# Spinoffs and Diseconomies of Scope in the U.S. Medical Laser Industry*

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ABSTRACT

This paper examines the role of spinoffs in addressing diseconomies of scope when firms expand into differentiated product markets. Using the U.S. medical laser industry as a unique setting, I study the operational tradeoffs between scale and scope that drive spinoff decisions independent of market power considerations. A key contribution is that I endogenize shifts in firms' organizational structure as part of their optimal strategy, departing from the current focus on mergers in the endogenous product choice literature. I leverage a novel dataset to accurately measure product differences between firms' origin and branch markets in terms of laser type (wavelength) and quality. My estimates suggest that, without spinning off, firms incur 70% higher fixed costs to produce branch market qualities that are highly differentiated from those of the origin. Firms also enjoy 10% fixed cost discounts for branch markets adjacent to their origin markets. Counterfactuals simulating no-spinoff scenarios reveal a 17.9% drop in total firm profit and a 7.6% decrease in overall welfare. At the market level, spinoffs are crucial for facilitating entry and competition in markets with one or no origin firms, as these experience a 9.3% decrease in consumer surplus when spinoffs are prohibited. In a monopolist setting, firm profit drops by 5.73%, while the fixed cost accrued increases by 59.1%.

Keywords: Spinoffs, Diseconomies of Scope, Firm Boundaries, Endogenous Product Choice, Multimarket Competition, Differentiated Products, Medical Laser Industry, Organizational Structure
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# 1 Introduction

There has been an expansive literature generated on firm boundaries following milestone works from Coase 1937[18], Teece 1980[35], and Grossman & Hart 1986[24]. A key issue involves firms branching out to markets outside their respective "origin market", or the market in which they initiated operations. Firms capable of producing in "branch markets", or markets beyond their origin market, must decide whether to produce as a centralized entity under the existing corporate structure or to grant more autonomy to new divisions by spinning them off as separate units. The continued occurrence of corporate spinoffs, where parent firms voluntarily split off divisions into separate companies, highlights this strategic decision-making process.

Official commentary and reports[1] on recent spinoff trends emphasize the importance for both parent and newly spun-off "daughter" entities of remaining focused on their respective origin markets. This underscores the presence of diseconomies of scope - costs and inefficiencies that accrue when firms attempt to extend into markets significantly different in type or quality characteristics from their origin market. By spinning off, firms are able to circumvent diseconomies of scope and operate in multiple markets of varying types and quality levels. Understanding the scope diseconomies driving spinoffs is crucial for analyzing firm efficiency impacts and product availability effects. The latter, in particular, could lead to policies that incentivize the firms to produce in branch markets that they otherwise would avoid, increasing product variety for consumers.

The objective of this paper is to examine, through the lens of spinoffs[2] in the U.S. medical laser industry, the key tradeoffs firms face when expanding boundaries across markets. This work aims to provide empirical evidence on how spinoffs impact firm profitability and product availability across different laser markets. I construct a market-level entry model akin to that of Mazzeo, Seim, & Varella 2018[29]. Firms, endowed with their respective market of origin and a quality level available across all markets, can choose which markets to operate in and how much to invest. Furthermore, firms can also decide whether or not to spin off in one of their active markets as a separate entity.

An example case can be found in Boston Scientific Group (BSG), which initially produced carbon dioxide (CO2) laser devices for skin ablation therapies. Post-2000, the firm started manufacturing other laser types under its brand. One device type it branched into in 2011 was urology laser devices using holmium yttrium-aluminum-garnet (Ho:YAG) as their core input. In March 2012, BSG struck a partnership with Israel-based laser manufacturer Lumenis Limited (Lumenis) to produce these urology laser devices on behalf of BSG in the U.S.[3]. There is a stark contrast between the product characteristics

[1] *Source:* https://www.goldmansachs.com/intelligence/podcasts/episodes/04-19-2022-snider-dubner.html

[2] Here, spinoffs encompass all forms of product separation, including when ownership is retained.

[3] It is worth noting that, following its founding in 2005, Lumenis did have some miscellaneous ties with BSG. However, it was in 2012 that BSG launched all its subsequent Ho:YAG laser types under the Lumenis name (June 2012). This was also the first year that Lumenis entered the Compustat database as a publicly traded entity with positive cash flows and investment levels. Therefore, I define 2012 as the year in which Lumenis became active in the U.S. medical laser industry as a spinoff of BSG producing urology laser devices.

of BSG's origin market (CO2) and the urology laser market (Ho:YAG). For example, BCG's CO2 laser devices operate at the wavelength of 10600 nm, with the maximum output level of 40 Watts at the time of its spinoff decision. In contrast, the Lumenis laser devices operate at wavelength of 2100 nm, with its maximum output level of 120 Watts.

The difference in laser type (wavelength) and quality (including watts) between the two BSG lasers represents the loss of focus that firms face when operating in two markets as a single enterprise. Therefore, these differences in type and quality are the key drivers behind the firm's spinoff decision. Accurately measuring the differences in market type and quality from the origin market offerings for each firm is crucial for estimating model parameters. I utilize the setting of the laser industry, in which product type difference is well-proxied by differences in wavelength spectra. For quality difference, I construct quality scores for each firm's products using a novel dataset with spinoff histories, prices, quantities sold, and proxies for three demand-relevant characteristics: irradiance, diameter, and power.

The standard industry setting would also have to consider the changes in market power as a result of spinoff activity. However, my setting is unique in that industrial laser markets are fragmented across the wavelength spectrum, as documented in prior works on the laser industry (Klepper & Sleeper 2005[27]; Bhaskarabhatla & Klepper 2014[9]). The lack of substitutability across different laser types allows me to isolate the spinoff decision from potential market power motivations. Instead, spinoffs can be attributed solely to operational cost differences for integrated vs. separate structures when producing across multiple markets.

The variation in how multimarket firms produce in their branch markets implies two opposing forces. First, there are diseconomies of scope, which I define as the added fixed cost accrued for producing in branch markets without spinoffs. This is proportional to the quality difference between the firm's origin market and the branch market. Second, there are economies of scale, which I define as the shared fixed cost firms can enjoy by producing in branch markets without spinoffs. This is inversely proportional to the wavelength difference between the firm's origin market and the branch market. My model captures these forces via two parameters: $\lambda^q$ represents the "scope" diseconomy of quality difference, while $\lambda^t$ is the "scale" economy from product type similarity.

I estimate these scale and scope parameters via the generalized method of moments (GMM) and then simulate a counterfactual scenario in which spinoffs are not allowed for firms producing in branch markets. Estimates suggest that without spinning off, firms incur 70 percent higher fixed costs to produce branch market qualities that are highly differentiated from those of the origin. These nonspinoff firms also enjoy 10 percent fixed cost discounts for branch markets adjacent to their origin markets. The two estimations capture the two opposing forces that drive a multimarket firm's spinoff decision. The counterfactual equilibrium without spinoffs shows a 7.6 percent welfare decrease, primarily driven by

reduced firm profits. Interestingly, consumer surplus effects are not uniform across markets. Markets with a single or no origin firm presence see 9.3 percent drops in consumer surplus, while those with 2+ origin firms experience 3.7 percent increases. This finding sheds light on why spinoffs arise from both the firm and consumer perspectives - for firms, spinoffs enhance efficiency in multimarket operation; for consumers, they facilitate the entry of higher-quality varieties in markets with a low presence of origin firms.

## Related Literature

My argument that this diseconomy of scope is the driving force behind spinoffs builds on the rich literature on firm boundaries. Much of this literature started with questions of vertical integration and "make-or-buy" decisions (Coase 1937[18]; Teece 1980[35]; Grossman & Hart 1986[24]). The literature soon branched out to horizontal integration to explore questions around the increased delegation of decision-making authority to branch sites or office managers. Existing works on horizontal integration largely focus on the managerial delegation of banks (Nakamura 1994[30]; Aghion & Tirole 1997[2]; Brickley et al. 2003[13]) or the locational choices of railroads (Growswich 2009[25]; Degiovanni & Yang (working)) and airports (Romero-Hernandez & Salgado 2006[33]; Bottasso et al. 2019[11]). Most, if not all, concentrate on operational scope within markets of homogeneous goods or services.

I contribute to this strand of literature by adding heterogeneity to the goods produced. Whereas wavelength difference can be paralleled with locational difference in the existing works on firm boundaries, quality difference is an extra dimension that few, if any, studies have incorporated in the firm's decision factors. The challenge lies in the accurate measurement of quality among different goods or services. I overcome this challenge by focusing on the medical laser industry, where a general consensus exists on how a laser product is valued, and by using a novel dataset that allows me to calculate how the individual product characteristics can be collapsed into a single quality score. This allows a tractable means to incorporate an additional economic force - quality difference between goods - that shapes firms' organizational boundary decisions.

Some extreme cases of diseconomies of scope involve work on spinoffs, which are mostly concentrated on the clash of incentives between daughter and parent firms (Anton & Yao 1994[3]; Hart & Holmstrom 2010[26]). Specifically for industrial lasers, Klepper & Sleeper 2005[27] is the milestone work that identifies the industry as heavily spinoff-driven. It identifies 79 out of 193 *de novo* entrants from 1960 to 1994 as "employee spinoffs"[4], or spinoffs created with former employees of incumbents. The paper constructs a model based on the premise that an employee spinoff occurs when the employees want to produce a laser type that their firm has chosen not to. Using a logit regression

[4] Although Klepper & Sleeper 2005 simply refer to these as "spinoffs", later studies have distinguished between "employee spinoffs" and "corporate spinoffs". The latter is a decision made by the firm, while the former is a decision made by the employees. See Buenstrof 2007 for further details.

with fixed effects, the paper shows that firms initially become increasingly more likely to experience spinoffs as they continue producing a laser product in any specific market k. The likelihood ratio peaks at year 14 and then reduces to return to the baseline ratio by year 28.

Successive studies on the laser industry have gone on to evaluate performance or analyze survival (Buenstrof 2007[14], Bhaskarabhatla 2013[8]), innovation (Blankenberg & Buenstrof 2016[10], and shake-outs (Bhaskarabhatla & Klepper 2014[9], Buenstrof 2017[15]). Later studies have highlighted another type of spinoff as a "corporate spinoff", or a spinoff initiated by firms for better productivity. This type of spinoff aligns with my definition of firm-initiated spinoffs. However, existing works relevant to corporate spinoffs treat them as an exogenous activity from the firms' perspective.

I contribute to this strand of literature by treating spinoffs as an endogenous activity of the firm. Through structural analysis, this paper provides a connection between spinoff activities and the role they play in firm performance and innovation. The result provides an overview of the significance of spinoffs that encompasses the multiple individual snapshots provided by the current literature on spinoffs in laser industries.

Another strand of related literature is the study of endogenous product choice, which seeks to identify the optimal choice of product characteristics for firms to produce given their subsequent strategy for quantity and price setting. The empirical pioneers (Seim 2006[34], Mazzeo, Seim, & Varela 2018[29]) have been followed by extensive applications (Wollmann 2018[38], Fan & Yang 2020[19], 2024[20]), most of which focus on product availability post-merger, the underlying market power the merged entity can exercise, and the welfare implications of this market power. However, as mergers face heavy antitrust scrutiny, empirical works studying mergers cannot consider mergers as part of a firm's strategy. Instead, they treat organizational changes across firms as exogenous events. Such a practical limitation constrains how much we can say about the role of organizational changes in the evolution of firms.

Similar to my contribution to the laser literature, I contribute to the endogenous product choice literature by examining the alternative to a spinoff. Such direction opens up a fresh perspective on how these models can be applied beyond merger analysis. Crucially, it allows spinoffs to be endogenized as part of a firm's optimal strategy, capturing an additional layer of firm dynamics and evolution that could be extended in future work. To the best of my knowledge, this paper is the first to suggest such direction in a structural empirical work.

The most relevant work at the cross-section of firm boundaries and product choice literature comes from Atalay et al. 2020[6], who provide reduced-form evidence of firms' tendency to drop products outside their core competency post-merger. With a distance measurement between products constructed via their respective categorization by the Universal Product Code (UPC), Atalay et al. run a logit

regression of the distance between each product and the acquiring firm's core products on the firm's decision to discontinue each product. Results show that products more distant from the firm's core products have higher log-odds of being discontinued within ten quarters post-merger[5], which (weakly) indicates a scope problem for firms branching out to unfamiliar products. This complements the idea of spinoffs as a potential solution to such a diseconomy of scope.

I aim to enhance their work in two areas. Firstly, I depart from their reduced-form approach and provide a structural analysis of firm scope based on a reasonable measurement of market difference in wavelength and quality. Instead of treating organizational change as an exogenous event, I assess spinoff creation as an endogenized decision of firms. The additional channel of firm incentives could be useful in further studies assessing conglomerate efficiencies. Secondly, I utilize a measurement that is better aligned as a correlation with firm efficiency. The distance measurement using UPC description codes, while novel in itself, is limited as a measurement proxy for differentiated operational inputs between product pairs, especially across different product types. In contrast, the measurement of both wavelength and quality across laser markets also serves as a reasonable indicator of how much more costly it is to integrate product pairs within a single enterprise. With such measurement, I establish a clearer correlation between market difference and the operational efficiency of the firm, something that could only be qualitatively suggested in Atalay et al. 2020[6].

Other related literature to note includes the study of innovation and strategy, within which a string of work provides evidence on the division of innovative labor through productivity in industries and patents (Bresnahan & Gambardella 1998 [12], Arora et al. 2020 [5]). Recent studies show historical evidence that large-scale firms' research and development has been breaking down in favor of university-oriented groups, a phenomenon coined as the "division of innovative labor". This trend is due to the increasing complexity of innovation and the trend of firms increasingly concentrating on their "core markets" (Arora, Belenzon, Patacconi 2018 [4]). I aim to provide empirical evidence for this line of literature with spinoffs as an exemplary case of the division of innovative labor.

Overall, this paper makes three main contributions to the literature. Firstly, it provides a structural extension to the analysis of firm boundaries. Most, if not all, existing empirical work on firm boundaries involves locational choice or managerial delegation over homogeneous goods (Aghion & Tirole 1997[2], Growswich 2009[25], Bottasso et al. 2019[11], Degiovanni & Yang (working)). A novel aspect of this paper is the incorporation of both product type (wavelength) and quality differences in measuring the differences between a firm's origin and branch market products. This allows an additional economic force - quality difference between goods - that shapes firms' organizational boundary decisions.

[5]Marginal effects at the mean are not reported.

Secondly, this paper provides a conceptual and technical departure from the product choice literature by focusing on spinoffs rather than mergers. The bulk of structural work on endogenous product choice has centered around counterfactual merger scenarios and their impacts on product availability and welfare (Mazzeo, Seim, & Varela 2018[29], Wollmann 2018[38], Fan & Yang 2020[19]). However, because mergers face heavy antitrust scrutiny, these models treat them as exogenous events rather than endogenizing them as part of firms' strategic choices. In contrast, this paper examines the alternative to spinoffs, opening a fresh perspective on how these models can be applied beyond merger analysis. Crucially, this approach allows spinoffs to be endogenized as part of a firm's optimal strategy, capturing an additional layer of firm dynamics and evolution that could be extended in future work.

Lastly, this paper links spinoff activities to an economic framework, thereby providing an overarching picture that encompasses the reduced-form results in the spinoff literature for the laser industry. Existing reduced-form results on firm performance and innovation can be jointly captured using the structural model provided in this paper. Through counterfactual analysis, I aim to identify the role that spinoff activity plays in both aspects of industry evolution.

The remainder of the paper is structured as follows. Section 2 provides more detailed background on the medical laser industry context and situates the paper within the literature. Section 3 describes the novel dataset employed and presents reduced-form evidence motivating the structural model. Section 4 outlines the general model setup and the key parameters to be estimated. Section 5 details the estimation method and results, including a visual illustration of how firms' spinoff decisions vary across branch markets. Section 6 describes the counterfactual scenario prohibiting spinoffs, the welfare calculation, and the computed impacts. Section 7 offers additional discussion interpreting the results and their significance. Finally, Section 8 concludes the paper.

# 2 Overview

In this section, I establish the setting of the medical laser industry and how its unique features allow me to resolve the two challenges in estimating the scale and scope behind firms' spinoff decisions: the measurability of product difference in type and quality and potential market power entangled with the firm's decision.

## 2.1 History of Medical Lasers

Lasers, or Light Amplification by Stimulated Emission of Radiation, are devices that use an energy source pumped onto a core material to produce a specific light emission. The devices then reflect the radiation created within the device to emit stable light energy as an output. The emitted energy of a laser device has a particular wavelength (nm) that depends on a number of factors including the aforementioned features of the laser device. Since the birth of this technology in the 1950s, lasers have

been utilized in various industrial sectors, most notably in metal welding, topographical sensors, and medical procedures. Historically, experimentation with lasers began within medical practices in the 1960s, although commercial availability started in the 1980s after the first successful clinical trial in 1983 by Choy and Ginsburg. The global medical laser market was valued at 5.84 billion USD in 2023 and is expected to grow at the rate of 16.8 percent annually in the next 8 years[6].

Around the 1990s, the invention of the Diode-Pumped Solid State (DPSS) laser technique allowed firms to produce lasers of different wavelengths, diversifying the medical applications of the devices to ophthalmology (eye surgeries and phototherapy), urology (kidney stone removal), cardiology (angioplasty), dermatology (skin ablation), and many others. A particular wavelength range is applied with a specific purpose in the industry that cannot be achieved by a laser of another wavelength. For example, a 10,600 nm laser is used for metal welding and skin ablations, while a 532 nm laser is used for photographic scanning and retinal therapy.

Within the medical sector, the performance of a laser device hinges on how much energy it can deliver to the treatment area, the level of output needed to achieve such energy level, and the accuracy and durability of such delivery. These criteria can be represented by the three key characteristics of a medical laser device: the output (in watts); the irradiance (in watts / $mm^2$) or the delivery of energy per unit of surface area; and the beam diameter (in mm). All medical laser devices are subject to FDA premarket approvals in the U.S., with higher performing laser devices also requiring that the manufacturing firms comply with a stricter level of regulation. The complexity of the premarket approval process has contributed to an ongoing trend in which medical laser startups are incentivized to design their teams to encourage acquisition by an incumbent firm with better knowledge of how to abide by such regulations. This tendency has created an environment in which few startups directly enter the market. Rather, they tend to start as a division of an incumbent firm, from which arises the economic tension of operating branch divisions together with the incumbent's market of origin. As illustrated in the case of BSG and Lumenis, a firm's decision to spin off a division arises from such tension. This tendency contributes to the medical laser industry being highly populated by firms who manufacture their products separately from their parent firms.

## 2.2 Economic Context

The U.S. laser industry is predominantly considered to be a group of isolated market segments, as documented in Bhaskarabhatla & Klepper 2014[9] and Agarwal & Braguinsky 2015[1]. It is also well-documented as an industry where spinoffs are prevalent[7], making it a good candidate for studying the economic forces behind spinoff activities. Segmented demand across laser types arises because the demand for each laser type is tied to its specific applications, as showcased in Table 1. For instance, lasers using

[6]Source: https://www.snsinsider.com/reports/medical-laser-market-3020

[7]Nine out of 31 medical laser manufacturers are spinoffs, as are 79 out of the 193 entrants in industrial laser manufacturing (Klepper & Sleeper 2005[27]

**Table 1: Typical Laser Characteristics and Industrial Applications**

| Laser | Type | Wavelength | Pulsed/CW | Output Power | Applications |
|---|---|---|---|---|---|
| ArF/Krf/XeCl/Xef | Gas (excimer) | 193/248/308/353 nm | ns | 10 W | UV lithography, laser surgery, LASIK, laser annealing |
| Nd: YAG, Nd: YVO | Solid-state | 532 nm | CW | 10 W | Phototherapy, medical scanning, retinal therapy |
| HeNe | Gas | 632.8 nm | CW | 10 mW | Interferometry, holography, barcode scanning |
| AlGalnP, AlGaAs | Semiconductor | 630-900 nm | CW, ms | 10 mW, 10 W | Optical disc (CD, DVD) reading/recording, laser pointers, solid-state laser pumping, machining |
| Ti:Saph | Solid-state | 650-1100 nm | CW-fs | 10 W | Spectroscopy, LIDAR, nonlinear frequency conversion, multiphoton microscopy |
| Yb:YAG | Solid-state | 1030 nm | CW-ps | n/a | Materials processing, optical refrigeration, LIDAR |
| Yb-glass | Fiber | 1030 nm | CW-fs | n/a | Materials processing, ultrashort pulse research, LIDAR |
| Nd:YAG | Solid-state | 1060 nm | CW-ps | n/a | Material processing, rangefinding, surgery, tattoo/hair removal, pumping other solid-state lasers |
| ND:glass | Fiber | 1060 nm | CW-fs | n/a | Material processing, pumping other solid-state lasers, extremely high power/energy systems for laser fusion |
| Er-glass | Fiber | 1530-1560 nm | CW | 10 W | Optical amplifiers for telecommunications |
| Tm:YAG, Ho:YAG | Solid-state | 2000-2100 nm | $\mu$s, ns | n/a | Tissue ablation, kidney stone removal, LIDAR |
| Cr:ZnSe | Solid-state | 2200-2800 nm | CW, fs | 10 W | MWIR laser radar, missile countermeasures, ultrafast and high-resolution spectroscopy, frequency metrology |
| CO2 | Gas | 10600 nm | CW, $\mu$s | n/a | Material processing, surgery, dental laser, military lasers |

**Figure 1: Wavelength Coverage among Dye Type Lasers and the Corresponding Output Level**[8]

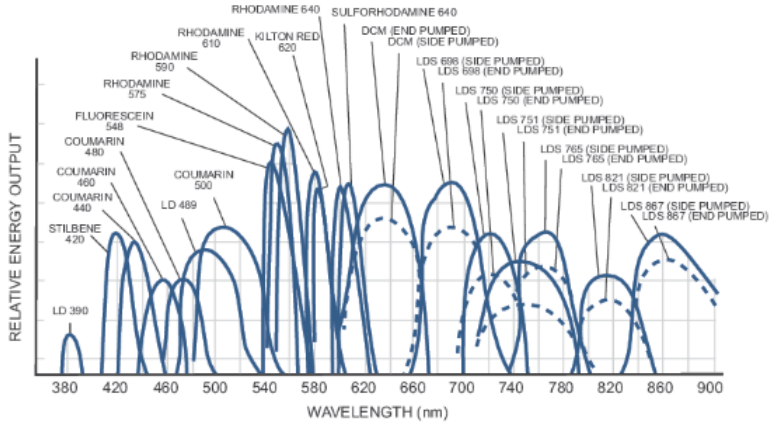



**Table 1** and **Figure 1** describe the specific laser types and their overall application across all industries. **Figure 1**, in particular, highlights the narrow bandwidth of wavelength coverage for each specific laser input. Even within the same laser type, changing the compound of the input materials means that the device generates a different optimal wavelength. Such exclusivity contributes to the lack of substitutability across laser types.

[8]Source: https://www.newport.com/n/laser-types; if lasers do not have a "typical" output power, this has been left blank.

carbon dioxide (CO2) as the gain medium produce infrared light at 10,600 nm, which is ideal for cutting and welding metal, whereas excimer lasers produce the ultraviolet light (193nm) used in optical surgeries – applications that the other laser types cannot effectively achieve.

The differentiation becomes even more distinct in the medical applications of these laser types, even across lasers that exhibit similar photonic properties. Consider carbon dioxide (CO2) and holmium yttrium-aluminum-garnet (Ho:YAG) lasers, for example. Both are infrared lasers sharing similar ablative properties and are used for the direct removal of surface areas through intense wavelengths of 2000 nm and beyond. However, CO2 lasers are mainly used for surface-level ablations such as skin ablations or dental surgeries, while Ho:YAG lasers are primarily used for internal tissue ablations such as transmyocardial surgeries or transurethral incision of the prostate (TUIP). Extensive clinical trials (Fisher et al. 1997[21], Chu et al. 2001[17], Natalin et al. 2008[31] Lee & Jeon 2021[28]) have studied the compatibility of these two laser types in medical fields, and the general consensus is that the two lasers cannot be adequately substituted for each other's respective medical applications. For skin ablations or dental surgeries, the relatively larger area of thermal damage created by Ho:YAG lasers on surface-level tissues at the same output level, as well as their uneven delivery of energy across the target surface, makes them suboptimal compared to CO2 lasers. Conversely, for urological or transmyocardial surgeries, the lack of an effective delivery system to internal channels renders CO2 lasers suboptimal compared to Ho:YAG lasers.

The lack of substitutability between CO2 and Ho:YAG lasers can be paralleled with a similar lack between other laser device pairs across different wavelength ranges. As illustrated in Figure 1, the wavelength coverage of each laser device is quite narrow, and even within the ranges covered, a device is often suboptimal outside its primary wavelength compared to another device customized to such wavelength.

The segmented nature of the laser industry across markets of different laser types means that the industry faces a problem of firm scope that is unconfounded with the problem of market power. Contrary to a standard industry setting where organizational changes across or within firms impact the market shares of the products produced within the industry, laser industry firms do not anticipate changes in market share as a result of either merging or splitting their production portfolio[9]. Therefore, the medical laser industry provides an ideal context for studying the horizontal boundaries of a firm's production plan, a task that is incredibly difficult in other industries where elements of both substitutability and cost synergies are involved over two products.

Instead, firms in the medical laser industry face operational efficiency tradeoffs when branching out to markets beyond their origin market. One key force at play is economies of scale. The level of

[9]Robustness checks were made to check for contradictory evidence. See Appendix Section 1.

similarity in wavelengths between the origin and branch markets determines the extent to which shared manufacturing inputs and processes can be leveraged. Lasers with relatively proximate wavelengths can be produced using the same core components like pump sources, gain media, and optical cavities, with only minor adjustments to the compounds and configurations needed[10]. Firms producing in branch markets sufficiently similar to their origin market in terms of wavelength spectrum can therefore utilize much of their existing manufacturing setup and capital investments. The advantage of using an existing setup lies in the lower incremental fixed costs from integrated production across closely-related markets - a source of scale economies - compared to operating the branch as a spinoff.

However, firms also encounter diseconomies of scope stemming from quality differentiation between origin and branch market product lines. Manufacturing higher quality laser devices with tighter tolerances and energy output levels requires adherence to stricter facility standards and environmental controls. Temperature, humidity, and particulate matter can all impact beam divergence and power inconsistencies to a greater degree for high-end, precision laser products. If a manufacturer geared towards mid-range quality origins were to integrate high-end branch market production, it would likely necessitate costly overhauls to its manufacturing conditions, equipment, and quality control processes.

Furthermore, the engineering expertise and specialized labor skills needed to handle the production, testing, and calibration of high-end laser systems differ substantially from those for lower quality products. Integrating heterogeneous quality levels across a single manufacturing operation could breed organizational tensions and costly coordination challenges as teams negotiate quality control redesigns. In contrast, separating the branch into an autonomous division streamlines these scope diseconomies. The potential for such additional costs from producing significantly differentiated quality levels within an integrated firm represents the diseconomies of scope at play.

Another important feature of the industry is a common consensus on how laser devices are valued in clinics and hospitals, mainly based on three product characteristics: output (in watts), irradiance (in watts/$mm^2$), and beam diameter (in mm). The output is the maximum output a laser device can generate; the irradiance is the actual level of energy delivered to the treatment area; and the beam diameter is the size of the beam. These three characteristics capture how powerful, durable, and efficient the lasers are in their applications. The well-quantified product characteristics associated with laser quality provide a reasonable measurement of how different each product is in quality level, both within and across laser types. This allows a tractable means to estimate diseconomies of scope in producing two laser types whose quality levels significantly differ from one another.

The three standout features of the medical laser industry - prevalence of spinoffs, the segmented demand across laser wavelengths, and reasonable measurements of type and quality differences between

[10]Details on the key input parts (pump source, gain medium, optical resonator) are documented in Appendix Section 2.

two laser pairs - provide a unique setting for the purpose of this paper. The demand-side effects can be ruled out as a result of spinoff activities, and the two opposing forces of scale and scope can be estimated through reasonable measurements of type and quality differences between origin and branch laser pairs. The segmented nature of laser markets allows me to fix the cross-price substitutability when firms decide whether to spin off one of their branch markets, making it possible to estimate the supply-side parameters with reasonable computational burden and data variation.

To summarize, there are two major challenges in empirically studying tradeoffs between operational scale and scope. One is that the operational cost synergy across different markets is generally difficult to measure, and the other is the existence of cross-price substitutability confounded on the demand side. Without knowing the cost information of each firm, the existence of substitutability induces the problem of observational equivalence if econometricians jointly back out both the cost and price elasticity structure in counterfactual studies of structural changes across or within firms.

The uniqueness of the industrial/medical laser industry, combined with the dataset I am using, makes it possible to bypass these two major problems. The difference in product types is reasonably measurable by product wavelength; the difference in quality is measured by constructing a quality score based on three demand-relevant product characteristics in the demand estimation; and there is no substitutability across the laser wavelength spectrum due to its segmented demand. Through such setting, this paper contributes to the literature of firm boundaries and endogenous product choice.

With the background information established, the next section provides the quality measurement score and explains how it is derived using data. I calculate the quality and wavelength difference between origin-branch product pairs within multimarket firms and use them to produce a set of descriptive statistics. I present them to motivate the structural model that I construct and use in the subsequent sections.

# 3 Data

## 3.1 Summary Statistics

The primary data source for retrieving annual sales is the National Establishment Time-Series (NETS) database. These data contain location and sales information for 82,765 physical enterprises (or manufacturing sites) in the U.S. and their respective owner firms, headquarters, and industry categories from 1990 to 2020. The variation in brand for each enterprise under each headquarters allows a crude differentiation of the product types produced by each firm at a single location. I link the data with two additional data sources: Securities Data Company (SDC) Platinum, which tracks all cases of mergers & acquisitions or corporate spinoffs from 1990 to 2020; and the S&P Compustat Database, which contains

monthly research and development investment information for publicly traded firms.

**Table 2: Supply Side Summary Statistics across Spinoffs/Others**

| | Total | Spinoffs | Others |
|---|---|---|---|
| N. Firms | 31 | 9 | 22 |
| N. Enterprises per Firm (Mean) | 12.96 | 3.49 | 15.65 |
| (SD) | (15.71) | (2.35) | (16.82) |
| Investment (Mean, $ Millions) | 468.39 | 60.79 | 604.90 |
| (SD) | (1525.92) | (134.16) | (1740.59) |
| Investment Percentage (Mean, %) | .085 | .082 | .087 |
| (SD) | (.077) | (.084) | (.073) |
| Revenue (Mean, $ Millions) | 4027.76 | 160.15 | 5127.61 |
| (SD) | (9545.03) | (261.20) | (10563.98) |

**Table 2** provides the mean and standard deviation of the number of enterprises, investment, and revenue of firms in the medical laser industry. "Enterprise" means the physical location from which the products are being manufactured.

I identify 9 firms that were spun off from a parent firm as a separate enterprise name. Unsurprisingly, the number of physical enterprises, annual revenue raised, and the aggregate dollar investment level across the U.S. for the spinoff firms are significantly lower than they are for the other laser firms. The difference in extensive margin between spinoffs and others shows the significantly smaller scale at which the spinoff firms operate. However, the average investment percentages are similar between spinoff firms and other firms at approximately 8.5 percent of the firms' total value. This implies that the intensive margins on quality improvements remain consistent across spinoffs and other firms. I rely on the summary statistics to impose an assumption that the investments in quality improvements are evenly distributed across product types.

For the demand side, I retrieve product characteristics, quantities, and pricing data from the Medical Device & Supply Audit (MDSA) data from IQVIA[11]. The data contain monthly purchase records for medical laser devices in the U.S. from 2016 to 2022. The product characteristics of each model in the dataset are matched between the FDA's premarket approval records and the medical device database, as well as with the service manuals available on the respective firms' websites. The three key characteristics are output, which is the maximum wattage the device can generate; irradiance, which is the delivery of energy on a set treatment surface; and diameter, which is the size of the beam that the device can handle. Table 2 lists sales information for each device across seven discretized markets, as well as the product characteristic information retrieved from the medical device database[12].

[11] Acquired from IQVIA; the data were generously funded by the Duke University Economics Department.
[12] For confidentiality, I scaled the true values by a hidden constant K.

**Table 3: Demand Side Summary Statistics across Markets**

| Wavelength Range | <500 | 500-600 | 600-1000 | 1000-1500 | 1500-2000 | 2000-2100 | >2100 |
|---|---|---|---|---|---|---|---|
| N (Product x Month) | 3166 | 5184 | 432 | 3805 | 720 | 6617 | 2950 |
| Price (Mean) | 67396 | 14520 | 114745 | 66426 | 13215 | 25347 | 23675 |
| (SD) | 35389 | 13485 | 167970 | 103926 | 3379 | 28439 | 28282 |
| Quantity (Mean) | 113 | 310 | 224 | 258 | 413 | 120 | 85 |
| (SD) | 152 | 613 | 208 | 653 | 427 | 203 | 118 |
| Power (W, Mean) | 17.53 | 10.47 | 6.16 | 27.94 | 42.5 | 45.96 | 49.37 |
| (SD) | 16.73 | 26.15 | 5.12 | 38.17 | 11.46 | 34.22 | 55.7 |
| Irradiance ($W/mm^2$, Mean) | 60.57 | 129.43 | 8.14 | 1307.18 | 1858.8 | 766.06 | 614.29 |
| (SD) | 7.33 | 691.14 | 5.54 | 2179.35 | 1525.76 | 1220.68 | 747.94 |
| Diameter (mm, Mean) | 2.87 | .62 | 1.17 | 1.87 | .41 | .52 | .76 |
| (SD) | 1.45 | .19 | .48 | 1.31 | .29 | .38 | .57 |

**Table 3** provides the mean and standard deviation of the price, quantity, and the three key characteristics of the laser devices sold between 2016 and 2022. For confidentiality, price has been inflated by a hidden constant K.

Starting from the nine discretizations of the overall industrial laser markets from Klepper & Sleeper 2005[27], I discretize the wavelength range into seven markets based on a combination of substitutability and the specific application for each wavelength range in the medical field. The comparison between CO2 (>2100 nm) and Ho:YAG (2000-2100 nm) lasers in the previous section is a standard example that showcases the mutually exclusive applications between the two lasers. By contrast, Klepper & Sleeper 2005[27] considers helium neodium (HeNe) and semiconductor lasers to be different markets, despite a later study by Bhaskarabhatla & Klepper 2014[9] finding that the two can be substituted. In such case, I consider the two laser types to be within the same market in the wavelength range of 600 to 1000 nm.

Even when the lasers are utilized within the same medical field, if one laser type cannot substitute for the application of another, they are considered to be separate markets. Consider the neodium yttrium orthovandate (Nd:YVO4), excimer, and CO2 lasers, for example. Both excimer and Nd:YVO4 lasers are used by ophthalmologists in eye treatment, and both Nd:YVO4 and CO2 lasers are used by dermatologists for skin treatment. However, even among ophthalmologists, excimer lasers are used exclusively for LASIK, while Nd:YVO4 lasers are used exclusively for retinal therapy. Likewise among dermatologists, Nd:YVO4 lasers are used exclusively for phototherapy, while CO2 lasers are used exclusively for surface-level skin ablations. Each laser within the two pairs cannot be substituted for the

other or its respective purpose. Therefore, the two market pairs are considered separate, even when they are used by the same medical professionals.

The three key variables related to quality levels are the following: maximum power (watts), which measures the maximum output level the device can utilize; irradiance (watts/$mm^2$), which measures the delivery rate of the produced output to a set surface; and beam diameter size (mm), which serves as a proxy for the beam size each device can handle, as well as for the device's durability. There is also an indicator variable that signifies whether a device has the built-in power generator needed to produce the energy output, which I will use as a control variable in the demand estimation. The products are produced by 31 manufacturers within the scope of the data, of which 9 are identified as having produced outside the (former) parent firm's respective headquarters. The distributions of the product characteristics are all right-skewed, which makes it reasonable to log-transform the characteristics for use in the regression.

## 3.2 Reduced-Form Results

First, I define how different a firm's branch market is from its origin market in type and quality. As illustrated in Section 2, type difference can be reasonably indexed by scalars representing the difference between the wavelength ranges of the origin and branch markets. Quality difference, on the other hand, needs more care, since there are multiple characteristics that constitute a high-quality laser device. To create a single quality index, I construct a simple demand model from which the coefficients of the key product characteristics are used to construct a weighted sum of the characteristics.

### 3.2.1 Demand and Quality Score Z

I provide two sets of results to motivate my model. The first is an ordinary least squares (OLS) regression of each product's price on the quality advantage it has over the industry average for three key characteristics. Using this data, I run a hedonic price regression with the price as the dependent variable and each product characteristic's advantage over its respective market's average as the independent variables. The industry advantage of each characteristic for market m at time t is calculated as follows[13]:

$$x_{mit}^{adv} = x_{mit} - \frac{1}{\#\mathcal{N}_m - 1} \sum_{j \neq i}^{\mathcal{N}_m} x_{mjt} \tag{1}$$

[13]For those periods and markets in which a single firm holds a monopoly, the characteristic advantages are simply calculated as the difference between $x_{mit}$ and the minimum characteristic level in the data.

**Table 4: Hedonic Regression on Product Characteristics**

| | (1) | (2) |
|---|---|---|
| | Log Price | Log Price |
| Max Output (W) | 0.125*** | -0.846*** |
| | (0.01) | (0.03) |
| Irradiance ($W/mm^2$) | -0.326*** | 0.367*** |
| | (0.01) | (0.03) |
| Diameter (mm) | -0.304*** | 0.756*** |
| | (0.03) | (0.06) |
| R-sqr | 0.085 | 0.674 |
| F | 265.66 | 172.86 |
| FE | No | Firm, Month |
| Obs. | 8565 | 8565 |
| Observations in Product x Month | | |
| Clustered at Firm x Month Level | | |
| * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ | | |

**Table 4** Each of the firm's characteristics is a log value. These are subtracted from the mean characteristics of the industry mean without the product. For those periods and markets in which a single firm holds a monopoly, the characteristic advantages are simply calculated as the difference between $x_{mit}$ and the minimum characteristic level in the data

Table 4 shows that price levels are significantly correlated with the three key characteristics, indicating that a 1 percent higher level of maximum output, irradiance, and beam diameter for each product over its respective industry average correlates to a 84.6 percent decrease, 36.7 percent increase, and 75.6 percent increase in pricing, respectively. The strong correlation also serves as a good relevance check for treating the characteristic advantage variables as product-specific markup shifters[14], to be used as differentiation instruments in the demand estimation.

Next, I provide a simple demand estimation of the industry to be used as part of the profit specification in the supply-side estimation. The utility of each hospital i in purchasing a product j at any time t in a given market m is specified as follows:

$$U_{ijt;m} = \alpha p_{jt} + X_j\beta + \gamma_{b(j)} + \eta_t + \xi_{jt;m} + \epsilon_{ijt} \tag{2}$$

where $p_{jt}$ is the log price, $X_j$ are the product characteristics, $\gamma_{b(j)}$ is a time-invariant fixed effect for the brand of product j, $\eta_t$ is the time fixed effect, $\xi_{jt;m}$ is the product-market-time specific heterogeneity observed by firms but not econometricians, and $\epsilon_{ijt}$ is the consumer-specific taste parameter with an i.i.d. type 1 extreme value distribution.

[14] Gandhi & Houde 2019[23]

The demand estimation is conducted using a standard logit model on market shares, following the methodology of Berry 1994[7] in inverting the discrete choice probabilities represented as market shares. As per the argument of no substitutability across markets, the shares are calculated exclusively within each market. The market is specified as the annual number of "community" hospitals[15] multiplied by the number of days within the month. "Community" hospitals are defined as all nonfederal, short-term general and specialty hospitals that are available to the public[16]. The specification implies that hospitals face a daily situation in which they encounter a patient requiring laser treatment[17]. I use the markup-shifter instruments from Section 3.1.1 to address price endogeneity due to unobserved heterogeneity.

**Table 5: Demand Estimation**

| | (1) | (2) | (3) | (4)† |
|---|---|---|---|---|
| | Log Share | Log Share | Log Share | Log Share |
| | OLS | OLS | IV | IV |
| Log Price | -0.355*** | -0.336*** | -1.933*** | -2.151*** |
| | (0.01) | (0.03) | (0.46) | (0.13) |
| Log Irradiance ($W/mm^2$) | 0.166*** | -0.015 | 0.384*** | 0.593*** |
| | (0.01) | (0.05) | (0.13) | (0.19) |
| Log Diameter ($mm$) | 0.137*** | -0.409*** | 0.315 | 1.096*** |
| | (0.02) | (0.11) | (0.25) | (0.30) |
| Log Power ($W$) | -0.197*** | 0.065 | -1.000*** | -1.985*** |
| | (0.01) | (0.06) | (0.32) | (0.25) |
| Built-In | -1.122*** | -0.998*** | 0.421 | 1.180*** |
| | (0.08) | (0.17) | (0.53) | (0.38) |
| R-sqr | 0.117 | 0.228 | . | . |
| F | 242.19 | 43.81 | 100.56 | 43.15 |
| FE | No | Firm, Month | Firm, Month | Firm, Month |
| Obs. | 8565 | 8565 | 8565 | 8565 |

Observations in Product x Month

Clustered by Firm x Month Level

† Column (4) includes the interaction and quadratic terms of the three characteristics

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 5** shows the demand estimation results in terms of log shares on the price and product characteristics. The characteristic advantages described in equation (1) are used as IV's for columns (3) and (4). The full result of column (4) with the interaction and quadratic term is in Appendix Section 3.

Table 5 lists the regression results of the demand-side model. Column (1) shows a simple OLS regression with a price sensitivity that indicates a much lower level of demand elasticity than is expected in a Bertrand competition. Adding fixed effects across firm and month in column (2) does not change

[15]Source: American Hospital Association (AHA)

[16]In short, "community" hospitals include all registered hospitals excluding prison hospitals and college infirmaries.

[17]An important assumption to note is that all purchases are made simultaneously across markets. There could be situations in which hospitals prefer to buy products in bulk to reduce the number of negotiation rounds with manufacturers. If purchase decisions are made sequentially, this could be problematic (e.g., conditional on purchasing laser type A from Firm i, how inclined are hospitals to purchase type B from the same firm versus laser type B from Firm j?).

the price sensitivity, indicating that the fixed effects themselves do not solve potential price endogeneity from unobserved heterogeneity.

With the markup shifters as instruments, columns (3) and (4) show that the price coefficient is amplified to approximately -2. The expected markup that firms expect to enjoy at baseline quality level is approximately 60 percent at monopoly and decreases as the number of competing firms with equal quality level increases. The prediction is reasonably consistent with the result for a classic Bertrand competition on homogeneous goods, in which a demand elasticity of 2 brings an optimal markup level of 50 percent at monopoly that shrinks as the number of competing firms increases. The statistical significance of the coefficients in column (3) is partially lost and then restored in column (4) with the interaction and quadratic terms of each of the characteristics[18]. The contrast implies the nonlinear marginal effect that each characteristic has on market share. Column (4) also shows that the significance of the three key characteristics is maintained and even amplified when controlling for the markup shifters in the first-stage analysis. This result could be interpreted as evidence that there is significant endogeneity between the unobserved heterogeneity and price that suppressed price sensitivity in the OLS regression.

One point to note in the results is that the marginal effect of the maximum output on demand is actually negative, which can be explained from a "gallon-per-mile" perspective. Given a fixed level of irradiance - which is the actual energy delivered to the treatment area - devices that can achieve such irradiance with lower power output would be considered more efficient and thus as having a preferred feature.

Based on the coefficients in column (4), I construct a scalar value for each device to serve as a quality index by measuring the quality difference between each firm's origin and branch market pairs. The quality measurement for each device is constructed using a second-order polynomial score $z$. The intuition behind the scoring is that it captures the product specifications acknowledged to yield higher overall performance levels in hospitals: how much energy the product can deliver to the treatment areas, how persistently it can deliver such energy, and how efficiently it can achieve that energy delivery. The scalar quality Z provides a general picture of how laser devices are valued in hospitals based on their combination of maximum output, irradiance, and beam diameter. With the type distance measured from the wavelength spectrum, later sections will show how the two dimensions are used to estimate the scale and scope effects of integrating branch markets as a single entity.

### 3.2.2 Spinoff Tendency: Quality and Wavelength Difference

Finally, I provide stylistic evidence of firms' spinoff tendencies via a simple linear probability model (LPM) of a spinoff indicator on the product distance between each firm's origin and branch

[18]The full result is in Appendix Section 3.

products using the difference measurements for laser type and quality. I also provide a distribution of quality levels among products integrated under the same enterprise versus those produced in separate enterprises. The contrast between the two groups illustrates the underlying diseconomy of scope that drives firms to spin off products with quality levels distinctly different from those in their origin market. The origin market is defined as the first market in which each firm started producing laser products[19].

Definitions of whether a product is separately manufactured are derived primarily from the NETS and SDC Platinum databases, which allow me to track the active physical enterprises in the U.S., the firms owning each enterprise, and the headquarters of each firm. Variation in firms sharing the same headquarters identifies the separation of product manufacturing at the brand level. I primarily use NETS and SDC Platinum to track production at the enterprise level and changes in ownership structures over time for the firms identified in my demand-side data. There are 9 manufacturer pairs out of 31 observable firms in the dataset that were spun off from their headquarter firms via a locational split, entry by acquisition, or a change in ownership. The portion of spinoff firms in the data is roughly consistent with the rate in the entire industry, which is approximately 33 percent.

Figure 2 shows a generally homogeneous range of quality scores for firms that produce in multiple markets as single entities both in their focal and their branch markets. In contrast, the quality scores of spun off products are highly dispersed, arguably at both extremes, indicating that firms are more likely to separate their production lines for both basic and high-end products.

**Figure 2: Quality Score across Spinoffs and Other Products**

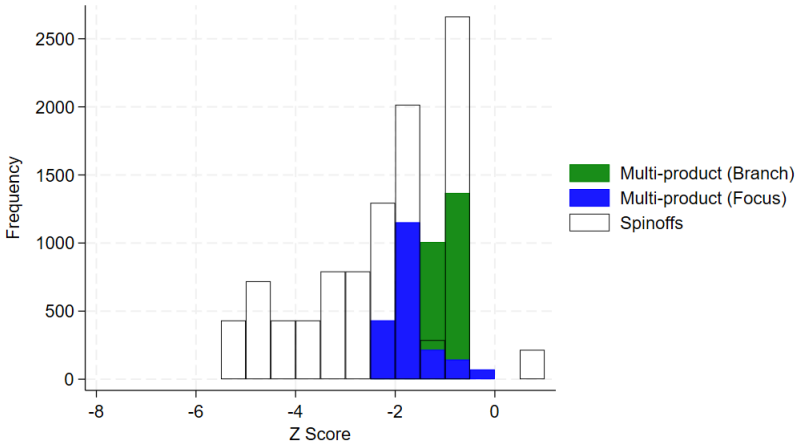



**Figure 2** shows the distribution of the quality score Z among multimarket firms. The spinoff products a have greater spread than the branch products produced by the origin firm as a single entity.

To further test the observations from Figure 2 on quality dispersions between integrated and spun off

[19] A robustness check using the "focal" market - the market with highest quantity sold or highest revenue raised - yields no significant difference in results.

divisions within firms, I test their correlation with the spinoff probabilities of multimarket firms using the following linear probability model setup:

$$Y_{imt} = \beta_0 + \beta_t d^t(m, O_i)_{it} + \beta_q d^q(m, O_i)_{it} + \upsilon_{imt} \tag{3}$$

where $Y_{imt}$ is a binary indicator with 1 meaning that the division for market m for firm i was spun off at time t. The independent variables $d^t(\cdot)$ and $d^q(\cdot)$ are the type and quality differences of each firm i's market m at time t in wavelength and quality, respectively. Formally, the type and quality differences of each firm's market are defined as follows:

$$d^t(m, O_i)_{it} = |m - O_i|$$
$$d^q(m, O_i)_{it} = |z^O_{it} - z^m_{it}|$$

where $(m, O_i)$ are the position indexes of the firm's branch and origin markets, respectively, within the wavelength spectrum; and $(z^O_{it},\ z^m_{it})$ are the quality measurements of the laser device sold by firm $i$ at time $t$[20].

**Table 6: Linear Probability Model of Spinoffs on Product Difference**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | spunoff | spunoff | spunoff | spunoff |
| Wavelength Difference | 0.011*** | 0.011 | 0.082*** | 0.082 |
| | (0.00) | (0.01) | (0.03) | (0.08) |
| Wavelength Difference (sq) | | | -0.013** | -0.013 |
| | | | (0.01) | (0.01) |
| Z Difference | 0.076*** | 0.076* | 0.090*** | 0.090** |
| | (0.01) | (0.04) | (0.01) | (0.04) |
| Constant | 0.025 | 0.025 | -0.058 | -0.058 |
| | (0.04) | (0.03) | (0.05) | (0.09) |
| R-sqr | 0.780 | 0.780 | 0.786 | 0.786 |
| Obs. | 237 | 237 | 237 | 237 |
| Cluster | No | Firm, Decade | No | Firm, Decade |
| Fixed Effect for Firms and Year | | | | |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 6** shows the linear probability model of spinoffs by product difference between the origin and the branch product wavelength and quality score Z

[20]There are some cases in which a multi-industry firm spun off its entire medical laser division; in such cases, I consider the origin market to be completely outside the laser market. I therefore set the type distance measurement as the maximum difference observable in the data and the quality distance measurement as the distance between the product's quality and the minimum quality score observed in the data; this approach follows the measurement of quality advantages in monopoly cases.

Table 6 reports the spinoff probability results, with columns (3) and (4) adding the quadratic term to the wavelength difference between the origin and branch markets. This approach tests the concavity of the spinoff tendencies by wavelength differences based on the real-life observation that the marginal input disparity between product wavelengths diminishes as the wavelength difference increases. Clustering the errors at the firm and decade level largely mutes the statistical significance for the results in columns (1) and (3), with quality difference being the only variable retaining significance[21]. The lack of robustness by clustering is mainly due to the lack of power the data have in observing spinoff occurrences, this lack being limited only to firms prespinoff with multimarket capabilities. However, the magnitude of the correlation is worth addressing to illustrate these differences as the main drivers of operational scale and scope.

Based on the results in column (4), a one standard deviation increase in quality difference (= 0.954) between a firm's focal and branch markets corresponds to an 8.59 percent increase in the firm's probability of spinning off the branch market. Considering the baseline probability of 1.1 percent[22], this corresponds to a 780 percent increase in the probability that firms will spin off their branch market as it becomes more distant in quality from their focal market. Likewise, one extra unit of wavelength difference between a firm's focal and branch markets and the baseline corresponds to a 4.3 percent increase in the firm's probability of spinning off, which in turn corresponds to a 290 percent increase in the probability that a firm would spin off its branch market as it becomes more distant in its wavelength range. Although lacking in statistical significance, the magnitude of the wavelength difference illustrates its correlation with firms' spinoff decisions.

Firms' tendency to incorporate products of a quality level similar to that of products in their respective market of origin illustrates a major source of diseconomies of scope across markets. The benefit of incorporating products outside their market of origin is exceeded by the added fixed costs they incur by incorporating additional products that require different expertise into their main manufacturing line. In practice, such dissonance in quality could manifest as added labor costs for calibrating products with huge technological distances, managerial disagreements on whether to integrate branch market product as an add-on to an existing established mainstream production, and additional lags in reaching consensus across different divisions that prioritize different areas of expertise.

The results in Table 6 and Figure 2 provide preliminary evidence that firms' spinoff decisions are driven by diseconomies of scope stemming from significant quality differences between their focal and potential branch markets. To empirically analyze the role of spinoffs on firm profits and product availability, I next construct a structural model that captures the forces of scale and scope impacting these spinoff decisions. I then provide a counterfactual scenario fixing the spinoff decision to 0 (i.e., integrating every branch

[21] Clustering by only firms would degrade the significance of the quality difference such that it becomes not significant in Column (2) and significant at the 10% level at Column (4).

[22] This baseline is for branch markets whose type is adjacent to the focal product.

product as a single entity). Section 4 presents the model setup with the six parameters to be estimated; this is followed by the estimation results in Section 5 and a welfare comparison between the spinoff and no-spinoff scenarios in Section 6.

# 4 Model

In this section, I provide a walkthrough of a four-stage static model across a finite number of markets discretized by the wavelength spectrum. Firms are endowed with their origin market and initial quality levels for each of their markets. With the initial endowment, they sequentially choose the market combination to enter, aggregate investment level, the decision to spin off one of the branch markets as a separate entity, and pricing for the markets they decide to enter. To simplify the computational burden, the model is set up as a decision problem for an individual firm facing an "industry state" for each market and whose transition probability is simulated under the assumption that the industry strategy is consistent with that individual firm's decision.

## 4.1 General Setup

Consider a firm's decision problem in a technologically driven industry segmented into $M$ markets. Each firm is endowed with a collection of discretized quality levels $z_{im}$ for each $m \in M$ market, with a finite ceiling at $\bar{z} \in \mathbb{N}$. Firms also have an "origin" market denoted as $O_i \in M$, defined as the first market in which it produced. All other markets $m \in \mathcal{M}_i \setminus O_i$ are defined as "branch" markets for firm i[23]. The firm's decision to spin off one of its branch products is indexed as variable $d_i$, where $d_i = m \in M$ indicates that the firm has created a new enterprise in market $m$ to produce a strict subset of their product types. I assume firms are allowed to make only one spinoff per period and cannot subsequently re-integrate the separated product type back into their mainline production.

Under this assumption, each firm $i$'s state $s_i$ is characterized as $(O_i, \{z_{im}\}_{m=1}^{M})$, where $O_i$ is the origin market of firm $i$, and $z_{im}$ is its initial quality for market m. The industry state $\mathcal{S}$ considered in each firm's decisions is characterized as $\{Z_{-im}, N_{-im}\}_{m=1}^{M}$, where each element pair $(Z_{-im}, N_{-im})$ indicates the average quality level of the competitors within market $m$ and the number of competing incumbents in market $m$, respectively. Firms produce a single product in each market but can produce multiple products across different markets. Firms can invest in markets, with the probability of quality improvement characterized as a function $\mathcal{P}(\tau|x)$ that is well-defined and strictly increasing in the investment level $x$. To focus on product choice, I simplify the model by assuming firms cannot invest in markets where they have zero quality level. The resulting profit is the sum of the profits collected from each of the entered markets, subtracting the fixed cost of operating in the market as either a single entity or a spinoff into the market.

[23]Intuitively, an origin market is the market in which the firm first produced and from which its production design and management structure originated.

The decision process has four stages per period. Given firm $i$'s origin market $O_i$ and its available quality levels $\{z_{im}\}_{m=1}^{M}$ for each market $m$, the firm acts as follows:

1. The firm chooses the market combination $\mathcal{M}_i \subseteq \mathcal{M}$ in which it will operate.

2. Upon choosing $\mathcal{M}_i$, the firm decides upon an aggregate investment level $X_i$, contingent on its state $s_i$ and the perceived probability of firm $i$'s industry state investment outcome in the subsequent stage $\hat{\mathcal{S}}$. The aggregate investment level $X_i$ is assumed to be distributed equally across $\mathcal{M}_i$.

3. Upon choosing $\mathcal{M}_i$, firm $i$'s updated quality state is revealed, and the firm decides $d_i$, or whether to spin off one of its active markets as a separate enterprise.

4. Given each firm's decision on market-level entry, investment, and spinoff, firms engage in a Bertrand competition against the industry state $(Z_{-im}, N_{-im})$, ex-ante to the expected marginal cost for each market $m \in \mathcal{M}_i$.

The adoption of the oblivious equilibrium following Weintraub, Benkard, & Roy 2009[37] simplifies the state spaces against which each firm makes decisions in the fourth stage of the model, which is important for two reasons: first, it significantly reduces computational burden, and second, it narrows the focus of this paper to the first three stages, which are key in estimating the tradeoffs between operational scale and scope.

The resulting equilibrium from the setup can be defined as an industry-level state $\mathcal{S}^* \equiv \{N_m^*, z_m^*, \}_{m=1}^{M}$, the firm's operational decision $\{\mathcal{M}_i^*, X_i^*, d_i^*\}$, and the firm's within-market decision $\{p_{mi}^*\}$ for $m \in \mathcal{M}_i$, such that

1. **(Optimal contingent plan)** The decisions made on each stage $(\mathcal{M}_i^*, X_i^*, d_i^*, \{p_{mi}^*\}_{m\in\mathcal{M}})$ optimize each of the sub-stage values.

2. **(Market Clearing)** The equilibrium strategy of individual firms $\{\mathcal{M}_i^*, s_i\}_{i=1}^{N}$ aggregates to the industry state $S^* \equiv \{N_m^*, z_m^*, \}_{m=1}^{M}$

I will now explain how each stage's value functions are specified and how the firms decide on market-level entry, investment, spinoff, and pricing at each of the stages.

### 4.1.1 Pricing

Starting from the last stage of the model, firm i participates in a Bertrand competition for each of the markets m that it decides to enter. I solve the optimal pricing of each firm i in market m as a system of first-order condition equations of the Bertrand competition. The pricing and the corresponding profit of market m depend on firm i's product quality in the market $z_m$, the industry state $((Z_{-im}, N_{-im}))$, and the price coefficient $\alpha$ taken from the demand system.

The assumption is that, in addition to its own quality level and marginal cost, each firm's decision is based on its ex-ante marginal cost and the level of industry quality and competition rather than upon the quality level and idiosyncratic shocks of the competing incumbents for each market m. Simplifying the industry state space reduces the computational burden to a feasible level. As established in the previous section, the demand pool is segmented across markets, meaning that the pricing decision for one market is independent of that for another. Therefore, the stage-4 payoff function $\Pi_4(\cdot)$ can be specified as an additive sum of the optimized profits of each market m in which firm $i$ is active, regardless of its spinoff decision $d_i$:

$$\Pi_4(s_i, \mathcal{M}_i, S) = \sum_{m \in \mathcal{M}_i} \pi_{im}[p^*_{im}; z_{im}, Z_{-im}, N_{-im}] \tag{4}$$

Such noncorrelation between a firm's spinoff decision $d_i$ and its pricing decision $p_{im}$ captures the fixed cross-price substitutability across laser markets as zero. Since decision $d_i$ in stage 3 does not impact the pricing decision in stage 4, I can attribute decision $d_i$ solely to the operational scale and scope of producing branch products of different wavelength and quality levels.

### 4.1.2 Spinoff Decision

I now move to the crucial part of the model, in which firms decide whether to spin off one of their markets or integrate all active markets as a single entity. Since the profit specification $\Pi(\cdot)$ remains invariant to $d_i$, the decision strictly revolves around how the fixed cost of operating in a specific market combination compares between integrating and spinning off. The difference between these two costs revolves around the tradeoff between operational scale and scope, which is specified as cost function $\mathcal{C}$:

$$\mathcal{C}(\mathcal{M}i; z, O_i) = \lambda^t_{\mathcal{M}i} + \lambda^q_{\mathcal{M}_i} + \eta_i \tag{5}$$

$$\lambda^t_{\mathcal{M}_i}(O_i) = f + \sum_{m \in \mathcal{M}_i \setminus O_i} [1 - (\lambda^t)^{(m-O_i)^2}] \cdot f \tag{6}$$

$$\lambda^q_{\mathcal{M}_i}(z, O_i) = \sum_{m \in \mathcal{M}_i} \lambda^q |z_m - z_a| \cdot \mathbb{1}[m \neq O^*_i] \cdot f \tag{7}$$

where $f$ is the baseline fixed cost of operating as a single product firm, and $z_i \equiv \{z_{im}\}_{m \in \mathcal{M}_i}$ is the collection of market-level qualities held by firm i by the third stage.

The functions $\lambda^t_{\mathcal{M}i}$ and $\lambda^q_{\mathcal{M}_i}$ are fixed cost specifications for producing lasers of multiple types and qualities. Respectively, they represent the economies of scale and diseconomies of scope in integrating product types outside the firm's market of origin, $O_i$. The "scale" parameter $\lambda^t$ captures the shared fixed cost of integrating products in the form of a discount parameter to the baseline fixed cost $f$, which is the default fixed cost of operating in market $O_i$. The magnitude of the discount shrinks the farther market $m$ is from the firm's market of origin, representing the relative insignificance of cost synergies for laser types less similar to those of $O_i$.

$\lambda^q$, on the other hand, captures the diseconomy of scope in producing a product outside $O_i$ with a significantly different quality level. The parameter represents the firm's tendency to incorporate products that are of a similar quality level to those in their respective market of origin. The more different the branch laser's technology is from that of $O_i$, the higher cost they must incur to incorporate this wider coverage of quality levels into the laser devices.

Based on these opposing forces of scale and scope, firms decide whether to integrate or spin off the production line for the market combination they select at stage 1. Should firm i spin off market m, it is choosing to let its spinoff in market m operate as a single-product firm, while firm i operates with the remaining set of markets. Therefore, the joint fixed cost $\mathcal{F}(\cdot)$ contingent on the spinoff decision, the optimal spinoff decision $d_i^*$, and the resulting stage-3 optimal payoff function $\Pi_3(\cdot)$ can be characterized as the following:

$$\mathcal{F}(d_i, s_i, \mathcal{M}_i) = \begin{cases} \underbrace{\mathcal{C}(\mathcal{M}_i; z, O_i)}_{\text{Fixed cost of integrating all } \mathcal{M}_i} & d_i = 0 \\ \underbrace{\mathcal{C}(\mathcal{M}_i \setminus m; z \setminus z_m, O_i) + f}_{\text{Fixed cost of spinning off market m}} & d_i = m \end{cases} \tag{8}$$

$$d_i^* = \underset{d_i}{argmin} \;\; \mathcal{F}(d_i, s_i, \mathcal{M}_i) \tag{9}$$

$$\Pi_3(s_i, \mathcal{M}_i, \mathcal{S}) = \Pi_4(s_i, \mathcal{M}_i, \mathcal{S}) - \mathcal{F}(d_i^*, s_i, \mathcal{M}_i) \tag{10}$$

where $\Pi_4(s_i, \mathcal{M}_i, \mathcal{S})$ is specified in equation (4). The spinoff-dependent fixed cost specification captures the tradeoff between scale and scope that drives firms to either integrate or separate their branch markets.

One point to reiterate is that I am considering spinoffs to include product separation both with and without ownership changes. The implication is that in both cases, the parent firm maximizes the joint profit of itself and its spinoff; when a firm spins off one of its divisions as an independent firm, it is obtaining the maximized valuation of its respective division as a separate entity[24]. When the firm chooses to hold ownership of its spinoff, the spinoff remains part of the parent firm, and thus the parent will naturally strive to maximize the joint profits across all markets in which it is active.

[24]There are previous works studying the asset pricing incentives of spin-off activities that may differ from product separation; however, the economic incentives to do so remain the same across the two types of separation, and thus I will treat them as indifferent in the model.

#### 4.1.3 Investment

Taking the contingent values in stage 3, firms engage in a one-shot aggregate investment decision in the second stage, their own state, their market-level entry decision, and the industry state $(s_i, \mathcal{M}_i, \mathcal{S})$. The expected stage-2 payoff given investment level $X_i$ can be characterized as the following:

$$\tilde{\Pi}_2(X_i, \mathcal{M}_i, s_i, \mathcal{S}) = [1 - X_i] \cdot \mathbb{E}_X[\Pi_3(s_i, \mathcal{M}_i, \hat{\mathcal{S}})|s_i, \hat{\mathcal{S}}] \tag{11}$$

where $X_i$ is the percentage of the expected next-stage profit level, and $\hat{\mathcal{S}}$ is the firm's perceived expected evolution of the industry quality level $\hat{\mathcal{S}}$ in the next period. Following Pakes & McGuire (1994)[32], the probability of improvement for quality $z_{im}$ in each market $m \in \mathcal{M}_i$ is specified as such:

$$\mathcal{P}(\tau|x) = \begin{cases} 1, & \frac{\kappa x}{1+\kappa x} \\ 0, & \frac{1}{1+\kappa x} \end{cases}$$

where $x = \frac{1}{\#\mathcal{M}_i} \cdot X_i$, and $\tau$ is a binary indicator in which 1 indicates a jump in the quality level of $z_{im}$ from its initial endowment. The probability of $\hat{\mathcal{S}}$ is determined by simulating the transition path given $(Z_{-im}, N_{-im})$ and $\mathcal{P}(\tau|x)$, assuming all incumbents adopt the same strategy as firm i. The simulated results are then averaged to assign probabilities for how firm i perceives the industry will evolve or stagnate in the next stage. Firms then would optimize their investment decision based on their sequential spinoff decision and pricing strategy given the expected profit for each market in the next period.

The optimal investment decision $X_i^*$ and the corresponding stage-2 optimal payoff function $\Pi_2$ can be characterized as the following:

$$X_i^* = \underset{X_i}{argmax} \ \ \tilde{\Pi}_2(X_i, s_i, \mathcal{M}_i, \mathcal{S}) \tag{12}$$

$$\Pi_2(s_i, \mathcal{M}_i, \mathcal{S}) = \tilde{\Pi}_2(X_i^*, s_i, \mathcal{M}_i, \mathcal{S}) \tag{13}$$

There are two major assumptions I make in this stage; the first is that the aggregate investment level $X$ is equally distributed across each firm's active market set $\mathcal{M}_i$. This assumption is mainly due to data limitations, since I do not observe the market-level investments that firms make each period. However, since in practice we can expect firms to centralize their investment around their focal market - which is more likely to create a higher difference in product quality between each firm's origin and branch markets - the equal investment assumption would favor integration. Therefore, the equal investment assumption would bias the estimation against diseconomies of scope, which is the key element I would like to emphasize from my results. Thus, a more granular dataset of brand-level investment information would serve to strengthen my argument, and the result I show in the later section would not be sensitive to the equal investment assumption.

Another, perhaps stronger, assumption is that each market is symmetric in its investment effect on technology evolution and that firms are only allowed to invest within the markets in which they operate. Relaxing this assumption would be a venue worthy of exploration in future studies with market-level investment information. However, such topic is not within the scope of this paper, and I leave this venue for future research.

#### 4.1.4 Market-Level Entry

Taking the contingent values into consideration, firms at stage 1 choose the market combination $\mathcal{M}_i$ in which they will participate, given a firm state $s_i$ with an initial endowment of quality $z \equiv \{z_{im}\}_{m=1}^{M}$ and a market of origin $O_i$[25]. The optimal payoff of the firm's own and industry state $\Pi(s_i, \mathcal{S})$ can be represented as such:

$$\mathcal{M}_i^* = \underset{\mathcal{M}_i}{argmax} \;\; \Pi_2(s_i, \mathcal{M}_i, \mathcal{S}) \tag{14}$$

$$\Pi(s_i, \mathcal{S}) = \Pi_2(s_i, \mathcal{M}_i^*, \mathcal{S}) \tag{15}$$

The market-level entry decision, while a straightforward decision, is a key link to the counterfactual in this paper and showcases why it is crucial to highlight the importance of diseconomies of scope in firms' production and spinoff decisions. Note that the firm's choice of markets would differ if the subsequent decision $d_i$ is fixed at 0; i.e., if the firms could only produce in the branch market as a single entity. The counterfactual represents a scenario in which the government prevents such expansion via a separate enterprise, a policy that could stem from classical notions that mergers are the predominant factor strengthening a firm's market power and/or surplus. However, such prohibition would be overlooking the existence of diseconomies of scope that may prevent firms from fully utilizing their existing technology. Without such consideration, the resulting market combination could be a strict subset of $\mathcal{M}_i$, in which the profit gained from the branch market cannot cover the cost of producing as a single entity. Firms' decision to enter into fewer markets would result in fewer products being available in the market, which in turn would provide a suboptimal level of welfare to the participants in the medical laser industry. How it affects the equilibrium competition level, quality level, and overall welfare is discussed in the next section.

[25]It should be noted that I impose an assumption that firms endowed with zero quality in a market $m$ cannot invest to break into that market. While this is a fairly strong assumption, it is due to computational limitations. An unconstrained algorithm requires each iteration to search among 128 possible product combinations per firm, which would exponentiate the computation time to an unreasonable level. Imposing such assumption reduces the number of product combination candidates to 16 at most, since the greatest number of nonzero qualities within firms observed in the data is four.

# 5 Results

## 5.1 Estimation and Identification

Table 7.1 summarizes the specifications for each stage of the model explained in the previous section, from which six parameters need to be estimated. The estimation step consists of constructing a profit mapping of each individual market from the three demand-side parameters $\{\alpha, \beta, \gamma\}$ and using the profit mapping to estimate the supply-side parameters $\{\kappa, \lambda^t, \lambda^q\}$. The demand side parameters are identified via variation in the price and quantity sold for each quality level and variation in the backed-out marginal cost given each firm's market-level proficiency. In using the moment equality conditions for the supply-side parameters, $\kappa$ is identified among single-market firms' investment levels, which are invariant to the scale and scope parameters. Variation in the firms' quality levels and their markets of origin pins down the ratio between $\lambda^t$ and $\lambda^q$. Finally, the market-level entry decision pins down the magnitude of $\lambda^t$ and $\lambda^q$; coupled with the ratio of the two already identified, pinning down the magnitude allows identification of both parameters. Details on the estimation steps are documented in Appendix Section 3.

**Table 7.1: Function & Parameter Configurations in the Model**

| *Functions* | Description | Specification |
|---|---|---|
| $u(\alpha, \beta)$ | Logit demand | $\alpha p + \beta z + \xi + \nu$ |
| $log(MC(z;\gamma))$ | Marginal cost function given quality z | $\gamma \cdot max(z_{jmt}) + \epsilon$ |
| $\mathcal{P}(\tau \mid x)$ | Improvement probability given investment level x | |
| | $\tau = 1$ (improvement) | $\frac{\kappa x}{1+\kappa x}$ |
| | $\tau = 0$ (stagnation) | $\frac{1}{1+\kappa x}$ |
| $\lambda^t_{\mathcal{M}_i}(O_i)$ | Fixed cost, scale component | $1 + \sum_{m \in \mathcal{M}_i \setminus O_i} [1 - (\lambda^t)^{(m-O_i)^2}]$ |
| $\lambda^q_{\mathcal{M}_i}(z, O_i)$ | Fixed cost, scope component | $\sum_{m \in \mathcal{M}_i \setminus O_i} \lambda^q \lvert z_m - z_a \rvert \cdot \mathbb{1}[m \neq O_i]$ |

**Table 7.1** shows the supply and demand side specification on utility, cost, and investment effectiveness. The baseline fixed cost f is normalized as 1, and the cost (de)synergy of integrating branch products applies only to the multimarket firms.

For each parameter configuration, there is an equilibrium search to pin down the aggregate investment levels anticipated by individual firms at the corresponding industry state $\mathcal{S}$. Starting from the initial draw of firm and industry states, each firm goes through the decision steps elaborated in the previous section. To avoid a multiple equilibria problem, I assume that the firms move sequentially such that, for each market, a) firms with a greater "highest" quality level across their market combination move first and b) given the same "highest" quality level, firms with a higher origin market quality level move first. The former assumes that technological leaders across the market would move first, and the latter assumes that firms act more quickly if they are specialized in their market of origin.

It should be noted that the identification relies on the profit and cost specifications normalized at the baseline fixed cost $f$, which I define as the minimum profit level of an active incumbent. This

assumption effectively imposes the current fixed cost as an upper bound to the possible baseline fixed costs, which are not observable in my data. Relaxing such assumption requires information on each firm's market-level fixed costs, and I defer such extension to future projects when such information does become available.

## 5.2 Results: Stylized Decision Sub-Strategy

Table 7.2 displays the result from the estimation steps. The $\lambda^t$ value of 0.1 indicates that firms enjoy a 10 percent discount in the fixed cost of producing, without spinoffs, in branch markets adjacent to their respective origin market. The discount level quickly decays by 0.1 as the branch markets become more different from the origin market based on wavelength range. For example, producing in markets a two unit distance from the firm's origin market would induce only a 1 percent discount in the fixed cost of producing without spinoffs, while this discount is 0.1 percent for markets a three unit distance away from the origin market.

**Table 7.2: Parameter Estimation Results**

| *Parameters* | Est. Results | Description |
|---|---|---|
| $\lambda^t$ | 0.1*** | Discount factor of baseline fixed cost (scale) |
| | (.020) | |
| $\lambda^q$ | 0.7*** | Added fixed cost of branch markets (scope) |
| | (.046) | |
| $\kappa$ | 0.1 | Parameter for improvement probabilities |
| | (.062) | |
| $\alpha$ | -3.83*** | Price sensitivity |
| | (.736) | |
| $\beta$ | 1.01*** | Quality differentiation |
| | (.278) | |
| $\gamma$ | -0.10*** | MC parameter by firm-market proficiency (max available by firm-mkt-time) |
| | (.001) | |

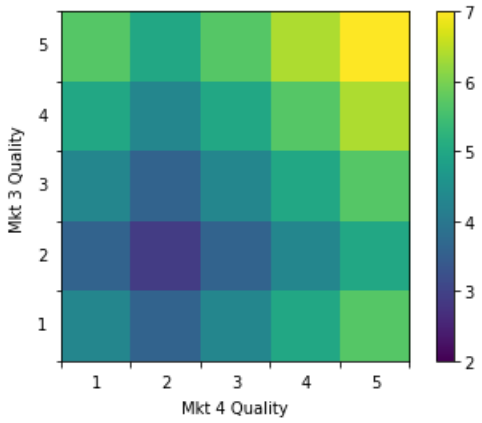
**Table 7.2** shows the estimation results of the six demand and supply side parameters. The synergy from producing a branch laser of similar type is quickly overshadowed by the added fixed cost of producing a branch laser of significantly different quality level.

The $\lambda^q$ value of 0.7 indicates that firms incur an additional 70 percent of their baseline fixed cost to produce, without spinoffs, in branch markets whose quality level is a unit level different from that of their origin market. The additional cost linearly increases as the quality level difference becomes larger; for example, producing in branch markets with a quality level two units different from that of the origin market results in the additional accrual of 140 percent of the baseline fixed cost.

## Equilibrium Example: Fixed Cost and Spinoff Decision

In order to illustrate how the scale and scope affect a firm's decision to spin off, I provide an example equilibrium spinoff decision for an imaginary firm i to illustrate the interacting forces that drive firms to integrate or separate. Consider a hypothetical firm $i$ with an origin market $O_i = 2$ at quality level 2 and that decided at Stage 1 to participate in markets 2, 3, and 4. Its realized fixed costs without spinoffs are depicted as such:

**Figure 3: Fixed Cost without Spinoffs**




$$O_i = 2, z_2 = 2, \mathcal{M}_i = \{2, 3, 4\}$$

**Figure 3** Shows the fixed cost of operating in the three markets without spinoffs. The only state in which the aggregate fixed cost is smaller than 3 is when the quality levels of the branch markets are the same as that of the origin market.

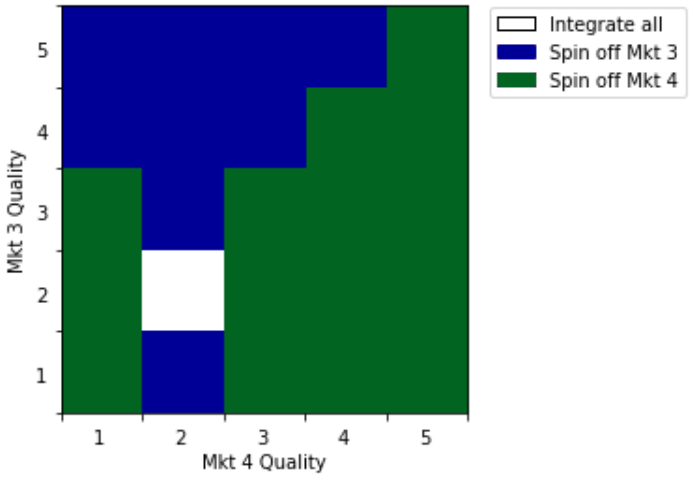
where the y and x axes represent the quality level that firm $i$ holds post-investment in markets 3 and 4, respectively. The scale is normalized around the baseline fixed cost f, which is the fixed cost of operating as a single market firm. Since the example firm i is operating in three markets, the initial fixed cost before considering the tradeoffs of scale and scope of operation is $3$[26].

The only state in which integration is the best decision is the state in which firm i's quality levels for both markets 3 and 4 are sufficiently similar to the quality level of its origin market $z_2 = 2$. In such state, firm $i$ enjoys a discount rate of 10 percent for market 3 and 1 percent for market 4 without experiencing any significant diseconomies of scope in producing branch products of different quality levels as a single entity. Since spinning off any of the branch markets in such state would forgo the benefits of scale without any payoffs, firm i's optimal decision is to integrate all of its branch markets as a single entity.

Figure 4 shows the optimal spinoff decision $d_i^*$ of example firm i; the white area ($d_i^* = 0$) represents the state in which firm i would decide to integrate both markets 3 and 4:

[26] A detailed comparison of fixed costs across spinoff decision $d_i$ is in Appendix Section 3.

**Figure 4: Optimal Spinoff Decision**




$O_i = 2, z_2 = 2, \mathcal{M}_i = \{2, 3, 4\}$

**Figure 4** shows the optimal spinoff decision for the example firm operating in three markets. Given the same amount of quality difference, the firm chooses to spin off in branch markets farther away from the origin market. However, if the firm's adjacent branch market product shows a higher level of quality difference from the origin product than those in markets farther away, the firm chooses to spin off the branch market adjacent to the origin market.

The synergy of integration is quickly overshadowed in other states in which the branch products are significantly different in quality from the origin product. Therefore, in such states, firm $i$ would choose to spin off at least one of the products ($d_i = \{3 \text{ or } 4\}$). How such sequence of spinoff occurs is also dependent on both the product and the quality similarities. Given the same level of diseconomies of scope, the market farther from the origin market $O_i$ is always favored over the adjacent market for spinning off because the firm enjoys inferior cost synergy when integrating a product that is less similar in its laser wavelength to that in the adjacent market. This can be seen in the area where the qualities of markets 3 and 4 are the same but differ from the origin market quality $z_2$. Although both markets are candidates for spinning off, the net gain of spinning off is higher for market 4, which is further away from the origin market $O_i = 2$; thus, market 4 is chosen over market 3 for spinning off.

In a more extreme case, when the market closer to the origin market has a stark technological difference from the origin market, while the market farther away has a similar level of technology with the latter, firm i would actually opt to separate the market that is closer to its market of origin. Such is depicted by the blue area in Figure 4.

This result, especially the scope parameter, provides evidence of how significant the role of spinoffs is in allowing firms to efficiently branch out of their origin markets. Unless the quality levels are homogeneous across the firm's active markets, firms are better off spinning off their branch markets as a separate entity. Without spinoffs, firms would have to incur higher costs to produce in branch markets.

In certain cases, these costs would exceed the additional profits accrued in the branch markets and would lead the firms not to produce in branch markets. How impactful such a decision is to the welfare of the industry participants is discussed in the next section.

# 6 Counterfactuals: Spinoffs vs. No-Spinoffs

Using the estimated parameters, I simulate a set of counterfactual scenarios in which firms are not allowed to spin off any of the branch markets in which they decide to remain active. Since each firm's state of the origin market and quality are treated as given in the model, equilibrium results are contingent on the initial draws for the number of incumbent firms in the industry and the state of each firm. Therefore, the type of industry represented by the results would hinge on the probability assigned to the drawing of each state. I list two sets of results, one depicting the actual medical laser industry and one depicting a conglomerate holding a monopoly over all markets.

## 6.1 Case #1: Medical Laser Industry

First, I tether my results to states that have been and could be reasonably reached in the industry. I take draws of the initial firm and industry states with probabilities based on how likely it is that these states will be reached from the observed data[27]. I run 100 simulations, each comprising 30 random draws of initial industry states, and derive equilibrium states under the standard scenario with spinoffs allowed and the counterfactual scenario with spinoffs not allowed. For each draw, I calculate the mean of market-level active incumbents, quality level, outside shares, and consumer surplus. Welfare for each iteration is calculated as the sum of aggregate firm value and consumer surplus. Then, I derive the means and the standard deviations of the equilibrium results across the 100 simulation sets[28].

**Table 8: Aggregate Result; Medical Laser Industry**

| | Spinoffs | No Spinoffs | % $\Delta*$ |
|---|---|---|---|
| Firm Profit (Mean, $ Millions) | 2756.3 | 2261.6 | -17.9 |
| Investment (%) | 0.015 | 0.007 | -53.3 |
| Fixed Cost (Mean, $ Millions) | 69.6 | 46.5 | -33.2 |
| Welfare (Mean, $ Millions) | 7744.6 | 7156.6 | -7.6 |

$* \ (\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100)$

**Table 8** shows the mean results for firm profits, investment, fixed cost, and welfare between the spinoff and no-spinoff scenarios. The decrease in the fixed cost indicates that firms are less likely to produce in branch markets without spinoffs.

[27]Details of the draw steps are in Appendix Section 3.

[28]The dollar values are scaled up from thousands to millions by multiplying the market size by 1000 to better represent the actual scale of the medical laser industry. The equilibrium results remain invariant to market size shifts, since the normalized fixed cost (the lowest profit level of an incumbent firm) is a multiplier of the market size.

Table 8 shows the equilibrium aggregate investment level, total profit of the incumbent firms, and welfare. Without spinoffs, aggregate welfare drops by 7.6 percent on average. The total fixed cost drops by 33.2 percent, which is a result of firms deciding to exit from branch markets in which they would otherwise remain if spinoffs were allowed[29]. Most of the decrease comes from the aggregate value of the firms, which drops by 17.9 percent. The result illustrates significant managerial implications for the role of spinoffs in firm profitability. Should firms produce in all of their active markets as a single enterprise, they would incur a significant additional fixed cost to produce branch market products of different quality levels. In more extreme states, they would choose not to enter certain branch markets, missing out on the profits in markets that they otherwise would have entered by spinning off the division in charge of said market. Combined with the fact that they would induce a higher level of fixed cost among branch markets in which they decide to remain active for both settings, the drop in welfare highlights the role of spinoffs in optimizing the firms' production and profitability in branch markets.

The investment level also shows a significant drop: from 1.5 percent to 0.7 percent of the firm's profit level. A decrease of 53.3 percent indicates that firms have a lower interest in investing for better product quality. Due to the static nature of the model, the subsequent effect of the investment drop in market quality is not captured in the welfare calculation. However, it should be noted that the long-term ramification of the investment drop would also amplify the role of spinoffs in welfare. I leave the study of the dynamic effects of spinoffs for future research.

With the welfare loss coming mostly from the firm side, one might consider spinoffs to be fairly irrelevant to consumer surplus. However, a market-level observation conveys that the role of spinoffs in consumer surplus differs across markets. Figure 5 displays how the number of origin firms in each market are distributed across the 30-year span from which the firm states are drawn. Markets 2, 4, 6, and 7 are largely populated with two or more origin firms, while markets 1, 3, and 5 mostly see one or no origin firms. Since the role of spinoffs on product availability only occurs through the branch markets, the welfare effects of the "no-spinoff" scenario should also be scrutinized differently across the number of origin firms populating the market.

Tables 9.1 and 9.2 display the market-level effect of spinoffs on the equilibrium number of firms, quality level, outside share, and consumer surplus. Consumer surplus for markets 1, 3, and 5 shows a 9.7 percent decrease without spinoffs, while that for markets 2, 4, 6, and 7 shows a 3.7 percent increase. The most extreme result is the case of market 5, where the results show that the market itself would not exist without spinoffs.

[29]The unilateral decrease in the equilibrium number of firms in the no-spinoff scenario in Table 9.1 supports the implication that firms are further discouraged from entering into branch markets when spinoffs are not allowed.

**Figure 5: Historical Number of Origin Firms across Markets**

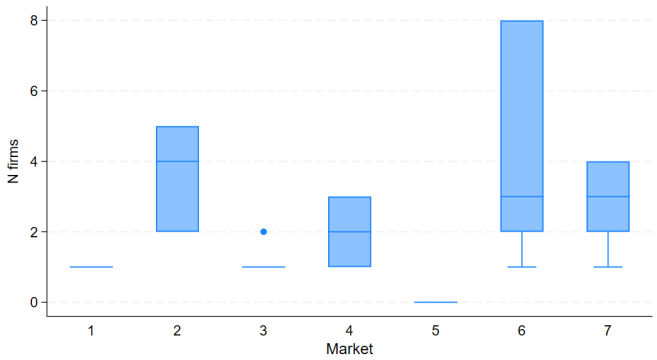



**Figure 5** displays the origin firm distribution over markets throughout the history of the medical laser market since 1990. Markets 1, 3, and 5 most often have 1 or 0 origin firms, while markets 2, 3, 6, and 7 most often have more than 2.

**Table 9.1: Market Level Incumbents & Average Quality; Medical Laser Industry**

| Mkt. (index) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Wavelength Range (nm) | ≤500 | 500-600 | 600-1000 | 1000-1500 | 1500-2000 | 2000-2100 | ≥2100 |
| N. Origin Firms | 1.00 | 4.16 | 1.33 | 2.54 | 0.00 | 5.86 | 3.25 |
| $N^*$ **(N. Firms)** | | | | | | | |
| Spinoffs | 1.58 | 4.08 | 1.67 | 2.6 | 0.11 | 5.43 | 11.21 |
| No Spinoffs | 0.82 | 3.8 | 1.13 | 2.06 | 0.00 | 4.40 | 4.81 |
| %Δ* | -48.1 | -6.9 | -32.3 | -20.8 | -100.0 | -19.0 | -57.1 |
| $Z^*$**(Quality)** | | | | | | | |
| Spinoffs | 2.59 | 3.89 | 3.37 | 1.85 | 0.13 | 2.65 | 1.27 |
| No Spinoffs | 2.07 | 4.19 | 3.69 | 2.02 | 0.00 | 2.59 | 2.01 |
| %Δ* | -20.1 | 7.7 | 9.5 | 9.2 | -100.0 | -2.3 | 58.3 |

$* \left(\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100\right)$

**Table 9.2: Market Level Outside Share & Consumer Surplus; Medical Laser Industry**

| Mkt. (index) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Wavelength Range (nm) | ≤500 | 500-600 | 600-1000 | 1000-1500 | 1500-2000 | 2000-2100 | ≥2100 |
| N. Origin Firms | 1.00 | 4.16 | 1.33 | 2.54 | 0.00 | 5.86 | 3.25 |
| $s_0^*$**(Outside Share)** | | | | | | | |
| Spinoffs | 0.70 | 0.22 | 0.55 | 0.67 | 0.99 | 0.46 | 0.68 |
| No Spinoffs | 0.80 | 0.18 | 0.55 | 0.62 | 1.00 | 0.52 | 0.67 |
| %Δ* | 14.3 | -18.2 | 0.0 | -7.5 | 1.0 | 13.04 | -1.47 |
| $CS^*$**(Consumer Surplus)** | | | | | | | |
| Spinoffs | 549.48 | 1427.54 | 818.69 | 604.86 | 22.4 | 985.62 | 579.76 |
| No Spinoffs | 368.82 | 1510.44 | 822.47 | 706.59 | 0.0 | 888.68 | 597.93 |
| %Δ* | -32.9 | 5.8 | 0.5 | 16.8 | -100.0 | -9.8 | 3.1 |

$* \left(\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100\right)$

**Tables 9.1** and **9.2** show the market-level means for the equilibrium incumbents, quality level, outside share, and consumer surplus in the spinoff and no-spinoff scenarios. The direction of the shifts from spinoff to no-spinoffs is mixed, based on the number of origin firms in each market and that market's position across the wavelength spectrum.

The driving sources of the consumer surplus shifts are also mixed across markets. For example, markets on the fringes (1,7) are likely to be more costly to reach as branch markets than those in the center (3, 4, 5) and therefore would likely be more affected in terms of the number of incumbents. The difference in market position can be implied by the incumbent firm shifts in markets 1 and 7, whose 48 percent and 57 percent decreases in equilibrium incumbents are the two highest percent changes[30] across markets. However, in the case of market 7 ($\geq$ 2100), the negative effect of having fewer firms is exceeded by the increase in average quality level due to having a large number of origin firms, which results in a net positive effect on consumer welfare in the counterfactual scenario. Such variation is likely due to the positioning of the high and low origin-firm markets, which are reasonably well spread out across the wavelength spectrum.

**Table 10: Consumer Surplus by Market Group**

| | Spinoffs | No Spinoffs | % $\Delta*$ |
|---|---|---|---|
| Markets 1, 3, 5 | 2219.8 | 2013.9 | -9.3 |
| Markets 2, 4, 6, 7 | 3734.3 | 3872.4 | 3.7 |
| Total | 6181.7 | 6072.4 | -1.8 |

$* \left(\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100\right)$

**Table 10** shows the consumer surplus, in $ millions, across two market groups. Markets with fewer than 2 origin firms on average experience a 9.3 decrease in consumer surplus in the no-spinoff scenario, while markets with more than 2 origin firms on average enjoy a 3.7 increase. There is an element of selection in quality of the active firms that contributes to the result.

The counterfactual analysis reveals that spinoffs play a crucial role in the industry by mitigating diseconomies of scope when firms extend into new markets. Without the ability to spin off divisions, incumbent firms would face substantially higher costs and reduced incentives to enter into branch markets. This results in a significant decline in aggregate firm value and a notable drop in overall welfare compared to when spinoffs are permitted.

At the market level, spinoffs are particularly valuable for facilitating entry and competition in markets that historically lack a strong presence of local origin firms. These markets with one or no origin firms experience a 9.3 percent decrease in consumer surplus without spinoffs, as firms choose not to branch out to markets requiring them to produce at significantly different quality levels. The heterogeneous effects highlight the type of markets for which spinoff creations could be incentivized to encourage greater product availability both in terms of quality and quantity. Overall, the results underscore spinoffs as an important competitive tool for overcoming scope diseconomies in multimarket, differentiated product industries.

[30] Market 5 not withstanding

### Case #1.2: Homogeneous Origin Firm Distribution

I additionally run a follow-up set of simulations in which there is only one origin firm per market. This set of simulations is to further illustrate that uneven origin firm distribution is the primary source of heterogeneous spinoff effects on consumers[31]. For each draw, I define seven firms and assign each of them a different respective origin market. I then randomly draw the quality levels of each firm-market pair. To streamline the computation time while retaining the main point of the results, I give higher probabilities of positive quality draws to markets farther away from the firms' respective origin markets[32]

**Table 11.1: Market Level Incumbents & Average Quality; One Origin Firm per Market**

| Mkt. (index) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Wavelength Range (nm) | ≤500 | 500-600 | 600-1000 | 1000-1500 | 1500-2000 | 2000-2100 | ≥2100 |
| N. Origin Firms | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| $N^*$ **(N. Firms)** | | | | | | | |
| Spinoffs | 3.15 | 3.16 | 3.13 | 3.15 | 3.17 | 3.16 | 3.15 |
| No Spinoffs | 3.11 | 3.12 | 3.09 | 3.13 | 3.11 | 3.11 | 3.11 |
| %Δ* | -1.3 | -1.3 | -1.3 | -1.6 | -1.3 | -1.3 | -1.3 |
| $Z^*$**(Quality)** | | | | | | | |
| Spinoffs | 2.52 | 2.53 | 2.53 | 2.53 | 2.52 | 2.52 | 2.52 |
| No Spinoffs | 2.49 | 2.49 | 2.49 | 2.49 | 2.49 | 2.48 | 2.49 |
| %Δ* | -1.2 | -1.6 | -1.6 | -1.6 | -1.2 | -1.6 | -1.2 |

$* \left(\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100\right)$

**Table 11.2: Market Level Outside Share & Consumer Surplus; One Origin Firm per Market**

| Mkt. (index) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Wavelength Range (nm) | ≤500 | 500-600 | 600-1000 | 1000-1500 | 1500-2000 | 2000-2100 | ≥2100 |
| N. Origin Firms | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| $s_0^*$**(Outside Share)** | | | | | | | |
| Spinoffs | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| No Spinoffs | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| %Δ* | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 |
| $CS^*$**(Consumer Surplus)** | | | | | | | |
| Spinoffs | 1118.22 | 1121.07 | 1144.55 | 1189.09 | 1147.21 | 1093.29 | 1154.00 |
| No Spinoffs | 975.83 | 977.37 | 992.73 | 958.57 | 1004.53 | 932.93 | 1002.90 |
| %Δ* | -12.7 | -12.8 | -13.2 | -19.4 | -12.4 | -14.6 | -13.1 |

$* \left(\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100\right)$

**Tables 11.1** and **11.2** show the market-level means for the equilibrium incumbents, quality level, outside share, and consumer surplus in the spinoff and no-spinoff scenarios where there is one origin firm per market. The shifts from spinoff to no-spinoff scenarios become largely homogeneous across markets. This supports the argument that the heterogeneity in Tables 9.1 and 9.2 is primarily driven by the uneven number of origin firms across markets.

[31] Aggregate result is at Appendix Section A4

[32] Simulations where all firms have non-zero quality across all markets serves to unnecessarily inflate the convergence time without much value compared to simulations where firms have zero quality on adjacent markets.

The uniform direction of the results from spinoff to no-spinoff scenario when given the same number of origin firms showcases the major source of heterogeneous effect of spinoffs in previous section. Given the same number of origin firms per market, spinoffs would play a similar role across all markets.

## 6.2 Case #2: Conglomerate Monopolist

To further illustrate the efficiency problem of a conglomerate, I now consider a monopoly setting in which there exists a single firm across all markets. I take draws of the initial firm and industry state and treat it as if a single firm is operating across all markets with the quality levels available in each of the markets. For each draw, I define the origin market of the monopolist as the market with the greatest number of origin firms. Similar to the previous setting, each market experiences an idiosyncratic shock to its quality level. I make 100 simulations of 30 draws of initial industry states. For each simulation, the equilibrium states are derived under the standard scenario with spinoffs allowed and the counterfactual scenario with spinoffs not allowed.

**Table 12: Aggregate Results; Monopolist Case**

| | Spinoffs | No Spinoffs | $\%\Delta*$ |
|---|---|---|---|
| Firm Profit (Mean, $ Millions) | 460.1 | 433.7 | -5.7 |
| Investment (Mean, %) | 0.060 | 0.007 | -88.33 |
| Fixed Cost (Mean, $ Millions) | 39.7 | 63.1 | 59.1 |
| Welfare (Mean, $ Millions) | 1698.5 | 1655.7 | -2.5 |

$* \ (\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100)$

**Table 12** shows the mean results for firm profits, investment, fixed cost, and welfare between the spinoff and no-spinoff scenarios in a monopolist setting. Compared to the results in Table 8, the percent change in firm profit and welfare is lower, while the percent change in fixed cost is much higher. This result signals that the monopolist is more willing to stay in branch markets despite the added fixed cost accrued.

Tables 12, 13.1, and 13.2 show the same set of equilibrium results displayed in the previous counterfactual analysis. The monopolist's profit and welfare in the no-spinoff scenario decrease by 5.7 and 2.5 percent, respectively. The lower magnitude of the drop compared to the results in Table 8 is due to the higher market power commanded by the monopolist across all markets. Therefore, in a no-spinoff scenario, the monopolist would more likely remain active in the branch markets despite the additional fixed cost accrued. The monopolist's behavior can also be seen in the percent changes in the number of incumbents in Table 12.1, as the magnitude of these is much more suppressed than it is for the competitive setting counterparts in Table 9.1. The highest percent change in Table 12.1 is in market 5, with the monopolist's probability of entry dropping by 14 percent in the nonspinoff scenario, whereas

in Table 9.1, market 5 does not exist in the nonspinoff scenario.

The percent change in the fixed cost best reflects the contrast between the monopolist and competitive settings. The total fixed cost in the former increases by 59.1 percent, which is a major departure from the 33.2 percent decrease in the latter. The contrast comes from the fact that the monopolist would more likely stay in branch markets in nonspinoff scenarios that it would exit in the competitive setting. Therefore, the nonspinoff scenario would see a further increase in fixed costs from those branch markets in which the monopolist decides to stay.

The result further emphasizes the managerial significance of spinoffs in firm optimization. Although its stronger market power may keep the monopolist active in the branch markets even when spinoffs are not allowed, it incurs a much higher level of fixed costs than it would given spinoffs.

**Table 13.1: Market Level Incumbents & Average Quality; Monopolist Case**

| Mkt. (index) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Wavelength Range (nm) | ≤500 | 500-600 | 600-1000 | 1000-1500 | 1500-2000 | 2000-2100 | ≥2100 |
| $N^*$ **(N. Firms)** | | | | | | | |
| Spinoffs | 0.34 | 0.51 | 0.33 | 0.31 | 0.04 | 0.77 | 0.37 |
| No Spinoffs | 0.33 | 0.50 | 0.30 | 0.27 | 0.03 | 0.74 | 0.29 |
| %Δ* | -1.5 | -1.7 | -8.9 | -12.2 | -14.0 | -3.5 | -21.9 |
| $Z^*$**(Quality)** | | | | | | | |
| Spinoffs | 0.855 | 1.63 | 0.72 | 0.64 | 0.08 | 2.78 | 0.71 |
| No Spinoffs | 0.849 | 1.62 | 0.69 | 0.60 | 0.08 | 2.75 | 0.63 |
| %Δ | -0.7 | -0.6 | -4.0 | -5.9 | -5.7 | -1.0 | -11.5 |

$* \ (\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100)$

**Table 13.2: Market Level Outside Share & Consumer Surplus; Monopolist Case**

| Market Index | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Wavelength Range (nm) | ≤500 | 500-600 | 600-1000 | 1000-1500 | 1500-2000 | 2000-2100 | ≥2100 |
| $s_0^*$**(Outside Share)** | | | | | | | |
| Spinoffs | 0.93 | 0.84 | 0.94 | 0.95 | 0.99 | 0.71 | 0.95 |
| No Spinoffs | 0.93 | 0.84 | 0.94 | 0.95 | 0.99 | 0.71 | 0.95 |
| %Δ* | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.4 |
| $CS^*$**(Consumer Surplus)** | | | | | | | |
| Spinoffs | 128.18 | 291.15 | 97.94 | 84.04 | 11.76 | 533.21 | 92.13 |
| No Spinoffs | 127.65 | 290.68 | 95.82 | 80.66 | 11.50 | 531.31 | 84.31 |
| %Δ* | -0.4 | -0.2 | -2.1 | -4.0 | -2.2 | -0.4 | -8.5 |

**Tables 13.1** and **13.2** show the market-level means for equilibrium incumbents, quality level, outside share, and consumer surplus in the spinoff and no-spinoff scenarios in a monopolist setting. The direction of the shifts from spinoff to no-spinoffs is unilateral, since the element of selection does not exist in the monopolist case.

Another departure from the previous counterfactual analysis is the unilateral decrease in the available products' quality and consumer surplus across all markets. In Table 9.1, there are certain markets, such as markets 2, 3, and 4, that see an increase in the average quality level of the available products in the nonspinoff scenario, whereas in Table 13.1, all markets see a decrease in quality level of between 0.7 and 11.5 percent. Likewise, in Table 9.2, the consumer surplus remains indifferent or sees an increase in markets 2, 3, 4 and 7 in the nonspinoff scenarios, while in Table 13.2, the consumer surplus in all markets drops by between 0.2 and 8.5 percent. Such contrast is not surprising; since there is no competing incumbent to keep the markets alive without the monopolist, there is no element of quality selection to shift the consumer surplus up in certain markets in the no-spinoff scenario. Therefore, spinoffs play a positive role in product quality level across all markets if they are all run by a single firm.

Lastly, the investment level in the no-spinoff scenario decreases by 88 percent for the monopolist, which is a more severe decrease than the 53 percent decrease in the competitive setting. It is also noteworthy that the investment level in the spinoff setting drops by 60 percent in the monopoly case compared to the competitive case, while it remains similar in the no-spinoff scenario whether it is run by a monopolist or not. Even in a setting where a firm can enjoy monopoly profits, not allowing spinoffs results in a reduction of the investment level to a level similar to that in the competitive setting. The result, therefore, emphasizes a role of spinoffs in innovation that is separate from their role in market competition. The increase in innovation expenditure regardless of competition intensity echoes the added focus of the parent and the spinoff on their respective origin markets, albeit in different magnitudes.

The two counterfactuals show the role of spinoffs in different venues. The competitive setting shows that, without spinoffs, firms would more likely exit from those branch markets with quality levels significantly different from that of their origin market. The effect on consumers alternates across markets; markets with a large enough number of origin firms are less affected by this tendency and actually enjoy a higher average quality through the process of selection in nonspinoff scenarios. Therefore, spinoffs play a bigger role in markets with a low number of origin firms. When aggregated, the welfare and profit decrease is driven by firms deciding to exit their respective branch markets.

In contrast, the monopolist setting shows that, without spinoffs, firms would more likely stay and accrue higher levels of fixed cost than they would with spinoffs. The focus is more on the firm side than on the consumer's side, since the welfare and profit decreases in a no-spinoff scenario are mainly driven by the fixed cost increase. The monopolist setting highlights the efficiency problem of operating as a conglomerate, where keeping the operation of every market under a single entity creates a much higher level of fixed cost that may be masked by the profitability the firm experiences by holding market power over the entire industry.

# 7 Conclusion

This paper examines the role of spinoffs in addressing diseconomies of scope when firms expand into differentiated product markets. The medical laser industry provides a unique setting to study these operational tradeoffs between scale and scope, independent of market power considerations. The industry's segmented nature across laser wavelengths allows firms to make spinoff decisions based solely on the cost differences of integrated versus separate structures when producing across multiple markets.

A key contribution of this paper is that it endogenizes shifts in firms' organizational structure as part of their optimal strategy. In contrast to the current trend in the endogenous product choice literature, which primarily focuses on merger analysis, this paper takes the opposite direction by examining spinoff activities. This novel approach allows spinoffs to be incorporated as an additional layer of firm dynamics and evolution.

The paper also leverages a unique dataset that enables an accurate measurement of product differences between firms' origin and branch markets, both in terms of laser type (wavelength) and quality. By constructing a quality score based on key product characteristics, the analysis captures the diseconomies of scope arising from producing branch market quality significantly differentiated from the origin quality level.

Counterfactual simulations reveal the importance of spinoffs for both firm profitability and product availability. Without the ability to spin off divisions, firms face substantially higher costs and reduced investment incentives, leading to a 17.9 percent drop in total firm profit and a 7.6 percent decrease in overall welfare. At the market level, spinoffs play a crucial role in facilitating entry into and competition within markets with 1 or no origin firms, as such markets experience a 9.3 percent decrease in consumer surplus when spinoffs are prohibited. The monopolist setting also shows the importance of spinoffs in cost efficiency, with the fixed cost accrued increasing by 59.1 percent.

This paper captures the essence of what spinoffs can achieve in terms of firm profits and product availability. By mitigating diseconomies of scope, spinoffs serve as a valuable competitive tool for firms expanding into differentiated product markets. The heterogeneous effects across markets highlight the potential for targeted policies to incentivize spinoff creation and enhance product variety in specific market segments.

The paper is not without its limitations; firstly, there are data limitations, notably the lack of market-level investment and fixed cost information for the firms. This requires me to make assumptions of equal investment distributions across markets and to normalize the profit and cost information to the upper bound of the baseline fixed cost $f$. These assumptions do not impact the direction of the result, as the equal investment assumption biases the estimation against diseconomies of scope. However, having

more granular information at the firm-market level would perhaps allow more accurate insights into the tradeoffs between operational scale and scope in the spinoff decision.

Related to the firm-market specific information, there are also computational limitations. The computational burden for estimation is severe, even with symmetric firm and market assumptions in terms of profit, baseline fixed cost, and investment efficiencies. Adding heterogeneity in any of the venues would require both much greater computing power and higher granularity in the observable data. I defer this addition to future research, in which spinoffs could be observed either across industries at a broader level or with detailed market-level data in a single industry at a narrower level. This paper serves as a step towards such future studies, which can investigate organizational changes more deeply and/or broadly in various economic contexts.

Overall, this paper provides a fresh perspective on the strategic role of organizational structure in multimarket, differentiated product industries. By endogenizing spinoff decisions and leveraging novel data to measure product differentiation, it contributes to our understanding of how firms navigate the tradeoffs between operational scale and scope in the pursuit of growth and profitability.

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# A Appendix

## A.1 Market Separability

As a robustness check to the previous line of work regarding the medical laser industry, I show a result that illustrates this industry's fragmented nature across laser types. I conduct a simple difference-in-difference (DiD) analysis for evidence of any sales or price shifts that occur in the industry after changes in firm structure, including mergers & acquisition, corporate spinoffs, or any product separation at a brand level that I am able to observe:

$$log(Y_{it}) - log(Y_{it-j}) = \beta_1 \mathbb{1}[merged_t == 1] + \beta_2 \mathbb{1}[acquired_t == 1] + \beta_3 X_{it} + \delta_t + \gamma_{\mathcal{M}(i)} + \eta_i + \epsilon_{it} \tag{A.1}$$

The $merged_t$ indicates that an establishment's owner was merged[33] with another entity at time t, while $acquired_t$ indicates that an establishment's owner has acquired another entity. I define both merging and acquiring as the sale/purchase of more than 50 percent of the shares of the firm's counterpart, and lagged sales/purchases in smaller increments are not considered. I shift my lag period $j$ up to three years, which is the upper limit of the results showing any kind of power in the pricing data. Control variables include aggregated employees at the firm level ($X_{it}$) and fixed effects for the firm and industry ($\eta_i$), headquarters location ($\gamma$) and time period ($\delta$).

**Table A1: Difference-in-Difference Results on Sales and Price in Medical Laser Establishments**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | 1yr lag | | 2yr lag | | 3yr lag | |
| | Sales | Price Lvl | Sales | Price Lvl | Sales | Price Lvl |
| Merged | -0.064 | 0.058 | -0.105 | -0.010 | 0.186 | 0.002 |
| | (0.25) | (0.20) | (0.33) | (0.28) | (0.40) | (0.14) |
| Acquired | -0.022 | 0.041 | -0.027 | 0.089 | -0.074 | -0.138 |
| | (0.08) | (0.46) | (0.11) | (0.56) | (0.14) | (0.29) |
| Emp_Agg | -0.000*** | | -0.000*** | | -0.000*** | |
| | (0.00) | | (0.00) | | (0.00) | |
| Constant | 0.072*** | -0.003 | 0.146*** | 0.051 | 0.213*** | 0.097*** |
| | (0.01) | (0.04) | (0.01) | (0.05) | (0.02) | (0.03) |
| R-sqr | 0.071 | 0.242 | 0.128 | 0.411 | 0.189 | 0.845 |
| Obs. | 3988 | 138 | 3722 | 112 | 3455 | 87 |
| FE | Firm, Industry, Location, and Time | | | | | |

Standard errors are in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The absence of statistical significance in both the price and sales change following ownership changes for enterprises in the laser industry implies two insights that support the view that the markets are separate from one another: first, there is no evidence that the firms in the laser industry are engaging in predatory pricing or killer acquisition to increase market power post-merger/acquisition; second, there is no evidence that these firms are merging the manufacturing process across different brands. This is

[33] Some of these cases include independent investor groups or shareholders, which I consider as being spun off as an independent entity.

consistent with the fact that, post-acquisition, firms in the medical laser industry tend to preserve the brand and model name of the target firm's products, and there is no case of complete discontinuation of the target firm's product type[34].

Both insights support findings from existing studies that the laser market is fragmented into multiple separate markets and that acquisition across markets can be reasonably interpreted as a decision to break into another market while maintaining separation in the manufacturing of the firm's existing and its acquired product types. This assumption allows a criterion (albeit a highly conservative one) for determining whether a product is produced at the same enterprise as the headquarters' main production line.

[34]There are partial discontinuations of lower-quality products, which is not differentiable from the "quality-pruning" practices that other single-product firms exercise.

## A.2 Detailed Industry Overview

This section provides further details on how lasers work, how they are manufactured, and how its application to medical fields has evolved over time. It is meant for readers who have already read Section 2 in the paper, and would like a more comprehensive view on lasers and medical laser industry [35].

### Lasers

Lasers, or Light Amplification by Stimulated Emission of Radiation, are devices that use an energy source pumped onto a core material to produce a specific light emission. These devices then reflect the radiation created within the device to emit stable light energy as an output.

**Figure A2.1: Laser Basics**

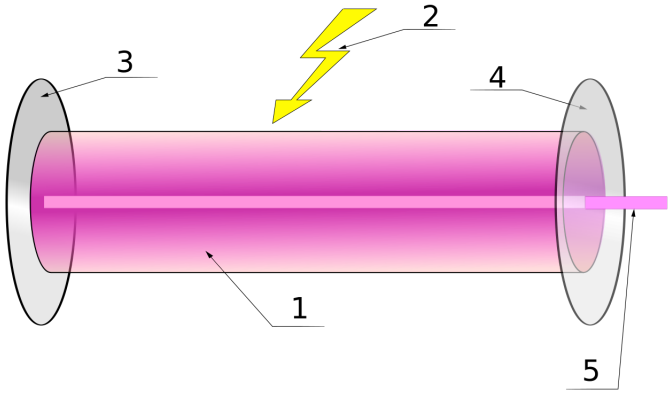



**Figure A2.1** shows how lasers are produced. It is largely comprised of three parts: gain medium (1), pumped energy (2), and optical resonators (3 and 4). The final product of beam (5) is dependent on the choice and positioning of the three parts.

Figure A2.1[36] is a simplified picture of how laser lights are produced in a laser device. Within the device is the gain medium (1), or the core material from which the respective particles can be stimulated to emit a certain type of radiation emission. An external energy source (2) is pumped into the gain medium to stimulate the particles (or photons) contained within, and the emitted radiation is reflected through a set of mirrors called the optical resonator (3 and 4). Through a series of reflections between the two mirror reflectors, the movement of the stimulated photons get amplified until they reach a certain level of output and wavelengths designed by the specifics of each devices. Eventually the amplified beam of light (5) protrudes out of the frontal mirror (4), giving the users the final product of energy. The output characteristics, such as power, irradiance, beam size, and the wavelengths, are predominantly determined by these three parts in the laser device.

[35] Disclaimer: I do not claim to know all the technical minutia of how the laser devices work. A physicist-level of detail should be directed to professional laser manuals and optical physics books

[36] By User:Tatoute - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=577575

The laser types are categorized based on the three components of the device. The most famous type category - solid state or gas - are based on whether the gain medium is solid or gas at operating environment. Additionally, the type of pumped energy, and how intensively the emitted photons are reflected between the optical resonators contribute to the properties of the final laser output. These can be more specifically categorized by wavelengths, in nanometers (nm), defined as the interval size of the emitted energy as it oscillates out of the frontal mirror.

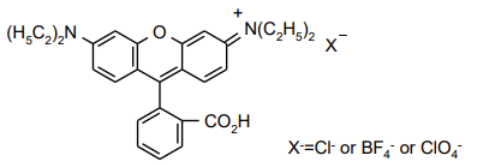
### Input Similarities

As illustrated in Table 1 and Figure 1 of Section 2.1, lasers of different wavelengths are applied to different medical purposes. Despite technological advancements that made some of the lasers substitutable - Helium-Neon (HeNe) laser of 632 nm and general Semiconductor lasers ranging between 630-900 nm - laser devices tailored to work on significantly different wavelength ranges are still largely considered to be unsubstitutable, especially in medical applications.

**Figure A2.2: Energy Source for Rhodamine 610 nm and 640 nm Lasers**

**Rhodamine 610**

**Synonym:** N-[9-(2-carboxyphenyl)-6-(diethylamino)-3H-xanthen-3-ylidine]-N-ethyl-ethanaminium chloride or perchlorate; Rhodamine B
**Catalog No.:** 06101 (chloride); 06102 (perchlorate); 06103 (tetrafluoroborate)
**CAS No.:** 81-88-9 (06101); 23857-51-4 (06102); N/A (06103) **MW:** 479.02 (06101); 543.02(06102); 530.38 (06103)
**Chemical Formula:** $C_{28}H_{31}N_2O_3.Cl$ (06101); $C_{28}H_{31}N_2O_3.ClO_4$ (06102); $C_{28}H_{31}N_2O_3.BF_4$ (06103)
**Appearance:** Green crystals or reddish-violet powder (06101); Green crystals (06102)
**Structure:**




**RHODAMINE 640 PERCHLORATE**

**Synonym:** 9-(2-carboxyphenyl)-2,3,6,7,12,13,16,17-octahydro-1H,5H,11H,15H,-xantheno[2,3,4-ij:5,6,7-i'j']-diquinolizin-4-ium perchlorate; Rhodamine 101
**Catalog No.:** 06400
**CAS No.:** 72102-91-1 **MW:** 591.05
**Chemical Formula:** $C_{32}H_{31}N_2O_3.ClO_4$
**Appearance:** Dark green crystals with bronze sheen
**Molar absorptivity (at 567nm):** 10.50 x $10^4$ L $mole^{-1}$ $cm^{-1}$
**Structure:**

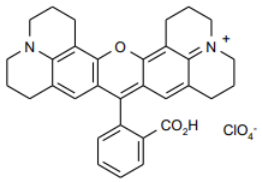



**Figure A2.2** is a component manual snippets of Rhodamine 610 nm (above) and 640 nm (below) lasers[37][38].The chemical inputs between the two laser devices are almost identical. Despite the different compound structure, firms would enjoy high levels of economies of scale by synchronizing production of the two lasers.

[37]Source: https://exciton.luxottica.com/pub/media/productattach/Datasheet/06400.pdf
[38]Source: https://exciton.luxottica.com/media/productattach/Datasheet/06102.pdf

While the bandwidth of wavelengths that each unique laser configuration can produce is highly narrow, producing two lasers of similar wavelength can be easier to manage than wavelengths farther away. Consider the two lasers of wavelengths 610 nm and 640 nm's in Figure A2.2, for instance. The two devices cannot produce lasers at each other's wavelengths, as stated in Figure 1 of Section 2.1. However, the type of inputs they require hugely overlaps with each other. Firstly, they share the exact same gain medium in Rhodamine. Secondly, the pumped energy source are almost identical: Carbon, Hydrogen, Oxygen, Dinitrogen Trioxide, and Chloride. The difference comes from how the chemical compounds are structured, but the large overlap in the inputs of the two lasers provides advantage to firms synchronizing production of the two lasers. Given similar quality levels, firms are better off integrating production of the two lasers, taking advantage of the economies of scale it provides.

Such advantage quickly diminishes as the wavelength difference between the two lasers gets bigger. Not only do you have different inputs, but also different production approach on how to tailor them for different medical applications. The regular channels in which economies of scales arise - bulk buying, efficient investment in capital, division of labor on homogeneous products, etc. - becomes muted. Combined with the absence of market power incentives by holding managerial control over multiple markets, firms' incentive to integrate two lasers of significantly different wavelengths becomes marginalized.

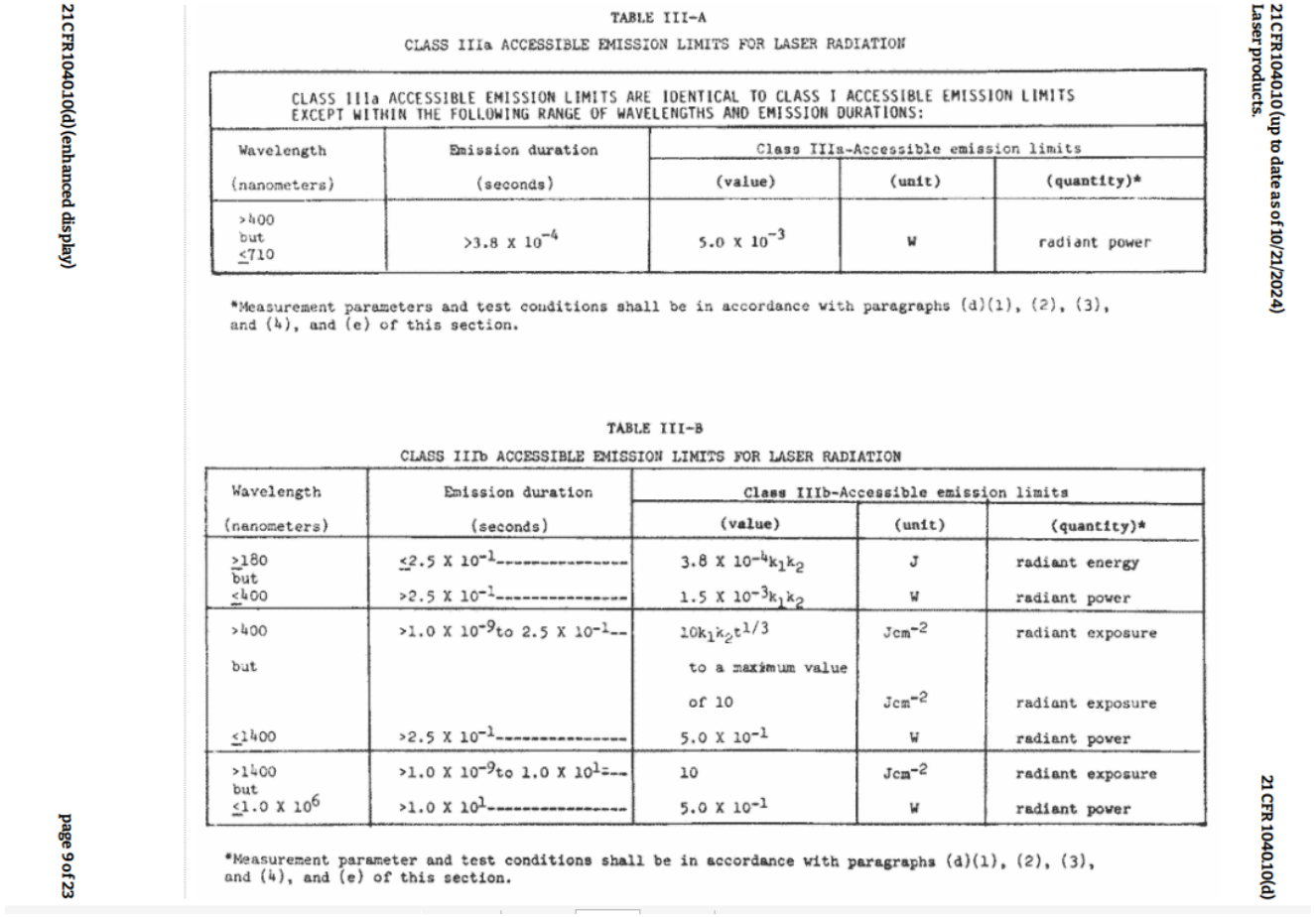
**Regulations**

A number of regulatory bodies are involved in the production of medical laser devices, most notably the Food and Drug Administration (FDA). All medical laser devices are subject to pre-market approval by the FDA, mainly based on the Federal Laser Product Performance Standards (FLPPS) under Title 21 Code of Federal Regulations (Subchapter J, Radiological Health) Parts 1010 and 1040. Manufacturers of laser devices are also required to comply with the standards from Federal Food, Drug and Cosmetic Act (FFDCA), Chapter V, Subchapter C - Electronic Product Radiation Control[39]. Depending on the inputs used, manufacturers are also subject to regulatory clearances from the Occupational Safety and Health Administration (OSHA), National Fire Protection Association (NFPA), International Electrotechnical Commision (IEC), and International Standard Organization (ISO).

Different inputs and expected output level requires different set of regulatory standards to abide by. For example, Figures A2.3 and A2.4 show the heterogeneity in one of the compliance items - accessible emissions limit in operation site - across laser quality and type.

[39]Source: https://www.govinfo.gov/content/pkg/USCODE-2010-title21/html/USCODE-2010-title21-chap9-subchapV-partC-sec360ii.htm

## Figure A2.3: FDA Accessible Emissions Limit, Laser Device Class IIIa and IIIb [40]



21CFR1040.10(d)(enhanced display)

TABLE III-A

CLASS IIIa ACCESSIBLE EMISSION LIMITS FOR LASER RADIATION

| CLASS IIIa ACCESSIBLE EMISSION LIMITS ARE IDENTICAL TO CLASS I ACCESSIBLE EMISSION LIMITS EXCEPT WITHIN THE FOLLOWING RANGE OF WAVELENGTHS AND EMISSION DURATIONS: | | | | |
|---|---|---|---|---|
| Wavelength (nanometers) | Emission duration (seconds) | Class IIIa-Accessible emission limits (value) | (unit) | (quantity)* |
| >400 but ≤710 | $>3.8 \times 10^{-4}$ | $5.0 \times 10^{-3}$ | W | radiant power |

*Measurement parameters and test conditions shall be in accordance with paragraphs (d)(1), (2), (3), and (4), and (e) of this section.

TABLE III-B

CLASS IIIb ACCESSIBLE EMISSION LIMITS FOR LASER RADIATION

| Wavelength (nanometers) | Emission duration (seconds) | Class IIIb-Accessible emission limits (value) | (unit) | (quantity)* |
|---|---|---|---|---|
| ≥180 but ≤400 | $\leq 2.5 \times 10^{-1}$ | $3.8 \times 10^{-4} k_1 k_2$ | J | radiant energy |
| | $>2.5 \times 10^{-1}$ | $1.5 \times 10^{-3} k_1 k_2$ | W | radiant power |
| >400 but ≤1400 | $>1.0 \times 10^{-9}$ to $2.5 \times 10^{-1}$ | $10 k_1 k_2 t^{1/3}$ to a maximum value of 10 | $Jcm^{-2}$ | radiant exposure |
| | | | $Jcm^{-2}$ | radiant exposure |
| | $>2.5 \times 10^{-1}$ | $5.0 \times 10^{-1}$ | W | radiant power |
| >1400 but ≤$1.0 \times 10^6$ | $>1.0 \times 10^{-9}$ to $1.0 \times 10^{1}$ | 10 | $Jcm^{-2}$ | radiant exposure |
| | $>1.0 \times 10^{1}$ | $5.0 \times 10^{-1}$ | W | radiant power |

*Measurement parameter and test conditions shall be in accordance with paragraphs (d)(1), (2), (3), and (4), and (e) of this section.

21CFR1040.10(up to date as of 10/21/2024) Laser products.

21 CFR 1040.10(d)

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**Figure A2.3** shows the accessible emission limits of the laser devices classified by IIIa or IIIb. The limits dependent on the solution factor parameters $k_1$ and $k_2$, which are dependent on the wavelength of the lasers produced from each device. The limits are stricter across difference classes of lasers, which corresponds to higher quality lasers requiring a stricter regulatory rules to abide by.

[40] Source: https://www.ecfr.gov/current/title-21/chapter-I/subchapter-J/part-1040/section-1040.10

**Figure A2.4: FDA Accessible Emissions Limit Parameters by Wavelength** [41]



TABLE V

SELECTED NUMERICAL SOLUTIONS FOR $k_1$ AND $k_2$

| Wavelength (nanometers) | $k_1$ | $k_2$ | | | | |
|---|---|---|---|---|---|---|
| | | $t \leq 100$ | $t = 300$ | $t = 1000$ | $t = 3000$ | $t \geq 10{,}000$ |
| 180 | 1.0 | 1.0 | | | | |
| 300 | 1.0 | | | | | |
| 302 | 1.0 | | | | | |
| 303 | 1.32 | | | | | |
| 304 | 2.09 | | | | | |
| 305 | 3.31 | | | | | |
| 306 | 5.25 | | | | | |
| 307 | 8.32 | | | | | |
| 308 | 13.2 | | | | | |
| 309 | 20.9 | | | | | |
| 310 | 33.1 | | | | | |
| 311 | 52.5 | | | | | |
| 312 | 83.2 | | | | | |
| 313 | 132.0 | | | | | |
| 314 | 209.0 | | | | | |
| 315 | 330.0 | | | | | |
| 400 | 330.0 | | | | | |
| 401 | 1.0 | | | | | |
| 500 | 1.0 | | | | | |
| 600 | 1.0 | | | | | |
| 700 | 1.0 | | | | | |
| 710 | 1.05 | 1 | 1 | 1.1 | 3.3 | 11.0 |
| 720 | 1.09 | 1 | 1 | 2.1 | 6.3 | 21.0 |
| 730 | 1.14 | 1 | 1 | 3.1 | 9.3 | 31.0 |
| 740 | 1.20 | 1 | 1.2 | 4.1 | 12.0 | 41.0 |
| 750 | 1.25 | 1 | 1.5 | 5.0 | 15.0 | 50.0 |
| 760 | 1.31 | 1 | 1.8 | 6.0 | 18.0 | 60.0 |
| 770 | 1.37 | 1 | 2.1 | 7.0 | 21.0 | 70.0 |
| 780 | 1.43 | 1 | 2.4 | 8.0 | 24.0 | 80.0 |
| 790 | 1.50 | 1 | 2.7 | 9.0 | 27.0 | 90.0 |
| 800 | 1.56 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 850 | 1.95 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 900 | 2.44 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 950 | 3.05 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 1000 | 3.82 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 1050 | 4.78 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 1060 | 5.00 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 1100 | 5.00 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 1400 | 5.00 | 1 | 3.0 | 10.0 | 30.0 | 100.0 |
| 1500 | 1.0 | 1.0 | | | | |
| 1600 | 1.0 | | | | | |
| $1.0 \times 10^6$ | 1.0 | | | | | |



**Figure A2.4** shows the solution factor parameters $k_1$ and $k_2$ across the laser wavelengths. These determine the accessible emission limits shown in Figure A2.3.

[41] Source: https://www.ecfr.gov/current/title-21/chapter-I/subchapter-J/part-1040/section-1040.10

The heterogeneity in the list of compliance to abide by contributes to the additional fixed cost accrued in producing multiple products of different wavelength and quality levels. Doing so requires the firm to comply by the union set of compliance involved in all of the products that the firm plans to produce as a single entity. The complexity of keeping track of a larger list of rules to abide by on behalf of each individual devices contributes to the additional costs accrued in integrating production of significantly different laser devices as a single entity. In contrast, separating production line via spinoffs would streamline the production process of multiple laser devices. Both the parent and the daughter firm can concentrate on keeping the regulatory process of their own products, without having to unnecessarily worry about regulations regarding each other's production lines.

**Manufacturing**

Pre- and post-market regulations are not the only source of complexities in producing laser devices of multiple type and quality. Manufacturing different lasers by itself requires additional amount of care in making sure that the production of one do not interfere with another.

Because laser manufacturers conduct performance tests by themselves during multiple stages of parts assembling, manufacturing facilities are designed as laboratory settings, from which they conduct the same type of laser operations as physicians would do in their respective hospitals. A prime example of how producing different lasers would complicate the manufacturing design can be found from the step when the optical resonators are put together with the gain medium. To guarantee purity of the output lasers, manufacturers take extra care in cleaning the parts thoroughly in a closed environment to prevent unwanted particles in the air to infiltrate into the optical resonators. Producing multiple laser devices of significantly different types would require an even more intensive care, since the particles that are accelerated in one division can leak into the other division.

**Figure A2.5: Manufacturing Sites of CO2 Laser**[42]




**Figure A2.5** is a snapshot of a "clean room", a secluded area where the resonators get assembled. The parts go into an intensive cleaning and get assembled in the clean room to rule out contamination from rogue particles.

[42]Source: Tour of TRUMPF laser manufacturing facility in Farmington, CT

Figure A2.5 is a snapshot of the assembling process in a virtual tour video of a laser manufacturing firm. The level of seclusion required in the process can be found in the following quote in the video:

*"...the first step for these parts is to get a thorough washing. We have a very extensive washing machine, which is an ultrasonic technology, to clean our parts before they enter into the clean room... The facility here **[Figure A2.5]** is a class 10,000 clean room, which is something you might see in a microchip manufacturing facility. This is done in order to ensure that no particles enter into the resonators and cause any kind of contamination which might degrade customer performance at the end."*
*- Mark Bronski, TRUMPF Facility Production Manager, 2010*

The manufacturing site in Figure A2.5 shows that the two of the three types of lasers they integrated production are manufactured within the same cleaning room. However, the two types in question are both CO2 lasers (10,600 nm), and the third type ("Solid State", 1030 nm) is not produced in the same room. The contrast between each product pairs of the three lasers is another good example of how economies of scale diminishes as firms try to produce laser types that are significantly different as a single entity. Producing lasers of similar wavelength range allows firms to produce both lasers within the same physical area, which is an example of economies of scale due to increased efficiency in capital investment. Producing lasers of significantly different wavelength range, on the other hand, requires firms to basically build separate production lines that should be secluded from each other. Having to build a completely separate manufacturing space, as well as taking even further measures to prevent infiltration of the particles produced from one laser to another, indicates that firms cannot expect any efficiency gains by integrating production the two laser types. Coupled with the complexities of producing lasers of different type and quality as shown in the Regulatory section, the manufacturing procedure serves as an example of the tradeoff between scale and scope that medical laser firms face when operating in multiple markets.

**Distribution: Potential Future Studies on Key Opinion Leaders**

So far, all the aspects I have discussed are strictly supply-side elements that I do take account in my main model. Distribution of the laser devices - specifically the interaction between the firm and the hospital - is a step in the medical laser industry that I rule out in my demand estimation and do not focus on. As a segue to a potential topic for future studies, I will discuss the general process of hospital-firm interactions and why it could be a venue for future study.

Distribution decisions of the medical laser devices are made between the respective firms and the hospitals. Typically, the procurement department in each hospitals take charge of identifying the product type the hospitals need, negotiating with the medical laser firms for optimal price, and requesting for specific customization. Through their respective procurement department, hospitals and the laser

manufacturers go through an iterative process on how the laser devices can be tailored to best serve for the hospital physicians they represent.

Such iterative process is important in the medical laser industry because of its highly specialized user base. Unlike a standard market setting in which consumers have no impact or influence on one another, the distribution cycle of medical laser devices are led by the leading physicians of each respective medical fields, who are often referred to as the Key Opinion Leaders (KOL). A lot of the purchase behaviors of hospitals are dependent on the choices or preference established by these KOLs, and the firms in the industry know that appealing to their preference is crucial in securing a steady market share in markets they are active in.

The co-dependency between the laser firms and the KOLs in the respective medical fields is illustrated from an interview with Laurent Attias, the vice president of Alcon, a producer of laser devices for ophthalmologic procedures. In a 2022 interview, he further recites the benefits of a continuous relationship with the KOLs, from which firms are tied to tailor their products:

*"When you are in a field like Ophthalmology, where those 8000 surgeons are also looking up to a smaller group called the Key Opinion Leaders ... if you are able to tap on those and work with them to develop technologies - work with them in consort[ium] - they spread the word through their access to the podium, press, all sort of channels ...*

*Especially with the device side, the rate of innovation in devices are fed through feedback ... therefore it becomes an iterative process, and it can only happen through the frequency of exchanges. It's an trial and error ... not only you are improving your relationship with the individual KOLs, you are improving your product too, the product gets widely accepted by your audience. You see, it's a self-feeding mechanism."*
*- Laurent Attias, WOW Series, 2022*[43]

The importance of the KOLs that Attias emphasizes as drivers of success in the medical laser industry indicates a stickiness in the demand side that is not often highlighted in papers using standard demand models. A number of theoretical and empirical works on dynamic demand (Fudenberg & Tirole 2000[22], Chen & Pearcy 2010[16], Tremblay 2019[36]) have focused on the pricing behavior of firms to induce or prevent brand switching. Most of the relevant papers treat individual consumers as equal - an assumption that could be expanded by adding consumer heterogeneity in a form of the number of KOLs each hospitals have under employment at the time of negotiation. Hospitals with larger number of KOLs would know that they have high influence on how each laser brands are evaluated across the market, and therefore would have higher bargaining power on the pricing of each medical devices.

[43]Source: https://www.youtube.com/watch?v=6ts9EAhkO2k

The presence of KOLs as a source of higher bargaining power can work in two venues. Firstly, one can shift from the supply-side focus of current paper to the demand side. A dynamic setting where firms price differently based on the past purchase history of hospitals with KOLs, for instance, would help investigating how much the market dominance of certain brands are internalized through the KOLs' influence.

On a different note, one can further deviate from the current framework to focus on the problem between hospitals and the KOLs. Hospitals, knowing the importance of the KOLs as the trend-setter in medical procedures, would be willing to pay a premium to recruit the KOLs in addition to the skillset and experience they had accumulated over the years. Such study could complement existing studies reporting the centralization of technology adoption in hospitals, by suggesting that part of the centralization could be explained through the channels of centralization of the KOLs in major hospitals.

**Overview Summary**

This section provides a detailed examination of laser technology and its application in the medical industry, beginning with the fundamental mechanics of laser operation. A laser device consists of three main components: a gain medium, pumped energy source, and optical resonators, which work together to produce specific wavelengths of light. I show how lasers of similar wavelengths often share input materials and manufacturing processes, creating potential economies of scale for manufacturers who produce lasers within similar wavelength ranges. However, these economies of scale diminish significantly when producing lasers of widely different wavelengths, as they require separate production facilities and different input materials.

On the other hand, the medical laser industry exhibits clear diseconomies of scope when firms attempt to produce multiple laser types as a single entity, driven primarily by regulatory and manufacturing complexities. When a firm produces lasers of different wavelengths, it must comply with the union set of all applicable regulations for each type - for instance, tracking different FDA emissions parameters ($k_1$ and $k_2$) and maintaining distinct testing protocols for each wavelength and output range. These regulatory requirements compound with manufacturing challenges, as seen in the TRUMPF facility example where lasers of significantly different wavelengths cannot share the same clean room facilities due to cross-contamination risks. Together, these factors create multiplicative rather than additive costs: each additional laser type not only brings its own regulatory burden but also requires separate manufacturing spaces and additional safeguards to prevent interference with existing production lines, making it more efficient to spin off certain products of significantly different type and quality into distinct entities.

The presence of Key Opinion Leaders (KOLs) in the medical laser industry creates unique feedback loops with manufacturers that warrant further research exploration. As illustrated by Laurent

Attias from Alcon, KOLs serve as both influential customers and product development partners, creating a "self-feeding mechanism" where their feedback drives innovation and their endorsements influence broader market adoption. This dynamic suggests two promising research directions: First, a demand-side analysis could examine how firms adjust pricing strategies based on hospitals' KOL employment, potentially revealing how market dominance is reinforced through KOL influence. Second, researchers could investigate the hospital-KOL relationship itself, particularly how hospitals' willingness to pay premiums for KOLs extends beyond their direct medical expertise to include their role in technology adoption and vendor relationships. This research could provide new insights into hospital technology centralization, suggesting that the concentration of KOLs in major hospitals partially explains observed patterns in medical technology adoption and distribution.

## A.3 Detailed Estimation Walkthrough

This section elaborates on how the specifics of the model described in sections 3, 4 and 5 are computed. It is meant for readers who have read sections 4 and 5 and want additional details on each of the stages.

### Full Demand Estimation Results

**Table 5A: Demand Estimation**

| | (1) Log Share OLS | (2) Log Share OLS | (3) Log Share IV | (4) Log Share IV |
|---|---|---|---|---|
| Log Price | -0.355*** | -0.336*** | -1.933*** | -2.151*** |
| | (0.01) | (0.03) | (0.46) | (0.13) |
| Log Irradiance ($W/mm^2$) | 0.166*** | -0.015 | 0.384*** | 0.593*** |
| | (0.01) | (0.05) | (0.13) | (0.19) |
| Log Diameter ($mm$) | 0.137*** | -0.409*** | 0.315 | 1.096*** |
| | (0.02) | (0.11) | (0.25) | (0.30) |
| Log Power ($W$) | -0.197*** | 0.065 | -1.000*** | -1.985*** |
| | (0.01) | (0.06) | (0.32) | (0.25) |
| Built-in | -1.122*** | -0.998*** | 0.421 | 1.180*** |
| | (0.08) | (0.17) | (0.53) | (0.38) |
| Diameter x Irradiance | | | | -0.290*** |
| | | | | (0.08) |
| Power x Diameter | | | | -0.249*** |
| | | | | (0.09) |
| Power x Irradiance | | | | 0.091 |
| | | | | (0.08) |
| Irradiance (sq.) | | | | -0.132*** |
| | | | | (0.04) |
| Diameter (sq.) | | | | -0.238*** |
| | | | | (0.07) |
| Power (sq.) | | | | 0.263*** |
| | | | | (0.06) |
| R-sqr | 0.117 | 0.228 | . | . |
| F | 242.19 | 43.81 | 100.56 | 43.15 |
| FE | No | Firm, Month | Firm, Month | Firm, Month |
| Obs. | 8565 | 8565 | 8565 | 8565 |

Observations in Product x Month

Clustered at the Firm x Month Level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Pricing**

The first-order condition for each firm $i$'s active market $m \in \mathcal{M}_i$ reduces to a simplified system of equations as follows:

$$1 + \alpha(p_i^* - \tilde{MC}_{im}(z_{im}))(s_{im} - 1) = 0$$

$$\#\ N_{-im} \text{ equations of: } \begin{cases} 1 + \alpha(p_m^* - \tilde{MC}_m(Z_{-im})(s_{-im} - 1) & = 0 \\ 1 + \alpha(p_m^* - \tilde{MC}_m(Z_{-im})(s_{-im} - 1) & = 0 \\ ... & \\ 1 + \alpha(p_m^* - \tilde{MC}_m(Z_{-im})(s_{-im} - 1) & = 0 \end{cases}$$

where

$$-log(MC_m(z_{im})) = \gamma z_{im} + \nu_{im}$$
$$-log(\tilde{MC}_m(Z_{-im})) = \gamma Z_{-im}$$

with $\alpha$ being the price coefficient taken from the demand system. The assumption is that, in addition to its own quality level and marginal cost, each firm's decision is based on its ex-ante marginal cost and the industry flow; this assumption is applied instead of tracking each quality level and the idiosyncratic shocks of firms' competing incumbents for each market. This approach relieves significant computational burden by reducing the industry state's dimensionality to only $(\bar{Z} \cdot \bar{N})$ for each market $m$. As established in the previous section, the demand pool is segmented across markets, meaning that the pricing decision in one market is independent of that for another.

**Estimation Algorithm**

The estimation step consists of constructing a profit mapping of each individual market from the three demand-side parameters $\{\alpha, \beta, \gamma\}$ and using the profit mapping to estimate the supply-side parameters $\{\kappa, \lambda^t, \lambda^q\}$. The steps are summarized as the following:

- **Demand**:
  1. Discretize the continuous quality score z across 5 quintiles.
  2. Collapse the quality of each firm-market-time triplet by taking an unweighted average of the quality score of the products available within the triplet.
  3. Use the Berry (1994)[7] inversion to transform the logit demand specification as a linear function of market share on price and product characteristics.
  4. Estimate $\alpha$ and $\beta$ by running a linear regression with the markup shifter as an instrument.
  5. Using the first order condition (F.O.C.) of Bertrand competition, back out the marginal costs by inverting cross-price elasticity.
  6. Run an OLS of the marginal costs on firm proficiency $max(z_{jmt})$ to retrieve $\gamma$
- **Supply**:
  7. Use the demand-side parameters $\{\alpha, \beta, \gamma\}$ to construct a profit mapping $\pi[z_j; Z_{-j}, N_{-j}]$ for each individual market. Normalize it to the minimum profit level among the incumbent firms to fix baseline fixed cost $f$ as 1.
  8. Estimate the supply-side parameters $\{\kappa, \lambda^t, \lambda^q\}$ using the generalized method of moments (GMM) with three moment equality conditions:
     - 8-1. Predicted aggregate investment level of each firm $X_{jt}$
     - 8-2. Predicted spinoff decision of each firm $d_{jt}$
     - 8-3. Predicted market-level entry decision of each firm $\mathcal{M}_{jt}$
  9. Use a bootstrap sampling with replacement to obtain the standard errors of the three supply-side parameters.

The demand side parameters are identified via variation in the price and quantity sold for each quality level and variation in the backed-out marginal cost by each firm's market-level proficiency. In using the moment equality conditions for the supply-side parameters, $\kappa$ is identified among the single-market firm's investment levels, which are invariant to the scale and scope parameters. Variation in the firm's different quality levels and their markets of origin pins down the ratio between $\lambda^t$ and $\lambda^q$. Finally, the market-level entry decision pins down the magnitude of $\lambda^t$ and $\lambda^q$; coupled with the ratio of the two identified, pinning down the magnitude identifies both parameters.

Again, it should be noted that the identification relies on the profit and cost specifications normalized at the baseline fixed cost $f$, which I define as the minimum profit level of an active incumbent. This assumption effectively imposes the current fixed cost as an upper bound of the possible baseline fixed costs that is not observable in my data. Relaxing such assumption requires information on each firm's market-level fixed costs, and I defer this extension to future projects when such information does become available.

**Equilibrium Search**

For each parameter configuration and draws of firm and industry states, there is an equilibrium search to pin down the equilibrium. The algorithm proceeds with the following:

1. For each market m, firms are ordered by their respective quality levels $z_m$ and whether their origin market $O_i$ is equal to m.
2. Each firm decides the optimal $\mathcal{M}_i$, the aggregate investment level $X$, the separation indicator $d_i$, and the subsequent price levels, and $P \equiv \{p_{im}\}_{m \in \mathcal{M}_i}$.
3. If there are multiple markets in which $d_m = 1$, compare the marginal net gain among each separation decision and determine to separate the market that maximizes the joint value of operating in $\mathcal{M}_i$: $d_i = argmax_{d_m} V(\cdot)$.
4. Once separated, the separate entity operates as if it is a single-product, independent firm in the next iteration.
5. After each iteration, each firm decision $M_i$ and the respective quality level $z_i$ are aggregated to update the industry state $\{N_m, z_m\}_{m=1}^{M}$. The per-market investment levels $x_{-im}$ that each firm faces are also aggregated.
6. Steps 1-5 repeat until there are no further firm changes to the production line.

The resulting equilibrium, again, can be defined as an industry-level state $\mathcal{S}^* \equiv \{N_m^*, z_m^*, \}_{m=1}^{M}$, a firm's operational decision $\{\mathcal{M}_i^*, d_i^*\}$, and a firm's within-market decision $\{X_{mi}^*, p_{mi}^*\}$ for $m \in \mathcal{M}_i$ such that:

1. **(Optimal contingent plan I)** For a given industry state $S^*$ and firm state $s_i$ of firm $i$, firm $i$'s market level entry decision vector $\mathcal{M}_i^*$ is such that:
   $\mathcal{M}_i^* = \underset{\mathcal{M}_i}{argmax} \quad \Pi_2(\mathcal{M}_i, s_i, \mathcal{S})$
2. **(Optimal contingent plan II)** Given any feasible market combination $\mathcal{M}_i$, firm $i$'s aggregate investment decision $X_i^*$ is such that:
   $X_i^* = \underset{X_i}{argmax} \quad \tilde{\Pi}_2(X, \mathcal{M}_i, s_i, \mathcal{S}^*) = [1 - X] \cdot \mathbb{E}_X[\Pi_3(d_i, s_i, \mathcal{M}_i) | s_i, \hat{\mathcal{S}}]$
3. **(Optimal contingent plan III)** Given any feasible market combination $\mathcal{M}_i$, firm $i$'s optimal spinoff decision $d_i^*$ is such that:
   $d_i^* = \underset{d_i}{argmin} \quad \mathcal{F}(d_i^*, s_i, \mathcal{M}_i)$
4. **(Optimal contingent plan IV)** Given any firm and industry state in each of the markets, firm $i$'s price decision $p_{im}^*$ in any market $m \in \mathcal{M}_i$ is such that
   $\{p_{im}^*\}_{m \in \mathcal{M}_i} = \sum_{m \in \mathcal{M}_i} \underset{p_{im}}{argmax} \quad \pi_{im}[p_{im}; z_{im}, Z_{-im}, N_{-im}]$ for $\forall m \in \mathcal{M}_i$

5. **(Market Clearing)** The equilibrium vectors of $\{\mathcal{M}_i^*, s_i\}_{i=1}^N$ aggregate to the industry state $S^* \equiv \{N_m^*, z_m^*, \}_{m=1}^M$

The conditions are identical to the equilibrium conditions touched upon in section 4, with further details on firms' optimization process at each of the decision stages.

**Firm & Industry State Draws**

Since each firm's state of origin market and quality are treated as given in the model, equilibrium results are contingent on the initial draws of the number of incumbent firms in the industry and each of their firm states. With the sheer number of possible states that could be drawn, most of which are unlikely to be reached in practice, a careful consideration on the probabilities assigned to each state to be drawn is necessary to make the result a reasonable depiction of what could actually happen in the medical laser industry.

To tether my results to scenarios that have been or could be reasonably reached in the industry, I construct the following algorithm to draw the initial firm and industry states:

1. Draw a year $t$ from 1990 to 2021; higher probabilities are assigned to years with a higher number of active incumbent firms.
2. Pull out the active incumbents in the drawn year and their respective firm states $\{O_i, z_i\}_{i=1}^{N_t}$ as observed in the data. The market-level intensity $\{N_{-im}\}_{m=1}^M$ element of the industry state and each firm's origin market $O_i$, are defined from the drawn year.
3. For each non-zero element of $z_i \equiv \{z_{im}\}_{m=1}^M$, take a draw from the standard normal distribution, add to each $z_{im}$, and round them up. For corner values ($z_{im} < 0$ or $z_{im} > 5$), set them back to the minimum/maximum quality values allowed in the model.
4. Aggregate the drawn $z_i$s to create industry state $\{Z_{-im}\}_{m=1}^M$ for each $i$

Steps 1 and 2 ensure that the draw is strictly based on historically observed states, while step 3 provides a moderate level of deviation in the endowed quality levels to capture the states that are unobserved in the data but could still be reasonably reached. Greater probabilities are assigned to later years in which not only more incumbents but also more markets are active. For instance, prior to 1997, there was only one laser type active in the medical laser market. Since these draws are less insightful in gauging the role of spinoffs, states where more markets are active are given more weight in the draws.

## A.4 Counterfactual #1.2: One Origin Firm per Market, Aggregate Level Result

This section reports the aggregate result of the counterfactual results of case 1.2, in which there is only one origin firm per market. Since the purpose of the case 1.2 is to illustrate the homogeneous effects of spinoffs on consumers across markets, aggregated results are not reported in the main section.

**Table 11A: Aggregate Results; One Origin Firm per Market**

| | Spinoffs | No Spinoffs | $\%\Delta*$ |
|---|---|---|---|
| Firm Profit (Mean, $ Millions) | 2023.9 | 1767.9 | -12.6 |
| Investment (Mean, %) | 0.10 | 0.002 | -97.3 |
| Fixed Cost (Mean, $ Millions) | 323.9 | 577.1 | 78.1 |
| Welfare (Mean, $ Millions) | 9991.4 | 8612.7 | -13.8 |

$* \left(\frac{\text{No Spinoff - Spinoff}}{\text{Spinoff}} \cdot 100\right)$

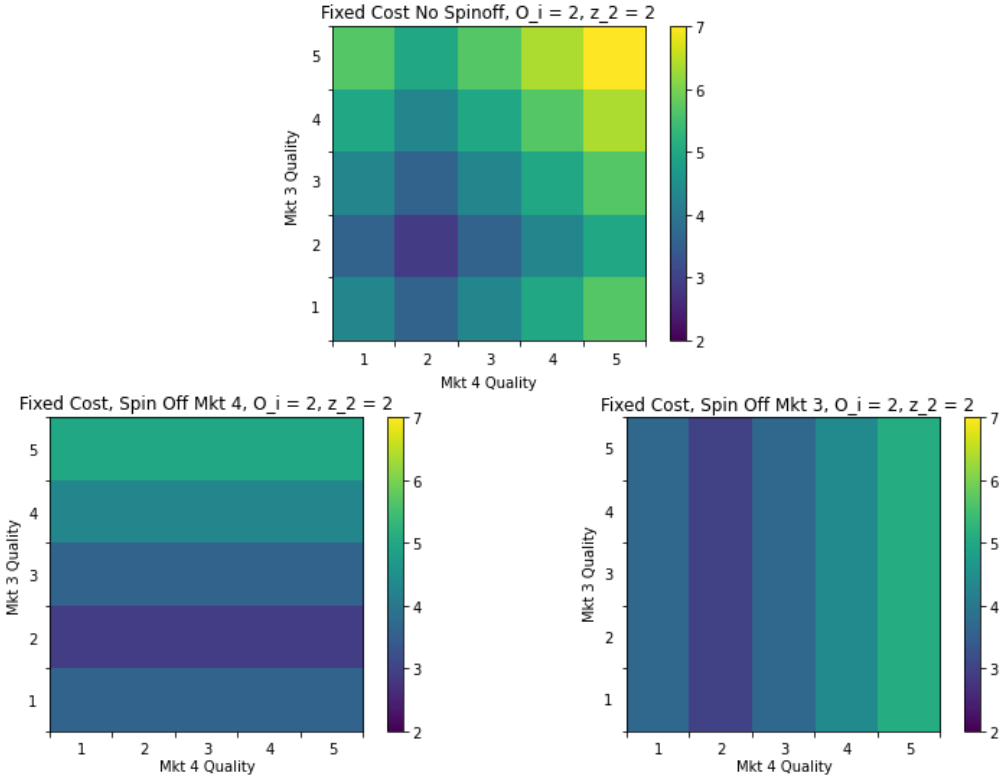
**Table 11A** shows the mean results for firm profits, investment, fixed cost, and welfare between the spinoff and no-spinoff scenarios where there is one origin firm per market.

**Table 11A** results share a mixture of the results on Tables 8 and 12. The percent changes of the firm profit are moderately muted compared to Table 8, but the fixed cost increase even further from Table 12. The result signals that the market power is still retained when there is only one origin firm per market. Therefore, firms still tend to stay in their branch market without spinoffs, resulting in an even higher increase in fixed cost accrued when spinoff channel is blocked.

## A.5 Supplemental Figures

This section provides a list of figures to supplement those used in the main section. Each figure is labeled after a corresponding figure in the main section. The section is meant for readers who would like a more detailed depiction of the results in the main section.

**Figure 3A: Fixed Cost across Spinoff Decisions $d_i$**




$O_i = 2, z_2 = 2, \mathcal{M}_i = \{2, 3, 4\}$