in a new product market. Pioneer disadvantages regarding technological and market are not limited to increased uncertainty. Even with perfect predictability, a pioneer will typically face higher costs for developing a technical solution and educating the market (Lieberman and Montgomery 1988). Unless barriers, such as patents, brands, or preemption of scarce resources, prevent imitation, followers will benefit from spillovers through reduced costs. Relatedly, Rasmusen and Yoon (2012) discuss the phenomenon of missing information superiority. This describes the lack of precedent for pioneer entrants, meaning that imitating the strategy of a (potentially) better-informed player is not a strategic option. By nature, pioneers cannot learn from the successes and/or failures of others in the same ways that later entrants can. As a result, pioneers bear

the cost of gathering resources, which may turn out to be "wrong" as the market evolves (Lieberman and Montgomery 1998, p. 1112).

In the context of MFTs, additional considerations are likely to be relevant. While the technology-seller/technology-buyer dyad faces the same pioneer disadvantages as an integrated innovator, the transaction occurring between the two adds new aspects to the relationship. First, higher technological and market uncertainty for pioneers translates into higher information asymmetries and transactional uncertainty for buyers of the technology (see, e.g., Stein and Henkel, 2017[27]). Second, buyers' risk aversion is an important driver in takeover decisions of publicly listed firms as previous scholars have found (e.g., Frijns et al., 2013). This is relevant for our setting where publicly listed firms dominate the buyers' landscape. Consequently, potential acquirer firms might want to keep the variance of expected acquisition outcomes low. This in turn makes early acquisitions of pioneer technologies less attractive and the buyer's absolute uncertainty tolerance may increase the transaction costs arising from an acquisition. Concretely, an acquisition introduces potential information asymmetry between seller and buyer; technological and market uncertainty compound this asymmetry, which will be particularly high for a pioneer's technologies since a "benchmark" for valuing a new product type does not yet exist.

3.2.2. Pioneer advantages

Referring to a product market setting, previous literature has also outlined a number of characteristic advantages associated with being a pioneer. Two are particularly prominent. First, previous literature notes that market position is an important benefit for early-movers (Lieberman and Montgomery 1988). Pioneers inherently avoid "me-too" positioning, are among the first to capture a significant share of a finite market, and team up with the most desirable partners. Consequently, first and early-movers often enjoy sustainable pricing and market share advantages (Makadok 1998). Another such market-related advantage is based on the notion of buyers' choice under uncertainty, and the observation that buyers show a tendency to stick to the first brand that offers a certain product or service when only imperfect information on product quality is available (Schmalensee 1982). Second, the presence of post-adoption switching costs among customers and users is typically advantageous for pioneers

[27] Stein and Henkel (2017) argue that information asymmetry between technology sellers and buyers is particularly high, if a product with a new functionality is subject to acquisition. This is close to our definition of a pioneering product.

(Lieberman and Montgomery 1988, Gomez and Maicas 2011). In the absence of competitors, pioneers cannot only capture a bigger share of market volume, but also lock-in customers and maintain their market position. This is particularly true if a product requires supplier-specific learning for successful use. In such a setting, pioneers can benefit from early customer lock-in to their specific technology. Consequently, high switching costs often "enhance value of market share obtained early in the evolution of a new market" (Lieberman and Montgomery 1988 p. 46, referring to Klemperer 1987 and Wernerfelt 1986, 1988). Mojir and Sudhir (2017) underscore this argument with empirical evidence from the medical device space itself, finding that buyers often face "pushback from the user (i.e., surgeon) in deciding to switch to a new (i.e., different) technology" (p. 38).

All these advantages of a pioneering integrated innovator translate into advantages of a pioneering technology-seller – at least to the extent that being early in an MFT goes along with early entry into the product market (an adaption of Ransbotham and Mitra 2010). This should translate into higher acquisition likelihood for early-movers, assuming that it is advantageous for the acquirer to enter the product market early.

In addition, pioneer entrants accrue several context-specific advantages. Ceteris paribus, being a pioneer in a new product category should result in receiving more media coverage, more attention from investors, and additional financing from more reputable investors. Therefore, the company is better positioned at later stages to find an attractive buyer for its technology.

Finally, Schoenecker and Cooper (1998) argue, and empirically establish, that a firm's market pioneering and early market entry are positively associated with its possessing greater technological resources. If potential acquirers use this association as a heuristic for their acquisition strategy, then 'being early' becomes an advantage for small new entrants because it sends a signal: established firms will expect to gain (better) access to desirable technology, skills, and capabilities by acquiring a pioneer, even if its technology is not actually of superior quality.

3.3. Hypotheses development

In this section, we discuss the context and incentives of pioneering small new entrants in MFTs and develop a set of hypotheses. A different logic applies to established firms that become new entrants to a market. We build upon the theoretical implications of pioneer (dis-)advantages outlined in the previous section in order to develop two hypotheses: the first

focuses on acquisition likelihood and the second on the timing of such acquisitions. Table 2 summarizes considerations and related literature behind our hypotheses.

3.3.1. Acquisition likelihood of pioneering small new entrants

We assume that most small new entrants would like to be – and indeed strive to be – acquired in settings where functioning MFTs exist. This is consistent with the theory of technology markets: when different *types* of firms specialize in different *activities* in the new product development processes (e.g. R&D, commercialization, sales, manufacturing, scale-up, etc.), "gains from trade" will exist. In turn, small firms will prefer to sell their technology to larger firms that have a comparative advantage in later stages of the innovation and commercialization process.[28]

Table 2: Summary of pioneer disadvantages and advantages

	Pioneer disadvantages	**Pioneer advantages**
in product markets[29] *and* in markets for technology	Higher technological uncertainty (Jones et al. 2000, Warner et al. 2006, Stern, 2017) Higher market uncertainty (Warner et al. 2006, Zhou and Nakamoto 2007) Learning from others' success and pitfalls (based on Rasmusen and Yoon 2012)	Market position (Lieberman and Montgomery 1988; Makadok 1998) Switching costs and lock-in effects (Gomez and Maicas 2011; Lieberman and Montgomery 1988, based on Klemperer 1987, and Wernerfelt 1986 and 1988) Buyers' choice under uncertainty (in adaption of Schmalensee 1982)
in markets for technology[30] specifically	Higher transaction uncertainty at a given point in time (in adaption of Stein and Henkel 2017), in particular technology uncertainty Longer time to acquisition	Higher exposure to potential technology buyers Earlier access to a new technology for buyers (Ransbotham & Mitra 2010) Association with desirable resources (adaption of Schoenecker & Cooper '98) Higher likelihood of acquisition

The central question here is whether it makes a difference from the technology buyer's perspective that a small new entrant is a pioneer in a product market. As noted above, many of the pioneer advantages appear to be structural advantages, giving one reason to believe that they can serve as the basis for durable competitive advantages. These include high

[28] We provide descriptive evidence for the benefit of acquisition to small new entrants in Section 6. In our sample, we find evidence that for the non-acquired firms, the average revenue five years after market entry is $13.5 million, while, at the same time, only two firms have annual revenues of >$30 million.

[29] Continuous success measures (sales growth, market share)

[30] Binary success measure (acquired, yes/no)

switching costs among customers, favorable market position (high visibility plus a large number of desirable partners), as well as high-quality technological resources, skills, and capabilities (due to self-selection). Thus, we hypothesize that, conditional on successful market entry, pioneers are more likely to experience acquisition than are late followers:

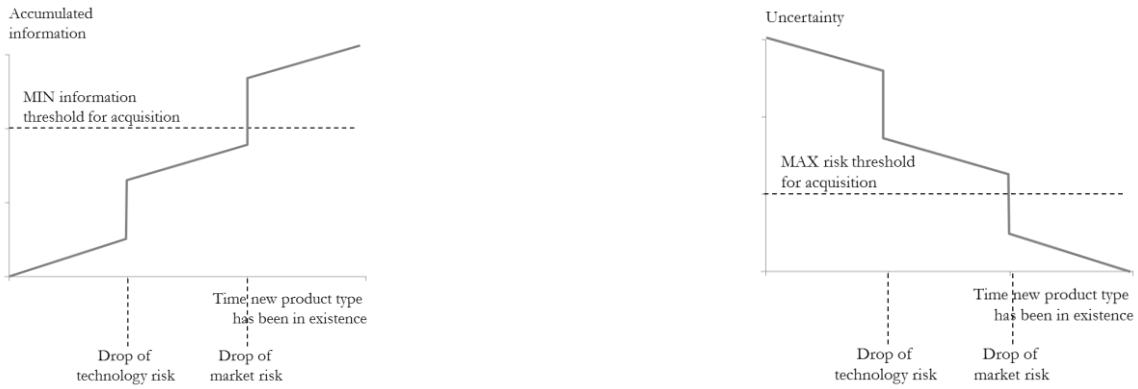
H1: Earlier market entry by a small new entrant is positively associated with acquisition likelihood.

3.3.2. Acquisition timing of pioneering small new entrants

Many challenges associated with pioneer entry are dynamic and diminish or even disappear over time. Perhaps the most obvious challenge is the absence of (accumulated) knowledge of a certain product type at the time when a pioneer enters a market that, by definition, was previously non-existent. As a result, pioneers are likely to carry additional technological and market risk than later followers. We further expect that technology buyers and their shareholders are risk averse and worried about high(er) levels of uncertainty around an acquisition (Asquith, 1983). As Alvarez and Stenbacka (2006) have shown, such uncertainty can delay takeovers and acquisitions until the associated risk has reached a certain acceptable threshold.

In a setting with technological uncertainty *and* product market uncertainty, technology buyers will want to accumulate a desired minimum stock of information on product type and product market (Figure 9, left), thereby reducing uncertainty about the expected value of a target below a certain threshold before making an acquisition (Figure 9, right).

Figure 9: Collecting information on a new product type and de-risking



Because part of the uncertainty surrounding a small new entrant is related to the newly created product category rather than to the firm itself, this component will be mechanically higher for pioneers than for later followers. As such, it will take longer for pioneers' products to fall below an acceptable risk threshold before acquisition. As a result, we hypothesize that:

H2a: Acquisition hazard increases at the time when the general technology risk of a new product type drops.

H2b: Acquisition hazard increases at the time when the general market risk of a new product type drops.

H2c: Acquisition hazard increases at the time when the firm-specific technology risk drops.

H2d: Among acquired firms, pioneers wait longer for acquisition after market entry.[31]

3.4. Empirical setting

The U.S. medical device industry is an ideal setting to study first- and early-mover advantages for two key reasons. First, the innovation process is highly standardized; any incumbent and small new entrant will have to pass the same clear set of milestones throughout the innovation process. Second, the regulatory environment leads to complete and precise observability of market entry, which is a particularly valuable feature for investigating both of our timing-related hypotheses on market entry.

3.4.1. The U.S. medical device industry

In the United States, the FDA, which certifies the safety and efficacy of all medical products, regulates and approves medical devices. The FDA is the sole regulatory authority that can grant access (in the form of regulatory approval) to a medical device manufacturer that wants to sell its products in the United States. The United States is the world's largest medical device market, worth more than $140 billion USD annually (Statista, 2018). FDA approval marks the endpoint of a lengthy, costly, and uncertain development process, and the presence of entry regulation largely determines several steps and actions that firms must take along the way. For example, after idea generation and early technological development, innovators typically work with the FDA to design clinical trials that are likely to meet the regulatory standards required for device approval (Kaplan and Stern, 2018).

FDA approval: discrete reduction in technology risk

In order to receive FDA approval, manufacturers must demonstrate that a device is safe and effective. Approval gives an innovator firm the right to legally market the medical device.

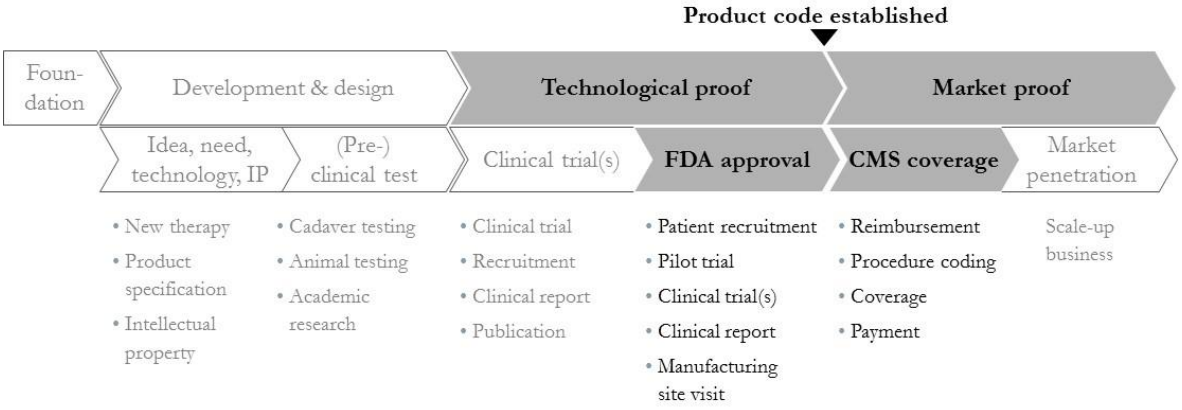
[31] We note that H2d is interrelated with H2a and H2b.

By definition, such an approval results in the resolution of a great deal of technological uncertainty around an innovation. Market uncertainty may take longer to resolve, lasting well into the device's commercialization.

CMS coverage: discrete reduction in market risk

In the regulated medical device setting, innovator firms may still have to convince national payers to reimburse health care providers for use of a new product type (in the United States, this includes both the Centers for Medicare and Medicaid Services (CMS), as well as private payers). Even after successful market entry and reimbursement approval, manufacturers must typically launch a sales plan in order to meaningfully penetrate a new product market. Medical device sales strategies recognize that doctors and health care delivery organizations may need to be educated about new technologies and convinced to use a new device type in medical procedures and diagnostics.

Figure 10: Pioneer's innovation process in the U.S. medical device industry



3.4.2. Product markets vs. markets for technology

MFTs differ from product markets in terms of the entrepreneurial outcomes that a small new firm can achieve when trying to benefit from an innovation. Product markets offer multiple dimensions of success and failure when an innovation is successfully commercialized (e.g., sales growth, market share, etc.). However, when an innovation is sold through a strategic firm acquisition (i.e. an MFT), the outcome is straightforward to measure: the innovator firm is either acquired or not and acquisition price can often be observed.[32] This creates a different

[32] Regression analyses on acquisition prices in Section 6 lend support to the view that there is no systematic association between target maturity and deal value and/or market entry timing and deal value.

profile of market opportunities and threats for small new entrants, because only one potential buyer (i.e., the acquirer) needs to be convinced of an innovation's value in order to achieve an outcome in an MFT, as compared to a large number of customers who have to be convinced in product markets.

Under what circumstances does this additional opportunity to monetize a pioneering innovation via firm acquisition exist? MFTs are common across industries where different groups of firms have differentiated advantages with respect to originating and commercializing innovations. A robust body of research, led by Scherer (1980), Christensen (1997), and Arora et al. (2001), has shown that young firms often excel in radical innovation, while incumbents excel in commercialization, sales, and scaling of a business model. Gans and Stern (2003) outline specific criteria under which an exchange between small new entrants and incumbents is likely. First among these are settings in which an "incumbent's complementary assets contribute to the value proposition from the new technology" (p. 340). In most cases, these assets include production, sales, and marketing resources, which a business uses to successfully scale around a new product. Second, this exchange is likely to occur when the "[new entrant's] innovation precludes development by incumbent" (p. 340), be it by intellectual property protection, regulatory approval, and/or a significant time-to-market advantage.

Therefore, MFTs are as important as product markets in almost any high-tech industry. Such settings have in common the fact that incumbents use external innovation to fuel their pipeline of new products (Gans and Stern, 2003), while new, small entrants compete against each other to be acquired by industry leaders (Arora et al., 2001, Gans and Stern 2003, Henkel et al. 2015).

3.4.3. Clear point of market entry

The American medical device innovation process is useful for study, as it positively affects observability of market entries and, thus, small new entrants. Lieberman and Montgomery (1988) agree with other scholars that the standard criterion for defining a first-mover is the fact that a firm is the first to bring a new product type to market (see also Schoenecker and Cooper, 1998, Makadok, 1998, Gomez and Maicas, 2011, and Rasmusen and Yoon, 2012). In the U.S. medical device setting, we can obtain precise (to the day) information on the timing of FDA approval of a new device, which marks U.S. market entry. Importantly, FDA approval requires that regulators visit and inspect up-and-running manufacturing plants and supply chain facilities as part of the approval process, so products are typically ready-to-ship

shortly after regulatory approval. Indeed, the manufacturers of all of the seven high-risk devices granted FDA approval between December 1, 2016 and January 31, 2017 marketed each within a few days or weeks of their approval date. We confirm this via our March 1, 2017 data extraction, and through industry press releases[33].

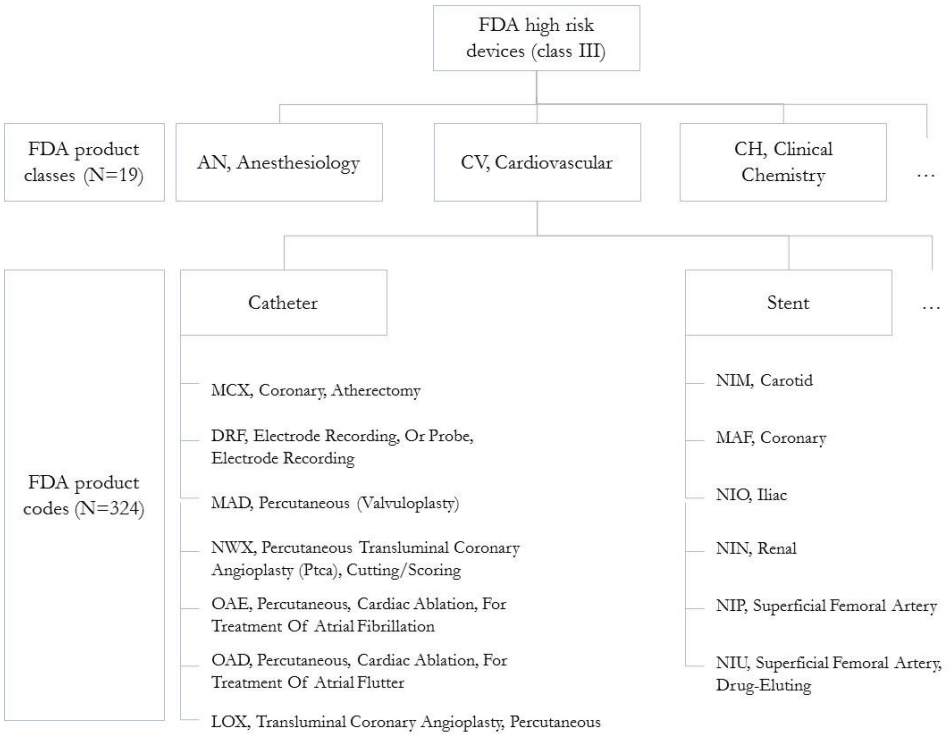
3.4.4. Comparability of products and substitutes

After establishing a method for identifying the date of market entry, it is still necessary to establish which products belong to the same product market in order to understand the timing and chronology of entrants within each product market. In this respect, FDA regulatory data is also valuable: because FDA regulators independently classify all devices and organize them into distinct and specific product codes and classes of therapeutic use, we can objectively compare products and identify substitutes[34]. Figure 11 provides an example of how the FDA's Center for Devices and Radiological Health (CDRH) classifies medical devices. As of the end of 2017, the FDA had established 324 unique product codes for high-risk devices, including implantable and/or life-sustaining anesthesiology, cardiovascular, and clinical chemistry devices (as opposed to low-risk devices such as bandages, wheelchairs, or alcohol control materials).

[33] https://www.medgadget.com, https://www.massdevice.com, https://www.prnewswire.com

[34] The FDA classification process of medical devices is confirmative to this interpretation: "A device will be assigned an existing classification product code when it has the same intended use, indications for use, and relies on technology that does not raise new safety and effectiveness questions. However, if the proposed device differs significantly from the predicate device with respect to technology, intended use or indications for use or is found not substantially equivalent, a new product code should be assigned" (Stern, 2017 citing 'Medical Device Classification Product Codes: Guidance for Industry and Food and Drug Administration Staff' (April 11, 2013))

Figure 11: Example classification of FDA product codes



3.4.5. Delineation of pioneers and later followers

Both of our hypotheses are related to the timing of market entry and the length of time a product market has been in existence. It is therefore crucial to accurately measure elapsed time since the first-mover entered the market and the timing of all follow-on entrants. This allows us to use a more nuanced definition of "pioneers" based on timing of market entry (relative to the establishment of a product market) rather than entry order, which is rather crude, discontinuous, and does not account for elapsed time. Specifically, among high-risk medical devices, a full observation of FDA product approvals over multiple decades helps to address this topic. If an innovation represents a novel product category, an independent committee classifies it as such and establishes a new product code. Subsequently (and in all already-established product codes), the FDA tracks approvals (by calendar date) in every product code over time.

3.5. Data and methodology

Our sample focuses on new firms in the medical device industry. We present the full set of products and technologies included in this study, as well as details on their acquisition activities and a sampling overview, in Table 3.

Table 3: Sample overview of small new entrants and acquisitions

FDA code	Code description	Created	Total	Acq	% Acq.	First-mover	Non-first-mover
Total			119	86	72%	56	63
MTV	Device, Needle Destruction	1997	7	3	43%	1	6
MUA	Bone Sonometer	1998	5	1	20%	0	5
LPB	Cardiac Ablation Percutaneous Catheter	1994	4	4	100%	1	3
MAF	Stent, Coronary	1991	4	4	100%	0	4
LZS	Excimer Laser System	1995	4	3	75%	1	3
DSQ	Ventricular (Assisst) Bypass	1992	3	2	67%	1	2
MGB	Device, Hemostasis, Vascular	1995	3	3	100%	0	3
MGR	Dressing, Wound And Burn, Interactive	1996	3	1	33%	0	3
MVF	System, Laser, Photodynamic Therapy	1995	3	3	100%	2	1
MWL	Lens,Contact(Rigid Gas Permeable)-Extended Wear	1986	3	1	33%	1	2
MJO	Prosthesis, Intervertebral Disc	2004	3	3	100%	1	2
MOZ	Acid, Hyaluronic, Intraarticular	1997	3	1	33%	1	2
LSZ	Ventilator, High Frequency	1988	2	1	50%	1	1
LPC	Device, Angioplasty, Laser, Coronary	1988	2	0	0%	1	1
MNO	System, Laser, Transmyocardial Revascularization	1998	2	1	50%	1	1
MDS	Sensor, Glucose, Invasive	1999	2	1	50%	1	1
LZD	Joint, Temporomandibular, Implant	1999	2	1	50%	1	1
MPV	Implant, Hearing, Active, Middle Ear, Partially Implan	2000	2	1	50%	1	1
LTI	Implant, Intragastric For Morbid Obesity	2001	2	1	50%	1	1
MEQ	System, Hyperthermia, Rf.,Thermotherapy	1996	2	1	50%	1	1
PMX	Absorbable Collagen Hemostatic Agent With Thromb	1999	2	2	100%	1	1
MNB	Device, Thermal Ablation, Endometrial	1997	2	2	100%	0	2
MKQ	Processor, Cervical Cytology Slide, Automated	1996	2	2	100%	1	1
MYN	Analyzer,Medical Image	1998	2	0	0%	0	2
OOY	Bronchial Thermoplasty System	2010	1	1	100%	1	0
DXY	Implantable Pacemaker Pulse-Generator	1988	1	1	100%	0	1
LPA	System, Esophageal Pacing	1986	1	1	100%	0	1
MAE	Occluder, Patent Ductus, Arteriosus	2003	1	1	100%	1	0
MAL	Graft, Vascular, Synthetic/Biologic Composite	1993	1	1	100%	1	0
MCX	Catheter, Coronary, Atherectomy	1990	1	1	100%	0	1
MIH	System, Endovascular Graft, Aortic Aneurysm Treatm	1999	1	1	100%	1	0
MLV	Transcatheter Septal Occluder	2001	1	1	100%	1	0
MRM	Defibrillator, Implantable, Dual-Chamber	1999	1	1	100%	1	0
MTE	System,Pacing,Temporary,Acute,Internal Atrial Defi.	2002	1	1	100%	1	0
NIM	Stent, Carotid	2004	1	1	100%	0	1
NWX	Catheter, Percutaneous Transluminal C.A., Cutting/Sc	2000	1	1	100%	1	0
OAD	Catheter, Percutaneous, Cardiac Ablation, Treatment (	2002	1	1	100%	0	1
NCT	Instrument, Glucose, Noninvasive Technology	2001	1	1	100%	1	0
NPZ	Bone Grafting Material, Dental, With Bio. Comp.	1999	1	1	100%	0	1
MRK	System, Imaging, Fluorescence	1996	1	1	100%	1	0
LNM	Agent, Bulking, Injectable For Gastro-Urology Use	1993	1	0	0%	0	1
NZC	Stent, Urethral, Prostatic, Semi-Permanent	2006	1	1	100%	1	0
OCK	Transurethral Occlusion Insert, Urinary I.-C., Female	1996	1	1	100%	1	0
DZE	Implant, Endosseous, Root-Form	1988	1	1	100%	1	0
FRO	Dressing, Wound, Drug	1989	1	1	100%	1	0
FTR	Prosthesis, Breast, Noninflatable, Internal, Silicone.	2006	1	0	0%	0	1
IMK	Wheelchair, Stair Climbing	1991	1	1	100%	1	0
MPN	Tissue Adhesive For The Topical Approx. Of Skin	1998	1	1	100%	1	0
MWA	System, Nucleic Acid Ampli., Mycobacterium Tuberc.	1995	1	1	100%	1	0
MYL	Assay,Enzyme Linked Immu.,Parvovirus B19 Igg	1999	1	1	100%	1	0
MZO	Assay,Enzyme Linked Immunosorbent,Hep C	1999	1	0	0%	1	0
NCD	Test, Immunity, Cell Mediated, Mycobacterium Tub.	2001	1	1	100%	1	0
MXM	Cap,Cooling (Infants)	2006	1	1	100%	1	0
NQR	Sealant, Dural	2005	1	1	100%	1	0
KNH	Laparoscopic Contraceptive Tubal Occ. Device	1993	1	1	100%	1	0
LLQ	Cap, Cervical, Contraceptive	1988	1	1	100%	1	0
MCN	Barrier, Absorable, Adhesion	1989	1	1	100%	1	0
MWM	Sensor,Electro-Optical(For Cervical Cancer)	2006	1	1	100%	1	0
NRZ	Ablation System, High Intensity Focused Ultrasound.	2004	1	1	100%	1	0
LQE	Implant, Corneal, Refractive	1999	1	1	100%	1	0
LWL	Fluid, Intraocular	1994	1	1	100%	0	1
MRJ	Ring, Endocapsular	2003	1	0	0%	1	0
NAA	Lens,Intraocular,Accommodative	2003	1	1	100%	1	0
LML	Ligaments And Tendons, Synthetic	1987	1	1	100%	0	1
MBS	Filler, Bone Void, Non-Osteoinduction	1993	1	1	100%	1	0
NBN	Generator, Shock-Wave, For Pain Relief	2000	1	0	0%	0	1
NEG	Finger Semi-Constr. Pyrolytic Carbon Uncem. Prost.	2001	1	1	100%	1	0
NTG	Prosthesis, Ankle, Uncemented, Non-Constrained	2009	1	1	100%	1	0
NXT	Prosthesis, Hip, Semi-Constrained, Metal/Metal, R.	2006	1	0	0%	0	1
OIS	Calcium Salt Bone V. Filler, Drillable, Non-Screw A.	1992	1	1	100%	1	0
MNM	Reader, Cervical Cytology Slide, Automated	1995	1	1	100%	1	0
MBS	Filler, Bone Void, Non-Osteoinduction	1993	1	1	100%	0	1
NBN	Generator, Shock-Wave, For Pain Relief	2000	1	1	100%	1	0
NRR	Lung Computed Tomography System, C.-A. Det.	2004	1	1	100%	1	0

We collect data in two steps: in the first step, we create a dataset of *all* high-risk medical devices brought to the U.S. market over more than two decades and subsequently narrow our

analysis to small new entrants. In the second step, we collect information on the products' paths to market, and assemble firm-specific information about company status and financials. The latter category includes information on whether or not a firm subsequently experienced acquisition, was operating independently, or was no longer in existence.

3.5.1. Data sampling

We begin with a comprehensive sample of all high-risk medical devices brought to market in newly established product codes from 1985 to 2010 (26 years in total). This allows us to follow all products for a full seven years after regulatory approval, leading to complete and consistent outcome information for all products and firms. We focus on the 203 unique product codes for high-risk devices[35] established by the FDA over our period of study. An independent classification panel assigns product codes, which identify a specific, categorical product type.[36] In the 203 relevant product codes, the FDA approved 627 devices during the observation period, and these approvals constitute the baseline sample for our analysis.[37] This sample allows us to see the entire set of high-risk devices that came to market in the United States over our period of study. The FDA product approval data come from the Evaluate MedTech database (EMT), which provides full coverage of all FDA high-risk device approvals over recent decades.

Our theoretical context concerns new product categories. Therefore, we include all firms that either established a new FDA product code or had a product approved in a newly created product code in the first seven years after its establishment. Choosing a cut-off after seven years is likely to be long enough to capture the vast majority of direct followers in the long-cycled medical device market (see e.g., Chatterji 2009), but also short enough to allow us to capture actual followers rather than later generations of the device type.[38]

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[35] High-risk devices are any implantable and/or life-sustaining devices that, in case of failure, have reasonable adverse health consequences to patients. Thus, these devices require Pre-Market-Approval (PMA) by the FDA (Sutton, 2018). We disregarded the other primary FDA market approval process, 510k, for this paper's empirical analysis, as it only applies to low- and medium- risk devices (e.g., bandages, wheelchairs, or alcohol control materials), which are "substantially equivalent to a legally marketed device that is not subject to PMA" (FDA, 2014, p.5). These devices follow a different, less regulated innovation path that, as a result, drives down the observability of (drops of) technology and market uncertainty.

[36] https://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/Overview/ClassifyYourDevice/ucm051530.htm

[37] We focus only on novel product approvals and do not consider supplementary approvals (modifications) to existing products in this study.

[38] We formally follow all small new entrants beyond the seven-year period from the time of product code creation (which is the criterion for us to consider a focal firm part of the sample as a direct follower). For example,

We next focus on the firms in our sample that will allow us to operationalize our research question, namely, our question about small new entrants in therapeutically relevant fields. We consider a firm *new* to the medical device industry if it has no more than five years of previous high-risk device experience before the FDA approval of a given product. This criterion excludes any established firm with significant device industry experience. A firm is considered *narrowly focused* if the number of previous product codes in which it has commercialized products is less than or equal to one.[39] This, in turn, ensures that the firm (and, if applicable, its acquisition) can clearly be associated with a specific technology, rather than a broad portfolio of products. Finally, we exclude devices in product codes with fewer than two successful FDA applications during our observation period in order to exclude niche products with limited therapeutic relevance. These criteria identify 80 small new entrants.

While this sample of 80 entrants is unambiguously relevant to this study, our ultimate goal is to account for the full set of small new entrants that were engaging in new product innovation – including the difficult-to-observe set of firms that may have been acquired *prior* to FDA approval. These firms represent a challenge because the "commercializing firm" listed on FDA approval letters will not be the innovator firm that created the device. To correct for this type of mis-assignment of innovator firm status, we perform an exhaustive search of press releases for all remaining 546 FDA approvals over our sample years (i.e. those by established firms),[40] resulting in the identification of 39 small new entrants to the existing sample of 80 firms. This leads to a total of 119 new, small entrants which are part of the final sample and illustrated as presented in our data sampling approach in Figure 12.

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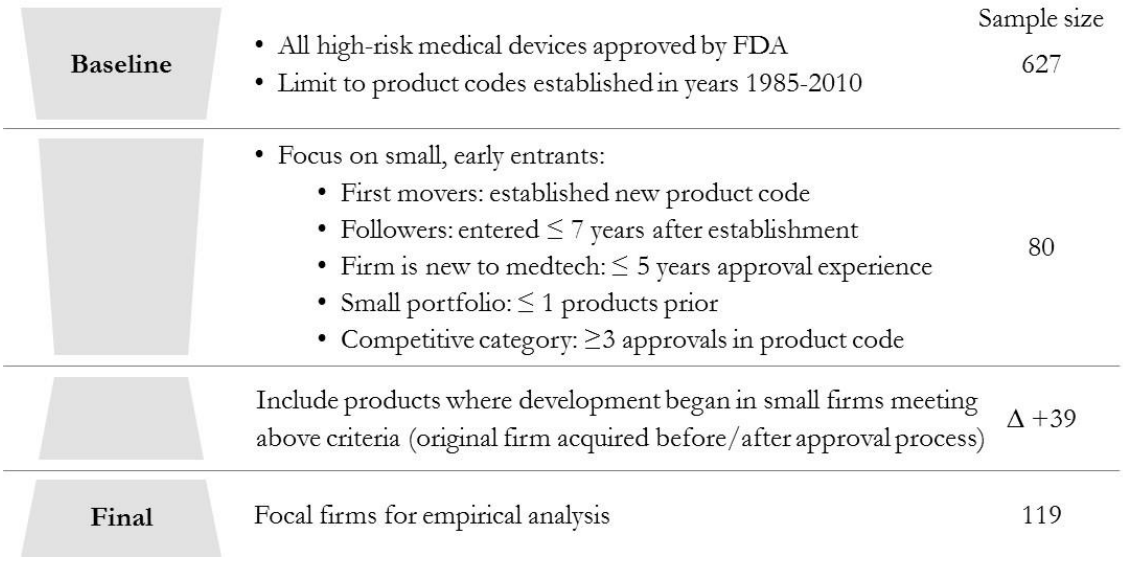
if the FDA creates a product code on January 2, 2000, we would track and include all approvals and entrants into that product code through January 1, 2007. However, for any products approved during that window, we continue to track acquisitions until the end of our period of observation. For example, if a small new entrant came to market with a new device in the above product code in 2006, and that firm experienced acquisition in 2017, we would capture that outcome.

[39] We identify 12 firms with one previous product approval each prior to the "focal' product approval, but have strong reason to believe that their acquisition, if any, would be associated with the second, focal device: first, in only four of these cases is the previous device also a novel, high-risk device (PMA). In all other cases, the firm's first device is a moderate-risk product representing only innovations that are substantially equivalent to marketed non-PMA device (FDA, 2014). Second, press releases at the time of the acquisition indicate that there is a clear link between the focal device and the acquisition, if any. However, we can also exclude all these firms and devices from our regression analyses (done in robustness checks) without meaningful changes to our results.

[40] We perform a manual press review and search for the device name and/or trademark under which an established firm has been marketing a certain FDA-approved device. If press releases indicate that a device that originated in a small firm experienced acquisition, then this FDA application is re-assigned ex-post to the small firm that led that device's development.

Figure 12: Data sampling approach of small new entrants



3.5.2. Product and financial data

For each product (new device), a clear understanding of important innovation milestones before and after FDA approval is essential. The most obvious of these relate to the establishment of intellectual property and a pathway for compensation. Therefore, we collect data on patents from the U.S. Patent and Trade Office (USPTO) database, and data on the timing of reimbursement decisions from the Centers for Medicare and Medicaid Services (CMS), including local and national coverage reports.

It is clearly crucial that we properly classify entrepreneurial outcomes for small new firms in our sample – i.e., whether a firm failed, remains standalone, or is acquired by the end of our period of observation. We therefore collect detailed, firm level financial and acquisition data for all firms in our dataset, as well as information about their potential acquirers. First, we collect data on each firm's status (failed, standalone, or acquired) over the seven-year window following its entry into our sample, as well as data on annual revenues from Mergermarket,[41] Google Finance,[42] and company press releases.[43] For those firms that were acquired, we collect additional information on the timing of each acquisition (announcement

[41] https://www.mergermarket.com
[42] https://www.google.com/finance
[43] In a similar fashion to the press release research described above, we identified 116 relevant press releases by buyer firms to validate information on acquired technologies, acquisition dates, and deal values related to the 86 new acquired small entrants.

date[44]) as well as all deals' transactional values, which is available for 87.2% of our overall sample. We collect acquisition data from the same sources noted above, as well as from S&P Capital IQ[45] and Bloomberg.[46] In order to look for evidence of patterns in acquisition behavior that we should control for, we investigate acquirer firms further. However, we do not find evidence of selection in acquisition behavior (e.g. it is not true that pioneers are more/less often purchased by top acquirers in the industry[47] or that pioneers are more/less often purchased by publicly listed firms).

3.5.3. Dependent variables

To evaluate hypothesis 1, we consider variables around acquisition likelihood of our interest. *Firm status* as measured by a multinomial variable that takes on the value of 0 if a small new entrant failed, 1 if the entrant remained standalone, and 2 if it is acquired over the seven years after coming to market. *Acquired status* is a binary version of firm status that takes on the value of 1 if the small new entrant is acquired.

To evaluate Hypotheses 2a through 2d, we look at variables around acquisition timing. *Time since incorporation* reflects a focal firm's age at any point in time until the firm fails, is acquired, or remains independent (as of December 31, 2017). It reflects the waiting time of a small new entrant. We calculate *Time since FDA approval* similarly; the only difference is that it starts with the date of a given firm's market entry (FDA approval).[48]

Conditional on acquisition, *Time to acquisition* reflects the (fixed) elapsed time in years between a device's FDA approval and the time of acquisition. We note that this time is negative in cases in which a firm is acquired prior to FDA approval. This measure is a good proxy for a firm's maturity at the time of acquisition (an adaptation of Chaudhuri et al. 2005, Ransbotham and Mitra 2010, Brueller et al., 2015).

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[44] As other scholars have done, we consider the announcement date as the date of acquisition (see, for example, Puranam et al. 2009, Ransbotham and Mitra 2010, Brueller et al. 2015) rather than the closing date. Press releases reliably report the announcement date (but not the closing date), especially for small transactions. For 29 of the 86 acquisitions in our sample, we know both dates, and press releases suggest only a small lag of 1.77 months between the announcement and the closing of an acquisition (standard deviation 1.98 months).

[45] https://www.capitaliq.com

[46] https://www.bloomberg.com

[47] Top 30 acquirers determined by historic deal-data in the medical device space covering more than 7,300 transactions between 1970-2016, Source: Capital IQ

[48] Inherently, *Time since FDA approval* cannot be calculated for small new entrants which are acquired *before* their FDA approval. Also, note that *Time since FDA approval* is never negative since in the survival model in which we employ this variable FDA approval of the focal firm is the starting time.

Deal value gives the natural logarithm of the acquisition price (in millions of dollars). Data on transaction values are available for 87% of all acquired firms. As in previous studies (e.g., Ransbotham and Mitra 2010), we expect that there will be limited data availability – particularly for small deals, since public disclosure of transaction details is not compulsory in many cases. As this may raise concerns that we observe a non-randomly selected sample of deal values, we consider the application of a Heckman-two-stage-regression to address potential selection bias.

3.5.4. Independent variables

As expected from our hypotheses, all of our independent variables are time-related.

Product code age at approval represents the elapsed time between the establishment of a product code (FDA approval of the first-mover) and the market entry of a given device (FDA approval of the focal firm). By definition, first-movers that establish a product code have a product code age at approval of 0, while other entrants can have any value up to 7 years. Translated into a time-varying covariate (tvc) for the survival analysis,

Product code age reflects the age of the relevant product code at any point in time through the end of observations of a given firm until the firm fails, is acquired, or remains independent (as of December 31, 2017).

Product code established is also a time-varying covariate, but is defined by the specific date of the FDA approval of the first-mover of a certain product code. The variable takes the value of one starting on the date of FDA approval, and we only consider it in the survival analysis. A change from zero to one of this binary variable marks a discrete and significant drop in technological risk for *any* given firm that enters this product code at a (potentially later) date.

Similarly, *FDA approval* is a time-varying covariate that switches from zero to one on the specific date of a given firm's FDA device approval. The date marks a discrete drop in technological risk of a given firm's specific device.

Product code reimbursed is also a time-varying covariate that takes the value of one following the date on which CMS makes the first (positive) coverage decision for a specific product type.[49] Beginning on this date, payers start to reimburse for procedures performed with the newly established device type. For our sample, the positive reimbursement decision,

[49] This includes 12 devices from small new entrants that CMS did not yet cover at the end of our period of observation (December 31, 2017).

on average, occurs 2.75 years after the first-mover's FDA approval for this product type and a standard deviation of 3.715. It implies a significant drop of market risk for any firm that enters this product market.

3.5.5. Control variables

A number of control variables capture characteristics of the target and the environment, respectively. *Patents at approval* gives the natural logarithm of the number of U.S. patents (+ 1) associated with a small new entrant at the time of FDA approval. Accounting for changes in the number of patents over time, *Patents* reflects the natural logarithm of the count of patents (+ 1) at any point in time during the observation period.[50]

Medical specialties are a set of categorical variables indicating the different therapeutic areas of the devices in our sample. These represent an aggregation of the 20 regulatory medical specialties defined by the FDA, reduced down to three broader categories with the support of a physician: cardiovascular devices, radiology devices, and other devices except radiology. [51] These categories allow us to account for differences across different medical practice area, which may have different clinical sales models, customer bases, and applicants, as well as different innovation models (e.g. different investments requirements, typical length of innovation- and product-life cycles due to the R&D process, etc.).

With respect to a new entrant's competitive environment, we account for regulation and likely buyer competition in MFTs. *Number of potential buyers at acquisition* gives the natural logarithm of the number of potential acquirers (+1). This measure controls for the degree of buyer competition in any of the cases where a small new entrant is acquired. Consistent with

[50] We construct a linear interpolation between three distinct points in time: the date on which a given firm receives an initial patent, the date of the device's FDA approval, and the end of the observation period (date of shutdown, acquisition, or December 31, 2017). Example: a firm incorporates on January 1, 1985, receives its first patent on January 1, 1990, holds 15 patents when its product receives FDA approval on January 1, 1995, and holds 20 patents upon acquisition on January 1, 2005. In this case, we have *Patents*=ln[0+1]=0 before January 1, 1990; a linear interpolation from ln[1+1] to ln[15+1] between January 1, 1990, to January 1, 1995; and a linear interpolation from ln[15+1] to ln[20+1] between January 1, 1995, and January 1, 2005.

[51] The FDA-defined class of *Cardiovascular* devices is not further aggregated beyond this, as it is unique and represents the largest category of high-risk devices (25% of sample). We also consider *Radiology* devices separately (7% of sample) due to their technological uniqueness, combined with the large (typically millions of dollars) investments that are required for a single device. All other devices are bundled beneath *Other devices* including devices in gastroenterology, urology, and gynecology (12% of sample), diagnostics (such as clinical chemistry, immunology, microbiology, and pathology) (8% of sample), general hospital (such as needles and devices for physical medicine) (7% of sample), general and plastic surgery, anesthesiology and orthopedics (25%), and dental, ear, nose, throat, neurology, and ophthalmic categories (16% of sample).

our patent control, *Number of potential buyers* translates this logic into a time-varying covariate: the variable reflects the natural logarithm of the amount of potential buyers at any point in time until the end of the observation period.[52] For both buyer-related variables, we follow Allain et al. (2016), who argue that the number of firms with a track record in related markets represents a reasonable proxy for the number of potential acquirers, since they have the capabilities needed to evaluate a potential acquisition target and to market that firm's device.[53] Acquiring a small new entrant likely requires specific organizational capabilities on the part of the buyer to ensure a sufficient degree and speed of integration (e.g., Ranft and Lord 2002, Angwin 2004, Homburg and Bucerius 2006, Puranam et al. 2009, Bauer and Matzler 2014). Therefore, we follow three principles in identifying the relevant set of potential buyers. First, a potential buyer must be *active* in a proximate product space. In line with Allain et al. 2016, we assume these candidates are likely to be able to assess the technological and market potential of a targeted new device. In our context specifically, this means firms have another product that is FDA-approved in the same regulatory medical specialty.[54] Second, a potential buyer must be a firm with at least five years of previous acquisition experience and a minimum of three acquisitions performed during this period. We choose cutoffs of five years and three acquisitions based on empirical evidence that shows deteriorating incremental value of M&A experience both from acquisitions dating further back in time, and from a higher number of such deals (Sampson, 2005). Finally, consistent with this, a potential buyer's acquisition experience must be relatively recent: the last acquisition must be within three years of the focal date.

3.6. Results and discussion

In the following section, we present the quantitative results of our study in five steps. First, we give an overview of summary statistics from our sample and provide descriptions of the included variables. Second, we investigate and validate one of the main assumptions of our hypotheses – namely, that small new entrants seek acquisition. Third, we introduce models

[52] We construct a linear interpolation between the same distinct points in time as for the patent control: the date on which a given firm receives an initial patent, the date of the device's FDA approval, and the end of the observation period (date of shutdown, acquisition, or December 31 2017).

[53] Allain et al. (2016) assess the number of potential licensees for a pharmaceutical drug.

[54] We note this by utilizing the original FDA classification into 20 different specialties (e.g., Cardiovascular, Hematology, Orthopedic). This means, for example, that a potential acquirer of a firm with a new innovation in cardiovascular must also be FDA-approved for at least one cardiovascular device (of course, not necessarily in the same FDA product code).

M1 and M2 to test our hypothesis on acquisition likelihood. Fourth, we present results of models M3 and M4, which test our hypotheses related to acquisition timing (H2a-H2d). Finally, we consider acquisition price in model M5, since this undoubtedly relates to acquisition timing.

3.6.1. Descriptive results

While Table 4 provides summary statistics, Table 5 shows correlations for the variables in our empirical analysis. We obtain a balanced sample of 119 devices from small new entrants, consisting of products from 56 first-movers (47%) and 63 followers (53%). Across all small new entrants, 86 firms (72% of those observed) were acquired. By itself, this finding suggests that a robust MFT exists in the high-risk medical device space.

Conditional on acquisition, the vast majority (86%) of small new entrants were acquired *after* their products' respective FDA approvals and also, inherently, after the first-mover's FDA approval in this product code. On average,

Table 4: Summary statistics

Variables		Obs	Mean	Median	Std. Dev.	Min	Max
Dependent	Firm status						
	Failed	119	0.0504	0	0.2197	0	1
	Independent	119	0.2269	0	0.4206	0	1
	Acquired (Acquisition status)	119	0.7227	1	0.4496	0	1
	Time since Incorporation	119	21.9248	19.6961	14.3047	2.9268	84.6845
	Time since FDA	119	9.6429	9.8125	8.1657	-6.8720	30.0862
	Time to acquisition	86	6.5718	6.0466	6.6461	-6.8767	28.3507
	Time until FDA (from incorp.)	119	12.2819	8.9966	11.4686	1.9083	77.0486
	Deal value	75	589.7918	157	1113.0626	0.4000	6200
	Revenue Independent (5y. after FDA)	18	13.4984	3.4605	19.1649	0.1000	76.2660
Independent	Product code age at approval	119	1.8553	0.5151	2.3362	0	7.0110
Control	Patents at approval	119	24.6807	4	139.2955	0	1510
	Patents at acquisition	86	54.4535	14.5000	276.9713	0	2564
	Potential buyers at acquisition	86	53.3837	44	40.7183	0	152
	Cardiovascular	119	0.2521	0	0.4361	0	1
	Others	119	0.6807	1	0.4682	0	1
	Radiology	119	0.0672	0	0.2515	0	1

Overview of (sub-) samples	Full sample	119	
	First movers	56	47%
	Non-first movers	63	53%
	Acquired	86	72%
	Acquired before approval	12	14%
	Acquired after approval	74	86%

an acquired firm experienced a sale about 6.57 years after its product's FDA approval. This delay reduces technological and market uncertainty on the part of the buyer.

Table 5: Pairwise correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1 Failed	1.0000											
2 Independent	-0.1248	1.0000										
3 Acquired	-0.3720*	-0.8745*	1.0000									
4 Time to acquisition	.	.	.	1.0000								
5 Deal value	.	.	.	0.1245	1.0000							
6 Product code age at approval	0.1458	0.1552	-0.2165	-0.3619*	0.0235	1.0000						
7 Patents at approval	-0.0380	-0.0504	0.0657	0.0890	0.0250	0.0647	1.0000					
8 Patents at acquisition	.	.	.	0.1582	0.0837	0.0466	0.9849*	1.0000				
9 Potential buyers at acquisition	.	.	.	0.4992*	-0.1426	-0.1012	-0.0369	-0.0078	1.0000			
10 Cardiovascular	-0.1338	-0.1297	0.1867	-0.1641	-0.0026	0.1473	-0.0086	-0.0626	0.0450	1.0000		
11 Others	0.0755	-0.0163	-0.0217	0.2112	0.0268	-0.1816	0.0251	0.0698	-0.0185	-0.8476*	1.0000	
12 Radiology	0.0915	0.2552*	-0.2835*	-0.1564	-0.0712	0.0826	-0.0318	-0.0263	-0.0796	-0.1559	-0.3920*	1.0000

Note: * < 0.01

3.6.2. Validation of assumptions

One of our central assumptions is that it is desirable for small new entrants to experience acquisition, as is the case in other high-tech settings such as software (see, e.g. Henkel et al. 2015). Our dataset provides descriptive support for this argument. Comparing deal values of all acquired small new entrants to the revenues for a majority of non-acquired entrants, we find that mean firm revenues five years after market entry are $13.5 million for the 18 non-acquired firms, with only two firms in this sample earning annual revenues greater than $30 million[55].

In contrast, among the 75 acquired firms for which deal value information is available, median and mean acquisition prices were ~$157 million and ~$590 million, respectively. Comparing the (more conservative) median of deal values of acquired firms with the average of revenues of non-acquired entrants results in a price/revenue- multiple of about 11 to 12. From the perspective of a seller, this would be quite attractive, given that the average price/revenue-multiple of the top 10 strategic M&A acquirers in health care and medical devices has historically been around four to six.[56] High exit multiples suggest that acquisitions

[55] For another 15 of these 33 firms, we cannot find revenue information on a year-by-year basis, which indicates they have remained small – or perhaps never became profitable and/or went bankrupt.

[56] Analyses of historic average price/revenue-multiples are based on >600 past transactions of Medtronic, GE, Essilor, Boston Scientific, Stryker, Integra Lifescience, Alere, Compus Medical, Siemens, Qiagen; Source: Capital IQ

are desirable for small new entrants, supporting the assumption that they would seek acquisition, even beyond the fact that small new entrants are more likely to be deficient in a broad set of necessary, complementary assets required to scale their business.[57]

At the same time, endogeneity concerns prohibit a causal interpretation of these findings. To the extent that the highest quality small new entrants experience acquisition, acquisition is positively correlated with firm quality. Thus, the hypothetical multiple of 11 to 12 calculated above would reflect the low quality of the non-acquired firms rather than the attractiveness of acquisition for acquired firms. However, a number of insights from discussions with entrepreneurs in the health care space suggest that it is beneficial for *any* small new entrant to experience acquisition: "[The acquirer] can … leverage our proposition to any of their other products and, more importantly, to their existing customer base. It's a win-win situation, because – in turn – it prevents us [the small new entrant] from duplicating resources necessary to reach all these customers" (Chief Commercial Officer of a small new entrant firm).[58]

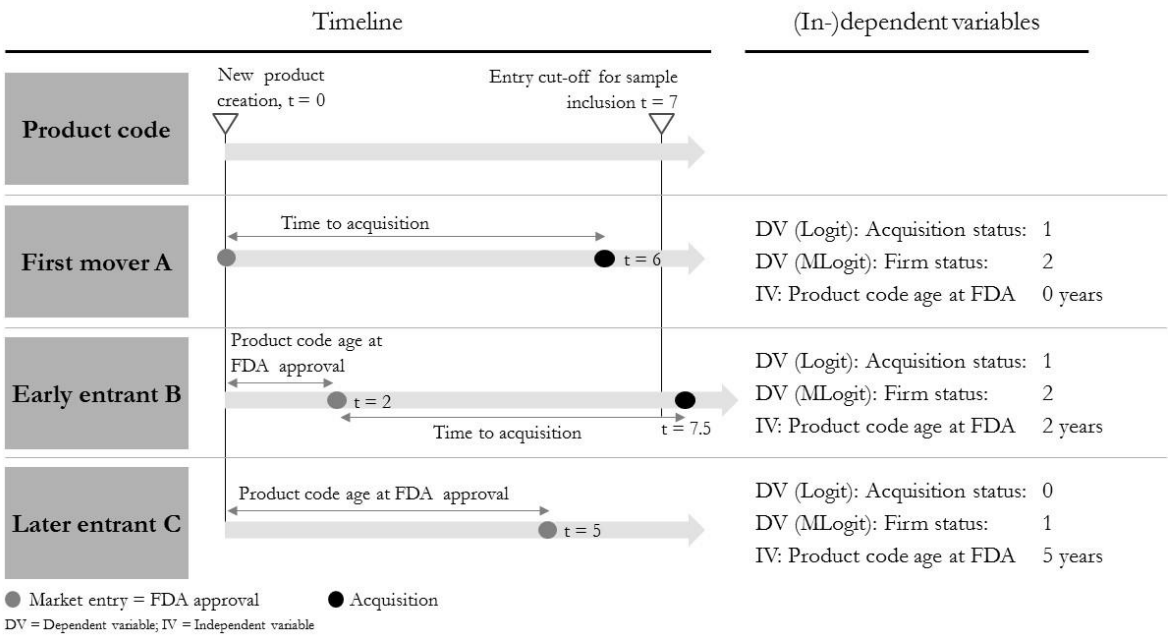
3.6.3. Analysis 1: Acquisition likelihood

In order to assess whether early market entry is positively associated with a higher likelihood of acquisition, we run two empirical models: the first, M1, applies a logit regression and considers *Acquisition status* as the dependent variable. The second model, M2, takes a slightly richer approach to considering firm outcomes and applies a multinomial logit specification. Accordingly, the variable, *Firm status,* reflects whether a small new entrant fails, remains independent, or experiences acquisition.

Figure 13 presents an example of three fictive cases for small new entrants A, B, and C in the same product code and shows how their firm-specific measures would differ in this case. In this example, A is the first-mover, and B follows with a similar approval two years later. Because both A and B are acquired at later points in time, their dependent variables show values of one (acquired) for *Acquisition status* and two (acquired) for *Firm status* – regardless of differences in their acquisition timing. In this example, C represents a later entrant, coming to market five years after the first-mover. Because C is still operating, but has not experienced acquisition by the end of our observation period, *Acquisition status* for C is zero (not acquired) and *Firm status* is one (independent).

[57] See e.g. Allain et al. (2016).
[58] Fireside talk at Harvard Business School (April 2018).

Figure 13: Illustration of M1, Logit model and M2, Multinomial Logit model



Based on this operationalization of our key outcomes of interest, the upper set of columns in Table 6 report our logit estimates of M1. The first column shows results for the full sample of 119 firms; among these, acquisition likelihood is unequally distributed in favor of pioneers at the 1% level. Coefficients reflect marginal effects at the sample means and suggest that entering a product code one year later is associated with a 4.0 percentage point lower likelihood of acquisition. A one standard deviation increase in the timing of product entry is associated with a nearly 11 percentage point (pp) decrease in the likelihood of acquisition – a substantial difference.[59] Moreover, and as reflected by the marginal effects in the second panel (-3.2 pp), third panel (-4.9 pp), and fourth panel (-4.5 pp) of M1, different sub-samples confirm the direction of the results seen in the main estimates. Excluding first-movers from the sample (second panel), we reduce our sample size by nearly half. As one would anticipate, this leads to reduced statistical significance due to the smaller sample size, but the magnitude and direction of the key coefficients are highly comparable.

[59] As an alternative independent variable, we consider *Cumulated Approvals before FDA*. The variable reflects the cumulated number of FDA-approved devices (startups plus incumbents) in the relevant product code at the time when the focal firm receives FDA approval. Using this metric as a control yields highly similar results for M1 and M2: a high number of comparable, previous approvals (by startups or incumbents) leads to a significantly lower likelihood of acquisition of the focal firm. However, we avoid using *Cumulated Approvals before FDA* in the same regression models with *Product code age at approval*, since these variables are highly collinear.

Table 6: M1 + M2: Logit and Multinomial Logit estimates on acquisition likelihood

	M1: Logit Model (DV = Acquisition status)			
	All firms	Without first movers	Without firms acquired before FDA approval	Without firms with a previous device
Product code age at approval	-0.0402**	-0.0320	-0.0488***	-0.0453**
	(0.0144)	(0.0241)	(0.0148)	(0.0143)
ln(Patents at approval+1)	0.0303	0.0198	0.0282	0.0285
	(0.0310)	(0.0392)	(0.0325)	(0.0309)
Cardiovascular	0.5016***	0.8172***	0.6012**	0.6043***
	(0.1481)	(0.1776)	(0.1862)	(0.1800)
Others (except radiology)	0.3154*	0.3466*	0.4184*	0.3971*
	(0.1352)	(0.1714)	(0.1784)	(0.1682)
N	119	63	107	107

	M2: Multinomial Logit Model (DV = Firm status)					
	All firms			Without first movers		
	Failed	Indepdt	Acqrd	Failed	Indepdt	Acqrd
Product code age at approval	0.0147†	0.0253†	-0.0400**	0.0158	0.0163	-0.0321
	(0.0083)	(0.0145)	(0.0144)	(0.0172)	(0.0254)	(0.0240)
ln(Patents at approval+1)	-0.0354	-0.0009	0.0363	-0.0350	0.0100	0.0251
	(0.0245)	(0.0295)	(0.0317)	(0.0378)	(0.0404)	(0.0399)
Cardiovascular	-0.6490	-0.1754	0.8245	-1.0640	-0.1664	1.2303
	(42.3271)	(16.5197)	(25.8083)	(133.3904)	(68.2533)	(65.1375)
Others (except radiology)	-0.0403	-0.2776*	0.3179*	-0.0511	-0.2964†	0.3476*
	(0.0501)	(0.1230)	(0.1347)	(0.0805)	(0.1526)	(0.1712)
N	119			63		

	M2: Multinomial Logit Model (DV = Firm status)					
	W/o firms acquired before FDA approval			W/o firms with a previous device		
Product code age at approval	0.0157†	0.0329*	-0.0485**	0.0132	0.0318*	-0.0450**
	(0.0086)	(0.0154)	(0.0148)	(0.0083)	(0.0147)	(0.0142)
ln(Patents at approval+1)	-0.0366	0.0032	0.0335	-0.0276	-0.0051	0.0327
	(0.0255)	(0.0317)	(0.0331)	(0.0229)	(0.0299)	(0.0315)
Cardiovascular	-0.6955	-0.2106	0.9061	-0.6230	-0.2510	0.8740
	(34.9880)	(15.6540)	(19.3356)	(40.0100)	(17.4539)	(22.5573)
Others (except radiology)	-0.0551	-0.3651*	0.4202*	-0.0673	-0.3306*	0.3979*
	(0.0568)	(0.1592)	(0.1779)	(0.0518)	(0.1538)	(0.1683)
N	107			107		

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001

Coefficients represent marginal effects at mean; values in brackets represent standard errors

Similar results are seen when dropping the subset of firms acquired before the completion of the FDA approval process (third panel), and dropping firms with previous FDA experience

(fourth panel)[60]. Consistent with that, our multinomial logit specification of M2 (lower set of columns) shows that firms with a low product code age at the approval are significantly more likely to be acquired than to end up failing or to remain independent.[61] These robustness checks increase our confidence that our results are not driven by a particular group of sub-samples of small new entrants. Broadly, our results support H1, which predicts that earlier market entry will be positively associated with acquisition likelihood. Thus, when acquisition is the goal, being early to market can be a clear advantage.

3.6.4. Analysis 2: Acquisition timing

In the next set of analyses, we test our second set of hypotheses related to whether newly introduced products need to surpass an (implicitly or explicitly) acceptable risk threshold before acquisition. H2a and H2b predict that acquisition hazard increases at the time when the general technology risk (H2a) and the general market risk (H2b) of a product type drops. Acquisition hazard should also increase at the time when the firm-specific technology risk drops. Among acquired firms, pioneers wait longer after market entry to be acquired (H2d). We employ two different types of regression models: M3 investigates H2a, H2b, and H2c and represents a survival analysis based on a Cox Proportional Hazard Model (CPHM). M4 is an ordinary least squares model (OLS) and tests H2d. The two models differ in terms of data structure, estimation mechanism, and underlying sample. In each case, we start with an illustrative case using the example entrants A, B, and C depicted in Figure 5 above.

There are two main components of a CPHM: 1) the baseline hazard function, which reflects how the "risk" of being acquired changes over time when covariates are held constant, and 2) terms which reflect how the hazard changes relative to the baseline due to differences in the explanatory covariates across firms and over time. The CPHM assumes that the hazard $h_i\big(t, X_i(t)\big)$ of individual observation i is a multiplier of the (typically unspecified) baseline hazard function, $h_0(t)$, and a second term, $\exp\big(Z_i(t)\big)$, which is an exponential function of all independent and control variables being part of our model (compared to e.g., Bradburn et al. 2003). The so-called "failure event" is defined here as an acquisition. As is typical of

[60] Excluding small new entrants that are FDA-approved for one device prior to the relevant device.

[61] Notably, post estimation tests (Wald and Likelihood ratio tests) justify collapsing the two potential firm statuses "failed" and "independent," (which is done implicitly in our Logit model with the binary outcomes acquired vs. non-acquired).

models of this type, a failure event may or may not happen before the end of the period of observation.[62] This feature allows us to include data from the full sample in our models, and to compare the 86 acquired vs. 33 non-acquired small new entrants.

Another advantage of using a CPHM is that it allows us to account for date-specific "game changing events" on the path to acquisition, since the model can incorporate date-specific time-varying covariates.[63] The resulting CPHM model specification is of the form $h_i\big(t, X_i(t)\big) = h_0(t) \cdot \exp\big(Z_i(t)\big)$, where $h_0(t)$ is the baseline hazard and $Z_i(t)$ is as follows:

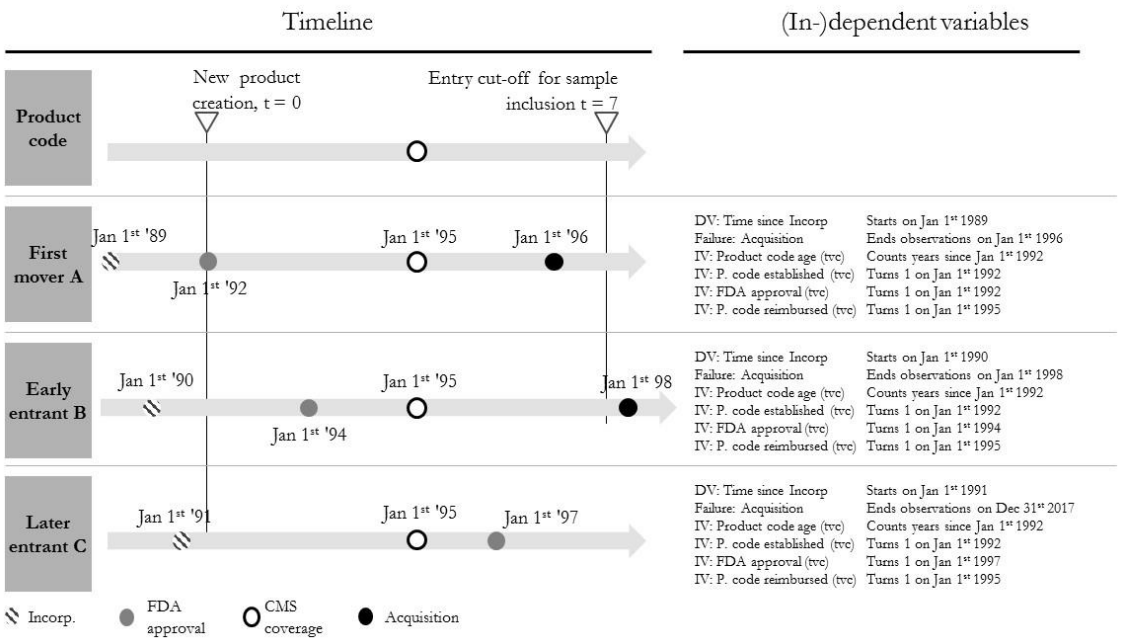
$$Z_i(t) = \beta_0 + \beta_1\left(t_{\text{FDA},i} - t_{\text{FDA,FM}}\right) + \beta_2 \text{FDA}_{FM_i}(t) + \beta_3 \text{FDA}_i(t) + \beta_4 \text{CMS}_{FM_i}(t) + \beta_5 \text{PAT}_i(t) + \beta_6 \text{BUY}_i(t) + Medical\ Speciality\ Controls,$$

where $t_{\text{FDA,FM}}$ and $t_{\text{FDA},i}$ denote the dates when the first-mover of the relevant product type and the focal firm i, respectively, receive FDA approval. Applying this model to our subject-specific dataset requires us to transpose the data into a date-specific (unbalanced) panel structure. The panel version of our dataset contains each major event and yields nearly 900,000 day-specific observations for all 119 small new entrants in the sample. The CPHM then estimates how the hazard of being acquired is associated with constant, firm-specific characteristics (e.g., *Cardiovascular* as medical specialty), and whether the hazard changes with milestone events occurring at discrete, observable points in time (e.g., *FDA approval* of the focal firm's product). Figure 14 uses the three previously mentioned cases of small new entrants (A, B, and C), and translates them into the data structure used in M3.

[62] We consider a small new entrant not acquired by the end of the observation period as right-censored.

[63] Covariates include product code age, an indicator for "product type has been established", an indicator for "focal firm's product has received FDA approval", an indicator for "product type has received positive reimbursement decision by major public health insurers", the number of patents held by the focal firm, and the number of potential buyers.

Figure 14: Illustration of M3, Survival model



Main = Time-independent covariate; TVC = Time-varying covariate; A takes value of 0 before acquisition and 1 after acquisition; B takes value of 0 before CMS decision and 1 after CMS decision; C is right-censored

Regarding the results of our regression, the left column of Table 7 reports estimates of the CPH model (M3), with the starting time for each firm being the date of its incorporation. Before running these regressions, we conduct a test on the scaled Schoenfeld residuals at failure time and find that M3 fulfills CPHM assumptions (see Grambsch & Therneau, 1994)[64]. All coefficients in this table are logarithms of the respective hazard ratio, where $\beta > 0$ indicates that an increase in the associated covariate can be associated with a higher acquisition hazard. In turn, a negative coefficient signifies a factor that decreases the hazard that a firm experiences acquisition.

With respect to general technological risk of a new product type, we find evidence that the acquisition hazard increases significantly at the time when the FDA approves a first-mover's innovation. This event represents a significant reduction in the general technology risk associated with this new product type (*Product type established*: $\beta = 0.1383$ at the 1% level).[65]. This finding supports H2a, which hypothesizes that the acquisition hazard increases at the time at which the general technology risk of a new product type falls.

[64] A central, underlying assumption of the CPHM is that the log hazard-ratio function of the model is constant over time. Using a nonzero slope test, we validate this assumption in terms of all variables individually and for the model entirely, and find no deviation. For details, see Grambsch and Therneau, 1994 cited in Stata, 2018.
[65] Results of a CPHM regression where we only include *Product type established* and controls for medical specialty confirm these results: *Product type established*: $\beta = 0.136$ at the 0.1% level.

Table 7: M3: Cox Proportional Hazards Model (CPHM) on acquisition hazard rates

M3: Survival model (Cox Proportional Hazard)		
Failure event: Acquisition		
	Starting time: incorporation of the focal firm	Starting time: FDA approval of the focal firm
Product type established (tvc)	0.1383**	
	(0.0457)	
Product type reimbursed (tvc)	0.0244	0.0417
	(0.0217)	(0.0456)
Product code age (tvc)	-0.0035**	-0.0290*
	(0.0012)	(0.0113)
FDA approval (tvc)	-0.0413	
	(0.0361)	
Patents (tvc)	0.0168**	0.0374***
	(0.0056)	(0.0107)
Buyers (tvc)	0.0260***	0.0176
	(0.0078)	(0.0184)
Cardiovascular	2.0119**	1.9011†
	(0.7518)	(1.0485)
Others (except radiology)	1.4973*	1.6671
	(0.7259)	(1.0228)
N (subjects)	119	107
N (failures)	86	74
Log likelihood	-283.86	-262.32
LR chi2	77.90	29.55

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001

tvc: Time-varying covariate

Values in brackets represent standard errors

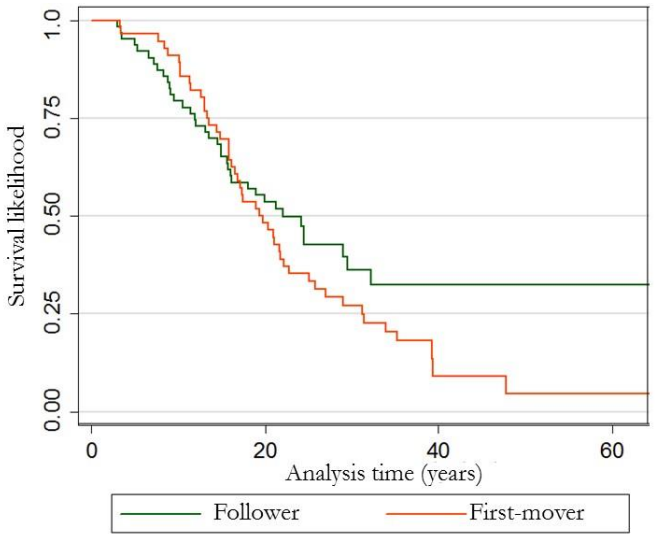
With respect to the general market risk of a new product type, the acquisition hazard has a positive coefficient, but the result is not statistically significant at conventional levels – i.e. acquisition hazard does not increase at the time that the first major decision for public insurers to reimburse for the product is made (mean of 2.75 years between FDA approval of the first-mover and CMS decision with a standard deviation of 3.715). Thus, we do not find evidence to support H2b, which states that the acquisition hazard will increase when the general market risk of a new product type falls.[66]

[66] Note: there is no firm-specific market risk that can be measured using these data, as CMS coverage is based on a product category rather than a firm-specific product (e.g., CMS decides on the reimbursement of ventricular assist devices generally, but not for Abiomed's 5000 BI-VENTRICULAR SUPPORT SYSTEM specifically).

Regarding the firm-specific technology risk, FDA approval of the focal firm's innovation does not seem to have a significant impact on its acquisition hazard.[67] Therefore, we do not find evidence for hypothesis H2c, which states that the acquisition hazard increases at the time at which the firm-specific technology risk falls. However, upon further reflection this finding may not be particularly surprising. Indeed, once a first-mover's innovation is FDA-approved, potential buyers can compare any given technology in the same product code to the reference technology of the first-mover. Thus, it might be relatively easy to assess the firm-specific technological risk in an MFT even before FDA approval of the focal device.

We also find a negative, statistically significant association between the control variable, *product code age* (at the time of FDA approval of the focal device), with the acquisition hazard. This finding is consistent with other evidence we find to support H1, which states that later market entry (i.e., later FDA approval) should be associated with a lower likelihood of acquisition. In summary, Figure 15 illustrates the results of the survival analysis. It translates all of these effects into a survival curve for the two clusters of firms, first-movers and followers.

Figure 15: Kaplan-Meier survival estimates



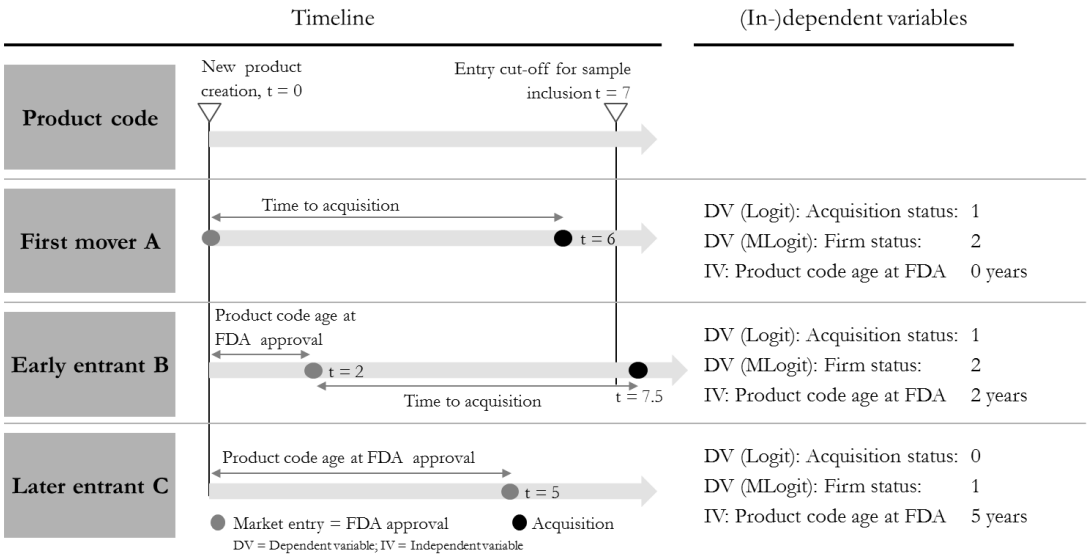
The right column of Table 7 presents a robustness test, in which the CPH model starts with the date of the FDA approval of the focal firm's device (rather than the firm's date of incorporation). The coefficients on our explanatory variables (*product type reimbursed* and

[67] "Long-lag-pioneers" (those approved <1 year after product code creation and acquired >10 years after approval) can explain the negative coefficient of FDA approval of a focal firm's device. As a corollary, when this sub-sample is removed from regressions, the coefficient becomes positive ($\beta = 0.0033$) and remains statistically insignificant.

product code age) have the same signs and similar levels of statistical significance as in the main model; the decline in market risk (as measured by public insurance reimbursement coverage for a new product type) remains statistically insignificant, while later market entry is significantly associated with a reduced acquisition hazard. Consistent with M1, M2, and M4, we perform further (unreported) robustness checks, which yield similar results to those seen in the main sample. These include removing a) first-movers, and b) firms with a previous FDA approval in the survival analysis; overall results remain unchanged when excluding these sub-samples.[68] [69]

Model M4 represents an OLS analysis conditional on acquisition and specifically considers the *Time to acquisition* of those firms that experience acquisition. Based on our selection criteria, we narrow our analysis to the 86 ultimately-acquired small new entrants. In the context of our example of firms A, B, and C in Figure 16, we would exclude firm C from this analysis, since it never experienced acquisition.

Figure 16: Illustration of M4, OLS model



[68] When excluding first-movers, *Product type established* has an estimated $\beta = 0.1402$ (significant at the 10% level) and *Product type reimbursed* has an estimated $\beta = 0.0040$ (not statistically significant). When excluding firms with a previous device: *Product type established* has an estimated $\beta = 0.1258$ (significant at the 1% level), *Product type reimbursed* has an estimated $\beta = 0.0370$ (not statistically significant).

[69] Results remain unchanged in terms of sign and statistical significance levels if we set *Product type reimbursed* from zero to one for those 14 small new entrants that are active in product types for which there is no explicit reimbursement code. These product types either represent general medical supply utilized for various therapies (such as needle destruction devices) or expensive, "elective" devices (such as stair-climbing wheelchairs, invasive glucose sensors) for which public reimbursement is unlikely from the very beginning, due to the availability of lower cost alternatives.

Table 8 reports the estimates of the M4 Ordinary Least Square (OLS) model. Referring to all 86 firms in the left column, we find that a higher *Product code age at approval* is negatively associated with *Time to acquisition* at the 1% level. The coefficient $\beta = -0.8575$, therefore, means that *Time to acquisition* decreases by 0.8 to 0.9 years for every year that has elapsed between product code establishment and a product's FDA approval in that product code. This result supports H2d, which states that, conditional on acquisition, early market entry is positively associated with a longer time to acquisition. The middle and right columns check for robustness by performing the same analysis, but exclude first-movers or firms acquired prior to their product's FDA approval.[70] As the robustness results indicate, all effects remain significant and coefficients stay directionally unchanged both when a) excluding first-movers ($\beta = -1.3351$ at the 0.1% level), b) excluding firms which are acquired prior to FDA product approval ($\beta = -0.7317$ at the 5% level), or c) excluding firms with a previous FDA product approval ($\beta = -0.9375$ at the 1% level) [71].

Table 8: M4 Linear regression model (OLS) on Time to acquisition

	M4: OLS Model (DV = Time to acquisition)			
	All acquired	Without first movers	Without firms acquired before FDA approval	Without firms with a previous device
Product code age at approval	-0.8575**	-1.3351***	-0.7317*	-0.9375**
	(0.2818)	(0.3578)	(0.3184)	(0.3194)
ln(Patents at acquisition+1)	0.9993*	1.6463**	0.4369	1.1102*
	(0.4294)	(0.5253)	(0.4742)	(0.4531)
ln(Potential buyers at acquisition+1)	1.8711***	2.1140***	1.7266**	1.9190***
	(0.4789)	(0.5507)	(0.5788)	(0.5130)
Cardiovascular	4.0415	1.4344	6.8587	6.7179
	(4.1282)	(5.1882)	(5.5340)	(5.9180)
Others (except radiology)	5.3981	0.9517	8.4795	8.1274
	(3.9998)	(5.0906)	(5.4173)	(5.7755)
constant	-6.0807	-2.7904	-6.4859	-9.1406
	(4.2062)	(5.0106)	(5.9511)	(6.1666)
N	86	39	74	78
R2	0.3509	0.5545	0.2200	0.3520

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001

Values in brackets represent standard errors

[70] Similar to the robustness checks performed on the (multinomial) logit models employed in M1 and M2.

[71] Moreover, we perform additional robustness checks separately for all different sub-sets of medical specialties. We find negative coefficients for each of the three groups. Thus, overall results do not seem driven by one distinct specialty.

3.6.5. Controlling for acquisition price

Is an acquisition at a later maturity (i.e., a longer time between market entry and acquisition) an advantage for pioneers? In other words, one might ask if pioneers have an incentive to postpone an acquisition in order to realize greater financial returns.

Table 9: M5: Heckman linear regression model (OLS) estimates on deal value

M5: Heckman OLS model (DV = Deal value)

Variable	All acquired	Acquired after FDA approval	Without firms with a previous device
Time to acquisition	-0.0263	0.0008	-0.0126
	(0.0389)	(0.0462)	(0.0375)
ln(Patents at acquisition+1)	0.4629**	0.5197**	0.3979*
	(0.1624)	(0.1792)	(0.1575)
ln(Potential buyers at acquisition+1)	-0.3522†	-0.4544*	-0.3604*
	(0.1815)	(0.2170)	(0.1769)
Cardiovascular	0.4984	-1.0568	-0.5919
	(1.4124)	(1.9840)	(1.7679)
Others (except radiology)	1.1516	-0.5099	-0.4063
	(1.3828)	(1.9839)	(1.7629)
constant	4.5084**	6.0747**	5.9374**
	(1.4902)	(2.1823)	(1.9415)
selection stage			
Buyer_Public	0.7726*	0.8778*	0.6898†
	(0.3580)	(0.3862)	(0.3733)
constant	0.7019**	0.6456*	0.7363**
	(0.2548)	(0.2604)	(0.2716)
N	86	74	78
N (uncensored)	75	64	68
Wald chi2	13.89	13.41	11.67
Prob>chi2	0.0163	0.0198	0.0396

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001

Values in brackets represent standard errors

Despite the fact that pioneers experience acquisition at later maturity, we find no evidence that these deals are in fact of higher value. In order to assess this potential story, we use the dependent variable from the previous model, *Time to acquisition*, as the explanatory variable in a predictive model of *Deal value* – all other variables remain unchanged. Table 9 presents estimates of the modified OLS model (M5) and suggests that a longer *Time to acquisition* (later maturity) is not associated with higher deal values.[72] [73]

[72] In an additional analysis, we observe similar findings if we substitute *Time to acquisition* with *Product code age at approval* in the estimation equation: timing of market entry and realized deal value of a given firm are not statistically significantly associated with each other.

[73] Data on the dependent variable, *Deal Value*, is available for 75 out of the 86 acquired firms in our sample. Because there might be systematic selection in the availability of this information, we perform a Heckman two-stage test. The selection stage includes the independent variables and all control variables, as well as the selection variable *Buyer Public* (yes/no), indicating whether the acquiring company is a publicly listed firm. We use *Buyer Public* as a selection variable since privately held firms tend to have less strict reporting requirements and, thus, might be less likely to release information on deal values.

3.7. Conclusions

3.7.1. Summary and contribution

This study takes a new perspective on first- and early-mover advantages. Previous research implicitly assumes that a new technology is stewarded by *one* firm through the entire innovation and commercialization process and that pioneers aim to monetize their innovations in product markets. However, MFTs play an important role in a number of prominent industries, and we argue that scholars must consider additional factors when assessing first-mover (dis-)advantages of small new entrants in such settings.

A key assumption underlying our study is that acquisition is desirable for small new entrants. This is because these firms are well positioned to innovate, but relative to incumbents, are less well positioned to scale-up their businesses[74], as small new entrants do not have (as many) already-established complementary resources.[75] On top of that, descriptive findings from our dataset support the idea that gains from technology markets might be higher than gains from product markets; the median deal value of roughly $150-160 million among acquired entrants is high relative to the approximately $13.5 million in annual revenues of non-acquired firms five years after their product's FDA approval.[76]

We argue that the binary outcome (i.e., being acquired, yes/no) creates different opportunities and threats for small new entrants in MFTs as compared to innovators entering emergent product markets, and thus has important new implications for whether it is advantageous to be early to market.

We find support for our first hypothesis, which predicts that acquisitions will be more likely among first- and early-movers; entering the market one year closer to the establishment of a new product type is associated with a four percentage point higher likelihood of acquisition. Thus, if acquisition is the goal, early market entry seems to be advantageous. However, pioneers need to reduce uncertainty (and technological uncertainty in particular) before they have a serious chance of experiencing acquisition. In survival models, we find evidence that a discrete change in the hazard of acquisition occurs at the time of one major milestone in the innovation process. In particular, the likelihood that a firm is acquired increases dramatically

[74] Compare e.g., Teece (1986) and Christensen (1997).

[75] Compare Arora et al. (2001), Higgins and Rodriguez (2006), Ransbotham and Mitra (2010), Brueller et al. (2015), and Henkel et al. (2015).

[76] This is especially true given a historic price/revenue-multiple of 4-6 for strategic acquisitions in the health care medical device space.

when the general technological risk of a new product type is resolved (Hypothesis 2a), which happens when the first-mover's product receives regulatory approval. Moreover, there are weak indications from some of our robustness tests that the acquisition hazard may also increase when the general market risk of the same product type is reduced (Hypothesis 2b). We do not find support for Hypothesis 2c, which states that the acquisition hazard increases at the time a given firm's innovation receives regulatory approval and, thus, the firm-specific technology risk falls.

Because pioneers have to overcome higher uncertainty, they face the disadvantage of needing to wait longer than later entrants for acquisition. This finding, too, supports our hypotheses. Conditional on acquisition, we find evidence that early market entry is positively associated with a longer time to acquisition (Hypothesis 2d); entering the market one year closer to the establishment of a new product type is associated with a 10.3-month longer wait for acquisition following product regulatory approval.

In summary, we find that due to the binary nature of (acquisition) outcomes, pioneer (dis-)advantages in MFT settings are more nuanced than those (dis-)advantages documented in simple product markets. Once pioneers have paved the way for a new product type and reduced general technological and market risk, they are rewarded through a higher acquisition likelihood. Therefore, early-movers need to wait significantly longer for an acquisition than later entrants. In contrast, later entrants can "piggy back" on early entrants' investments in mitigating technological and market uncertainty. Moreover, later entrants may not need to convince prospective buyers that their offerings are superior to those of the firms acquired earlier, because later buyers necessarily need to identify acquisition targets among the set of small firms that have not yet experienced acquisition. This situation is notably different from what is observed in simple product markets, where customers can buy directly from the pioneer.

3.7.2. Limitations

The empirical portion of this study is situated in the high-risk medical device industry in the United States. We believe that this is a uniquely advantageous setting for undertaking such research, because the necessity of regulatory approval ensures the observability of crucial information on market entry and timing. However, we acknowledge that different industries may have unique features that could lead to differences in how and when technologies are de-risked, and, therefore, how and when incumbents approach technology acquisitions.

In our analysis, we are constrained to those small new entrants that entered the market successfully (i.e., those that received FDA approval for a new device). This means that we do not observe the full set of products for which small new entrants embarked on early stage R&D activities; rather, we observe only those product concepts that were successfully commercialized.[77] However, our hypotheses focus on the activities that occur in the commercialization stage of new product development. As such, we are less concerned with earlier R&D failures, although additional study of their determinants among new entrants versus incumbents merits additional attention.

Beyond this, we want to address an inherent concern around the endogenous nature of first-movers and pioneers. It might be the case that higher quality firms are able to both obtain FDA product approval earlier *and* are more likely to have acquisition success. Alternatively, in an explanation suggesting the opposite association between product quality and the timing of regulatory approval, a firm might sacrifice possible improvements in product quality to accelerate its market entry. However, our findings on deal values mitigate many endogeneity concerns; despite the fact that first-movers experience acquisition at a later maturity, there is no indication that they experience acquisition at higher deal values, which usually are associated with higher quality of the team and its innovation.

3.7.3. Practical implications

Our results have important implications for a variety of stakeholders. From the perspective of small new entrants and their investors, the timing of market entry is an important determinant of the likelihood of an exit via acquisition. In ex-ante assessments of their specific skills, resources, and capabilities, new firms should consider two possible trajectories. If they decide to become pioneers in a new product market, they can expect to have a higher chance of being acquired. However, at the same time, this strategy carries the expectation of a lengthier process that includes waiting for proof of (general) technological feasibility and market existence.

[77] In order to avoid millions of dollars of upfront costs associated with preparations for FDA approval[77] (Carpenter et al. 2010), ventures typically follow a "fail fast approach". In this regard, previous empirical studies (e.g., Gompers 1995) confirm that financiers often split-up their funding of ventures into several rounds in order to infuse additional capital (only) if success of a given venture is foreseeable. In our specific case, this means that the number of firms with a fair chance of market entry (and acquisition) is determined years before actual FDA approval. We try to capture most of these firms through our work to include *any* device in the sample acquired before FDA approval that subsequently came to market under an incumbent's name.

If, instead, a new firm decides to enter an existing market as a later entrant, it can piggy back on pioneers' investments in reducing technological and market risks and, in turn, aim for a short(er)-term exit. However, this strategy comes with its own risk – namely, a lower probability of acquisition.

For technology buyers, it is important to consider crucial milestones in the commercialization process that will de-risk new technologies in sourcing potential acquisition targets. Many buyers appear to prioritize a reduction of acquisition risk (i.e., acquiring pioneers late or at least after a significant drop in technological and market risk) over strategic concerns such as preempting competitors from acquisition. Our study should provide M&A managers a new perspective on technology acquisitions.

4. The value of acquiring a pioneer in markets for technology

Pioneer advantages have been frequently studied from the perspective of the innovating firm. Such a firm can either sell its innovation to end customers or to another firm via markets for technology. The latter case raises a question as to whether and how the acquiring firm benefits from buying an extremely novel entrant – i.e. a "pioneer." In this exploratory study, I ask two questions: first, do capital markets reward buyers for acquiring an entrant offering a new product type? And within a new product type, do capital markets reward buyers more for the acquisition of a pioneering firm which – at the leading edge – paves the way for this new product type? The answer to both questions is nonobvious given that many firms decide on "safe bets" in their internal R&D in order to satisfy shareholders with predictable outcomes. This study focuses on the U.S. medical device industry which allows to delineate between acquisitions of pioneers and acquisitions of later followers. I use an event study approach to assess immediate stock market reactions to such acquisitions. My results provide evidence that acquiring a target firm with a novel product type is associated with a positive abnormal stock return and that capital markets particularly value acquisitions of pioneers – however, effects are only significant on the day of acquisition.

4.1. Introduction

Acquisitions of pioneering technologies may significantly affect capital market valuations of high-tech firms. "Natus Medical to acquire Olympic Medical"[78] is one of these press releases which, at a first glance, appear like pro-forma notifications to investors. However, the notification triggered a stock price reaction that made Natus outperform the NASDAQ by +6 to 7% on the day of announcement, equaling an extra $49 million USD of market capitalization if considering the trading days directly after as well. What made capital markets so enthusiastic about this acquisition? The acquired firm, Olympic, was the first to be FDA-approved for cooling caps for infants, and it brought the device to the U.S. market shortly after the acquisition. In other words, Natus had acquired a target that would massively help to fuel and extend its leading position in the newborn care market.

[78] Natus Medical, October, 16th 2006

The example of Natus and Olympic illustrates that innovation and M&A strategy are fundamentally intertwined. Yet, existing management literature leaves a gap in this regard since it focuses on capital market valuations of pioneering technology that was developed internally. Conditional on market launch, scholars found that stock markets react more positively to a product launch by first-movers as compared to later imitators (Lee et al. 2000). Consistently, Krieger et al. (2018) argue that novel product development are perceived more valuable by shareholders than the development of "me-too" products. However, the same authors argue that "it may not be the case that novel products are ex-ante preferable to me-too products" (Krieger et al. 2018, p. 38), since they carry an increased risk of failure prior to market launch. They stress that the base amount of incumbents' R&D budgets is often dedicated to products that are less risky in terms of their return on invest.

This picture is incomplete as, in many cases, incumbents acquire pioneering technologies by targeting small new entrants. The reaction of capital markets to such external technology acquisition deserves studying because it is substantially different from the reaction to internally developed innovations in at least three regards. First, acquisitions are singular events in time, and thus easier to evaluate for capital markets than long-cycled internal development projects. Second, acquisitions give the buying incumbent the opportunity to outsource the risk of the innovation failing to a small new entrant. For example, when Natus acquired Olympic the risk of failure was significantly lower than at the time Olympic had started its pioneering innovation. Third, competition between several potential buyers may affect the value split between buyer and seller shareholders.

Existing research on acquisitions has not yet addressed this fundamental gap. While Carow et al. (2004) or McNamara et al. (2008) do study buyers' early-mover advantages, their definition of early mover refers to acquisition timing relative to the peak of an acquisition market cycle rather than to the market entry timing of the acquired firm.[79]

Consequently, I ask two questions. First, do capital markets value buyers for acquiring a small new entrant of a new product type? Second, do capital markets specifically value buyers for the acquisition of one of the pioneering small new entrants of a new product type? The answers to these questions are not obvious since potential positive effects from developing a

[79] Their findings suggest that the acquirer's stock returns are higher for acquisitions which take place before the acquisition market peaks. In other words, early movers among buyers can achieve extra returns from acquisitions at the beginning of an acquisition wave.

new market and leveraging the acquired time-to-market advantages of a pioneer are accompanied by the risks inherent to new product types and to pioneering market offerings in particular. In addition to that, there is often more than one potential buyer for a specific (pioneering) entrant – thus, buyers might compete away excess capital market returns when bidding for higher purchasing prices. I take an exploratory rather than a hypothesis-driven approach because the capital market reaction to an acquisition is the result of several partly counteracting effects, and their relative sizes are not amenable to hypothesizing.

I chose the U.S. medical device market as the empirical setting for this study. Due to the regulatory environment, the innovation process in this high-tech space is highly standardized along milestones which have to be passed by each new device. Furthermore, consistent information is publicly available on new product types, market entrants, and product substitutes over the last decades. This setting is suitable for this study because it implies that capital markets should be well informed about new devices and about the market positions of incumbents and of potential acquisition targets, and shareholders should use this information in their assessment of the acquisition. As a starting point, I utilize the data set by Fischer et al. (2018) that covers all high-risk medical devices that came to market over a period of more than 25 years. I focus on those 57 small new entrants that were subject to an acquisition by a publicly listed firm. To this dataset I add longitudinal buyer-specific information about their capital market performance (individual stock price vs. market index) at and around the time of the respective acquisition. I then perform an event study to test if capital markets reward incumbents for acquiring entrants which offer new product types and for acquiring pioneering entrants in particular.

Results of my empirical analysis suggest that capital markets appreciate the acquisitions of novel products and especially of pioneers, but the effects are limited to the day of acquisition. Acquiring a small new entrant of a new product type is associated with a standardized abnormal return of +1.47 on the date when the acquisition is announced. Within such a new product type, capital markets particularly value the acquisition of a pioneer: such an acquisition comes with +0.534 of standardized abnormal return in comparison to the acquisition of a firm that, all else equal, enters the market with a comparable product one year later. In robustness checks applying alternative metrics for the dependent variable (i.e., abnormal returns and absolute abnormal returns), I obtain consistent results with respect to the signs of the coefficients, though partly not significant. For all models, effects become less or even

non-significant when I enter more variables into the model, and when I extend the event window (up to 20 trading days before and after the acquisition).

The given results complement findings regarding the often seen scenario in which big firms internally spend their "first research dollars on less risky, less novel compounds" (Krieger et al. 2018, p. 38). When a technology is acquired externally, my findings suggest that capital markets tend to value high product novelty and a target firm's pioneering market position. From a perspective of shareholder value optimization, results are in line with the common strategy of incumbents to focus internal R&D resources on predictable, less risky product improvements (compare Henkel et al. 2015), while focusing external M&A resources on the sourcing of pioneering innovations.

The remainder of this paper is structured as follows: first, I provide theoretical background on the valuation of new product innovation and (technology) acquisitions. Next, I discuss to which extent the acquisition of novel-product-type targets might (not) pay off for buyers in form of an extra return – especially, if buyers decide in favor of a pioneering small new entrant. Then, I provide the necessary background on the chosen empirical setting as well as on the data and methodology, before I present and discuss quantitative results and conclude with general implications and limitations.

4.2. Theory

In this exploratory study I seek to understand the consequences for an incumbent's valuation from acquiring a small new entrant for the purpose of obtaining a product innovation. Particularly, I am interested in the consequences of acquiring pioneering small new entrants. Thus, I revisit two separate streams of literature: one is about capital market reactions to internal product innovation and the moderating role of the innovator's market timing (i.e., early- or late-mover); the other, about capital markets' valuation of externally acquired product innovation. Finally, I synthesize both literature streams and lay out arguments which speak for or against the existence of excess returns in case of acquisitions of new-product-type innovations and in particular pioneering entrants.

4.2.1. Valuation of internal product R&D and first-mover advantages

To what extent does new product development pay off for big firms? With regard to shareholder value, should they focus their R&D on truly novel, early-mover or on "me too", later-mover innovations? The overall answer is two-fold. Pioneering innovation usually pays off

if it achieves market launch. However, incumbents are not always better off choosing a first-mover R&D project for their own product development because it carries a higher risk to fail before launch.

For new product introductions generally, literature has shown that stock markets react positively (compare Chaney et al., 1991). For the introduction of pioneering products specifically, scholars have analyzed the different pioneer (dis-)advantages as reflected in the innovator's market valuation. With regard to the valuation of pioneer (dis-)advantages, Lee et al. (2000) analyze stock market reactions to the introduction of internally developed early-mover vs. later-mover products. Conditional on market launch, their empirics suggest that shareholders react significantly more positive to the introduction of a pioneer product in comparison to later imitations.[80] This finding should relate to how big firms select internal R&D projects, and in particular how they choose between radical and incremental projects. With the U.S. pharmaceutical sector as their empirical setting, Krieger et al. (2018) investigate how the novelty of a chemical compound affects the stock market reaction to patent grant and to FDA approval of the resulting drug. Their findings are ambiguous: on the one hand, developing novel drugs is more valuable than incremental work from a standpoint of the innovator's stock price reaction, a finding consistent with Lee et al. (2000). On the other hand, Krieger et al. (2018) concede that novel product development, ex ante, may not always be the higher-return-on-investment choice because these projects carry a higher risk to fail which, in turn, is considered in capital market valuations. Relatedly, Heeley and Jacobson (2008) study the association between a firm's new inventions with its stock market performance. The authors find a non-monotonic relationship between the recency of the technological inputs to the firm's patents (captured in cited patents) and its financial performance, increasing for intermediate-aged and decreasing for mature as well as for nascent technological inputs. In other words, stock markets do not seem to appreciate inventions based on highly novel inputs, which should plausibly translate into pioneering products.

How do stock markets value technology acquisition? While the question to what extent the acquisition of a pioneering entrant comes with positive stock price reactions for buyers has not been addressed, various other aspects of technology acquisitions are well understood.

[80] Other related studies analyze capital market reactions the granting of intellectual property. For example, Austin (1993) finds patent grants to publicly listed biotech firms in the U.S. to be associated with a positive abnormal return at the issue date. Hall et al. (2005) find a positive association between the stock price development of a publicly traded firm and its intangible stock of knowledge as measured by metrics such as Patent-to-R&D or R&D-to-Assets.

Specifically, markets seem to prefer (a) same-industry deals that come (b) early in the acquisition market cycle, and which aim (c) at young target firms.

Regarding the valuation of overlap in the buyer-target-portfolio (a), Wann and Lamb (2016) evaluate the differences in market reactions to same- and cross-industry M&A deals of over four decades (1971-2013)[81]. Their outcomes suggest that markets prefer mergers which strengthen the footprint of the buyer in its existing business over diversifying mergers. They find that (during non-recession times) buyers closing on a same-industry target achieve small but higher cumulative abnormal returns than their peers acquiring a cross-industry target. Campbell et al. (2016) support this view when finding evidence that industry relatedness between the acquirer and the acquiree is an opportunity for the synergetic potential of an acquisition, and thus positively relates to the investors' perspective on a given acquisition.

With regard to the timing of acquisitions within an acquisition market cycle (b), Carow et al. (2004, p. 563) find that "strategic pioneers" – firms "acting in manners consistent with having superior information" – generate a higher combined value from acquisitions prior to the peak of industry acquisition waves. Moreover, the authors argue that buyers can choose from the greatest pool of potential targets at the *early* stage on an acquisition wave. Relatedly, but focusing on general market conditions rather than specific acquisition market cycles, Bouwman et al. (2009) investigate the relationship between market timing of such acquisitions and buyer's returns. They find that buying in times of high market valuations comes with superior ad-hoc returns, but lower long-term operating performance than deals in times of low market valuations.

Finally, studying acquisition valuation and target maturity (c), Ransbotham and Mitra (2010) find target age to be negatively associated with changes in the acquirer's valuation.

4.2.2. Valuation (dis-) advantages from acquiring small new entrants

Assuming an incumbent firm seeks to improve its innovation pipeline and increase its market valuation through acquisition of an innovative new firm – should it choose a firm offering an entirely new product type? And if so, should it bid for one of the pioneering small new entrants within this novel product space, or should it try to acquire one of the later followers?

Regarding the acquisition of an entrant offering a *new product type*, it is not sufficiently clear whether buyers should expect positive abnormal returns on capital markets. One can

[81] As part of their study, Wann and Lamb (2016) investigate investors' reactions to M&A deals at different stages of macro-economic cycles (recessions vs. non-recessions).

argue in favor of a valuation premium taking into account that acquiring a novel product type can be complementary to a more incremental internal innovation strategy. Previous researchers have shown that, in cases of success, capital markets reward publicly listed firms for truly novel product innovation over incremental innovation; however, publicly listed firms usually do not allocate much of their R&D budget to high-risk projects (Krieger et al. 2018). In such a setting, the acquisition of a new-product-type target might "legitimize" buyers for a high valuation (because of a high product novelty) when, at the same time, it relieves the buyer from potential risk-related valuation discounts during the innovation process (because a good share of the risk is borne by the acquired entrant)[82].

On the other hand, one can argue against a valuation premium considering that typically there is more than one potential buyer targeting a specific entrant of a new product type. In such a case, potential buyers may compete away excess capital market returns and, as a consequence, stock markets should react with an absence of any abnormal return.

Regarding the acquisition of one of the *pioneering entrants* (within such a new product type), there is no clear prediction of abnormal buyers' returns either. On the one hand, one could expect positive excess returns for a pioneering acquisition because pioneers obtain attractive stand-alone target characteristics that are clear-to-communicate and easy-to-package in a compelling equity story for capital markets. Early movers, by definition, are in a favorable market position to capture a large share of the newly rising market because of switching costs and lock-in effects (compare e.g., Lieberman and Montgomery 1988).These advantages should transfer to the buyer in case of an acquisition and might positively affect the buyer's valuation. So, if there is a clear pioneer available within a market for technologies, this likely helps the buying incumbent to establish, expand, or defend its segmental leadership.

On the other hand, there are reasons to question the existence of excess returns for acquisitions of a pioneer. Management scholars have found that investors have limited power to value complex innovations (compare e.g., Cohen et al. 2013 or Hirshleifer et al. 2013)[83]. Investors might overreact to pioneer acquisitions as these acquisition are likely to get more

[82] Chambers et al. 2002 find that it is difficult for capital markets to incorporate the full riskiness of a R&D investment into firm valuations. I argue that the incumbents' risk of being mispriced by capital markets will be higher for new product types as investors will rarely find any reference products or benchmarks to compare the project with. If a small new entrant develops the same new product type instead, and if the incumbent can acquire the new product type afterwards, capital markets might value this outsourcing of risk. In other words, they might reward the acquirer by excess stock returns when the small new entrant is acquired.

[83] Cohen et al. (2013) and Hirshleifer et al. (2013) both argue that investors have limited processing power for complex innovations in patents and thus undervalue innovative firms.

attention – but also this situation might end up in some short-term neutralization of abnormal returns as investors lose excitement. Moreover, to the extent that several potential buyers value the pioneering entrant equally they should make competing bids for it in such a way that the pioneer's shareholders appropriate this firm's incremental value in their negotiations with potential buyers. In turn, if the acquirer's shareholders are aware of this logic, then there should be no extra premium (abnormal return) for acquiring the pioneering entrant.

4.3. Empirical setting, data, and methodology

In the following, I describe characteristics of the U.S. medical device industry. Then, I present the data set for the quantitative study, introduce the event study methodology, and provide an overview of the variables used.

4.3.1. The U.S. medical device industry and capital market information

The U.S. Food and Drug Administration (FDA) regulates the biggest global market for medical technology; any new device to be sold on the U.S. market requires its approval. FDA approval marks the gate between an R&D process that usually takes several years and product commercialization on a market of a total worth of more than $140 billion USD annually (Statista, 2018).

The FDA assigns a new product code by an independent committee once a new device type with a novel therapeutic use has been created. Moreover, the administration releases a public ad-hoc information once a device (coming from a specific firm) has gained FDA approval for a certain product code. Thus, buyers and capital markets obtain precise, date-specific information on the timing of U.S. market entry for new devices, and in particular for each device coming from a small new entrant. Moreover, capital markets can compare product substitutes based on the publicly available FDA information: FDA's Center for Devices and Radiological Health (CDRH) classifies any newly approved medical device into a systematic scheme of more than 300 different product codes for the high-risk device space alone.[84] This implies a notable advantage for my empirical study: I may assume that buyers, but also capital markets are informed about product substitutes of potential acquisition targets. In other industries, this crucial information is usually only available after a lengthy due diligence process, with often less than reliable outcomes. Within a given product code, the

[84] FDA, as of December 2017

FDA approvals granted to different entrants at different points in time can be put into relation with each other: this allows me (but also capital markets) to calculate the exact temporal distance between the first-mover's market entry and later followers.

In summary, the later stages of the innovation process in the U.S. medical device space are not only highly standardized, but also very transparent to capital markets. The regulatory environment requires to make information publicly available, which informs capital markets about when a new product type is created, who pioneers it, and who follows. The FDA has released a comprehensive set of information on new product types, market entrants, and product substitutes over the last decades. This comes with another advantage for my empirical study: I may assume that capital markets are fully informed about the relative market position of (new) entrants and potential acquisition targets, and shareholders can use this information in their assessment of the acquisition. In turn, this helps to investigate the relationship between the acquisition of novel technologies and shareholder value.

4.3.2. Sampling and data collection

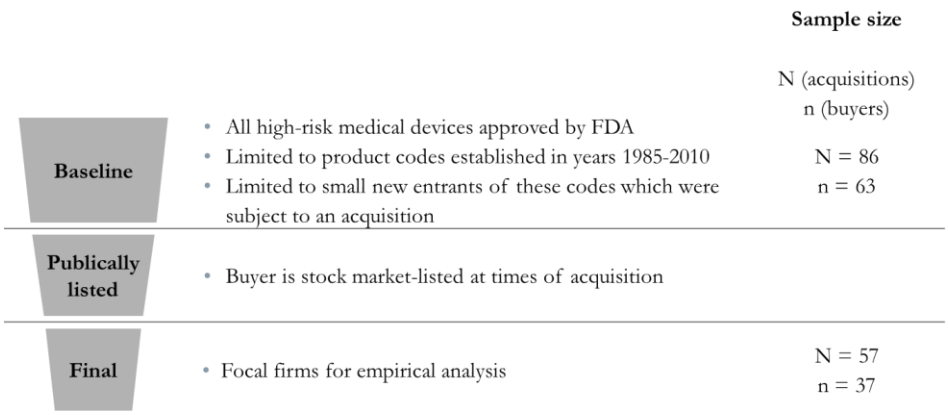
I start from the data set established by Fischer et al. (2018), which captures all high-risk medical devices that came to market in new product codes between 1985 and 2010. Of those, 119 devices were introduced by small new entrants.[85] All these small new entrants are at the edge of a new device type, which means they are either in a first-mover position or follow within seven years after the respective code was created.[86] Among these 119 firms are 86 acquired entrants, which I use as the baseline sample for the present study. I draw all FDA- and product-related data – on the acquired entrants, the buyers, and potential other buyers – from the Evaluate MedTech database (EMT), which captures all FDA device approvals for the relevant time period. Data on the U.S. intellectual property of acquired firms are taken from the online database of the U.S. Patent and Trademark Office.

In a next step, I identify those 57 out of the 86 small new entrants which were acquired by a publicly listed company. Figure 17 gives an overview of the selection process.

[85] Fischer et al. (2018) consider a firm to be a small new entrant if it has no more than five years of previous high-risk device experience, if its portfolio is narrowly focused, and if it establishes a FDA product code with therapeutic relevance (with more than one successful approval during the observation period) or follows within 7 years.

[86] Fischer et al. (2018) argue that the period of seven years should be long enough to observe most of the followers with a comparable technology, but short enough to exclude evolutionary generations of this device which are unlikely to be direct substitutes.

Figure 17: Data sampling approach of acquisitions of listed buyers



Deal-related data, like deal values and announcement dates, I pulled together from Mergermarket,[87] Google Finance,[88] CapitalIQ[89], and I triangulated them with ad-hoc disclosures to capital markets. Associated with the 57 acquired targets I find 37 different buyers; most of which are prominent medical device players such as Medtronic, BostonScientific, Johnson & Johnson, or Abbott Laboratories.

Next, I match the data on acquisition targets with a newly created set of buyer-related data. Drawn from the Bloomberg database it comprises daily data on the buyers' stock performance, their market capitalization, and the corresponding market index (NYSE, NASDAQ, DAX, Topix, SMI, FTSE MIB).[90] The resulting number of 57 acquisitions necessarily restricts the number of explanatory variables that I can employ. However, this is not unusually small as compared to other acquisition-focused event studies in the management literature (see Mc Williams et al. 1997 referring to e.g., Chatterjee 1986, Singh and Montgomery 1987, Seth 1990). Table 10 shows the final sample including a list of acquirers, the number of associated targets, and corresponding indices.

[87] https://www.mergermarket.com
[88] https://www.google.com/finance
[89] https://www.capitaliq.com
[90] https://www.bloomberg.com

Table 10: Sample: overview of listed buyers and acquisitions

Acquirer	Index	Acquisitions
Total		57
BOSTONSCIENTIFIC	NYSE Composite Index	12
MEDTRONIC	NYSE Composite Index	6
HOLOGIC	NASDAQ Composite Index	3
ABBOTT LABORATORIES	NYSE Composite Index	2
INTEGRA LIFESCIENCES	NASDAQ Composite Index	2
ST JUDE MEDICAL	NYSE Composite Index	2
3M	NYSE Composite Index	1
ABIOMED	NASDAQ Composite Index	1
ALLERGAN	NYSE Composite Index	1
AngioDynamics	NASDAQ Composite Index	1
Angiotech	NASDAQ Composite Index	1
ANIKA THERAPEUTICS	NASDAQ Composite Index	1
ANIMAS	NASDAQ Composite Index	1
BAXTER	NYSE Composite Index	1
BECTON DICKINSON	NYSE Composite Index	1
BIOMET	NYSE Composite Index	1
Cardinal Health	NYSE Composite Index	1
DIASORIN	FTSE MIB	1
Elbit Imaging Ltd.	NASDAQ Composite Index	1
Endo International	NASDAQ Composite Index	1
JOHNSON & JOHNSON	NYSE Composite Index	1
LEMAITRE VASCULAR	NASDAQ Composite Index	1
Linde	DAX Index	1
Merck	NYSE Composite Index	1
Merit Medical Systems	NASDAQ Composite Index	1
Mylan Teoranta Limited	NASDAQ Composite Index	1
NATUS MEDICAL	NASDAQ Composite Index	1
Olympus	Topix Index	1
OSI Systems	NASDAQ Composite Index	1
QIAGEN	NASDAQ Composite Index	1
STRYKER	NYSE Composite Index	1
SYNTHES	SMI Index	1
Thermo Fisher Scientific	NYSE Composite Index	1
TriPath Imaging, Inc	NASDAQ Composite Index	1
VALEANT PHARMACEUTICALS	NYSE Composite Index	1
World Holdings Co.	Topix Index	1

4.3.3. Event study methodology

Does the acquisition of product innovation pay off for buyers? Principally, can buyers expect a positive abnormal return from acquiring a new device type? Specifically, can buyers expect a positive abnormal return when acquiring one of the early movers of a new device type? To address these questions I employ an event study. This is a standard tool of research in finance research and tests whether financial markets react significantly to a specific event at a certain

point in time (compare Brown, Warner 1985). The method identifies the effect of unanticipated events on stock price (McWilliams 1997) and, inherently, requires that the focal firms (here: acquirers of small new entrants) are publicly listed companies. Following earlier studies (e.g., McWilliams et al., 1997, and Gompers et al., 2009), I pursue a three-step approach.

First, I calculate buyers' expected returns. The model calculates an expected return for every acquirer within a certain time period around the acquisition (event window). Doing so, it utilizes pre-event market valuation data of a firm (estimation window). Mathematically, it measures firm-specific return against the development of the relevant market index. Consistent with former scholars, I apply the capital asset pricing model (CAPM) to calculate expected returns (compare e.g., Austin 1993, MacKinley 1997). The CAPM assumes a systematic relationship between the return of the focal firm (i.e., the acquirer of a small new entrant) and the underlying market portfolio[91]:

$$E(R_i) = R_f + \beta_i(R_m - R_f)$$

where R_f is the risk-free rate, $(R_m - R_f)$ is the market premium of the value-weighted underlying stock index, and β_i is a firm-specific multiplier capturing the extent to which the assets moves with the market.[92] As the estimation period for the expected return I choose 250 days (compare Mc Williams and Siegel 1997, Chacko et al. 2001), leaving a 30-days gap between the estimation window and the event window. Doing so, I circumvent potential interferences between estimated and actual returns.

Second, I derive buyers' abnormal returns as the difference between their actual returns and expected returns. Technically, the model compares the expected returns for the event window with the actual returns observed for this period[93]. The event window is not limited to the date of acquisition, but may comprise a trading period of several days before and after the acquisition.

Third, I interpret abnormal returns as the part of returns which is unexplained by the market model. This allows me to interpret abnormal returns as the reaction of financial markets to the acquisition of a small new entrant by the focal firm. Figure 18 graphically summarizes key parameters and applied metrics of the event study.

[91] Following the methodology of Campbell et al. (2010), I apply the national market index as the relevant market portfolio. The authors find that the utilization of local market indices is suitable to create powerful analyses of stock-price reactions in multi-country event-study designs.

[92] Technically, β_i is the correlation coefficient between the return of firm i and the market return multiplied by the standard deviation of the acquirer's return and normalized by the standard deviation of the market return.

[93] The gap between the estimation window and the event window is 30 days.

Figure 18: Event study parameters

Parameter	Implementation
• Event:	Acquisition of a new device, pioneers or later follower
• Event window:	Acquisition date, +/-1,3,5,10 days (compare Austin 1993, Lee et al. 2000, Ransbotham and Mitra 2010, Lee et al. 2000, Kogan et al. 2017)
• Estimation period:	250 days (compare Mc Williams, Siegel 1997, Chacko et al. 2001)
• Gap:	30 days
• Applied Metrics:	Higher weight to stock price reactions that occur for otherwise stable (compare Boehmer et al.1991, Mc Williams, Siegel 1997)

4.3.4.Dependent variables

I apply three different metrics in order to assess abnormal returns of acquisitions of small new entrants; two of these are relative, one is absolute.

As one of the relative metrics, *Abnormal Return (AR)* measures the difference between the actual and the expected stock price on the date of acquisition (t=0) and in percent. This basic metric can be expressed by the following relationship:

$$AR_{it} = R_{it} - E(R_{it})$$

where AR_{it} represents the abnormal return of the acquirer i on the acquisition's announcement date t, R_{it} represents the actual return accordingly, and $E(R_{it})$ represents the expected return.

As the second relative metric, *Standardized Abnormal Returns (SAR)* represents the main dependent variable. It is commonly used for event studies in the economics and finance space (compare Mac Kinley, 1997). Its advantage over *Abnormal Return* is that the stock price movement on the acquisition date is being put into relation with the variance of the respective (buyer's) stock in the past. Thereby, *SAR* calibrates the *event-related* variance of stock prices in such a way that it gives a higher weight to stock price reactions that occur for otherwise stable (as opposed to volatile) stocks (Dodd and Warner 1983, Boehmer et al.1991, Mc Williams and Siegel 1997). *SAR* is given by:

$$SAR_{it} = \frac{AR_{it}}{\sigma_i}$$

where σ_i is the standard deviation of the acquirer's stock returns during the estimation window.

As an alternative, absolute metric, *Absolute Abnormal Return (AAR)*, describes the extra-gain (or loss) of market capitalization that is associated with a certain acquisition. Mathematically, it consists of the *Abnormal Return* multiplied by a buyer's market capitalization one day prior to the acquisition announcement (compare Kumar et al., 2015).

Moreover, I calculate the *Cumulative Abnormal Return (CAR)* in order to assess the abnormal return of a buyer in a time window around the announcement date of an acquisition (compare e.g., Kogan et al., 2017). Concretely, In include 1, 3, 5, 10 trading days before and 1, 3, 5, 10 trading days after the acquisition into the analysis. This means that I consider cumulative returns of up to 20 trading days around the technology acquisition. In an analogous fashion, I construct the cumulative metrics *Standardized Cumulative Abnormal Return (SCAR)* and *Cumulative Absolute Abnormal Returns (CAAR)*[94].

4.3.5. Independent variables

Product code age at approval is the main explanatory variable. It measures the elapsed time between the establishment of a new device type (i.e., the date of the first-mover's FDA approval) and the FDA approval of the firm in focus of a given acquisition. Since I restrict the sample to acquired entrants whose devices received FDA approval in the 7-year period after the creation of the respective FDA code, *product code age at approval* is between 0 and 7 years.

The following set of control variables capture characteristics of the targeted innovator, the buyer and the acquisition environment. I operationalize control variables describing the sell-side (i.e., the innovating small new entrant) in line with Fischer et al. (2018). *Time to acquisition* reflects the period between a small new firm's FDA approval and the buyer's announcement of the acquisition. It controls for the maturity level of the acquired firm and the concomitant reduction of technological and market uncertainty, an important aspect particularly for early-mover acquisitions. *Patents at acquisition* equals the natural logarithm of

[94] For CAAR, I consider the market capitalization at the beginning of a given event period. For example, in order to come up with the CAAR +/-10 days (around the acquisition announcement), I consider the market capitalization 10 days prior to acquisition multiplied by the relative *Abnormal Return*, CAR +/-10 days.

the number of U.S. patents (+1) of the targeted firm at the time of acquisition. Dummy variables for *Medical specialties* control for the medical field of the target firm of an acquisition, aggregated to clusters of cardiovascular devices, radiology devices, and other devices.[95] *Deal value* describes the natural logarithm of the acquisition price (in $ millions). Incorporating this variable allows me to control for effects from potential under- or over-payments. Data on transaction values are available for 53 out of all 57 acquired small new entrants (93%). *Number of potential buyers at acquisition* describes the natural logarithm of the number of big companies (+1) which might have both an interest and the required resources to acquire the respective small new entrant. The variable controls for the degree of buyer competition associated with the focal acquisition. Doing so, I am specifically interested in their role as competitors for a given target, but indirectly I also capture how rivals react to their competitors' M&A moves more generally (compare Uhlenbruck et al., 2017). I follow the same approach as Fischer et al. (2018), based on Allain et al. (2016), and define distinct criteria which qualify a company to be a potential acquirer for a given acquisition target: the company must have been present in a related product market before, and must have a sufficient M&A track record. Regarding the market-relatedness, a potential buyer must have an FDA-approved device in the same medical class[96] as the targeted small new entrant. Regarding the M&A track record, a potential buyer should have performed at least three acquisitions over five years, the last of which took place three years or less prior to the focal announcement.

On the buy-side (i.e., the acquiring incumbent), *acquisition weight* describes the ratio of the deal value and the buyer's market capitalization on the date of the acquisition announcement (compare Ransbotham and Mitra, 2010). It controls for effects of the relative size of a target firm in comparison to the acquirer. I expect relatively large acquisition to have a higher effect on the buyer's stock price.

Buyer-target overlap is a dummy variable indicating whether a given buyer has been active in the same product like the acquired targeted small new entrant prior to acquisition. It

[95] I aggregate the FDA's 20 regulatory product classes to three fields in order to save on degrees of freedom in the regression analysis. Among the full sample of 57 acquired firms, the *Cardiovascular* device class accounts for 35% of all targeted firms while *Radiology* as a class represents 4% of the sample. I consider these devices separately because of their technological distance to all other devices in the sample and due to the high investment costs. *Others* includes all remaining product classes, such as gastroenterology, urology, and gynecology (12%), any diagnostics product class (14%), surgical and orthopedic product classes (26%), as well as a collection of head-related product classes like dental, ear, nose, throat, neurology, and ophthalmic (9%).

[96] Based on the original FDA classification of 20 different medical classes. See also Fischer et al. (2018).

takes on the value of one if on the announcement date the buyer has an FDA-approved product in the same FDA product class as the acquired firm.[97]

Buyer previously invested is a dummy variable which takes a value of one if the acquirer has been invested into the target prior to acquisition. Thereby, I control for the fact that an acquisition might come less unexpected for shareholders in cases where the acquired firm had already been on the radar of the buyer before the 100% acquisition happened.

[97] For example, this means that *Buyer-target-overlap* is equal to one if the acquirer of a cardiovascular-target was FDA-approved for at least one device in the FDA's cardiovascular product class before (even if for a different FDA product code).

4.4. Results and discussion

I present the results of my quantitative study in three steps. First, I give an overview of summary statistics and correlations. Second, I introduce model M1 in order to test if extra returns exist for novel-product-type acquisitions. Third, I present models M2 and investigate if there are excess returns for pioneer acquisitions within a novel product type. As robustness checks, I expand my main model in three directions (M2a – M2c).

4.4.1. Descriptive statistics and correlations

Table 11 shows summary statistics and Table 12 shows correlations for all variables of the empirical analysis. The average standardized abnormal return across all acquisitions is +1.47; the average abnormal return, +0.65%.[98] These values are in the same range like event studies which also focus on the acquisition of high-tech start-ups.[99]

Table 11: Summary statistics

Variables		Obs	Mean	Median	Std. Dev.	Min	Max
Dependent variables	Abnormal Returns						
	SAR	57.00	1.47	0.51	3.72	-3.76	9.35
	AR	57.00	0.65	0.64	2.05	-2.93	3.94
	AAR	57.00	143.08	32.68	359.24	-245.82	982.13
Independent variable	Product code age at approval	57.00	1.66	0.00	2.40	0.00	7.01
Control variables	Time to acquisition	57.00	6.33	6.01	7.02	-6.88	28.35
	Patents at acquisition	57.00	72.82	15.00	339.37	0.00	2564.00
	Potential buyers at acquisition	57.00	49.95	44.00	38.40	0.00	138.00
	Deal value	53.00	712.16	193.50	1267.25	1.10	6200.00
	Acquisition weight	53.00	0.13	0.03	0.31	0.00	1.98
	Buyer-marketcap at acqusition	57.00	20892.24	6590.05	35640.71	52.88	201033.76
	Buyer-target-overlap	57.00	0.70	1.00	0.46	0.00	1.00
	Buyer previously invested	57.00	0.12	0.00	0.33	0.00	1.00
	Cardiovascular	57.00	0.35	0.00	0.48	0.00	1.00
	Others	57.00	0.61	1.00	0.49	0.00	1.00
	Radiology	57.00	0.04	0.00	0.19	0.00	1.00

Dependent variables winsorized at the 10% and 90% level

On average, the acquisition targets in the sample entered a novel product type 1.66 years after the code was created[100], and acquisitions took place 6.3 years after the respective product's FDA approval. Correlations indicate that *Deal Value* and *Acquisition Weight* should not be used in the same regression (corr = 0.77).

[98] To prevent regression results from being skewed by outliers, I winsorize all return-related variables at the 10% and 90% level. A 5%- winsorization (similar to Carow et al., 2004) on each tail delivers similar, but (mostly) less significant results.

[99] Compare e.g., Ransbotham and Mitra (2010).

[100] The sample of acquisition targets consist almost equally of first movers (55%), which establish a new code, and followers (45%), which follow in an existing code over the period of 7 years after it was created.

Table 12: Pairwise correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 SAR	1.000													
2 AR	0.697*	1.000												
3 AAR	0.489*	0.466*	1.000											
4 Product code age at approval	-0.343*	-0.318	-0.238	1.000										
5 Time to acquisition	0.249	0.142	0.170	-0.400*	1.000									
6 ln(Patents at acquisition+1)	0.079	-0.146	-0.057	-0.005	0.261	1.000								
7 ln(Potential buyers at acquisition+1)	0.059	0.011	-0.005	-0.130	0.440*	0.111	1.000							
8 Deal value	-0.042	-0.048	-0.047	0.020	0.120	0.317	-0.100	1.000						
9 Acquisition weight	-0.130	-0.079	-0.160	0.025	0.141	0.256	-0.150	0.766*	1.000					
10 Buyer-target-overlap	-0.182	-0.145	-0.039	0.075	-0.290	0.115	0.073	0.219	0.124	1.000				
11 Buyer previously invested	0.052	0.042	0.111	-0.005	-0.083	-0.130	0.095	-0.095	-0.070	-0.223	1.000			
12 Cardiovascular	-0.164	-0.141	-0.219	0.444*	-0.364*	0.031	-0.150	-0.019	-0.074	0.238*	-0.051	1.000		
13 Others	0.176	0.112	0.238	-0.423*	0.424*	0.036	0.172	0.056	0.082	-0.201	0.077	-0.927*	1.000	
14 Radiology	-0.040	0.072	-0.058	-0.032	-0.176	-0.175	-0.050	-0.094	-0.023	-0.084	-0.071	-0.140	-0.240	1.000

Note: * < 0.01

Return variables winsorized at the 10% and 90% level

4.4.2. Analysis 1: Acquiring new-product-type innovation

Table 13 shows the results of model M1. Testing H1, the goal is to find out whether the acquisition of a small new entrant in a novel product type comes with an abnormal return for the acquirer (regardless if, a certain new product type, the acquired firm is an early or later mover). By a one-sample T-test, M1 tests the null hypothesis that the mean of abnormal returns equals zero.

M1: One-sample t-test

	All firms			
Variables	Obs	Mean	Std. Dev.	p-value: mean =0
Standardized (Cumulated) Abnormal Return				
SAR	57.00	1.47	0.49	0.42%
SCAR +/-1 day	57.00	0.53	0.43	22.75%
SCAR +/-3 days	57.00	-0.44	0.35	21.18%
SCAR +/-5 days	57.00	-0.61	0.33	6.82%
SCAR +/-10 days	57.00	-0.34	0.32	29.09%
(Cumulated) Abnormal Return (in%)				
AR	57.00	0.65	0.27	1.97%
CAR +/-1 day	57.00	0.43	0.51	40.20%
CAR +/-3 days	57.00	-0.13	0.76	86.54%
CAR +/-5 days	57.00	-1.19	0.74	11.53%
CAR +/-10 days	57.00	-0.60	1.13	59.89%
(Cumulated) Abnormal Return (C)AR in MUSD				
AAR	57.00	143.08	47.58	0.39%
CAAR +/-1 day	57.00	176.05	43.75	0.02%
CAAR +/-3 days	57.00	62.36	61.13	31.21%
CAAR +/-5 days	57.00	-122.41	60.47	4.77%
CAAR +/-10 days	57.00	-118.81	95.64	21.93%

One-sample t-test (Ho: mean=0)
p-value of a two-sided t-test
Variables winsorized at the 10% and 90% level

Table 13: M1: One-sample T-test of abnormal returns for new-product-type acquisitions

As reflected by the p-values of the main dependent variable, *Standardized Abnormal Return*, results of M1 suggest that the null hypothesis can be rejected at the 1% level. Instead, there seems to be a significant, abnormal return on the announcement date of such an acquisition. Consistent with that, the first robustness check using *Abnormal Return* as the dependent variable (middle set of rows) suggests that acquiring a small new entrant in a new product type comes with +0.65% of extra stock return on the announcement date at the 2% level. Results of the second robustness check using *Absolute Abnormal Returns* point into the same direction: the *Absolute Abnormal Return* (lower set of rows) of such an acquisition is $143.08 million on the date of announcement (1% level). However, most of these effects are significant only on the day of acquisition and become insignificant when looking at cumulative returns of "longer" periods of (up to) 20 trading days.

4.4.3. Analysis 2: Acquiring a pioneering new entrant

Table 14 shows the estimates of the main OLS-model M2. Here, the independent variable relates to market entry timing of the acquired firm; *Product code age at approval* is the time between the market entry of the acquired firm and the market entry of the first-mover.

In specification 1, I enter the independent variable in the regression and find that *Product code age at approval* is negatively associated with *Standardized Abnormal Return* at the 1% level. The coefficient $\beta = -0.534$ indicates that the *Standardized Abnormal Return* decreases by 0.534 for each year that has elapsed between product code creation and the acquiree's FDA approval in that product code. Vice versa, capital markets seem to value pioneer acquisitions by a significant excess return on the stock price as compared to the acquisition of an equivalent company entering the market one year later.

Table 14: M2: Linear regression model (OLS) on Standardized Abnormal Return (SAR)

	M2: OLS model (DV = Standardized Abnormal Return, date of acquisition)								
	All firms								
	Specification 1	Specification 2	Specification 3	Specification 4	Specification 5	Specification 6	Specification 7	Specification 8	Specification 9
Product code age at approval	-0.534**	-0.451*	-0.459*	-0.455*	-0.447†	-0.420†	-0.426†	-0.421†	-0.420
	(0.20)	(0.22)	(0.22)	(0.22)	(0.22)	(0.22)	(0.22)	(0.23)	(0.25)
Time to acquisition		0.071	0.063	0.075	0.120	0.143	0.131	0.138	0.135
		(0.07)	(0.08)	(0.09)	(0.09)	(0.09)	(0.10)	(0.11)	(0.11)
ln(Patents at acquisition+1)			0.118	0.116	0.067	0.093	0.120	0.128	0.126
			(0.34)	(0.34)	(0.39)	(0.37)	(0.39)	(0.39)	(0.41)
ln(Potential buyers at acquisition+1)				-0.130	-0.074	-0.141	-0.105	-0.140	-0.137
				(0.40)	(0.44)	(0.43)	(0.46)	(0.47)	(0.49)
ln(Deal value)					-0.144				
					(0.26)				
Acquisition weight						-2.172	-2.082	-2.122	-2.118
						(1.70)	(1.76)	(1.78)	(1.84)
Buyer-target-overlap							-0.307	-0.184	-0.198
							(1.25)	(1.31)	(1.37)
Buyer previously invested								0.527	0.503
								(1.56)	(1.62)
Cardiovascular									0.191
									(2.95)
Others									0.244
									(2.85)
N	57	57	57	57	53	53	53	53	53
R^2	0.118	0.133	0.135	0.136	0.188	0.210	0.211	0.213	0.213

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001

Values in breakets represent standard errors

Dependent variable winsorized at the 10% and 90% level

Peu-a-peu, I enter the control variables for target- and buyer-related characteristics reflected by specifications 2 to 9. For any of those specifications, the coefficient for *Product code age at approval* remains negative which, in turn, indicates greater abnormal returns for pioneer acquisitions than for acquisitions of followers. The level of significance of the main variable disappears the more control variables I add into the model. This is not totally surprising given a sample size of 57 in combination with up to ten explanatory variables.

I check for robustness of results by three analyses. First, I replace the main OLS-model M2 by a two-sample T-test (M2a) and build two categories of acquired firms: I delineate 32 first-movers from 25 followers in the sample, and assess whether the standardized abnormal returns for these two groups are significantly different from each other. Table 15 shows that excess returns are distributed in favor of the group of first-movers which seem to be valued by SAR = 2.83 on the announcement date, while follower-acquisitions are only valued by SAR =-0.26 (0.1% level). However, I observe similar results only for a short-term period of +/-3 trading days around the acquisition.

Table 15: M2a: Two-sample T-test of abnormal returns for acquisitions

M2a: Two-sample t-test

	All firms									
	First-mover			Follower			Group comparison			
Variables	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Diff (mean)	p(Diff<0)	p(Diff=0)	p(Diff>0)
Standardized (Cumulated) Abnormal Return										
SAR	32	2.83	3.86	25	-0.26	2.75	3.08	0.04%	0.09%	99.96%
SCAR +/-1 day	32	1.27	3.27	25	-0.42	3.04	1.69	2.44%	4.88%	97.56%
SCAR +/-3 days	32	-0.13	2.84	25	-0.84	2.34	0.71	15.30%	30.59%	84.70%
SCAR +/-5 days	32	-0.67	2.52	25	-0.54	2.50	-0.13	57.82%	84.37%	42.18%
SCAR +/-10 days	32	-0.09	2.41	25	-0.67	2.46	0.58	18.88%	37.76%	81.12%

Two-sample t-test (Ho: mean(First-mover)=mean(Follower)

p-value of a two-sided t-test

Variables winsorized at the 10% and 90% level

Second, I return to the OLS-model but I exclude different sub-samples from the analysis. The results of this robustness check, M2b, are presented in Table 16.[101] Except the case where I remove all first-mover acquisitions from the sample, coefficients remain unchanged. However, effects lose their significance when taking out up to 61% of the sample.

Table 16: M2b: Linear regression model (OLS) on SAR for different sub-samples

	M2b: OLS model (DV = Standardized Abnormal Return, date of acquisition)	
	Without first movers	Without firms acquired before FDA approval
	Specification 8	Specification 8
Product code age at approval	0.362	-0.448†
	(0.45)	(0.22)
Time to acquisition	0.137	0.197†
	(0.22)	(0.10)
ln(Patents at acquisition+1)	-0.022	0.111
	(0.58)	(0.38)
ln(Potential buyers at acquisition+1)	-0.421	-0.096
	(0.77)	(0.49)
Acquisition weight	-6.671	-1.982
	(7.22)	(1.57)
Buyer-target-overlap	0.031	-0.642
	(1.92)	(1.21)
Buyer previously invested	0.668	0.918
	(2.62)	(1.49)
N	23	44
R^2	0.092	0.330

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001
Values in breakets represent standard errors
Dependent variable winsorized at the 10% and 90% level

[101] For the robustness checks, I use specification 8. This specification contains the full set of control variables except the dummies for medical specialty (*Cardiovascular, Other*). I exclude them because of the very small sample sizes (and more limited degrees of freedom). Moreover, these dummies had a non-significant effect in the main model, M2.

Third, I derive M2c and apply alternative metrics as dependent to the OLS-model. I present the results on *Abnormal Returns* (AR, in %) in Table 17. A coefficient of β = -0.272 (5% level) for the Abnormal Return indicates that excess returns shrink by 0.272% for each year that has elapsed the product code creation and the acquiree's FDA approval.

Table 17: M2c: Linear regression model (OLS) on Abnormal Return (AR)

M2c: OLS model (DV = Abnormal Return, AR, in %, date of acquisition)

	All firms								
	Specification 1	Specification 2	Specification 3	Specification 4	Specification 5	Specification 6	Specification 7	Specification 8	Specification 9
Product code age at approval	-0.272*	-0.266*	-0.249*	-0.247*	-0.219†	-0.216†	-0.221†	-0.221†	-0.213
	(0.11)	(0.12)	(0.12)	(0.12)	(0.13)	(0.13)	(0.13)	(0.13)	(0.14)
Time to acquisition		0.005	0.020	0.027	0.047	0.049	0.039	0.039	0.047
		(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)
ln(Patents at acquisition+1)			-0.233	-0.233	-0.244	-0.219	-0.196	-0.195	-0.183
			(0.19)	(0.19)	(0.22)	(0.21)	(0.22)	(0.22)	(0.23)
ln(Potential buyers at acquisition+1)				-0.074	0.054	0.027	0.058	0.054	0.043
				(0.22)	(0.24)	(0.24)	(0.26)	(0.27)	(0.28)
Deal value					0.016				
					(0.15)				
Acquisition weight						-0.365	-0.287	-0.292	-0.331
						(0.97)	(1.00)	(1.01)	(1.04)
Buyer-target-overlap							-0.266	-0.251	-0.190
							(0.71)	(0.74)	(0.78)
Buyer previously invested								0.062	0.134
								(0.89)	(0.92)
Cardiovascular									-0.712
									(1.67)
Others									-0.724
									(1.62)
N	57	57	57	57	53	53	53	53	53
R^2	0.101	0.102	0.127	0.129	0.142	0.144	0.147	0.147	0.151

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001
Values in breakets represent standard errors
Dependent variable winsorized at the 10% and 90% level

This goes hand in hand with -$35.754 million absolute abnormal return (at a 10% level) which is reflected in Table 18, *Absolute Abnormal Returns* (AAR, in $ millions). Findings for both alternative excess return metrics are consistent with the main OLS-model; as well as the fact the results become non-significant the more variables I add to the equation.

Table 18: M2c: Linear regression model (OLS) on Absolute Abnormal Returns (AAR)

M2c: OLS model (DV = Absolute Abnormal Return in MUSD, date of acquisition)

	All firms								
	Specification 1	Specification 2	Specification 3	Specification 4	Specification 5	Specification 6	Specification 7	Specification 8	Specification 9
Product code age at approval	-35.754†	-30.411	-28.824	-28.076	-27.535	-25.936	-23.101	-21.299	-12.649
	(19.64)	(21.56)	(21.81)	(21.98)	(22.72)	(22.42)	(22.44)	(22.43)	(24.59)
Time to acquisition		4.548	5.959	8.088	12.255	13.868	20.029†	22.641*	20.607†
		(7.35)	(7.71)	(8.52)	(9.03)	(9.00)	(10.32)	(10.54)	(11.13)
ln(Patents at acquisition+1)			-21.974	-22.196	-42.573	-25.358	-38.615	-36.040	-29.729
			(33.94)	(34.15)	(39.43)	(37.26)	(38.68)	(38.62)	(39.94)
ln(Potential buyers at acquisition+1)				-24.288	-16.696	-34.258	-51.670	-63.295	-62.353
				(40.24)	(44.47)	(43.74)	(45.87)	(46.85)	(47.56)
ln(Deal value)					13.597				
					(26.96)				
Acquisition weight						-222.718	-266.684	-279.889	-300.205
						(173.33)	(176.34)	(176.15)	(180.13)
Buyer-target-overlap							150.405	191.571	202.372
							(124.99)	(129.71)	(133.93)
Buyer previously invested								176.033	169.416
								(154.38)	(158.53)
Cardiovascular									-62.248
									(289.21)
Others									63.075
									(279.35)
N	57	57	57	57	53	53	53	53	53
R^2	0.057	0.063	0.071	0.077	0.114	0.139	0.165	0.189	0.207

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001

Values in breakets represent standard errors

Absolute Abnormal Returns = (Buyer-market cap on acquisition date) x (Abnormal return, in % on acquisition date)

Dependent variable winsorized at the 10% and 90% level

Lastly, I present cumulative excess returns for the main model as well as for all my alternative models in Table 19. Using specifications 1 and 8, I find that effects of higher rewards for pioneer acquisitions fade away for any event period longer than the announcement date itself. Other events are likely to outweigh the valuation effects of these relatively small acquisitions (median deal value is $193.5 million).

Table 19: M2c: Linear regression model (OLS) on (cumulative) SAR, AR, AAR

M2c: OLS model (DV = Abnormal returns on the date of acquisition and around)

	SAR / SCAR: Standardized Abnormal Return					AR / CAR: Abnormal Return					AAR / CAAR: Absolute Abnormal Return				
	Acquisition date	+/- 1 day	+/- 3 days	+/- 5 days	+/- 10 days	Acquisition date	+/- 1 day	+/- 3 days	+/- 5 days	+/- 10 days	Acquisition date	+/- 1 day	+/- 3 days	+/- 5 days	+/- 10 days
Specification 1															
Product code age at approval	-0.534**	-0.331†	-0.125	-0.056	-0.086	-0.272*	-0.283	-0.125	-0.119	0.140	-35.754†	-8.419	26.213	18.255	51.122
	(0.20)	(0.18)	(0.15)	(0.14)	(0.14)	(0.11)	(0.21)	(0.32)	(0.32)	(0.48)	(19.64)	(18.56)	(25.74)	(25.58)	(40.06)
N	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57
R^2	0.118	0.060	0.013	0.003	0.007	0.101	0.031	0.003	0.003	0.002	0.057	0.004	0.019	0.009	0.029
Specification 8															
Product code age at approval	-0.421†	-0.186	-0.179	-0.139	-0.159	-0.221†	-0.249	-0.128	-0.141	0.028	-21.299	11.048	24.529	9.086	41.527
	(0.23)	(0.20)	(0.17)	(0.16)	(0.16)	(0.13)	(0.25)	(0.39)	(0.36)	(0.55)	(22.43)	(20.81)	(31.02)	(30.18)	(46.87)
Time to acquisition	0.138	0.100	-0.091	-0.115	-0.090	0.039	-0.029	-0.056	-0.158	-0.212	22.641*	23.319*	-0.237	-10.564	-8.088
	(0.11)	(0.10)	(0.08)	(0.08)	(0.07)	(0.06)	(0.12)	(0.18)	(0.17)	(0.26)	(10.54)	(9.78)	(14.57)	(14.18)	(22.02)
ln(Patents at acquisition+1)	0.128	-0.351	-0.186	-0.199	0.120	-0.195	-0.460	-0.186	-0.059	0.749	-36.040	-71.020†	3.709	9.440	64.868
	(0.39)	(0.35)	(0.30)	(0.28)	(0.27)	(0.22)	(0.43)	(0.67)	(0.63)	(0.95)	(38.62)	(35.84)	(53.43)	(51.97)	(80.72)
ln(Potential buyers at acquisition+1)	-0.140	0.053	0.226	0.302	0.508	0.054	0.501	0.455	1.271	2.063†	-63.295	-44.164	-8.066	29.093	91.903
	(0.47)	(0.43)	(0.36)	(0.33)	(0.32)	(0.27)	(0.53)	(0.81)	(0.76)	(1.16)	(46.85)	(43.47)	(64.80)	(63.04)	(97.90)
Acquisition weight	-2.122	-1.960	-0.503	-0.262	0.582	-0.292	1.276	0.327	0.483	-1.370	-279.889	-178.125	-78.734	66.524	95.576
	(1.78)	(1.60)	(1.35)	(1.26)	(1.22)	(1.01)	(1.98)	(3.05)	(2.87)	(4.35)	(176.15)	(163.44)	(243.66)	(237.03)	(368.13)
Buyer-target-overlap	-0.184	0.174	-0.970	-1.724†	-1.420	-0.251	-0.794	-0.905	-2.898	-2.463	191.571	236.083†	-3.325	-179.378	-56.958
	(1.31)	(1.18)	(0.99)	(0.92)	(0.90)	(0.74)	(1.46)	(2.24)	(2.11)	(3.21)	(129.71)	(120.35)	(179.43)	(174.54)	(271.08)
Buyer previously invested	0.527	0.863	-0.642	-1.604	-1.460	0.062	1.062	-0.867	-1.906	-2.804	176.033	98.559	4.216	11.432	53.313
	(1.56)	(1.40)	(1.18)	(1.10)	(1.07)	(0.89)	(1.74)	(2.67)	(2.51)	(3.81)	(154.38)	(143.24)	(213.55)	(207.74)	(322.64)
N	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
R^2	0.213	0.144	0.087	0.148	0.101	0.147	0.100	0.014	0.083	0.088	0.189	0.162	0.020	0.035	0.056

Significance levels: † <0.10 * < 0.05 ** < 0.01 *** < 0.001

Values in breakets represent standard errors

Dependent variable winsorized at the 10% and 90% level

4.5. Conclusions

This exploratory study underlines the need to understand both advantages and disadvantages for corporate buyers in a setting where they can acquire pioneering products in markets for technology. This question is relevant for practitioners because high-tech firms like Medtronic leverage technology acquisitions in order to complement their internal R&D programs: "merges and acquisitions supplement that [i.e., the organic growth of the company]. Medtronic's focus … has been on smaller 'tuck-in' acquisitions and it will remain so…", says the current CEO, Omar Ishrak.[102] I perform research on this question in a setting where the rise of new product types and the time when small new entrants come to market are observable. An event study allows me to assess stock market reactions to such acquisitions.

4.5.1. Summary and contribution

I find that the acquisition of a target with a new product type is related to a standardized abnormal return of +1.47 on the date of acquisition announcement. However, the effect does not seem to be durable; it becomes non-significant over a short-term period of a few days around the acquisition. Furthermore, capital markets seem to value the acquisition of a pioneer over an acquisition of a firm that, ceteris paribus, enters the market with a comparable product one year later by a standardized abnormal return of +0.534. Alternative metrics[103] indicate market premiums for pioneering acquisitions as well. The effect loses its significance the more control variables I add to the regression, and also when I extend the observation period beyond the actual date of acquisition announcement. My findings are consistent with a strategy in which an incumbent can maximize its shareholder value by focusing (greater) internal R&D resources on predictable, less risky developments, while focusing (greater) external M&A resources on novel innovations.

4.5.2. Limitations

Similar to other event studies, the given quantitative analysis is limited in various ways. First, the sample of acquisitions appears relatively small and leaves me with limited degrees of

[102] Medtronic's CEO, Ishark (2018); tuck-in acquisitions are corporate transactions in which a big firm typically fully acquires a small firm for its technological platform or other operations-related aspects

[103] *Abnormal Return (AR)* and *Absolute Abnormal Return (AAR)*

freedom to include explanatory variables or control variables in the regression model. However, the sample size is not unusually small if compared to earlier acquisition-related management event studies (see the review by Mc Williams et al. 1997, pp. 631-633).

Second, I am limited to publicly listed buyers and publicly announced deals (compare e.g., Brown and Warner 1980, 1985; Mc Williams et al. 1997). I am confident that this does not bias results systematically by, for example, missing out on smaller deals. What makes me cautiously optimistic is that the chosen empirical setting allows me to also see the non-acquired small new entrants, and thus to triangulate the (completeness of) buyers' press releases with information released by potential sellers[104].

Third, a fundamental question is whether the acquisition of a (pioneering) entrant within a new product code really arises unexpectedly for capital markets. I control for this in two ways: In the short-term, I not only look at the returns *on* the event date, but also *before and after* the acquisition. In the long-term, I consider potential previous relationships between the buyer and the seller of a focal acquisition. For example, I control for effects from prior minority investments, which make 100% acquisitions less surprising for capital markets.

Fourth, I acknowledge that the event-study methodology is limited in its capability to assess the longer-term value of acquisitions.[105] Concretely, for the given study, this means that a great share of the value of an acquired new product type will come from synergetic effects with the buyers' existing portfolio of products and customers. Forecasting and evaluating this impact on the date of acquisition is difficult and unlikely to be fully reflected in the utilized excess return measures even if I assume that capital markets behave rationally.

Finally, the analysis might suffer from a selection bias insofar as it is possible that those firms buy pioneers that have the highest synergies with them. As a result, the increased abnormal returns from buying a pioneer compared to a follower would at least partly be explained by the match between buyer and seller and not by the choice of the target alone. I

[104] I start-off from a sample that captures any entrant on the relevant market. This allows me to trace-back potential seller's press releases and to cross-check the completeness of information from buyer's press releases.

[105] Finance scholars like Lyon et al. (1999) or Mitchell and Stafford (2000) suggest buy-and-hold returns (BHAR). This method compares long-term returns of the focal acquirer with a sample of *non*-acquiring firms with matching firm size, focus of business, book-to-market ration. However, in the given empirical setting, it is not possible to find *non*-acquiring incumbents because the environment is very M&A-active. For example, it is hard to find (more than) five control firms which are similar to the focal acquirer in terms of medical specialty, size, and finance ratios, but which are *not* M&A-active. Similar concerns in different high-tech settings are shared by other scholars: Wann and Lamb (2016) outline the limits of long-term valuation effects of same-industry vs. cross-industry mergers; Ransbotham and Mitra (2010) comment on the limits of assessing long-term valuations effects of high-tech targets acquired at different levels of maturity.

address this issue to some extent by accounting for characteristics of the buyer that could be associated with potential synergies (e.g., overlapping portfolios).

5. Conclusion and future research

5.1. Findings and contribution

Findings of my dissertation suggest that innovation milestones catalyze the technology exchange between small new entrants and big established incumbents. Milestones seem to organize markets for technology in two essential ways: the target firm selected for an acquisition and the timing of such an acquisition seem to relate to which potential target firm reaches these milestones early or even first.

The research objective of the first study for this work is to explore factors and trigger points for the timing of technology acquisitions. The research question can be defined as the following: are there specific innovation milestones triggering the acquisition of a small new entrant and its newly developed product? In a qualitative study, I find that potential buyers of a new product type orient their M&A decisions to specific innovation milestones, which indicate the extent to which a targeted small new entrant has de-risked its innovative product type. Product approval (and thus market entry timing) provides the major trigger for the acquisition of such a small new entrant – this milestone, in the given setting, also marks a drop in technological risk of the entrant's newly developed product. This finding is a new contribution to timing-related acquisition research, which, so far, has been focusing on other explanations for acquisition timing, such as M&A market waves (Carow et al. 2004), target firms' maturity (Ransbotham and Mitra, 2010), or buyers' M&A routine (Brueller et al., 2015).

In the second study, and in a joint attempt with Joachim Henkel (TUM) and Ariel Dora Stern (Harvard Business School), I examine whether it is advantageous for small new entrants to reach market entry early when their goal is to be acquired. In an MFT setting, I find that this binary outcome – being acquired, yes or no – offers new entrants first-mover (dis)advantages which are substantially different from first-mover (dis-)advantages in product markets. For example, one of the key differences is that MFTs reward pioneers by offering a higher likelihood of acquisition, but only after these pioneers have paved the way for a new product type and have reduced the general technological risk. Therefore, pioneers have to wait longer until (acquisition) success materializes. In contrast, later followers can leverage pioneers' investments and benefit from their position in a smaller pool for (later) buyers to tap. Another upside for later movers is that there is no threat of facing the classical "later-mover dilemma" known from product markets, where, theoretically, all end customers can

buy the pioneer's product. As a downside, later entrants are less likely to be acquired than are pioneers. In summary, the most important contribution of this study is to bridge the gap between the literature on pioneer mover (dis)advantages and the literature on MFTs.

In the third study of this dissertation, I touch upon a similar set of questions but from a different angle. The research objective here is to better understand whether it is beneficial for shareholders of the acquiring incumbent when the selected small new entrant comes early to market with a new product. I find that, indeed, capital markets reward acquisitions of new-product-type target firms by a short-term excess return on the date of acquisition. This seems to be especially the case for incumbents acquiring one of the pioneering entrants within a given new product type.

Across all three studies, I come to the conclusion that clear innovation milestones have the power to catalyze the technology transfer between small new entrants and incumbents. Within technology markets, the milestone concept may become the focus for sellers, buyers, and shareholders alike, and thus help to coordinate these various players. For example, if such a milestone indicates the timing of market entry of different small firms with a similar product, this milestone helps potential buyers to judge the segmental position of any of these small new entrants. For the self-selling small new entrant, this implies that the market-entry milestone may signal a leading position in a newly rising product segment. For the acquiring incumbent, this implies, in turn, that a signal of (early) market entry can be a means to justify and explain to shareholders why a given target firm is selected for acquisition.

If there is a milestone that indicates a systematic reduction of technology and/or market risk, this milestone helps to determine acquisition timing, namely, the maturity level of the acquired entrant. Assuming a small new entrant is confident about its product innovation, it may want to wait until the risk has successfully dropped along these milestones, and thereby product quality has become obvious to other market participants (and potential bidders). The same "de-risking logic" behind these milestones may also help the acquiring incumbent in its attempt to determine transaction timing – it helps the incumbent to hedge the risk of the innovation failing after the acquisition.

5.2. Future research

There is room for future research in at least three dimensions. First, I want to encourage future researchers to conduct similar research on technology acquisitions for other high-tech indus-

tries outside the medical device space. In my dissertation, I highlight the importance of observable milestones along the innovation process with regard to who gets acquired (i.e., early-movers or later follower) and when (i.e., early or late after market entry). However, the complication is that the nature and quality of milestones is likely different from the (U.S.) medical device setting which is applied in my study. For example, in the given setting, FDA approval is of three-folded importance as it signals 1.) the market entry of small new entrants, 2.) the general drop of technology risk for a new product type, and 3.) the firm-specific drop of technology risk. Thus, I propose to do similar research in another high-tech industry and to find out if technology sellers and buyers watch out for specific innovation milestones in a similar fashion. There are good reasons to believe that milestones indicating a drop of of technology- and market-risk may also apply to other industries and that they are equally relevant for acquisition decision making in such different settings.

Second, I propose future research in those fields of innovation for which important acquisition triggers like market entry *do not exist*. For example, how about the timing of acquisitions that regard any kind of process innovation? What are suitable "milestone equivalents" in those cases? Various use cases from high-tech industries reflect the high relevance of this type of innovation – new process technologies like S&OP tools, artificial intelligence in manufacturing, operations, after sales, or other digital technologies are just to mention some examples.

Third, I see potential for research on a debate which is independent of innovation milestones. This debate regards the question of how a big firm's R&D strategy interferes with its M&A strategy, and how this firm can avoid the silo thinking of its R&D and M&A departments. My findings are supportive to an innovation strategy in which a big high-tech firm spends its own R&D budget on predictable (rather incremental) new products and complements its in-house development by acquiring (more radical) pioneering small new entrants. The complication inherent to acquisitions is that suitable M&A opportunities are hardly predictable; and for potential corporate buyers it is even harder to forecast whether it will be the "lucky one" closing a deal – or whether it will be one of its direct competitors. Thus, more research is needed at the converging edge of in-house R&D and external technology sourcing (M&A). Concretely, *one* vehicle that might be interesting for in-depth research is corporate venture capital (CVC) as it helps to bridge the gap between a firm's R&D- and M&A strategies. Obviously, CVC is interesting to study from at least two different angles: First, CVC is

typically associated with a minority investment into a small new firm. Thus, it allows incumbents to capture a much higher share of the target landscape than betting the same amount of money on only one (maybe the wrong) horse. Doing so, CVC also helps to hedge against the risk of radical innovation failing at a pre-mature stage. Second, CVC facilitates an *early* and in-depth relationship with the founders of promising small new entrants – and to benefit from these personal relationships when the target firm is up for acquisition (and the level of competition among numerous potential buyers is likely high).

6. References

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