Received: 24 December 2019 | Revised: 25 October 2022 | Accepted: 13 November 2022 | Published on: 9 December 2022

DOI: 10.1002/smj.3478

RESEARCH ARTICLE

STRATEGIC MANAGEMENT JOURNAL WILEY

Weathering a demand shock: The impact of prior vertical scope on post-shock firm response

Najoung Lim[1] | **Seojin Kim**[2] | **Rajshree Agarwal**[3]

[1]Melbourne Business School, University of Melbourne, Carlton, Victoria, Australia

[2]LeBow College of Business, Drexel University, Philadelphia, PA

[3]Robert H. Smith School of Business, University of Maryland, College Park, Maryland, USA

Correspondence
Najoung Lim, Melbourne Business School, University of Melbourne, Carlton, Victoria 3053, Australia.
Email: n.lim@mbs.edu

[Correction made on 17 January 2023 after first online publication: Affiliation of Seojin Kim has been updated in this version.]

Abstract

Research Summary: We examine how and why pre-existing vertical scope may cause differences in product market exit rates after sudden and exogenous decreases in demand. Our empirical context is the U.S. medical diagnostic imaging industry (2004–2009), wherein a major Medicare reform created a derived demand shock to equipment manufacturers. Using a difference-in-difference-in-difference design, we find integrated firms were more likely to exit than nonintegrated firms. Building on the literature conceptualizing firms' pre-shock vertical scope as a representation of existing resources and governance choices, we explain that integrated and nonintegrated firms responded differently by leveraging their own distinctive capabilities. Our qualitative insights suggest that higher market exit of integrated firms was driven by their higher adjustment costs due to frictions across strategies for demand management versus cost reduction.

Managerial Summary: This study investigates whether having a dedicated sales force or utilizing third-party distributors can help mitigate the adverse effect of an abrupt demand decrease on manufacturers. In the context of the US medical imaging equipment industry affected by the 2005 Deficit Reduction Act, we show that all firms implemented strategies for demand management, cost reduction, and product portfolio reconfiguration in response. Manufacturers using external distributors experienced fewer frictions across these strategies than those with an internal sales force and

were less likely to exit. Thus, a firms' vertical scope can impact how they cope with environmental changes.

KEYWORDS

demand shock, market exit, medical diagnostic imaging, Medicare reform, vertical scope

1 | INTRODUCTION

Negative environmental shocks—such as a sudden decrease in demand—create a new "equilibrium state" in the market, with potential shakeout of firms in the new reality. These shocks pose unique and important sets of strategic problems to firms distinct from other types of environmental changes, such as technological shocks or evolutionary trends (Argyres, Mahoney, & Nickerson, 2019; Bigelow, Nickerson, & Park, 2019). Negative demand shocks may not uniformly affect all firms, however. Heterogeneity of firms in integration of value chain activities and associated differences in positioning and capabilities (Ghemawat, 1991; Helfat & Campo-Rembado, 2016; Karim, 2006) implies the same shock may create differences in (involuntary) decisions to exit the market and concomitant firm responses (Argyres et al., 2019). Though scholars have examined how firms adjust their vertical scope when faced with environmental changes (Kapoor & Adner, 2012; Qian, Agarwal, & Hoetker, 2012), left relatively unexamined is how *prior differences* in vertical firm scope may affect firms' ability to adapt to environmental changes, or exit the market altogether.

We conceptualize firms' pre-shock vertical scope as a representation of its existing set of resources and governance choices (Argyres, Felin, Foss, & Zenger, 2012), and examine how and why pre-existing vertical scope may cause differences in product market exit rates after a negative demand shock. In contrast to the vast amount of research on environmental factors affecting firms' boundary choice, fewer studies focus on the role played by firms' existent vertical scope on such market outcomes, and underlying ability to adjust to the change in market conditions. Answering the research question requires an empirical disentangling of the endogeneity arising from the interdependence between firms' adjustment and vertical scope decision. Though an instrumental variable approach may be used (Argyres & Mostafa, 2016; Forbes & Lederman, 2010; Kosová, Lafontaine, & Perrigot, 2013), an inherent challenge stems from firms adjusting transaction costs and capabilities in ways that also affect vertical scope (Forbes & Lederman, 2010; Richardson, 1996). In this paper, we tackle this challenge by utilizing an industry-wide shock to investigate how differences in pre-shock vertical scope and organization of transactions may affect the firm's post-shock strategies. We use a research question guided abductive approach, given competing theoretical reasons for why vertical integration may increase or decrease the likelihood of market exit. This allows the empirics to reveal the statistical regularity between firms' vertical scope and market exit within our context. We then examine plausible mechanisms for how vertical scope shaped firms' efforts to adjust to the demand shock through additional analysis.

The U.S. diagnostic imaging industry in 2004–2009 serves as an ideal setting for our study's difference-in-difference-in-difference (DDD) research design. Medical devices are a context extensively used to examine firm structure of value chain activities and capability (re-)configuration (Chatterji, Cunningham, & Joseph, 2019; Karim & Mitchell, 2000). Medical diagnostic imaging firms exhibit variation in existing vertical scope of manufacturing and downstream

distribution activities and provide diagnostic equipment across a broad range of markets. During our focal period, the 2005 Federal Deficit Reduction Act reduced reimbursement rates for a specific set of diagnostic imaging services, causing an adverse derived demand shock for some, but not all diagnostic imaging markets. Thus, DDD coefficient estimates enable us to isolate the effect of vertical scope on market exit after the demand shock. Moreover, rich quantitative and qualitative data from diverse sources enable us to probe into different mechanisms of firm's adjustment efforts.

The statistical analysis reveals integrated firms were more likely to exit markets affected by the adverse demand shock relative to nonintegrated firms. Though we cannot completely disentangle exit due to voluntary decisions (resource redeployment), additional quantitative and qualitative analyses suggest higher adjustment costs (competitive pressures) were very much at play. Both firm types engaged in demand management by addressing shifts in customer needs for cost-effective products and entering unaffected foreign markets.[1] Also, both firm types pursued cost reduction to remain profitable. However, each firm type pursued these goals differently, driven by the organization of capabilities as associated with their downstream vertical scope. Nonintegrated firms utilized and expanded their distribution networks for demand management and to achieve cost-effectiveness simultaneously, including through forging alliances with distributors in unaffected foreign markets. Integrated firms' efforts at demand management through use of specialized sales force ran counter to their efforts for cost containment through decrease of sales personnel. Moreover, those who sought to expand into foreign markets did so by using a dual mode of forming alliances with distributors in other countries. Thus, integrated firms experienced greater adjustment costs, particularly due to frictions across strategies for demand management versus cost reduction.

The paper contributes to existing literature on vertical integration-performance relationship (Forbes & Lederman, 2010; Gartenberg & Pierce, 2017; Zhang & Tong, 2021) by unpacking how prior vertical scope affects post-shock firm responses and market exits. Although theoretical priors preclude an unequivocal prediction (Argyres & Bigelow, 2010; Chatterji et al., 2019; Folta, Helfat, & Karim, 2016; Wang, Aggarwal, & Wu, 2020), our empirical analysis establishes the existence of the relationship and suggests why integrated firms were more likely to exit than nonintegrated firms. Our study also extends work on the integration of transaction cost economics, capabilities, and positioning perspectives (Argyres et al., 2019; Zenger, Felin, & Bigelow, 2011) by investigating how pre-existing vertical boundaries are associated with distinctive firm capabilities, leading to different product offerings and market portfolios. Finally, our paper contributes to the strategy research on firms' responses to environmental shocks (Ahuja, Lampert, & Tandon, 2014; Argyres et al., 2019) by isolating firms' decisions for adjustment from decisions for boundary choices.

2 | CAN VERTICAL SCOPE EXPLAIN MARKET EXIT UNDER NEGATIVE DEMAND SHOCK?

2.1 | Negative demand shock and firms' strategic heterogeneity

Our outcome of interest is market exit, a critical measure of firms' adaptation and performance after an environmental change (Agarwal & Gort, 1996; Hannan & Freeman, 1977; Suarez &

[1]Demand management is the process of forecasting demand, capturing customers' requirements, and synchronizing them with firms' production and distribution capabilities; and "a good demand management process can enable a company to be ... more reactive to unanticipated demand" (Croxton, Lambert, García-Dastugue, & Rogers, 2002, p. 51).

Utterback, 1995). It has been examined within automobiles (Argyres & Bigelow, 2007), chemicals (Lieberman, 1990), information technology industries (Cottrell & Nault, 2004), medical devices (Mitchell & Singh, 1996) and retail (Sohl & Folta, 2021). Exit reflects the fundamental strategy question of whether a firm can/should continue operations, salient when the fit between a firm's resources and its environment shifts due to external forces (Helfat & Lieberman, 2002).

We focus on a negative demand shock, an important and sudden industry level change that decreases aggregate demand and creates unexpected changes in customer preferences (Albuquerque & Bronnenberg, 2012; Argyres et al., 2019; Priem, 2007; Wang et al., 2020). Negative demand shocks may originate from various events that are often independent of firms' control and hard to anticipate, including natural disasters, technological advances, economic recession, or government policy. Downward shifts of the aggregate demand curve create an excess supply at the earlier equilibrium price and result in competitive pressures for firms to reduce quantity, lower price, or exit the industry. Conditional on firms' ability and willingness to respond, the market structure may be fundamentally altered, as exit results in shakeouts that decrease aggregate supply curves too.

While the above logic of negative demand shocks resulting in firm shakeout from markets is based on economic fundamentals, the strategic question of interest is tied to heterogeneity among firms that create differences in individual firm demand. Put differently, negative demand shocks may not affect all firms uniformly. Instead, these reductions depend on individual demand elasticities and importantly, on the focal firm's responses to the adverse shock. Firm response begins with the need to assess the negative impact on expected profitability. Each firm has to sense-make the effects on its individual demand and identify how to adjust its existing activities to bring its capabilities into closer alignment with new market conditions (Argyres et al., 2019). Engaging in such strategic renewal requires firms to incur adjustment costs, as associated with defining the problem-solution scope (Nickerson & Zenger, 2004), workforce adjustment (Davis & Haltiwanger, 1992), modification of transactions with other value chain participants (Susarla, 2012), or reconfiguration of capabilities (Folta et al., 2016). Moreover, adjustment pressures manifest in two ways—managing demand and reducing costs. Managing demand requires each firm to devise and enact strategies to retain the existing customer base or generate new demand to minimize a leftward shift in its individual demand curve. Reducing cost requires the firm to create efficiencies in operations both within and across value chain activities, enabling a rightward shift in its individual supply curve.

Differences across firms will likely result in differences in the strategies they undertake to manage demand and reduce cost. As each firm assesses their ability to adjust to the adverse demand shock, in the extreme case, it may deem the disruptive effect to be higher than its opportunity cost and exit the market (quantity reduces to zero) without attempting any adjustment, i.e., voluntary exit. Such a choice is more likely if the firm believes that the net benefit of redeploying its capabilities in other businesses (Anand & Singh, 1997; Lieberman, Lee, & Folta, 2017) or selling its assets (Fortune & Mitchell, 2012) is greater than the net benefits of adjustment. Alternatively, a firm may deem the adjustments to be manageable and choose to stay. However, such a choice could still result ultimately in market exit. This outcome is more likely if firms fail to match their product offerings with post-shock demand conditions or incur higher adjustment costs relative to their competitors. This will result in their succumbing to competitive pressures and exiting the product market in spite of their adjustment efforts, i.e., forced or involuntary exit.

2.2 | Heterogeneity in capabilities of integrated versus nonintegrated firms

Firms' configuration of capabilities can be an important source of variation in explaining firms' market exit after a negative demand shock. We focus on firms' pre-existing downstream vertical scope as a key source of firm heterogeneity, building on prior studies that integrate transaction cost economics (TCE) and resource-based view (RBV) lenses (Argyres & Bigelow, 2010; Brahm & Tarziján, 2014; Jacobides & Winter, 2005; Qian et al., 2012; Zenger et al., 2011). This literature highlights "*integration of a given activity varies from firm to firm and depends on its history and the idiosyncratic activities in which it is already engaged in and the extant resources it possesses*" (Zenger et al., 2011, p. 120). Vertical scope also reflects firms' efforts at optimizing the fit of their resources and capabilities with desired strategic positioning in the industry (Argyres & Bigelow, 2010; Brahm & Tarziján, 2014). Thus, a firm's vertical scope represents path-dependent decisions regarding governance and capability development within and across firm boundaries to establish a position.

Integration of manufacturing and downstream capabilities is associated with several properties that affect adjustment costs post demand shock. Firm-specific investments in sales and distribution imply more control and decision rights over the distribution and sales process, thus reducing frictions and misalignment of interests (Brahm & Tarziján, 2014; Zenger et al., 2011). The common codes and routines developed within the firm also enable efficient communication and coordination (Helfat & Campo-Rembado, 2016). These streamlined routines reduce information asymmetry by facilitating real-time incorporation of information across manufacturing and downstream operations (Forbes & Lederman, 2010). Integration also enables direct relational capital with buyers for learning and knowledge, which mitigates coordination and trust-based challenges and increases buyer switching costs (Wang et al., 2020). Such direct relational capital permits firms to acquire fast and accurate information about buyer needs and associated tradeoffs between price and quality so as to incorporate them in their products and services (Argyres & Bigelow, 2010). Vertical integration of downstream capabilities also complements a diversification strategy, inasmuch as the associated brand and reputation provide synergies for other businesses targeting the same customer segment (Harrigan, 1985). Taken together, integrated manufacturing and downstream capabilities allow firms to create customized products to accommodate heterogeneous buyer preferences (Argyres & Bigelow, 2010), by offering various product models representing different "mix and match" of features (e.g., product attributes, price, sales, marketing, maintenance, and service).

Meanwhile, nonintegration of manufacturing and downstream capabilities reflects a host of other properties that can guide strategic adjustment. Both manufacturers and distributors can develop specialized capabilities for their own value chain activities to create product or service improvements and generate internal efficiencies (Jacobides & Winter, 2005; Kogut & Zander, 1992; Langlois & Robertson, 1995). By increasing the aggregation of orders from multiple buyers for standardized products, distributors may help manufacturers secure purchasing orders even when demand is decreasing, as well as provide more precise forecasting of future orders (Vats, Soni, Rathore, & Yadav, 2019). Manufacturers can rely on distributors with pre-existing logistics network and end-customer relationships to obtain speedy and efficient access to diverse geographic locations (Johanson & Vahlne, 2009). To do so, they may opt towards developing standardized knowledge for reduced asset-specificity and leakage hazards (Argyres & Bigelow, 2010). Moreover, nonintegrated manufacturers may develop relational capital with distributors for knowledge sharing and creation of complementarities (Dyer &

Singh, 1998). Such relational capital also embeds effective governance to mitigate transaction hazards and sustain long term commitments (Kale, Singh, & Perlmutter, 2000). Nonintegration may not preclude diversification, as nonintegrated firms may develop relational capital with distributors within the focal market, and with the same or other distributors across a diversified business portfolio (Hoetker, 2005). Taken together, these properties associated with nonintegration allow firms to lower resource commitments by reducing scope of value chain activities and leveraging standardized products in distributor networks for economies of scale.[2]

2.3 | Research question approach

In summary, post-aggregate-demand shock, differences in pre-existing vertical scope manifest in a differential impact on integrated and nonintegrated firms' individual demand curves. Also, to weather the demand shock, each firm type is likely to enact different strategies to match with their capabilities, relationships, and positioning. Thus, differences in strategies and positioning resulting from pre-existing vertical scope will lead to differences in rates of market exit. These firm-level consequences imply important changes in firm composition and associated structural changes in the industry regarding value chain configuration. Prior studies on vertical scope have been less attentive to conceptually separating out firms' boundary choices and their actions driving post-shock product market exit. Instead, the focus has been on how firms move to a new strategic position after an industry-wide shock by internalizing transactions to build capabilities (e.g., Argyres & Zenger, 2012) or to create real options under demand uncertainty (e.g., Barney & Lee, 2000). While prior work in strategy has actively investigated how firm capabilities lead to different rates of market exit (Furr & Kapoor, 2018; Lieberman et al., 2017), still less understood is how capability differentials leading to different exit rates are associated with variation in firms' vertical scope. Departing from the disproportionate amount of work on factors affecting firms' boundary decisions, we disentangle the concurrence of the firm's boundary choices and strategic actions followed by a negative demand shock by accepting firms' their predefined vertical boundaries as given.

It is a priori unclear from the theoretical rationale above whether a particular vertical firm scope is dominated by the other in terms of market exit under the negative demand shock. Remaining agnostic on a positive or negative relationship, we adopt a research question-based abductive approach to ask: *how does a firm's pre-existing vertical scope affect its likelihood of market exit post a negative demand shock?* Following recent emphasis on abduction (King, Goldfarb, & Simcoe, 2020), we first allow the empirics to reveal existence of the relationship. Conditional on the statistical finding, we shed light on potential differences in the adjustment strategies of integrated and nonintegrated firms, building on a set of quantitative and qualitative analyses. Lastly, we link our empirical findings to theoretical backdrop and provide discussion to best explain the patterns we find.

[2]Capability alignment for customization/standardization may correlate with positioning in terms of differentiation/low price respectively, but this is not necessary. Customization through mix and match of modular components can cater to both lower price/lower quality and higher price/higher quality preferences, while standardization may focus on fewer product offerings, but at the higher end of quality and price distribution. Thus, standardized products offered by nonintegrated firms may have higher, similar, or lower price (and quality) features than the "average" price and quality features offered across customized options offered by integrated firms.

3 | RESEARCH CONTEXT: DEMAND SHOCK IN MEDICAL DIAGNOSTIC IMAGING

The medical diagnostic imaging industry includes various markets reflecting unique production technologies and user applications: X-ray, computed tomography (CT), magnetic resonance imaging (MRI), ultrasonography, and nuclear medicine. On the supply side, all medical imaging equipment serve the common purpose of internal body visualization. But, the technologies vary in their ability to process different properties of human tissues, resulting in images that are markedly different and often complementary to each other. On the demand side, the major buyers of imaging equipment are hospitals and independent imaging facilities (Figure 1a). These facilities serve physicians who order body scans, and the choice (or combination) of diagnostic imaging is determined by medical needs and treatment plan. Hospitals and imaging centers generate most revenues for diagnostic imaging services from public and private insurance reimbursements, which in turn become a source of budget for purchasing and upgrading imaging equipment in hospitals.

Differences across imaging markets in technology and end-use imply device manufacturers vary in their degree of product diversification (i.e., number of markets served in diagnostic imaging) and organization of value chain activities. Here, downstream complementary assets (distribution and sales) and associated market positioning define a firm's vertical scope (Chatterji et al., 2019; Mitchell, 1989). As seen in Figure 1b, in addition to manufacturing, vertically integrated imaging manufacturers distribute and sell their products directly to customers (i.e., hospitals and imaging facilities), while nonintegrated firms sell through third-party distributors. Consistent with mature industry life stages (Helfat, 2015; Kapoor, 2013; Qian et al., 2012), 50% of the firms were nonintegrated by the mid-1970 s (McKay, 1983) and through our study period.

The purchase of imaging equipment by hospitals and imaging centers is dictated by the need for replacement or upgrade of their current equipment (Sferrella, 2012). Here too, integrated and nonintegrated firms differ in product and associated service offerings. Integrated imaging firms often offer greater variety in products and services: imaging facilities may choose a full-service contract directly from a manufacturer for purchase, installment, maintenance, and upgrades of various equipment end-customers, often in conversation with the vendor's sales representatives about the facilities' specific needs. Imaging facilities may also opt for a purchase and a maintenance/upgrade plan separately for each equipment each year with different options of coverage (Understanding How to Procure Medical Diagnostic Imaging Equipment, 2019). Nonintegrated firms typically do not deliver technical information or services, and let distributors communicate with hospitals and imaging facilities for the purchase of their products.[3]

3.1 | Demand shock: The deficit reduction act

The Federal Medicare program is the largest insurance payor for healthcare in the U.S. In 2006, Medicare covered roughly 43 million people, of whom 36 million were over 65 years

[3]While integrated imaging firms offered a greater variety of product models, there is no evidence of their products being higher priced on average than nonintegrated firms. Advertisements by both types of firms across multiple issues of *Diagnostic Imaging* during our sample period revealed that neither firm pursued a cost-leadership positioning (i.e., we found no ads touting lower prices of diagnostic imaging equipment).

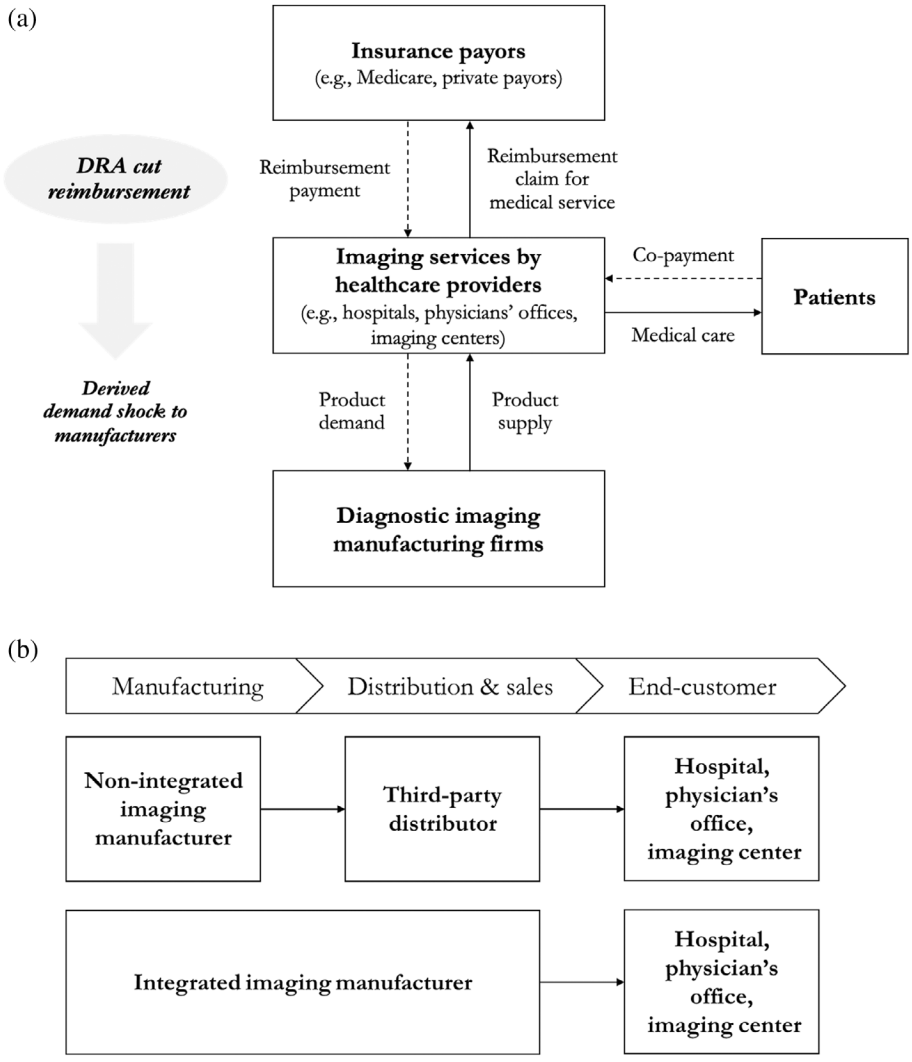

FIGURE 1 (a) Transaction flow in medical imaging industry. (b) Downstream value chain activities of medical imaging device manufacturers, by integration type

(CMS, 2007).[4] Medicare reimbursement rates directly affect hospitals and diagnostic imaging facilities; moreover, many private insurers base their own reimbursement rates on Medicare rates. The Deficit Reduction Act (DRA)—an effort to balance the national budget and reduce the deficit—was a major legislative change impacting Medicare payment policy. It was signed into law on February 8, 2006 and took effect on January 1, 2007.[5] Its sudden and unexpected nature is illustrated by the following quote in *Diagnostic Imaging*, the leading trade magazine: "*After a late-night congressional session in December, Congress passed the Deficit Reduction Act,*

[4]People under age 65 and covered under Medicare include those with disabilities and end-stage renal disease.
[5]See the text of original provisions in Data S1. Importantly, until the law was signed, there was significant uncertainty regarding the timing, types, and severity of the DRA effect on healthcare providers (e.g., ambulatory services, hospital outpatient, independent clinics) and medical services (e.g., heart surgery, medical imaging, and physical therapy).

sending a shock wave that's still reverberating through the radiology community. Referred to by many in this community as 'reduction without proper representation," this draconian act ... has left many in a quandary, stipulating substantial cuts in services including MRI, CT, PET, ultrasound, nuclear medicine, vascular imaging, and bone densitometry. The only exception is mammography" (Renard, 2006). Lobbying efforts occurred *after* the passing of DRA and were unsuccessful in reducing the adverse impact on imaging services (Goldstein, 2007).

The DRA imposed caps on payment rates for some, but not all, medical imaging services covered by Medicare. For affected imaging services, most scans performed were paid an amount less than the cost of performing the procedure in an office setting (Dallessio, 2007). Moreover, reduced Medicare revenue was not offset by other private payors, as many private payors adopted Medicare's cuts in creating their own new payment standards. Collectively, this resulted in declining revenues for imaging facilities (Levin, Rao, & Parker, 2012). For example, the Government Accountability Office Report (GAO, 2008) estimated that the DRA created a 12.9% decline ($1.7 billion) between 2006 and 2007 alone. Moreover, payment for the three advanced imaging services (MRI, CT, and nuclear medicine) dropped by 14.8% in 2007. Thus, changes in Medicare reimbursement policies had a significant and sudden effect on revenue streams of all the imaging equipment customers.

The DRA's imaging reimbursements cut became an adverse derived demand shock on imaging device manufacturers (Figure 1a). It significantly shifted purchasing decisions of imaging facilities, primarily manifesting in a need to contain overall operating costs and become more efficient in utilization of medical diagnostic equipment. Imaging facilities substantially reduced their routinized, large-scale commitments to upgrade and replace major equipment after the DRA. For example, hospitals and medical clinics reduced capital investment in new facilities, expansions, or upgrades, and began to cancel, postpone, or scale down plans for purchase or lease of imaging equipment (Moser & Hastreiter, 2009). Radiologists expressed concern about reduced patient access to state-of-the-art equipment, noting that when "*government and other payors take money out of radiology, ... we end up with are fewer dollars to upgrade or replace our major equipment*." (Radiology Today Interview, 2008). Major imaging device manufacturers voiced similar concerns in their annual reports as they were experiencing the chain reaction of the DRA. The negative impact lasted for several years. For example, Philips (2008) acknowledged their "*sales growth was hampered by a declining US imaging market, triggered by the Deficit Reduction Act*", and Analogic Corp (2009) noted their medical imaging products revenue was adversely impacted by the DRA. Similarly, GE reported "*not so healthy*" operating profits due to "*the 2006 law that reduced Medicare reimbursements by 20% for scans at physician offices, which made doctors and hospitals less likely to order their new machines*" (Glader, 2008).

4 | STATISTICAL ANALYSIS OF VERTICAL SCOPE AND MARKET EXIT

In this section, we first allow quantitative evidence to reveal existence of the relationship between firms' vertical scope and post-shock market exit. We use the DRA as a negative derived demand shock on diagnostic imaging equipment manufacturers in the markets affected by the Medicare reform and conduct difference-in-difference-in-differences (DDD) estimations for firms' market exit. We use the same quantitative sample to explore whether firms engaged in alternative strategies to weather the shock, the results of which are presented in the next section.

4.1 | Quantitative data and sample

Our primary source of quantitative data is the Medical Device Register (MDR) directories (2004–2010), a comprehensive compilation of medical products and manufacturers in the U.S. We describe our process for identifying sample firms, their product markets, and device segments below.

The MDR contains information regarding a firm's FDA medical specialty areas, the highest-level categorization of medical device markets and defined as the firm's *medical device segments* in our analysis. This includes diagnostic imaging related segments (i.e., "Radiology", "Ophthalmic", and "Dental") and all medical device segments outside imaging. We identify *imaging markets* based on FDA product categories (assigned a unique code) within each device segment. Specifically, we identify all the product codes for imaging device equipment (e.g., "90QJT" for "Chest Diagnostic Radiographic Unit" in Radiology). Because both treated and control markets are within medical imaging, they have many similar characteristics including key stakeholders (e.g., end-customers), regulation (e.g., FDA approvals), industry value chain (e.g., distribution), and payment systems (Figure 1a, b). The five treated markets affected by the demand shock (i.e., imaging services experiencing revenue cuts) are X-ray, computed tomography, magnetic resonance imaging, ultrasound, and nuclear medicine. The three control markets include mammography (covered by Medicare but exempt from DRA), dental, and ophthalmic imaging (both not covered by Medicare and untreated by the demand shock).

For each firm, we identify various FDA *product categories* offered within each market and year (e.g., Ultrasound product categories include Ultrasonic Imaging System, Ultrasonic Probe, Ultrasound Computers, Ultrasound Scanners, etc.). Firms may also offer *product lines* representing variations within each product code. Each variation may require a firm to obtain FDA's 510(k) approval (e.g., within Ultrasonic Imaging System, the firm Aloka may offer "Aloka Prosound 2 Diagnostic Ultrasound System," "Aloka Prosound 6 Diagnostic Ultrasound System," or "Aloka SD-3500 Ultrasound System," etc.).[6] We extract information from the MDR on revenues and diversification at the firm-year level, and firm's product categories and distribution types (e.g., direct sales, indirect sales, OEM, importer, exporter) among other firm-market level information.

Our final sample (i.e., imaging equipment manufacturers offering at least one imaging product in treated or control markets during the 2004–2009 period) comprises a total of 1,043 firm-market-year observations based on 199 unique corporate-level firms (104 unique firms in treated markets, 75 in control markets, and 20 in both treated and control markets). Thus, a "treated firm" indicates the focal firm's business was in a DRA-affected market. The period of 2004–2009 spans 3 years before and after the policy change took effect (the year 2007) to capture the near-term effects of the reimbursement cut. As discussed later, we validate various assumptions: qualitative data confirm our control group was unaffected by the DRA, and robustness checks ensure that our results are not sensitive to the choice of the control group or the time window.

[6]A 510(k) is a submission made to the FDA before commercializing a medical device, and its approval requires "demonstration of substantial equivalence to another legally US marketed device" (https://www.fda.gov/medical-devices/premarket-submissions/premarket-notification-510k).

4.2 | Variables

4.2.1 | Dependent variables

Our key dependent variable of interest Market $\text{Exit}_{i,m,t+1}$ indicates a firm's exit from the focal product market in the following year. If a firm exited from a market in a certain year, the firm is no longer in our sample after the exit year unless it has another business in other treated or control product markets. In subsequent sections, we examine alternative firm responses for each firm-year. These include R&D adjustments, such as log number of Patent $\text{Applications}_{i,t+1}$ and log number of FDA $510(k)$ $\text{Applications}_{i,t+1}$ all of which were subsequently approved. We also examine market adjustments. Change in Product $\text{Categories}_{i,m,t+1}$ takes the value of 1 if the number of imaging products offered by the focal firm in the market increases from year t to year $t+1$, 0 if unchanged, and -1 if decreases. Entry into Other $\text{Segments}_{i,t+1}$ takes the value of 1 if the focal firm entered a different medical device segment outside of imaging in year $t+1$ and 0 otherwise.

4.2.2 | Independent variables

We employ three key variables in our DDD design. Demand shock_t equals 1 for the years 2007–2009 post the Medicare reimbursement cut and 0 for the years 2004–2006. $\text{Treated}_{i,m}$ is an indicator that takes the value of 1 if the firm was in one of the five imaging markets (treated group as noted above) in pre-shock period and affected by the DRA, and 0 for the control markets. $\text{Integrated}_{i,m}$ takes the value of 1 if the firm has the internalized distribution and sales function in the focal market, and 0 otherwise.[7] $\text{Integrated}_{i,m}$ takes 1 if the firm owned internalized sales force in the pre-treatment period. Other than two cases, firms are either integrated or non-integrated across all markets and the variable is time invariant within the firm's focal market (results are robust to the exclusion of the two firms). Moreover, the vertical scope decision preceded the entire study period (i.e., occurred prior to 2004), which allows us to rule out confounding factors, including the firm's simultaneous decisions to change the vertical scope.

4.2.3 | Control variables

We use several control variables in the regressions to account for other firm-level factors that may impact the likelihood of an exit event or other firm responses. Firm $\text{Revenue}_{i,t}$ is a categorical variable that takes values from 1(<$1 M) through 9 (>$1B) based on annual revenues of the focal firm, to account for the firm's ability to respond differing by size.[8] We use log count of the firm's product offerings within imaging in year t as Product Categories within $\text{Imaging}_{i,t}$, and log count of the medical device segments where the firm operates in year t as Medical Device $\text{Segments}_{i,t}$ to control for the presence in multiple diagnostic imaging markets and in other medical device segments (outside medical imaging). Finally, $\text{Diversified}_{i,t}$ dummy

[7]For firm-year level analyses, $Integrated_i$ equals 1 if a corporate firm has at least one business unit vertically integrated.
[8]Firm Revenue variable equals 9 if the firm's revenue in a given year is greater than $1B, 8 if 500 M ∼ 1B, 7 if 100 ∼ 500 M, 6 if 50 ∼ 100 M, 5 if 25 ∼ 50 M, 4 if 10 ∼ 25 M, 3 if 5 ∼ 10 M, 2 if 1 ∼ 5 M, and 1 if below 1 M. Categorization follows the information given in the MDR.

captures whether the firm operated in non-medical imaging device industries in year t. Finally, we also control for Patent Stock$_{i,t}$ using a logged cumulative count of its applications from establishment through year t.

Table 1 provides summary statistics and correlation matrices. Panel A reveals that the mean values of variables are similar across treated and control groups as well as across integrated and nonintegrated firms, except for higher patent applications and patent stocks for the treated group. Figure 2 depicts raw trends in average exit rates. In Panel A, the average exit rates for both treated and control groups were decreasing pre-shock, but the treated group shows an upward trend post 2007. Panels B and C of Figure 2 reveals differences in trends by vertical scope. Notable is the sharper divergence between treated integrated and nonintegrated firms than those in control group.

4.3 | Model specification

We use linear probability (OLS) models for great interpretability of coefficients, especially of interaction terms, and ensured robustness to alternative specifications (e.g., logit). Also, we cluster standard errors by firm to account for dependence across observations within the same firm. For all our dependent variables, we start with a difference-in-differences (DD) model to first understand the impact of the DRA on market exit of treated and control groups (See [i]). We then add the firm's pre-existing vertical scope for conducting additional subsample analyses and a DDD estimation (See [ii]). Thus, the two models take the following forms, respectively:

$$Y_{i,m,t+1} = \gamma_m + \lambda_t + \beta \cdot X_{i,t} + \delta \cdot \text{Demand shock}_t \cdot \text{Treated}_{i,m} + \varepsilon_{i,m,t} \quad \text{(i)}$$

$$\begin{aligned} Y_{i,m,t+1} = {} & \gamma_m + \lambda_t + \beta \cdot X_{i,t} + \delta_1 \cdot \text{Integrated}_{i,m} \cdot \text{Demand shock}_t \\ & + \delta_2 \cdot \text{Integrated}_{i,m} \cdot \text{Treated}_{i,m} + \delta_3 \cdot \text{Demand shock}_t \cdot \text{Treated}_{i,m} \\ & + \theta \cdot \text{Demand shock}_t \cdot \text{Treated}_{i,m} \cdot \text{Integrated}_{i,m} + \varepsilon_{i,m,t} \end{aligned} \quad \text{(ii)}$$

$Y_{i,m,t+1}$ indicates the firm's response to a demand shock in year $t+1$. γ_m is market-fixed effects for each of the eight markets, λ_t represents year-fixed effects, and $X_{i,t}$ indicates the firm-year level controls noted above. δ is our coefficient of interest in the DD models, which captures the impact of the DRA by comparing the change in the dependent variable pre- and post-2007 for the treated group compared with the control group. θ is our coefficient of interest in the DDD models, which compares the difference in effects for integrated and nonintegrated firms in the treated group to the corresponding difference in the control group.

4.4 | Results

4.4.1 | Market exit

The results for the DD models are provided in Table 2, Columns 1–3. Column 1 reports uncontrolled difference-in-differences; Column 2 includes year- and market-fixed effects; and Column

TABLE 1 Descriptive statistics

	Treated			Control			Difference	
Panel A. Summary statistics	***N***	**Mean**	***SD***	***N***	**Mean**	***SD***	**Mean**	***SE***
Market exit	601	0.07	0.25	442	0.05	0.22	0.016	0.015
Patent applications[a]	490	0.20	0.73	389	0.08	0.40	0.123	0.055
510(k) applications[a]	490	0.08	0.38	389	0.05	0.47	0.028	0.043
Change in product categories	560	−0.01	0.27	419	−0.01	0.21	0.007	0.011
Entry into other segments[a]	490	0.06	0.26	389	0.03	0.28	0.026	0.018
Demand shock	601	0.48	0.50	442	0.47	0.50	0.016	0.016
Integrated	601	0.54	0.50	442	0.44	0.50	0.106	0.068
Firm revenue	601	3.35	2.15	442	3.01	1.78	0.345	0.282
Product categories within imaging	601	0.95	0.42	442	0.89	0.38	0.063	0.053
Medical device segments	601	1.24	0.52	442	1.30	0.58	−0.055	0.070
Patent stock	601	0.72	1.82	442	0.27	1.11	0.448	0.163
Diversified	601	0.57	0.50	442	0.59	0.49	−0.018	0.067

	Treated						Control					
	Integrated			Nonintegrated			Integrated			Nonintegrated		
Panel B. Correlation table	***N***	**Mean**	***SD***	***N***	**Mean**	***SD***	***N***	**Mean**	***SD***	***N***	**Mean**	***SD***
Market exit	326	0.08	0.27	275	0.06	0.23	193	0.05	0.22	249	0.05	0.22
Patent applications[a]	274	0.20	0.82	216	0.20	0.60	177	0.08	0.47	212	0.07	0.34
510(k) applications[a]	274	0.09	0.44	216	0.07	0.28	177	0.10	0.69	212	0.01	0.07
Change in product categories	301	−0.01	0.28	259	−0.00	0.26	183	−0.03	0.18	236	0.00	0.23
Entry into other segments[a]	274	0.07	0.29	216	0.05	0.21	177	0.05	0.38	212	0.02	0.15
Demand shock	326	0.49	0.50	275	0.48	0.50	193	0.48	0.50	249	0.46	0.50
Firm revenue	326	3.29	2.33	275	3.43	1.91	193	2.78	1.80	249	3.18	1.74

TABLE 1 (Continued)

	Treated						Control					
	Integrated			Nonintegrated			Integrated			Nonintegrated		
Panel B. Correlation table	***N***	**Mean**	***SD***	***N***	**Mean**	***SD***	***N***	**Mean**	***SD***	***N***	**Mean**	***SD***
Product categories within imaging	326	0.88	0.41	275	1.02	0.41	193	0.84	0.32	249	0.92	0.41
Medical device segments	326	1.22	0.53	275	1.27	0.50	193	1.30	0.60	249	1.29	0.56
Patent stock	326	0.80	2.04	275	0.63	1.51	193	0.37	1.39	249	0.20	0.83
Diversified	326	0.59	0.49	275	0.55	0.50	193	0.65	0.48	249	0.54	0.50

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Market exit	1.00									
(2) Change in product categories	N/A[b]	1.00								
(3) Demand shock	−0.01	−0.07	1.00							
(4) Treated	0.03	0.01	0.02	1.00						
(5) Integrated	0.03	−0.03	0.02	0.10	1.00					
(6) Firm revenue	0.04	0.01	0.02	0.09	−0.05	1.00				
(7) Product categories within imaging	−0.07	−0.21	0.00	0.08	−0.14	0.20	1.00			
(8) Medical device segments	0.02	−0.03	−0.01	−0.05	−0.03	0.18	0.20	1.00		
(9) Patent stock	−0.02	−0.02	−0.05	0.14	0.07	0.22	0.21	0.09	1.00	
(10) Diversified	0.06	−0.05	0.01	−0.02	0.07	0.23	−0.07	0.25	0.13	1.00

Note: Firm-market-year level.

[a]The marked variables are at the firm level to reflect our analyses in Table 5, and all other variables are at the firm-market level which is our main unit of analysis as in Table 2.

[b]If a firm exited a product market in year t, changes in the number of product categories in year $t + 1$ are not tracible.

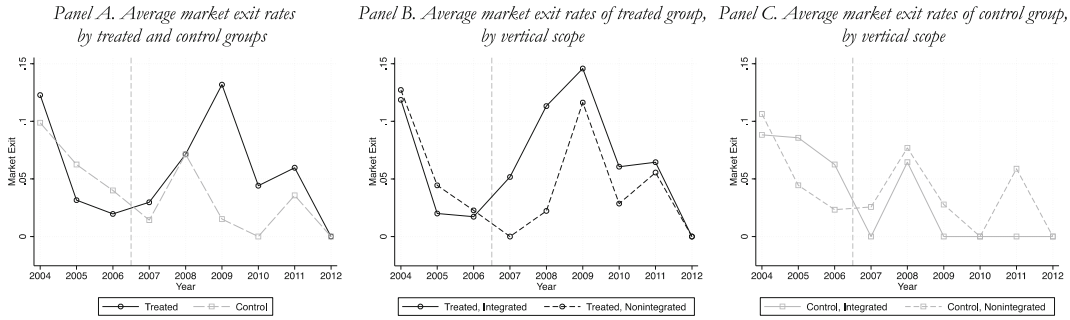

FIGURE 2 Raw trends in average market exit rates from 2004 to 2012

3 further adds firm-level controls. Based on Column 3 (full set of controls), the term *Demand Shock* × *Treated* ($\delta = 0.054$, $SE = 0.029$) indicates that the negative demand shock was associated with a 5.4 percentage point increase in the likelihood of firms' market exit.

Columns 4 and 5 present subsample analyses for integrated and nonintegrated firms. For the integrated subsample, the *Demand Shock* × *Treated* ($\delta = 0.107$, $SE = 0.046$) indicates the negative demand shock was associated with a 10.7 percentage point increase in the likelihood of the integrated firms' market exit. However, there was no such effect for the nonintegrated subsample ($\delta = 0.002$, $SE = 0.035$). Columns 6 and 7 provide results for treated and control group subsamples. Here, for the treated group, the term *Integrated* × *Demand Shock* ($\delta = 0.072$, $SE = 0.042$) indicates being integrated increased the likelihood of market exit by 7.2 percentage points under the demand shock. However, there was no such effect of being integrated for the control group ($\delta = -0.052$, $SE = 0.042$). Finally, in Columns 8 and 9, we estimate triple differences models. Focusing on Column 9 with the full set of controls, the triple interaction term *Demand Shock* × *Treated* × *Integrated* ($\theta = 0.114$, $SE = 0.058$) reveals that relative to nonintegrated firms, a negative demand shock increases the likelihood of integrated firms' market exit by 11.4 percentage point.

4.4.2 | Market exit for subsamples based on firm characteristics

Our subsample analysis explores underlying mechanisms that may correlate with firm characteristics (diversification, ownership structure, and revenue size) and condition market exit. In Table 3, we present results with market-, year-fixed effects and controls. To explore whether firms with a diversified product portfolio are more likely to strategically retreat from an adversely affected market and redeploy resources (Folta et al., 2016; Lieberman et al., 2017), we group the sample firms based on whether they (a) were specialists in the medical imaging segment, (b) concurrently operated in other medical device segments, or (c) were conglomerates that also had any businesses outside of the medical device industry before the demand shock. Panel A of Table 3 reveals a robust effect on increased exit *Demand Shock* × *Treated* ($\delta = 0.199$, $SE = 0.078$) for firms that are vertically integrated *and* diversified within medical devices (Column 3), in terms of both statistical and economic magnitudes. In contrast, the estimates are not precise enough due to the reduced sample size to draw any conclusions for specialized imaging firms (Columns 1 and 2) and for conglomerates (Columns 5 and 6) regardless of their vertical scope. The analysis is consistent with the conjecture that integrated firms diversified

TABLE 2 Vertical scope and market exit after the DRA

	Full sample			Subsample				Triple diff	
DV: Market exit	(1)	(2)	(3)	Int. (4)	Nonint. (5)	Treated (6)	Control (7)	(8)	(9)
Integrated	0.011	0.009	0.002			−0.018	0.011	0.020	0.005
	(0.017)	(0.019)	(0.022)			(0.041)	(0.037)	(0.034)	(0.036)
	[0.536]	[0.645]	[0.931]			[0.659]	[0.778]	[0.563]	[0.881]
Demand shock	−0.034							−0.015	
	(0.021)							(0.028)	
	[0.105]							[0.584]	
Treated	−0.008							0.010	
	(0.022)							(0.031)	
	[0.725]							[0.747]	
Integrated × demand shock						0.072	−0.052	−0.008	−0.045
						(0.042)	(0.042)	(0.039)	(0.041)
						[0.090]	[0.217]	[0.832]	[0.276]
Integrated × treated								−0.042	−0.022
								(0.042)	(0.050)
								[0.320]	[0.658]
Demand shock × treated	0.049	0.050	0.054	0.107	0.002			−0.036	−0.003
	(0.030)	(0.029)	(0.029)	(0.046)	(0.035)			(0.045)	(0.037)
	[0.101]	[0.090]	[0.063]	[0.022]	[0.961]			[0.436]	[0.930]
Demand shock × treated × integrated								0.112	0.114
								(0.059)	(0.058)
								[0.058]	[0.050]

TABLE 2 (Continued)

	Full sample			Subsample				Triple diff	
DV: Market exit	**(1)**	**(2)**	**(3)**	**Int. (4)**	**Nonint. (5)**	**Treated (6)**	**Control (7)**	**(8)**	**(9)**
N (firm-market-years)	1,043	1,043	1,043	519	524	601	442	1,043	1,043
n (firms)	199	199	199	105	96	124	95	199	199
R^2	0.00	0.02	0.06	0.08	0.10	0.09	0.05	0.03	0.06
Market FE		✓	✓	✓	✓	✓	✓		✓
Year FE		✓	✓	✓	✓	✓	✓		✓
Controls			✓	✓	✓	✓	✓		✓

Note: Standard errors clustered by firm in parentheses and *p* values in square brackets. Control variables are firm revenue (categorical), product categories, medical device segments, patent stock and diversification indicator variable. The terms *Demand Shock* in Columns 2–7, 9 and *Treated* in Columns 2–5, 9 are subsumed after the inclusion of fixed effects.

TABLE 3 Market exit after DRA for subsamples based on firm characteristics

Panel A. Degree of diversification[a]						
	Imaging		**Other medical devices**		**Conglomerate**	
DV: Market exit	**Int. (1)**	**Nonint. (2)**	**Int. (3)**	**Nonint. (4)**	**Int. (5)**	**Nonint. (6)**
Demand shock × treated	0.052	0.042	0.199	−0.046	0.087	0.041
	(0.033)	(0.060)	(0.078)	(0.030)	(0.095)	(0.089)
	[0.131]	[0.493]	[0.015]	[0.131]	[0.363]	[0.648]
N (firm-market-years)	143	113	171	270	204	139
n (firms)	26	25	34	42	45	29
R^2	0.14	0.15	0.20	0.17	0.15	0.18

Panel B. Firm ownership and size								
	Public		**Private**		**Large**		**Small**	
DV: Market exit	**Int. (1)**	**Nonint. (2)**	**Int. (3)**	**Nonint. (4)**	**Int. (5)**	**Nonint. (6)**	**Int. (7)**	**Nonint. (8)**
Demand shock × treated	0.109	0.044	0.103	−0.003	0.119	0.049	0.114	−0.005
	(0.096)	(0.055)	(0.051)	(0.036)	(0.127)	(0.058)	(0.046)	(0.038)
	[0.269]	[0.449]	[0.047]	[0.925]	[0.358]	[0.410]	[0.015]	[0.894]
N (firm-market-years)	113	73	406	451	112	114	406	409
n (firms)	19	10	86	86	29	20	77	77
R^2	0.37	0.59	0.07	0.07	0.24	0.31	0.04	0.09

Note: We estimated specifications at the firm-market-year level. Standard errors clustered by firm in parentheses and *p* values in square brackets. Large firms are defined as firms with revenue greater than $25 M before the demand shock. All models include market-, year-fixed effects, and controls. Control variables are firm revenue (categorical), product categories, medical device segments, patent stock, and diversification indicator variable.

[a]These three firm categories are mutually exclusive—imaging specialists were operating only within medical imaging segment, medical device firms operated in other medical device segments, and conglomerates had businesses outside of medical device sector before the demand shock.

within medical devices were able to redeploy their direct salesforce for other medical device segments by backing out from the less profitable treated product markets.

To explore whether firm size may buffer firms from the effects of the negative demand shock, we examine two proxies: ownership structure (public vs private) and revenue size (large vs small) in Panel B of Table 3. Post shock, private and small integrated firms each had 10.3 ($SE = 0.051$) and 11.4 percentage points ($SE = 0.046$) higher likelihood of market exit in the treated group relative to the control group, respectively (Columns 3 and 7). Conversely, we do not find such support for private or small nonintegrated firms (Columns 4 and 8), or for any public (Columns 1 and 2) or large firms (Columns 5 and 6). The result is consistent with the conjecture that size may buffer demand adversity, but the estimates are less precise due to smaller sample sizes.

4.5 | Sensitivity analyses

We conducted robustness tests to ascertain assumptions and address concerns regarding our identification strategy (See Table 4), with Figures and Tables beginning with an A to denote availability in the Online supporting information (hereafter supporting information).

4.5.1 | Pre-trend analysis

If the industry participants anticipated the regulatory measure to address growth in federal healthcare imaging costs, our assumption of an exogenous and sudden demand shock becomes doubtful. We bolster our contextual knowledge and conduct several analyses. First, the trend in the total number of U.S. diagnostic imaging facilities (Figure S1) confirms the number continuously increased from 5,163 in 2003 to 6,514 in 2012, with a brief period of stagnation in 2010. Second, we conduct an event study analysis by allowing different coefficients each year for being in a treated product market (Figure 3).

$$\text{Exit}_{i,m,t+1} = \gamma_m + \lambda_t + \beta \cdot X_{i,t} + \sum_{\tau=2004}^{2009} \delta_\tau \cdot \lambda_t \cdot \text{Treated}_m + \varepsilon_{i,m,t}$$

Following standard practice, the reference year is 2006, 1 year before the DRA took effect. λ_t represents year dummies that equal to 1 if $t = \tau$, 0 otherwise ($\tau = 2004, 2005, 2007, 2008, 2009$). The event study coefficient δ_τ captures the effect of being in a treated market in year t relative to the omitted year. In Figure 3, we display event study coefficients of the difference-in-differences estimation (Panel A), of subsample analyses corresponding to the specifications in Columns 4 and 5 of Table 2 (Panel B), and of the three-way interaction term in triple differences estimation in Column 9 of Table 2 (Panel C). Together, the results indicate insufficient evidence of a pre-trend and support our observation that an increase in market exit was *not* because of an already accelerating trend in the treated markets due to market anticipation. Lastly, the estimate using an advanced cutoff year (2006) provides insufficient support for the idea that the DRA effect might have kicked in during pre-treatment period because it was announced in 2006 (Table A2).

TABLE 4 Summary of robustness checks for market exit analysis

Concerns	Robustness checks
A. Exogeneity of the DRA shock on imaging device manufacturers	
1. The common trends assumption between the treated and control groups may not hold, resulting in biased estimates.	Figure 2 depict no differences in the time trends between treated and control groups during the pre-treatment period. Event study analysis (Figure 3) provides support for the parallel trend assumption.
2. Manufacturers might have expected a negative impact of the DRA in the pre-treatment period and made strategic moves early on, rendering the year 2007 cutoff and our study period window arbitrary.	Event study analysis (Figure 3) provides no evidence for the pre-shock expectation. Figure S1 shows that the total number of outstanding imaging centers continued to grow during our pre-treatment period, providing evidence that the market did not make strategic moves in anticipation of the policy change. Figure S3 suggests that the length of pre-period does not determine the size of the DRA effect. Estimates using the cutoff year 2006 (Table S1) does not support pre-treatment effect. None of 199 firms in our sample shifted its vertical scope during the study period.
3. The DRA might not have a significant impact on manufacturers, but other events may have driven the exit.	Scholarly research in medical imaging and our qualitative data suggest that the DRA was a watershed demand shock on the treated firms.
B. Control group validity	
5. The control group may not be comparable to the DRA-affected imaging (treated) group.	Figure S4 suggests that our results are not driven by the choice of any control market or by an artifact of control group selection. Results remain consistent excluding firms in both treated and control markets (Table S5).
6. Treated and control groups may each represent unbalanced distribution of integrated firms.	Results remain consistent using coarsened exact matching (Table S3).
C. Sample selection and other concerns	
7. Manufacturers may have changed their vertical scope over time.	None of 199 firms in our sample shifted vertical scope during the study period.
8. Sample selection problem may arise from not including manufacturers that concurrently use internalized and external distributors.	Results are robust to the extended sample of manufacturers (Table S4), which includes integrated, nonintegrated, and hybrid manufacturers using dual distribution modes.
9. Firms in both treated and control markets may confound our results.	Results remain robust to excluding firms in both treated and control markets (Table S5).

4.5.2 | Study period window

To ensure our estimates are robust to the different lengths of study periods, we estimated coefficients using three different pre-periods (from 3 to 5 years) × 6 different post-periods (from 1 to

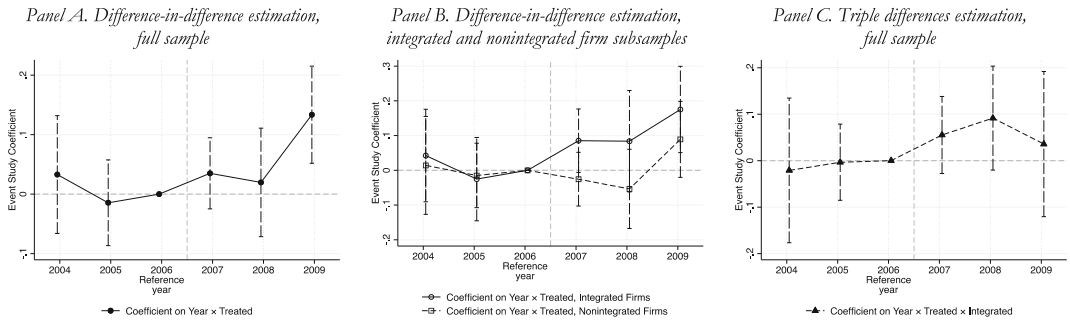

FIGURE 3 Event study plots for market exit. *Source*: The specification includes controls and market-fixed effects, with standard errors clustered by firm. In Panel A, the plot displays coefficients on *Demand Shock* × *Treated*. In Panel B, the solid line plots the same coefficient estimates with the sample confined to integrated firms, and the dotted line corresponds to nonintegrated firms. In Panel C, the plot displays coefficients on *Demand Shock* × *Treated* × *Integrated*.

6 years) from separate regressions (corresponding to Column 3 in Table 2). The results in Figure A3 confirms the observed effects are not driven by our choice of period lengths.

4.5.3 | Control and treated group validity

We reran our main specification using different combinations of control markets (mammography, dental and ophthalmic imaging) (Figure S4). The similar patterns across different sets suggest results are not driven by the choice of a particular market as control group. Similarly, we ran separate estimations for each treated market using our main control group (Figure S5). The results remain robust, but with less precise estimates due to the loss of sample size. To address the concern that the treated and control groups may present different distributions of vertically integrated firms, we used coarsened exact matching (Table S3); effects are largely unchanged but the loss of degrees of freedom results in imprecise estimates.

4.5.4 | Sample selection

Our main analysis excluded the firms using *both* direct sales force and independent distributors. Inclusion of hybrid firms provides consistent results with our main findings (Table A4). The results remain robust to the exclusion of firms in *both* treated and control markets, ruling out the possibility of idiosyncratic patterns driven by these firms (Table S5).

5 | EVIDENCE OF FIRMS' RESPONSES TO DEMAND SHOCK

We now switch focus to heterogeneity in firms' adjustment based on their vertical scope. Specifically, we rely on both quantitative and qualitative data to examine the strategic responses by integrated and nonintegrated firms and examine how differences in adjustment efforts may

have contributed to the higher exit rates of integrated firms versus nonintegrated firms post-demand shock.

5.1 | Statistical analysis of alternative firms' responses

Using the same sample set as in the market exit analysis, we investigate alternative firm responses to the shock, namely *Patent Applications, 510(k) Applications, Changes in Product Categories*, and *Entry into Other Segments*. The four panels of Table 5 run the DD and DDD analyses for each dependent variable. In Columns 1–3 of each panel, we provide estimates for full sample, integrated and nonintegrated subsamples, respectively, using firm-, year-fixed effects and controls. The within-firm analysis controls for unobserved heterogeneity of firm characteristics that might affect firms' choice of market responses. In Column 4, the DDD model examines across-firm differences based on vertical scope through the main and the interaction terms with *Integrated*, so firm-fixed effects are not included (recall that *Integrated* is a time invariant variable by firm).

Firms may adapt to decreasing demand by adjusting their R&D investment or commercialization of new product varieties (Krieger, Li, & Thakor, 2020). Estimates in Column 1, Panels A and B suggest firms in the treated markets reduced the number of both *Patent Applications* (*Demand Shock* × *Treated* [$\delta = -0.161$, $SE = 0.053$]) and *510(k) Applications* (*Demand Shock* × *Treated* [$\delta = -0.056$, $SE = 0.018$]) after the shock. Subsample analyses further suggest both integrated and nonintegrated firms in treated markets reduced post-shock patent applications (Panel A, Column 2 and 3). In terms of *510(k) Applications*, integrated firms in treated markets reduced applications by 6.5% ($SE = 0.022$) post demand shock (Panel B, Column 2), while the comparable estimate for nonintegrated firms is statistically weak (Panel B, Column 3).[9] The DDD estimation also does not reveal meaningful differences between integrated and nonintegrated firms (Column 4 in Panels A and B). In Table A6, we compared the average number of 510(k) applications within each imaging market by vertical scope and by period. While both firms are similar in how many product categories they commercialize, nonintegrated firms had a lower mean *and* variance than integrated firms both pre- and post-shock, suggesting that nonintegrated firms offered fewer product variations.

Firms may also respond by making changes in their product portfolio or entering unaffected medical device segments. The estimates for both variables—*Changes in Product Categories* (Panel C), and *Entry into Other Segments* (Panel D) are not precise across specifications. We have little evidence that treated firms responded by adjusting product lines in a single market or expanding into other related product markets as a response to minimize the negative impact on the focal product markets.

5.2 | Qualitative evidence of firms' responses

We turn to examination of qualitative evidence, as reflected in company annual reports, earnings call transcripts and press releases from LexisNexis, and articles in trade magazines (e.g., Diagnostic Imaging, Imaging Technology News). Given difficulty of information access on private firms, we focused on all 18 public imaging firms in the post-shock treated markets

[9] 6.5% is calculated by $[\exp(-0.067)-1]\times 100 = -6.48$, since the dependent variable is log transformed.

TABLE 5 Other firm responses to the demand shock

	Panel A: Patent applications				Panel B: 510(k) applications			
Dependent variable	**Full (1)**	**Int. (2)**	**Nonint. (3)**	**DDD (4)**	**Full (1)**	**Int. (2)**	**Nonint. (3)**	**DDD (4)**
Demand shock × treated	−0.161	−0.134	−0.174	−0.128	−0.056	−0.067	−0.035	−0.005
	(0.053)	(0.061)	(0.089)	(0.078)	(0.018)	(0.022)	(0.026)	(0.036)
	[0.003]	[0.030]	[0.054]	[0.104]	[0.002]	[0.003]	[0.187]	[0.885]
Demand shock × treated × integrated				−0.008				−0.044
				(0.096)				(0.044)
				[0.933]				[0.313]
N (firm-year)	802	409	392	802	802	409	392	802
n (firms)	157	83	74	157	157	83	74	157
R^2	0.70	0.80	0.58	0.54	0.85	0.89	0.76	0.30
Firm FE	✓	✓	✓		✓	✓	✓	
Year FE	✓	✓	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓	✓	✓
	Panel C: Changes in product categories				**Panel D: Entry into other segments**			
Dependent variable	**Full (1)**	**Int. (2)**	**Nonint. (3)**	**DDD (4)**	**Full (1)**	**Int. (2)**	**Nonint. (3)**	**DDD (4)**
Demand shock × treated	−0.025	0.009	−0.038	−0.031	0.007	−0.012	0.033	0.038
	(0.031)	(0.048)	(0.038)	(0.041)	(0.021)	(0.033)	(0.024)	(0.030)
	[0.412]	[0.850]	[0.319]	[0.459]	[0.744]	[0.725]	[0.177]	[0.213]
Demand shock × treated × integrated				−0.023				−0.035
				(0.059)				(0.042)
				[0.694]				[0.396]

TABLE 5 (Continued)

	Panel C: Changes in product categories				Panel D: Entry into other segments			
Dependent variable	**Full (1)**	**Int. (2)**	**Nonint. (3)**	**DDD (4)**	**Full (1)**	**Int. (2)**	**Nonint. (3)**	**DDD (4)**
N (C: Firm-market-year; D: Firm-year)	945	465	480	945	846	435	410	846
n (firms)	157	83	75	157	166	88	78	166
R^2	0.38	0.47	0.34	0.06	0.38	0.41	0.38	0.08
Firm-market FE	✓	✓	✓					
Firm FE					✓	✓	✓	
Year FE	✓	✓	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓	✓	✓

Note: Specifications are at the firm-year level for Panel A, B and at the firm-market-year level for Panel C, D. Standard errors in parentheses and *p* values in square brackets. All two-way interactions are included. Controls are firm revenue (categorical), product categories, medical device segments, patent stock, and diversification indicator variable.

(12 integrated, six nonintegrated), and five public firms in the post-shock control markets.[10] Altogether, we reviewed more than 200 documents to cull insights on whether nonintegrated and integrated firms revealed different adjustment patterns. Four of the 12 integrated and one of the six nonintegrated firms discontinued product offering in the treated markets after the shock, while the rest continued operations. We categorized each type of firms' actions into demand management for existing imaging products, firm-wide cost reduction efforts, and rearrangement of overall product portfolios by adding or removing product lines. Table S7 summarizes the qualitative findings. Data S2 and Table S8 list additional qualitative data sources and representative quotes by firm vertical scope and action not presented below.

5.2.1 | Discussion of DRA by treated and control firms

Among the treated group, both integrated and nonintegrated firms expressed similar concerns about the DRA and reimbursement cut. Ten of the 18 treated firms explicitly discussed the potential adverse market effects caused by the federal reimbursement reductions.[11] Five firms reported a negative impact on their operations after implementation of the DRA. The other five firms reported concerns that legislative reforms resulting in restrictive reimbursement practices of insurance payors could decrease demand for their products and imaging facilities' willingness to pay. Several firms also indicated delay in customers' plans to purchase imaging equipment as customers were assessing the impact of the DRA on their businesses. Meanwhile, the qualitative data validate the assumption that control group manufacturers were untreated by the shock—none of the control group firms' annual reports and earnings calls released during this period mentioned the DRA and reimbursement reductions.

5.2.2 | Integrated firms' responses of demand management

Nine of 12 integrated manufacturers (75%) actively engaged in post-shock demand management by putting even greater emphasis on their internalized distribution and sales functions, changing product features, and increasing presence in foreign imaging markets. Six of them (50%) focused on customized product/service offerings to close deals and maintain customer relationships. Such actions included increased advertising and highlighting of affordability of their products to financially constrained imaging facilities, and willingness to make concessions on pricing and service agreements. For example, Fonar (2008) stated the intention to leverage its highly experienced sales support and launch advertising campaigns directed at physicians, noting that "*our business plan includes an aggressive program for manufacturing and selling our Upright MRI scanners ... by the replacement of existing MRI scanners ... and delivering state-of-the-art, innovative and high quality equipment upgrades at competitive prices*." Some firms even increased investments in sales personnel. Imaging Dynamics (2008) noted they were "*recruiting an experienced and high-profile sales leader with the intent and expectation to improve results in*

[10]We have 33 public firm-market pairs in quantitative sample. Among 26 firms in treated markets, eight exited before the shock, leaving a total 18 qualitative sample firms (c.f., two of seven control firms exited control markets pre-shock).
[11]The eight firms not discussing the reimbursement cut were either foreign firms or operating in multiple industry sectors. It is thus unlikely that the DRA's effect on their medical imaging division was considerably large enough to affect overall profitability, leading them to not mention the DRA as a critical market risk factor in 10 K reports.

North America." IRIS International pursued a similar measure by increasing marketing headcount for customer contacts in 2009. However, integrated manufacturers experienced difficulties in realizing the intended benefits of this strategy, leading several of them to subsequently downsize sales force. Imaging Dynamics backtracked on their sales force expansion and instead switched to cost reduction, as did Siemens.

Consistent with their diverse and customized product offering strategy (see Table S6), 50% of the integrated firms responded by changing features to cater to changing customer preferences. For instance, Siemens' offered SPECT imaging system was "*modified to lower the overall price, yet still offer high-image quality*" as a part of the firm's "*three-pronged approach to the current cost pressures in the medical imaging market*" (Lee, 2008). Siemens also enabled upgrades to its Symbia E "*to accommodate a larger workload … allows checking the system status through remote access and diagnostics to enable system corrections to reduce downtime and therefore cost*" (Lee, 2008). Positron Corp refocused on cardiac PET imaging to target a less competitive, niche market by combining "*low cost technology and disease specific software solutions*" (Positron Introduces New Attrius, 2007). The company's president stated "*[t]he Attrius is the only dedicated cardiac PET scanner on the market … Market dynamics combined with our cost-effective scanner offering will allow the Company to seize a leading market position as a unique niche player in the nuclear cardiology market segment*" ("Positron Introduces New Attrius," 2007).

Notably, 42% of integrated firms generated demand through entering foreign imaging markets, but by a dual distribution mode (staying integrated for the U.S. but using distributors for foreign markets). Fonar (2009) noted that "*during the fiscal year ended June 30, 2009, 13.2% of the company's revenues were generated by foreign sales, as compared with 2.4% for fiscal 2008*." Imaging Dynamic Corp (2009) also selectively diversified and enhanced their global distribution channels. The company's top management stated that "*the company plans to further expand IDC's global position … [a]s the industry continues to respond to the effects of the Deficit Reduction Act*" (Spotlight: IDC CEO says, 2008), and noted the motivation to capture the markets "*because [the firm] can have "the right price point*" (Fosse, 2009).

5.2.3 | Integrated firms' response of cost reduction

Cost reduction efforts were noted by 67% of integrated firms, mostly in the realm of manufacturing and overhead costs. Boston Scientific Corp (2009) announced a plan "*aimed at simplifying plant network, reducing manufacturing costs and improving gross margins*." Also, Fonar Corp (2008) stated it "*instituted an aggressive program of cost cutting during and following the end of fiscal 2008*" including "*consolidating … office spaces, reductions in the size of workforce, compensation and benefits, as well as across the board reduction of expenses. The cost reductions were intended to enable us to withstand periods of low volumes of MRI scanner sales, such as we have experienced in fiscal 2007 and 2008*." Other integrated firms such as CR Bard, Alcon (a subsidiary of Nestle), and Volcano Corp announced similar cost reduction programs to eliminate SG&A, personnel and manufacturing costs.

5.2.4 | Integrated firms' response of product portfolio reconfiguration

Fifty percent of public integrated firms engaged in reconfiguring product lines by discontinuing the DRA-affected products and/or launching new products in unaffected segments. Two public

integrated firms, Eastman Kodak and MDS divested imaging businesses, and IRIS International divested imaging research subsidiary.[12] Notably, two public firms, Boston Scientific and MDS restructured or divested non-core businesses outside imaging. The intent was largely for discontinuation of unprofitable businesses: they reported struggles with high operational costs and slower growth of product lines with relatively low margins.

In addition to varying product lines in treated markets as noted above, Siemens increased its presence in untreated markets by introducing a new mammography digital system and acquiring two diagnostic firms to enter the in vitro diagnostics segment. Siemens explicitly noted these measures were in response to the DRA and added, "*we are addressing new markets and new customers ... if you see the customer base of our IVD business, of our IT business, of our imaging business, there is not 100% overlap. So, we can benefit from the cross-selling to the customers. We do have access, we do have excellent relationships in the different business areas we are in*" (Siemens, 2008).

5.2.5 | Nonintegrated firms' response of demand management

Unlike integrated firms, four of six nonintegrated firms (67%) reported efforts at generating demand by highlighting cost-effectiveness of their products and placing greater emphasis on foreign imaging markets. Four nonintegrated firms (67%) increased foreign market presence by leveraging and expanding distributor networks. For example, Del Global Technologies Corp (2008) described that its "*[distributor] network has expanded during fiscal year 2008 when [the company] has partnered with one of the largest dealer buying groups to distribute digital and general radiographic imaging equipment*." In pursuing this strategy, Del Global (2009) noted that in "*international markets ... despite the fact they too are in economic slumps, the demand for medical products remains high as these emerging economies present new opportunities*." Similarly, Afp Imaging Corp (2008) attempted to diversify its revenue streams in foreign markets through a "*worldwide introduction of the company's new vertical three-dimensional CT scanner*," and Analogic Corp (2007) made efforts to offset substantial losses in the digital X-ray business by expanding its "*Dent-X division's Canadian dealer sales network in dental market through a cooperative agreement*" with a new distributor.

Most nonintegrated firms relied on increased standardization (as in Table A6) and two of our public firms (33%) noted doing so with a special focus on cost-effective products. Del Global (2008) touted their "*low-cost offerings for customers [so they could] obtain better patient images within a fraction of the time and with lower overall costs*." Similarly, Analogic Corp (2008) highlighted that "*some of the benefits that have driven customer interest ... [is] a lower end-to-end cost of the system*."

5.2.6 | Nonintegrated firms' response of cost reduction

Compared with integrated firms, even greater proportion of nonintegrated firms (5 of 6, 83%) reported efforts to economize costs, including personnel costs. Nonintegrated firms streamlined operations by implementing cost control programs such as shedding selling, general, and

[12]Nestle, another public integrated firm exited a post-shock treated market, divesting an eye-care company Alcon in 2008. However, this divestiture process began in 2002, and Alcon was in the ophthalmic imaging (control) market.

administrative costs and fixed costs associated with personnel and facilities. For example, X-Rite Inc (2007) was able to achieve cost savings by "*reduced duplicative management level headcount, consolidate territories, etc*." In 2009, Analogic Corp (2009) "*in response to a lower demand, implemented cost control programs*," including reduction of workforce by 145 employees worldwide (9% of total workforce). Del Global (2009) also embarked on "*major cost reduction programs and lean initiatives*," one of which was to move headquarter facilities and reduce floor space.

Nonintegrated firms (33%) could leverage prior relational capital with distributors and diversify risks by exploiting efficiencies in demand forecasting and superior inventory management (Jacobs, 2010). Such value chain rationalization required close coordination with distributors given conflicting goals because "*many distributors continue to reduce their on-hand inventory based on their own economic circumstances*" (Afp Imaging Corp, 2009b). Esco Technologies (2009) noted "*our distributors were … managing their inventories down to … an absolute minimum. So … they needed to have a reasonably significant restocking order to be able to get their inventory back on track … [to] meet the demand in the short-term*." Analogic Corp noted working with distributors to rationalize inventory in light of declined overall demand after the DRA resulted in an inventory adjustment and continued improvement in 2009.

5.2.7 | Nonintegrated firms' response of product portfolio reconfiguration

Compared with integrated firms, only one of six (17%) nonintegrated firms discontinued product offering in the treated market. However, 50% of them entered unaffected markets and reported leveraging distributor networks when doing so. X-Rite introduced a new dental spot measurement device in 2007, and The Cooper Companies (2007) expanded its business by acquiring a medical device firm that specialized in "*diagnostic and therapeutic medical instruments … in women's healthcare and other specialty instruments relating to dermatology, ophthalmology, anesthesiology, dentistry, and veterinary medicine*." Primarily focusing on unaffected imaging markets, Afp Imaging Corp (2007, 2009a) "*made aggressive [product] launch into the dental market*," which was accompanied by the acquisition of "*a global supplier of state-of-the-art, in-office three-dimensional dental computed tomography* (CT)," and a "*worldwide introduction of the company's new vertical three-dimensional CT scanner*." The company further pursued "*various sales opportunities in both the domestic and international markets with specific emphasis in the growing veterinary markets*" (Afp Imaging Corp, 2007).

6 | THEORETICAL IMPLICATIONS: EFFECT OF VERTICAL SCOPE ON POST-SHOCK FIRM ADJUSTMENT AND PRODUCT MARKET EXIT

We now articulate theoretical implications of the findings by tying it back to the received scholarly literature. This illuminates the mechanisms driving the relationship between firms' vertical scope and post-shock adjustment for eventual differences in rates of market exit (See Figure 4).

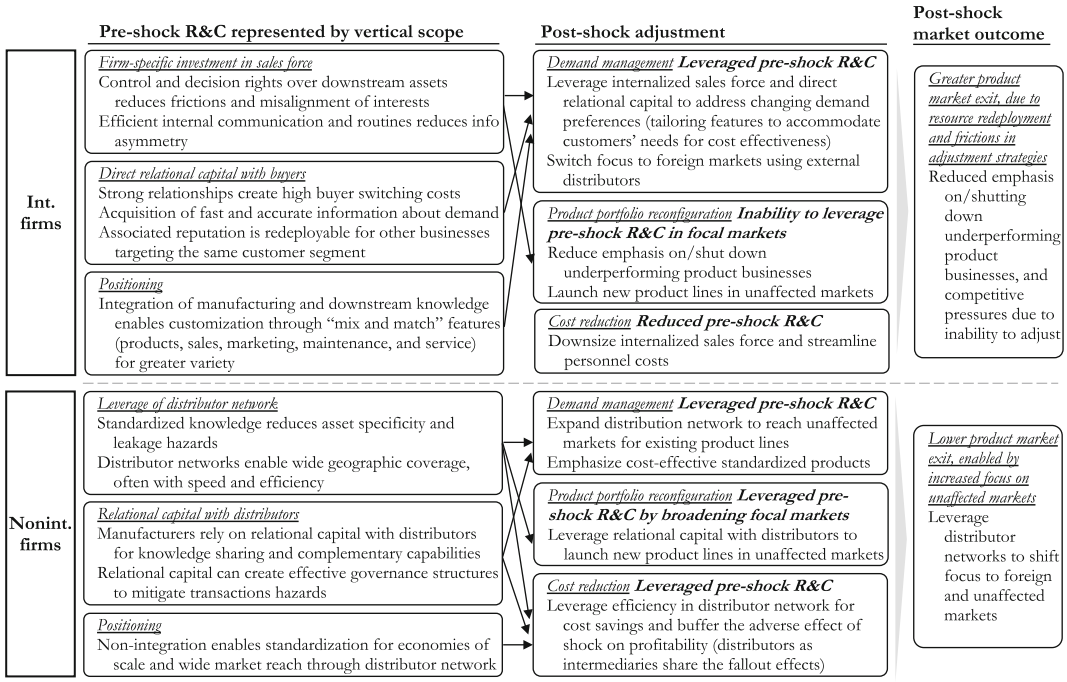

FIGURE 4 Firms' vertical scope, post-shock responses, and market outcome

6.1 | Integrated firms' pre-shock resources and capabilities and post-shock response

6.1.1 | Pre-shock resources and capabilities

Prior to the demand shock, vertically integrated manufacturers had cospecialized capabilities, reflected in an internalized sales force and relational capital with existing customers. Scholars have noted these capabilities translate into heightened trust, shared routines, and mutual understanding developed through repeated transactions (Chatterji et al., 2019; Hoetker, 2005; Kale et al., 2000). Indeed, integrated firms in our context leveraged specialized sales force and direct relational capital to provide a range of products catering to both high- and low-end segments. On the high end, state-of-the-art technology and focus on reliability, versatility, image quality, and other product features were sustained by continuous innovation (Mitchell, 1989; Steinberg & Cohen, 1984; Tilly & Handel, 2002). Additionally, Tilly and Handel (2002: p. 160) note that by the late 1990 s, these manufacturers also served lower-end segments by (a) removing "*less needed or non-reimbursed functions from the equipment*," (b) offering mid- to low-end systems to "*first time buyers and imaging facilities that needed backup systems*," (c) equipment that "*scan specific sites and deliver lower quality whole-body images*," or (d) systems that "*require less space and installation costs*." Importantly, these manufacturers also engaged in design-based cost reduction strategies to reduce "overall costs" to buyers. This included (a) designs that "*increase throughput of patients*," such as by introducing machines that "*can pivot between two rooms, reducing idle time*," (b) providing high-end machines to enable "*less invasive form of surgery [to] save money by minimizing risk of complications and long hospital stays*", and (c) "*promoting picture archiving*

communications systems (PACS) as a way to cut down on diagnostic imaging costs themselves." Consistently, the integrated firms had capabilities to tailor product/service offerings to meet imaging facilities' needs and to maintain customer relationships via dedicated sales force.

6.2 | Post-shock firm adjustment by integrated firms

6.2.1 | Demand management adjustments

Vertically integrated firms leveraged their capabilities to mitigate the adverse effects on their individual demand curve. Consistent with scholarly literature (Chatterji et al., 2019; Rangan, Corey, & Cespedes, 1993), they relied on pre-shock capabilities and positioning: the internal salesforce utilized their in-depth customer relationships to learn about changes in customer preferences and create adaptive responses. Coordinated operational routines within the firm's boundaries (Aggarwal & Wu, 2015; Nickerson & Zenger, 2004) allowed them to negotiate prices and other sales terms and provide enhanced technology-related support services (Forbes & Lederman, 2010). They tailored features and services to accommodate a shift in customer preferences towards enhanced cost effectiveness (Wang et al., 2020) by (a) removal of expensive modular features and services and (b) addition of new modular features and services that helped customers achieve *overall* cost savings (the new features reduced customers' operational costs through reduced human capital costs or increased equipment utilization). Also, while integrated firms on average reduced new product applications to FDA after the shock, their product applications reflected a focus on a change in product features to lower overall price to accommodate cost pressures. In addition, some integrated firms switched focus to unaffected foreign markets to manage demand. However, given prohibitive time and cost requirements for building their own internal sales force, pursuing foreign markets required them to contract with external distributors with requisite local knowledge for timely reorientation (Manning, Larsen, & Bharati, 2015). Thus, integrated firms that expanded into foreign markets had to shift to a dual distribution mode.

6.2.2 | Product Portfolio reconfiguration

Scholars have noted that firm-specific investments in sales force and direct relational capital with buyers may be redeployed to other businesses both within current boundaries and for the future (Anand & Singh, 1997; Helfat & Eisenhardt, 2004; Karim & Capron, 2016; Lieberman et al., 2017). Our empirical evidence is consistent: integrated firms reconfigured their product portfolios by reducing emphasis on or shutting down underperforming product lines hurt by adverse demand conditions. Indeed, our quantitative subsample analysis indicated that integrated firms that exited treated markets mostly consisted of those also operating in other imaging device segments. Consistently, our qualitative evidence suggested that integrated firms launched new product lines in the medical device markets unaffected by the reimbursement cut. To the extent that integration is also positively correlated with diversification, they temporarily or permanently redeployed direct sales force from focal markets to other unaffected businesses (Folta et al., 2016).

Notably, we found that private or small-sized integrated firms were more adversely affected than the similar sized nonintegrated firms. Since demand management through specialized

distribution/sales force or restructuring product portfolio requires resources to support strategic renewal (Agarwal & Helfat, 2009), it is probable that private or small firms constrained in resources were not able to actively engage in adjustment (Covin & Slevin, 1989; Rajan & Zingales, 1995).

6.2.3 | Cost reduction efforts

The arrows in Figure 4 reveal that while pre-shock resources and capabilities were leveraged by integrated firms for both demand management and product portfolio reconfiguration, there was no such connection with their cost reduction efforts. Our empirical evidence showed some integrated firms responded by rationalizing operational costs or reducing headcounts, consistent with received literature as an adjustment response to adverse market conditions (Baumol, Blinder, & Wolff, 2003; Cascio, Chatrath, & Christie-David, 2021; Dewitt, 1998). Alternatively, and as noted above, many integrated firms redeployed their salesforce by reconfiguring product portfolios. However, others *increased* investments in specialized sales force to address the demand management needs noted above, which increased costs and ran counter to their cost reduction efforts. Either case inevitably created friction between demand management, product portfolio reconfiguration and cost reduction efforts for integrated firms. Specifically, scaling down investment in direct sales force to streamline personnel costs eroded their value creation potential (Guthrie & Datta, 2008), or was not feasible due to the need to accommodate adjustments for changing customer preferences through use of specialized assets (Harrigan, 1985; Jacobides, 2008).

6.3 | Nonintegrated firms' pre-shock resources and capabilities and post-shock response

6.3.1 | Pre-shock resources and capabilities

Prior to the demand shock, nonintegrated firms accessed wide market reach through a distributor network. Consistent with scholarly work, nonintegrated firms leveraged partners' local knowledge and access to consumers within distributor networks, creating increased geographical scope (within the U.S. and internationally) and enabling economies of scale (McKay, 1983; Mitchell, Shaver, & Yeung, 1992; Mitchell & Singh, 1992). Moreover, nonintegrated firms achieved operational efficiency by contracting with distributors managing large-scale warehousing, delivery, and customer services, and benefited from financial risk management due to outsourcing of downstream operations (Hisey, Jacoby, Heim, & Mancke, 2019). In terms of positioning, while both types of firms had similar numbers of product categories, nonintegrated firms had more standardization—relative to integrated firms, they offered fewer variations in each product category (as in Table S5). The lack of downstream capabilities also implied that nonintegrated firms tended to have less control over final product prices due to the presence of distributors (Kurihara, Sakayori, & Takagi, 2020), potentially limiting their ability to compete on price for imaging facilities.

6.4 | Post-shock firm adjustment by nonintegrated firms

6.4.1 | Demand management adjustments

Nonintegrated firms' resources and positioning situated them to leverage existing distributor network and product portfolios to mitigate adverse effects on individual demand. Their relational capital with existing distributors helped them drive down purchase prices but achieve added revenue through bulk sales and economies of scale (Schneller, 2009). Such responses, as indicated by the qualitative evidence, included emphasis on cost-effectiveness of their standardized products, accommodating the change in preferences of budget constrained hospitals. Moreover, by leveraging alliance management capabilities developed in existing relationships, nonintegrated firms forged new distributor relationships (Ireland, Hitt, & Vaidyanath, 2002; Kale & Singh, 2007) to expand their network to wider geographic markets (Swaminathan & Moorman, 2009). Together, existing and new distributor relationships helped them reach new markets for existing product lines with low search costs, particularly in unaffected geographic segments.

6.4.2 | Product Portfolio reconfiguration

Similar to their expansion strategy for foreign markets, nonintegrated firms leveraged their alliance management capabilities developed in existing relationships to forge new distributor relationships in unaffected product segments. The qualitative evidence showed nonintegrated firms engaged in product portfolio reconfiguration through their existing and new distributor networks to expand into other medical device segments excluded from the regulation change, as is consistent with received wisdom (Ireland et al., 2002; Kale & Singh, 2007).

6.4.3 | Cost reduction efforts

The arrows in Figure 4 reveal that pre-shock resources and capabilities also positioned nonintegrated firms to engage in several cost reduction efforts. Here again, they were able to leverage relationships with distributors, in a manner that was synergistic with their demand management and product portfolio reconfiguration efforts. Outsourcing downstream activities required partners to share rents during periods of high demand, but also enabled the sharing of risks associated with inventory management given lower demand (Hisey et al., 2019). Since distributors were better able to rationalize across large inventories through bulk sales (Holcomb & Hitt, 2007), distributors' support for value chain efficiency likely helped nonintegrated firms in cost-cutting efforts. Given that downstream contracting was already outsourced, nonintegrated manufacturing firms needed to make fewer internal adjustments across the value chain (Jacobides, 2005). Also, distributors alleviated costs associated with pricing adjustment, given their own specialized routines and extensive experience in contract renegotiation (Jacobides, 2005; Jacobides & Winter, 2005). Finally, external arrangements are easier to downsize by severance or reoptimization (Milgrom & Roberts, 1990; Susarla, 2012), thus providing nonintegrated firms greater flexibility in reducing costs.

6.5 | Post-shock market outcomes

While both types of firms pursued demand management, product portfolio reconfiguration and cost reduction, their post-shock market outcome resulted from the way existing downstream vertical scope created differences in opportunities and challenges encountered in adjustment efforts to the adverse aggregate demand shock.

In terms of sustaining and generating demand in the affected markets, both integrated and nonintegrated firms addressed customers' greater needs for cost effective products. However, while integrated firms focused on product-design-based strategies by providing cost-efficient features and customer services to reduce overall costs for users, nonintegrated firms presented the imaging technology that can be more cost-efficient for users. Both types explored unaffected foreign markets, but integrated firms had to use external distributors engaging in a dual distribution mode. In contrast, all the nonintegrated firms that entered foreign markets continued to use external distribution partners only, leveraging existing alliance capabilities. Lastly, both exhibited considerable efforts to reshape product portfolio and to streamline costs. However, integrated firms' product reconfiguration in part resulted in retreating from underperforming businesses to redeploy direct sales force unable to leverage in the focal market, and their cost reduction efforts ran counter to demand management. On the contrary, nonintegrated firms' adjustment worked in synergy through leveraging their pre-shock resources and capabilities—distributor relationships. Taken together, integrated firms were less capable of post-shock adjustment under the constrained demand than nonintegrated firms, which resulted in the market outcome of exits either driven by redeployment motive (i.e., voluntary exit) or by competitive pressure (i.e., involuntary exit).

7 | DISCUSSION AND CONCLUSION

Scholars have integrated transaction costs and capabilities view to examine firms' choices of vertical scope and associated capability configuration and positioning (Argyres et al., 2012; Chatterji et al., 2019; Karim & Capron, 2016), particularly in light of environmental changes or shocks (Bigelow et al., 2019; Wang et al., 2020). Less understood is how (pre-existing) vertical scope impacts a firm's ability to cope with an adverse environmental shock, to enable a causal disentanglement of otherwise endogenous and interdependent decisions of adjustment and vertical scope choices. Theoretically, it is unclear whether integrated or nonintegrated firms may be better able to overcome an adverse shock, given that pre-existing differences in capabilities and positioning associated with vertical scope may also manifest in differences in response to the adverse shock.

Accordingly, we used a research-question based abductive approach to examine the effects of a negative derived demand shock due to the Deficit Reduction Act on medical diagnostic imaging firms. Our quantitative DDD analysis revealed integrated imaging manufacturers were more likely to exit treated markets than nonintegrated imaging manufacturers, which was robust to several alternative specifications and tests. Moreover, the adverse demand shock resulted in higher market exit for treated integrated firms, particularly for subsamples of private/small firms (consistent with resource constraint mechanism), and firms diversified in other medical devices (consistent with resource redeployment mechanism). There seems to be no systematic difference, however, between integrated and nonintegrated firms in other responses such as reductions in patent and 510(k) applications, changes in product categories within

imaging and entry into unaffected markets. Additional quantitative analyses, bolstered with in-depth qualitative examination of public firms, showcase that both types of firms engaged in demand management and cost reduction in a manner consistent with their pre-exiting capabilities and positioning. Integrated firms leveraged specialized sales force and stayed the course with customization to offer either niche or overall-cost-reducing products that catered to shifting customer preferences. Nonintegrated firms utilized and expanded distributor networks while also emphasizing cost-effectiveness of their more standardized offerings. Both types entered unaffected and foreign markets and interestingly, some integrated firms switched to a hybrid strategy by using distributors to expand into foreign markets. The evidence suggests integrated firms' higher exit rates result from both a deliberate redeployment of resources and competitive pressures because their adjustment strategies were not as effective as intended.

We note several limitations. Our single industry study provides insights for an important economic sector of medical devices, but the idiosyncrasies of this industry limit the generalizability of our findings. Moreover, our results focusing on a specific shock—a legislative change that created derived demand pressures—may not be generalizable to other environmental shocks. We hope future studies examine other industries and environmental shocks to build a deeper understanding of contingency factors that may impact how environmental shocks may change the relationship between prior vertical firm scope and outcomes in an industry. Second, we do not differentiate firms' exit modes in examining market exit, (e.g., divestitures, bankruptcies, redeployment to alternative businesses) (Folta et al., 2016; Fortune & Mitchell, 2012; Karim & Capron, 2016). Also, our data cannot empirically distinguish between firms' voluntary and involuntary exits. Although our theoretical discussion and qualitative evidence suggest firms may exit for different reasons, sample size and lack of information constrained our ability to do so. We hope future studies can dwell into this issue further. Third, despite of our DDD research design and supplementary analyses, data limitations precluded us from observing and quantifying firms' internal decision and cost structure, heterogeneity in specialized sales force or distributor relationships across markets/time, and pricing strategies that may be at play. Similarly, lack of qualitative data limited our ability to assess responses by private and small firms. We hope future studies address these issues building on our paper.

This paper makes several contributions to the literature it draws upon. First, our paper contributes to the literature that integrates organizational economics and capabilities approach to understand firm boundaries and heterogeneity (Argyres, 2011; Argyres et al., 2012; Williamson, 1999). Building on the insight that firms' vertical scope arises from the heterogeneity in managerial choices concerning combination and governance of activities and assets, we documented potential directions of adjustment pursued by firms with different vertical scopes. While prior literature largely highlighted how capability differentials among firms aids the understanding of firm boundary choices (e.g., Brahm & Tarziján, 2014; Jain & Thietart, 2014), our paper takes existing vertical scope as given and sheds light on how prior boundary choices can explain firm behaviors and outcomes.

Second, we contribute to the strategy research on firms' responses to environmental shocks by answering the call on empirical studies to evaluate the importance of adjustment costs (Ahuja et al., 2014; Argyres et al., 2019). By disentangling decisions to adjust to an environmental shock from decisions of firm boundary choices, we isolate the effect of vertical scope on response to environmental changes. Moreover, we add to the existing literature that has noted integrated firms may be more responsive to changes in demand (Richardson, 1996), face fixed cost barriers to exit (Harrigan, 1985; Nickerson & Silverman, 2003), strategically choose to bear fixed costs even when conditions favor lower cost specialized firms (Helfat & Campo-

Rembado, 2016), or expedite market exit due to relatedness among firms' businesses (Lieberman et al., 2017). Our finding adds to this conversation by documenting that firms with internalized downstream activities may be more likely to respond by exiting markets when faced with a demand shock due to either active resource redeployment or greater competitive pressures.

Third, we add to literature on firm scope and performance by providing evidence that vertical scope plays an important role in firm adjustment and subsequent market outcome. Prior work has noted the effect of vertical (dis)integration on performance through a multitude of mechanisms, many of which interact with other organizational design elements such as corporate governance (Gartenberg & Pierce, 2017), interdependencies in activities (Zhang & Tong, 2021), or incentive alignment (Forbes & Lederman, 2010). Our study provides another important mechanism: the assessment of costs and direction of adjustment for environmental changes.

Finally, our study provides an empirical resolution of a theoretical puzzle in an important economic sector, through the use of a research design that plausibly establishes a causal relationship. Our DDD research design helped address endogeneity concerns regarding firm's prior vertical scope (with no switching observed in our sample period) and the adverse derived demand shock (which occurred independent of the firm's original strategic intent for downstream [non]integration). Moreover, we actively relied on in-depth contextual knowledge and provided the qualitative insights that are complementary to the statistical results obtained using quantitative data. Together, by theoretically situating an important strategic inquiry and substantiating it with diverse sources of evidence, our work makes a methodological contribution to a recent emphasis in the field on the research question-based abductive approach (King et al., 2020).

ACKNOWLEDGEMENTS

Authors contributed equally. Data collection was funded by the Ed Snider Center for Enterprise and Markets and the SRF Dissertation Research Grant. We thank the editor and the two anonymous reviewers for helpful guidance. The manuscript has also benefited from the comments by Connie Helfat, Evan Starr, Serguey Braguinsky, Sonali Shah, the attendees of presentations at the 2020 Academy of Management and the University of Maryland Presentation Series. All errors and omissions are ours.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Najoung Lim https://orcid.org/0000-0001-8751-3578
Seojin Kim https://orcid.org/0000-0003-4390-6999
Rajshree Agarwal https://orcid.org/0000-0002-7272-314X

REFERENCES

Afp Imaging Corp. (2007). 2007 10-K form. https://www.sec.gov/edgar.shtml
Afp Imaging Corp. (2008). 2008 10-K form. https://www.sec.gov/edgar.shtml
Afp Imaging Corp. (2009a). Afp imaging expands dent-X sales force in Canada with global practice solutions, *LLC* [Press release]. LexisNexis.

Afp Imaging Corp. (2009b). 2009 10-Q form for the quarterly period ended March 31, 2009. https://www.sec.gov/edgar.shtml

Agarwal, R., & Gort, M. (1996). The evolution of markets and entry, exit and survival of firms. *The Review of Economics and Statistics*, *78*, 489–498.

Agarwal, R., & Helfat, C. E. (2009). Strategic renewal of organizations. *Organization Science*, *20*(2), 281–293.

Aggarwal, V. A., & Wu, B. (2015). Organizational constraints to adaptation: Intrafirm asymmetry in the locus of coordination. *Organization Science*, *26*(1), 218–238.

Ahuja, G., Lampert, C. M., & Tandon, V. (2014). Paradigm-changing vs. paradigm-deepening innovation: How firm scope influences firm technological response to shocks. *Organization Science*, *25*(3), 653–669.

Albuquerque, P., & Bronnenberg, B. J. (2012). Measuring the impact of negative demand shocks on car dealer networks. *Marketing Science*, *31*(1), 4–23.

Analogic Corp. (2007). Q2 2007 Analogic corporation earnings conference call. LexisNexis.

Analogic Corp. (2008). Analogic Corporation Annual Stockholders Meeting. LexisNexis.

Analogic Corp. (2009). 2009 10-K Form. https://www.sec.gov/edgar.shtml

Anand, J., & Singh, H. (1997). Asset redeployment, acquisitions, and corporate strategy in declining industries. *Strategic Management Journal*, *18*(S1), 99–118.

Argyres, N. (2011). Using organizational economics to study organizational capability development and strategy. *Organization Science*, *22*(5), 1138–1143.

Argyres, N., & Bigelow, L. (2007). Does transaction misalignment matter for firm survival at all stages of the industry life cycle? *Management Science*, *53*(8), 1332–1344.

Argyres, N., & Bigelow, L. (2010). Innovation, modularity, and vertical deintegration: Evidence from the early US auto industry. *Organization Science*, *21*(4), 842–853.

Argyres, N., Mahoney, J. T., & Nickerson, J. (2019). Strategic responses to shocks: Comparative adjustment costs, transaction costs, and opportunity costs. *Strategic Management Journal*, *40*, 357–376.

Argyres, N., & Mostafa, R. (2016). Knowledge inheritance, vertical integration, and entrant survival in the early US auto industry. *Academy of Management Journal*, *59*(4), 1474–1492.

Argyres, N. S., Felin, T., Foss, N., & Zenger, T. (2012). Organizational economics of capability and heterogeneity. *Organization Science*, *23*(5), 1213–1226.

Argyres, N. S., & Zenger, T. R. (2012). Capabilities, transaction costs, and firm boundaries. *Organization Science*, *23*(6), 1643–1657.

Barney, J. B., & Lee, W. (2000). *Multiple considerations in making governance choices: Implications of transaction cost economics, real options theory, and knowledge-based theories of the firm* (pp. 21–55). Oxford, UK: Oxford University Press.

Baumol, W. J., Blinder, A. S., & Wolff, E. N. (2003). *Downsizing in America: Reality, causes, and consequences*. New York: Russell Sage Foundation.

Bigelow, L., Nickerson, J. A., & Park, W.-Y. (2019). When and how to shift gears: Dynamic trade-offs among adjustment, opportunity, and transaction costs in response to an innovation shock. *Strategic Management Journal*, *40*, 377–407.

Boston Scientific Corp. (2009). 2008 10-K form. https://www.sec.gov/edgar.shtml

Brahm, F., & Tarziján, J. (2014). Transactional hazards, institutional change, and capabilities: Integrating the theories of the firm. *Strategic Management Journal*, *35*(2), 224–245.

Cascio, W. F., Chatrath, A., & Christie-David, R. A. (2021). Antecedents and consequences of employee and asset restructuring. *Academy of Management Journal*, *64*(2), 587–613.

Centers for Medicare & Medicaid Services (CMS), The U.S. Department of Health and Human Services. (2007). 2007 CMS statistics. https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/CMS-Statistics-Reference-Booklet/Downloads/2007CMSStatistics.pdf

Chatterji, A. K., Cunningham, C. M., & Joseph, J. E. (2019). The limits of relational governance: Sales force strategies in the U.S. medical device industry. *Strategic Management Journal*, *40*, 55–78.

Fonar Corp. (2008). 2008 10-K Form. https://www.sec.gov/edgar.shtml

Fonar Corp. (2009). 2009 10-K Form. https://www.sec.gov/edgar.shtml

Cottrell, T., & Nault, B. R. (2004). Product variety and firm survival in the microcomputer software industry. *Strategic Management Journal*, *25*(10), 1005–1025.

Covin, J. G., & Slevin, D. P. (1989). Strategic management of small firms in hostile and benign environments. *Strategic Management Journal*, *10*(1), 75–87.

Croxton, K. L., Lambert, D. M., García-Dastugue, S. J., & Rogers, D. S. (2002). The demand management process. *The International Journal of Logistics Management*, *13*(2), 51–66.

Dallessio, K. M. (2007). Technology and industry: DRA and its effect on imaging centers. *Applied Radiology*. https://appliedradiology.com/articles/technology-and-industry-dra-and-its-effect-on-imaging-centers

Davis, S. J., & Haltiwanger, J. (1992). Gross job creation, gross job destruction, and employment reallocation. *The Quarterly Journal of Economics*, *107*(3), 819–863.

Del Global Technologies Corp. (2008). 2008 10-K form. https://www.sec.gov/edgar.shtml

Del Global Technologies Corp. (2009). Q2 2009 Del global Technologies earnings conference call. Retrieved from LexisNexis.

Dewitt, R. L. (1998). Firm, industry, and strategy influences on choice of downsizing approach. *Strategic Management Journal*, *19*(1), 59–79.

Dyer, J. H., & Singh, H. (1998). The relational view: Cooperative strategy and sources of interorganizational competitive advantage. *Academy of Management Review*, *23*(4), 660–679.

Folta, T. B., Helfat, C. E., & Karim, S. (2016). Examining resource redeployment in multi-business firms. In *Resource redeployment and corporate strategy* (pp. 1–17). Bingley: Emerald Group Publishing Ltd..

Forbes, S. J., & Lederman, M. (2010). Does vertical integration affect firm performance? Evidence from the Airline Industry. *The RAND Journal of Economics*, *41*(4), 765–790.

Fortune, A., & Mitchell, W. (2012). Unpacking firm exit at the firm and industry levels: The adaptation and selection of firm capabilities. *Strategic Management Journal*, *33*(7), 794–819.

Fosse, L. (2009). Canadian digital radiography manufacturer imaging dynamics company is successful in capturing industry market share in emerging international markets. CEOCFO Interviews.com. https://www.ceocfointerviews.com/interviews/IDL-ImagingDynamics09.htm

Furr, N., & Kapoor, R. (2018). Capabilities, technologies, and firm exit during industry shakeout: Evidence from the global solar photovoltaic industry. *Strategic Management Journal*, *39*(1), 33–61.

Gartenberg, C., & Pierce, L. (2017). Subprime governance: Agency costs in vertically integrated banks and the 2008 mortgage crisis. *Strategic Management Journal*, *38*(2), 300–321.

Ghemawat, P. (1991). *Commitment: The dynamic of strategy*. New York: Free Press.

Glader, P. (2008). Curing what ails GE's health unit. *The Wall Street Journal*. https://www.wsj.com/articles/SB122299075448300439

Goldstein, J. (2007, June 27). Medicare cuts hurt sales of imaging equipment. *The Wall Street Journal*. https://health.maryland.gov/newsclippings/archives/2007/jun07/062707.htm#Medicare_Cuts_Hurt_Sales_of_Imaging_Equipment_

Guthrie, J. P., & Datta, D. K. (2008). Dumb and dumber: The impact of downsizing on firm performance as moderated by industry conditions. *Organization Science*, *19*(1), 108–123.

Hannan, M. T., & Freeman, J. (1977). The population ecology of organizations. *American Journal of Sociology*, *82*(5), 929–964.

Harrigan, K. R. (1985). Vertical integration and corporate strategy. *Academy of Management Journal*, *28*(2), 397–425.

Helfat, C. E. (2015). Vertical firm structure and industry evolution. *Industrial and Corporate Change*, *24*(4), 803–818.

Helfat, C. E., & Campo-Rembado, M. A. (2016). Integrative capabilities, vertical integration, and innovation over successive technology lifecycles. *Organization Science*, *27*(2), 249–264.

Helfat, C. E., & Eisenhardt, K. M. (2004). Inter-temporal economies of scope, organizational modularity, and the dynamics of diversification. *Strategic Management Journal*, *25*(13), 1217–1232.

Helfat, C. E., & Lieberman, M. B. (2002). The birth of capabilities: Market entry and the importance of pre-history. *Industrial and Corporate Change*, *11*(4), 725–760.

Hisey, T., Jacoby, R., Heim, M., & Mancke, J. (2019). *The role of distributors in the US health care industry*. Deloitte: Healthcare Distribution Alliance.

Hoetker, G. (2005). How much you know versus how well I know you: Selecting a supplier for a technically innovative component. *Strategic Management Journal*, *26*(1), 75–96.

Holcomb, T. R., & Hitt, M. A. (2007). Toward a model of strategic outsourcing. *Journal of Operations Management*, *25*(2), 464–481.

Imaging Dynamics Corp. (2008). Q2 2008 earnings conference call. LexisNexis.

Imaging Dynamics Corp. (2009). Q4 2008 earnings conference call. LexisNexis.

Ireland, R. D., Hitt, M. A., & Vaidyanath, D. (2002). Alliance management as a source of competitive advantage. *Journal of Management*, *28*(3), 413–446.

Jacobides, M. G. (2005). Industry change through vertical disintegration: How and why markets emerged in mortgage banking. *Academy of Management Journal*, *48*(3), 465–498.

Jacobides, M. G. (2008). How capability differences, transaction costs, and learning curves interact to shape vertical scope. *Organization Science*, *19*(2), 306–326.

Jacobides, M. G., & Winter, S. G. (2005). The co-evolution of capabilities and transaction costs: Explaining the institutional structure of production. *Strategic Management Journal*, *26*(5), 395–413.

Jacobs, B.E. (2010). Adding value as a wholesale distributor. Medical Product Outsourcing. https://www.mpomag.com/issues/2010-03/view_columns/adding-value-as-a-wholesale-distributor/

Jain, A., & Thietart, R. A. (2014). Capabilities as shift parameters for the outsourcing decision. *Strategic Management Journal*, *35*(12), 1881–1890.

Johanson, J., & Vahlne, J. E. (2009). The Uppsala internationalization process model revisited: From liability of foreignness to liability of outsidership. *Journal of International Business Studies*, *40*(9), 1411–1431.

Kale, P., & Singh, H. (2007). Building firm capabilities through learning: The role of the alliance learning process in alliance capability and firm-level alliance success. *Strategic Management Journal*, *28*(10), 981–1000.

Kale, P., Singh, H., & Perlmutter, H. (2000). Learning and protection of proprietary assets in strategic alliances: Building relational capital. *Strategic Management Journal*, *21*(3), 217–237.

Kapoor, R. (2013). Persistence of integration in the face of specialization: How firms navigated the winds of disintegration and shaped the architecture of the semiconductor industry. *Organization Science*, *24*(4), 1195–1213.

Kapoor, R., & Adner, R. (2012). What firms make vs. what they know: How firms' production and knowledge boundaries affect competitive advantage in the face of technological change. *Organization Science*, *23*(5), 1227–1248.

Karim, S. (2006). Modularity in organizational structure: The reconfiguration of internally developed and acquired business units. *Strategic Management Journal*, *27*(9), 799–823.

Karim, S., & Capron, L. (2016). Reconfiguration: Adding, redeploying, recombining and divesting resources and business units. *Strategic Management Journal*, *37*(13), E54–E62.

Karim, S., & Mitchell, W. (2000). Path-dependent and path-breaking change: Reconfiguring business resources following acquisitions in the U.S. medical sector, 1978-1995. *Strategic Management Journal*, *21*(10/11), 1061–1081.

King, A., Goldfarb, B., & Simcoe, T. (2020). Learning from testimony on quantitative research in management. *Academy of Management Review*, *46*(3), 465–488.

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

Kosová, R., Lafontaine, F., & Perrigot, R. (2013). Organizational form and performance: Evidence from the hotel industry. *Review of Economics and Statistics*, *95*(4), 1303–1323.

Krieger, J., Li, X., & Thakor, R. T. (2020). Find and replace: R&D investment following the erosion of existing products (working paper No.19-058). Harvard Business School Entrepreneurial Management.

Kurihara, J., Sakayori, S., & Takagi, Y. (2020). *The changing landscape of the medical devices industry in the APAC region*. KPMG. https://assets.kpmg/content/dam/kpmg/jp/pdf/2020/jp-medical-device-apac-en.pdf

Langlois, R. N., & Robertson, P. L. (1995). *Firms, markets, and economic change: A dynamic theory of business institutions*. London: Routledge.

Lee, P. (2008). SPECT adapts to DRA downturn. Imaging Technology News. https://www.itnonline.com/article/spect-adapts-dra-downturn

Levin, D. C., Rao, V. M., & Parker, L. (2012). Trends in the utilization of outpatient advanced imaging after the deficit reduction act. *Journal of the American College of Radiology*, *9*(1), 27–32.

Lieberman, M. B. (1990). Exit from declining industries: "Shakeout" or "stakeout"? *The Rand Journal of Economics*, *21*, 538–554.

Lieberman, M. B., Lee, G. K., & Folta, T. B. (2017). Entry, exit, and the potential for resource redeployment. *Strategic Management Journal*, *38*(3), 526–544.

Manning, S., Larsen, M., & Bharati, P. (2015). Global delivery models: The role of talent, speed and time zones in the global outsourcing industry. *Journal of International Business Studies*, *46*, 850–887.

McKay, N. L. (1983). The economics of the medical diagnostic imaging equipment industry (Doctoral dissertation, Massachusetts Institute of Technology).

Milgrom, P., & Roberts, J. (1990). The economics of modern manufacturing: Technology, strategy, and organization. *American Economic Review*, *80*(3), 511–528.

Mitchell, W. (1989). Whether and when? Probability and timing of incumbents' entry into emerging industrial subfields. *Administrative Science Quarterly*, *34*, 208–230.

Mitchell, W., Shaver, J. M., & Yeung, B. (1992). Getting there in a global industry: Impacts on performance of changing international presence. *Strategic Management Journal*, *13*(6), 419–432.

Mitchell, W., & Singh, K. (1992). Incumbents' use of pre-entry alliances before expansion into new technical subfields of an industry. *Journal of Economic Behavior & Organization*, *18*(3), 347–372.

Mitchell, W., & Singh, K. (1996). Survival of businesses using collaborative relationships to commercialize complex goods. *Strategic Management Journal*, *17*(3), 169–195.

Moser, J. W., & Hastreiter, D. M. (2009). 2007 survey of radiologists: Source of income and impact of the deficit reduction act of 2005. *Journal of American College of Radiology*, *6*(6), 408–416.

Nickerson, J. A., & Silverman, B. S. (2003). Why firms want to organize efficiently and what keeps them from doing so: Inappropriate governance, performance, and adaptation in a deregulated industry. *Administrative Science Quarterly*, *48*(3), 433–465.

Nickerson, J. A., & Zenger, T. R. (2004). A knowledge-based theory of the firm: The problem-solving perspective. *Organization Science*, *15*(6), 617–632.

Philips N.V. (2008). 2007 Annual Report. https://www.philips.com/c-dam/corporate/about-philips/investors/financial-results/annual-reports/Philips2007_AnnualReport.pdf

Positron Introduces New Attrius Cardiac PET Scanner. (2007). Med Device Online. https://www.meddeviceonline.com/doc/positron-introduces-new-attrius-cardiac-pet-s-0001

Priem, R. L. (2007). A consumer perspective on value creation. *Academy of Management Review*, *32*(1), 219–235.

Qian, L., Agarwal, R., & Hoetker, G. (2012). Configuration of value chain activities: The effect of pre-entry capabilities, transaction hazards, and industry evolution on decisions to internalize. *Organization Science*, *23*(5), 1330–1349.

Radiology Today. (2008). Radiology Today Interview: Financial Issues Facing Radiology Executives. *Radiology Today*, *9*(24), 40.

Rajan, R. G., & Zingales, L. (1995). What do we know about capital structure? Some evidence from international data. *The Journal of Finance*, *50*(5), 1421–1460.

Rangan, V. K., Corey, E. R., & Cespedes, F. (1993). Transaction cost theory: Inferences from clinical field research on downstream vertical integration. *Organization Science*, *4*(3), 454–477.

Renard, S. R. (2006). The Deficit Reduction Act: What we can do about it. Diagnostic Imaging. https://www.diagnosticimaging.com/view/deficit-reduction-act-what-we-can-do-about-it

Richardson, J. (1996). Vertical integration and rapid response in fashion apparel. *Organization Science*, *7*(4), 400–412.

Schneller, E. S. (2009). The value of group purchasing—2009: Meeting the needs for strategic savings. https://www.supplychainassociation.org/wp-content/uploads/2018/05/schneller.pdf

Sferrella, S. (2012). Equipment service: Total cost of ownership. Radiology Business. https://www.radiologybusiness.com/topics/technology-management/equipment-service-total-cost-ownership

Siemens AG. (2008). Siemens AG Capital Market Day. LexisNexis.

Sohl, T., & Folta, T. B. (2021). Market exit and the potential for resource redeployment: Evidence from the global retail sector. *Strategic Management Journal*, *42*(12), 2273–2293.

Spotlight: IDC CEO. (2008). Spotlight: IDC CEO says industry focus on bottom line fuels DR growth. Health imaging. https://www.healthimaging.com/topics/diagnostic-imaging/spotlight-idc-ceo-says-industry-focus-bottom-line-fuels-dr-growth

Steinberg, E. P., & Cohen, A. B. (1984). *Nuclear magnetic resonance imaging technology: A clinical, industrial, and policy analysis, and policy analysis*. Health Technology Case Study 27. Washington, DC: U.S. Congress, Office of Technology Assessment.

Suarez, F. F., & Utterback, J. M. (1995). Dominant designs and the survival of firms. *Strategic Management Journal*, *16*(6), 415–430.

Susarla, A. (2012). Contractual flexibility, rent seeking, and renegotiation design: An empirical analysis of information technology outsourcing contracts. *Management Science*, *58*(7), 1388–1407.

Swaminathan, V., & Moorman, C. (2009). Marketing alliances, firm networks, and firm value creation. *Journal of Marketing*, *73*(5), 52–69.

ESCO Technologies. (2009). *Q3 2009 ESCO Technologies Inc. Earnings Conference Call*.

The Cooper Companies (2007), 2007 10-K Form. https://www.sec.gov/edgar.shtml

The U.S. Government accountability office (GAO). (2008). Medicare: Trends in fees, utilization and expenditures for imaging services before and after implementation of the Deficit Reduction Act of 2005. https://www.gao.gov/new.items/d081102r.pdf

Tilly, C., & Handel, M. (2002). What prognosis for good jobs? The US medical diagnostic imaging equipment industry. In *Corporate governance and sustainable prosperity* (pp. 141–182). London: Palgrave Macmillan.

Understanding How to Procure Medical Diagnostic Imaging Equipment. (2019). The World Bank. https://thedocs.worldbank.org/en/doc/258511553620191211-0290022019/original/ProcurementGuidanceMDIEquipmentBuyers.pdf

Vats, P., Soni, G., Rathore, A. P. S., & Yadav, S. P. (2019). A demand aggregation approach for inventory control in two echelon supply chain under uncertainty. *Opsearch*, *56*(3), 840–868.

Wang, T., Aggarwal, V. A., & Wu, B. (2020). Capability interactions and adaptation to demand-side change. *Strategic Management Journal*, *41*(9), 1595–1627.

Williamson, O. E. (1999). Strategy research: Governance and competence perspectives. *Strategic Management Journal*, *20*(12), 1087–1108.

X-Rite, Inc. (2007). *Q4 2006 X rite earnings conference call. LexisNexis*.

Zenger, T. R., Felin, T., & Bigelow, L. (2011). Theories of the firm–market boundary. *Academy of Management Annals*, *5*(1), 89–133.

Zhang, Y., & Tong, T. W. (2021). How vertical integration affects firm innovation: Quasi-experimental evidence. *Organization Science*, *32*(2), 455–479.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Lim, N., Kim, S., & Agarwal, R. (2023). Weathering a demand shock: The impact of prior vertical scope on post-shock firm response. *Strategic Management Journal*, *44*(8), 1965–2004. https://doi.org/10.1002/smj.3478