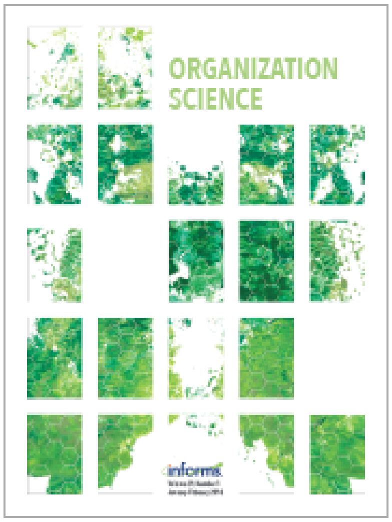


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# Specializing in Generality: Firm Strategies When Intermediate Markets Work

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**Abstract.** This paper studies the relationship between two decisions shaping the organizational configuration of a firm: whether to make the upstream resources more general and deployable to more markets (versus keeping them tailored to a few markets) and whether to trade with downstream firms as an upstream supplier of intermediate products and services (versus directly entering downstream markets). Although the literature has looked at these two decisions separately, we argue that they depend on each other. This has the important implication that they can generate organizational complementarities, inducing firms to implement them jointly. We are motivated in particular by the observation that an increasing number of firms invest in general upstream resources and exploit them as upstream suppliers of intermediate services or products—a strategy that we refer to as *specialization in generality*. Interestingly, prior literature has mostly highlighted the use of general upstream resources to enter new downstream markets. We identify the supply and demand conditions under which specialization in generality is instead more likely to emerge: lack of prior downstream assets on the supply side and a roughly equal distribution of buyers across intermediate markets (a "broad" demand) on the demand side. We test our predictions using a sample of firms in the U.S. laser industry between 1993 and 2001. A regulatory shock that increases the value of trading relative to downstream entry provides the setting for a quasi-natural experiment, which corroborates our theoretical predictions.



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**Keywords:** technology generality • intermediate markets • technology trading • downstream entry

## Introduction

Upstream resources, such as technological knowledge, are the essence of a firm's opportunity set. These resources are typically scale-free and as such generate "excess" capacity that can be used at zero or low cost in multiple businesses (Levinthal and Wu 2010), extending "the productive possibilities that" the firm's managers "see and take advantage of" (Penrose 1959, p. 28). However, not all upstream resources are equally deployable across diverse settings. Some are specific to certain applications, and others are more easily reconfigured for alternative uses, such that they produce higher excess capacity potentially deployable in multiple businesses (Helfat and Eisenhardt 2004). This characteristic is referred to as the generality, general-purpose nature (Bresnahan and Trajtenberg 1995), or fungibility (e.g., Kim and Bettis 2014) of an upstream resource.

A leading argument in the resource-based view theory of entry and diversification is that entry into new *downstream* markets is the dominant option for taking advantage of a general upstream resource stock (Penrose 1959, Teece 1980, Montgomery and Wernerfelt 1988). However, an emergent literature in economics and organizational theory emphasizes the increasing importance of vertical disintegration and the emergence of *intermediate* markets, whereby upstream suppliers provide intermediate products and services to downstream firms (e.g., Baldwin and Clark 2000, Arora et al. 2001, Jacobides and Winter 2005, Kapoor and Adner 2012, Conti et al. 2013, Dushnitsky and Klueter 2017, Moeen and Agarwal 2017).

The existence of intermediate markets naturally expands the options for using a general upstream resource stock. General resources could, in fact, be exploited not only via direct entry into new downstream markets, but also via trading in the corresponding intermediate markets. The presence of intermediate markets also changes the incentives to invest in the generality of the upstream resource stock. Absent intermediate markets, only those few firms that control the costly assets for entering and operating downstream will find investing in the generality of upstream resources attractive (Nelson 1959). However, when trading in intermediate markets is a viable option, investment in a general upstream resource stock might appeal to a larger pool of firms, including those interested in operating as upstream suppliers only (Bresnahan and Gambardella 1998).

Based on these considerations, we maintain that two decisions are *endogenous* to each other and, therefore, *jointly* taken by firms: whether (1) to invest (versus not invest) in general upstream resources and (2) to trade in intermediate markets (versus directly entering downstream). In doing so, we depart from literature that takes as exogenous either the level of upstream resource generality (e.g., Penrose 1959) or the exploitation mode of upstream resources, whether via entry (e.g., Nelson 1959) or trading (Bresnahan and Gambardella 1998). We build on the intuition that some supply-and-demand conditions generate complementarity between the activities of investing in general upstream resources and of trading as upstream suppliers of intermediate products or services. Firms facing such conditions will likely undertake both these activities together (Milgrom and Roberts 1990), pursuing a strategy that we refer to as *specialization in generality*.[1]

On the supply side, the complementarity between investing in generality (versus not investing) and trading (versus entering downstream) depends on whether firms own downstream assets and capabilities that are reusable in new downstream markets (Teece 1986). On the demand side, this complementarity depends on the distribution of downstream firms across markets. Downstream firms represent potential buyers of intermediate products and services. Hence, we refer to "broad" demand for intermediate products and services to describe the case of several equally relevant downstream markets, each populated by a similar number of downstream firms. We refer to "deep" demand to describe a situation of few large markets populated by most firms (Bresnahan and Gambardella 1998).

To test our theoretical predictions, we empirically assess how firms that do not have downstream assets and capabilities (versus firms that own them) and firms facing a broader (versus deeper) demand respond to a shock that increases the value of trading in intermediate markets relative to the value of entry in downstream markets. There is evidence for complementarity if, when the value of trading vis-à-vis entry increases, firms are not only more likely to trade, but also more likely to invest in resource generality.

We offer a first empirical test of our theoretical framework based on a sample of firms in the U.S. laser industry between 1993 and 2001, which is an ideal empirical setting because it satisfies some necessary conditions for our theory to be valid. First, the crucial upstream resource in this industry is the technological know-how for producing the laser technology itself. This know-how can be more or less general as connected to laser technologies having a higher or lower number of applications (each linked to a specific downstream market). Second, in the laser industry, specialized and integrated firms coexist with some firms vertically specializing upstream in the production of lasers (standalone intermediate technologies), some firms specializing downstream in the production of laser systems ("ready-to-use" downstream products), and some firms doing both. This implies that, in this context, intermediate markets exist and work smoothly. Such industry conditions are obviously necessary but not sufficient for observing firms' specialization in generality, which is a strategy that individual firms choose on the basis of firm-specific contingencies. As we said, in the current study, we identify two of these contingencies: supply characteristics (lack versus presence of downstream assets) and the demand characteristics (breadth versus depth of demand) the firm is facing.

Finally, during our sample period, an exogenous regulatory shock affecting U.S. firms increased the relative value of trading in intermediate markets versus entering downstream markets (by increasing the cost of the latter activity relative to the former activity). We use this shock to test our hypotheses on the complementarity between investing in the know-how for producing more general lasers (versus not investing) and trading these lasers in intermediate markets (versus entering downstream markets). Our difference-in-difference analysis tests whether firms located in states enacting a regulation—our treatment group—that increases production costs in downstream markets are more likely to specialize in generality than firms in the other states—our control group. We employ both bivariate probit and linear probability models for the four possible strategies defined by the choice of investing versus not investing in general upstream resources on one hand and trading in intermediate markets versus entering downstream markets on the other hand. We find results consistent with our predictions.

Overall, our work offers a theoretical as well as an empirical contribution. From a theoretical point of view, this paper contributes to the organizational research on vertical integration and disintegration (e.g., Jacobides and Winter 2005, Argyres and Zenger 2012), showing how the decision about a firm's vertical scope cannot be isolated from the decision about investment in different types of upstream resources and capabilities. Furthermore, showing that there might be complementarity between these two decisions is important for organizational research scholars who are interested in understanding how a strategy can emerge and persist as a result of complementarity between organizational activities (e.g., Thompson 1967, Galbraith 1973, Milgrom and Roberts 1990). In this respect, this paper emphasizes two conditions determining whether investment in general resources is exploited via vertical integration or via upstream vertical specialization. The corresponding different strategies have not been systematically studied by prior research. Finally, from an empirical point of view, the realization that two activities are jointly chosen by firms (and so depend on each other) suggests the importance of overcoming the natural estimation bias that arises by considering either the former or the latter activity as exogenous. For instance, studies analyzing firm entry in a new market as a function of the generality of the firm resource stock should adopt an appropriate identification strategy (e.g., instrumental variables) to obtain reliable estimates.

## Specialization in Generality as a Distinct Firm Strategy

General upstream resources generate an impetus toward the division of labor and vertical disintegration in the economy (Rosenberg 1982). Indeed, such general resources generate services and products used by a wide variety of downstream firms in different industries, which fosters the emergence of a class of companies investing in general upstream resources and trading in intermediate markets (Bresnahan and Gambardella 1998). We define the strategy pursued by such companies as specialization in generality (see also Conti et al. 2019).

Specialization in generality has not been explicitly recognized as a strategy by extant research. For instance, the innovation literature has usually considered firms' decision to trade in intermediate markets for technology and their decision to invest in technology generality as independent and, as a result, has investigated them separately. A first stream of literature has focused only on firms' decision to trade resources in intermediate markets versus entering downstream. The gist of this research is that this decision should be taken based on firms' comparative strength. Hence, some firms (namely the small and entrepreneurial ones) are better off specializing in the production of technologies and trading them in intermediate markets. Other firms (namely the large and established ones) should buy technologies in intermediate markets and embed such technologies into downstream products (e.g., Teece 1986, Arora et al. 2001, Gans and Stern 2003).

A second stream of literature has focused only on firms' investment in general technological resources (called general-purpose technologies or GPTs). Most of this research has taken a social-welfare perspective and investigated the supply or demand configurations that determine a socially optimal investment in GPTs (e.g., Bresnahan and Trajtenberg 1995, Bresnahan and Gambardella 1998). However, research in this stream has not considered the individual firm perspective. It has, therefore, overlooked the reason why firms invest in general technology in the first place: either for trading in intermediate markets or for entering downstream. Some attempts to link these two literature streams have been made. For instance, both Gambardella and McGahan 2010 and Gambardella and Giarratana 2013 argue that general technological resources represent a great opportunity for small and young firms aimed at trading in intermediate markets. Yet such work has not considered the interdependence between resource generality and the decision to use such generality via trading or entry.

The interdependence between firms' resources and vertical scope has been studied by a research stream within the organizational and strategy literature (e.g., Jacobides and Winter 2005, Argyres and Zenger 2012). Contributions in this area, for instance, have elaborated on the relationship between the superiority of resources possessed by a firm and its vertical scope (Jacobides and Winter 2005). Or they have focused on the unique complementarity between a focal resource and the bundle of resources already possessed by firms as the core force leading to vertical integration (Argyres and Zenger 2012). However, these studies have neglected the generality of a firm's resource stock as a factor determining firms' vertical scope beyond the firms' resource-stock superiority (Jacobides and Winter 2005) or internal complementarity (Argyres and Zenger 2012). Even more importantly, these works have considered firms' extant resource stock as exogenous, at least in the short term, rather than the outcome itself of a strategic choice.

However, whether to invest (or not) in upstream resource generality and whether to trade the services or products deriving from these resources in intermediate markets (versus use them to enter downstream) are endogenous and interrelated choices, generating potential complementarities. As such, they are likely to be jointly taken by firms as part of a cohesive strategy. The strategy this paper focuses on, specialization in generality, emerges when firms simultaneously choose to invest in upstream resource generality and to trade in intermediate markets because there is complementarity between the two activities. Several cases of this strategy can be identified. For instance, the most valuable resource that IDEO—a leading design company known for pioneering a new business model—has invested in is the overall procedural knowledge for designing new ideas. This knowledge was developed to be extremely general, such that it could lead to developing products in multiple downstream market domains, such as electronics, robotics, and apparel. However, IDEO has not entered these downstream markets. Doing so would have required downstream assets and capabilities that are costly and time-consuming to develop, generating considerable diseconomies of scope for IDEO, which began as a small company with no downstream assets or capabilities. By taking advantage of corporate downsizing in the 1990s and the creation of "markets for designing," IDEO traded in intermediate markets the services coming from its procedural and general knowledge, offering design services to several companies operating in several downstream markets (such as Apple, AT&T, Samsung, Philips, Amtrak, Steelcase, Baxter International, and NEC Corporation).

Similarly, Echelon, an industrial automation company, developed technological knowledge about a universal automated control system (LonWorks) with applications in sectors as diverse as elevators, manufacturing processes, cars, and utilities (Thoma 2009). Because of the high costs of entering and operating in these downstream markets, the company chose not to enter any of them, focusing instead on increasing the generality of its controller and expanding its span of applications to trade its product in intermediate markets (Gambardella and McGahan 2010).

Even the transformation of IBM from a mainframe-computer producer to a service-based firm, offering its general knowledge to other companies operating in multiple businesses, might be seen as an example of our specialization-in-generality strategy. IBM operated in downstream markets in the early 1990s. However, the rise of both UNIX (the open system environment developed by Sun and HP) and the personal computer challenged IBM's downstream position in mainframes (Christensen 1997, Bresnahan et al. 2012, Gans 2016), rendering the company's downstream assets and capabilities obsolete. IBM responded to this shock by simultaneously investing in more general upstream resource capabilities (reinforcing its upstream IT-based capability to solve complex business problems in different contexts) and selling the services deriving from this general capability in intermediate markets to firms operating in different downstream sectors (Rothaermel et al. 2016). As Louis Gerstner (2002, p. 123), the CEO who engineered this transformation between 1993 and 2002, puts it, "We decided to stake the company's future on a totally different view of the industry." This totally different view could be considered an instance of specialization in generality.

Whereas these companies operate in highly innovative industries, the choice about whether to specialize in generality (to invest in general resources and trade in intermediate markets) is also faced by companies in more traditional sectors. Consider the steel industry. There are different types of steel, having unique physical, chemical, and environmental properties, which present different degrees of generality. For example, stainless steels are usually general in that they can be used in household hardware, surgical instruments, automotive, aerospace, and construction; maraging steels or weathering steels are instead much less general as they are mainly used in aerospace and architecture, respectively. In this context, some steel producers, such as Acerinox, have decided to invest exclusively in the knowledge and assets needed to produce and trade the former (more general) versus the latter steel types; in other words, they have specialized in generality.

However, investment in general resources is not always associated with upstream vertical specialization and trading. Rather, some companies see generality as an opportunity to enter multiple downstream markets, consistent with the classical view of general resources as an option for downstream entry and diversification (e.g., Penrose 1959). For example, steel firms such as ArcelorMittal and Nucor have utilized their knowledge in general steel production to invest in downstream operations, such as building and construction (ArcelorMittal 2009). Similarly, in a different setting, 3M has used its general technological knowledge about adhesive technologies to vertically integrate into some industries in which those adhesive technologies are applicable, such as the home care and cleaning, home improvement, home office and school supplies, and personal healthcare sectors.

Thus, the goal of our paper is to understand the conditions under which companies invest in general upstream resources and exploit such generality not to enter new downstream markets, but rather to trade the resulting services or products in intermediate markets. In other words, we aim to identify the conditions that are conducive to complementarity between investment in the generality of upstream resources and vertical specialization via trading in intermediate markets (rather than between investment in upstream resource generality and entry into new downstream markets). This approach underscores that our paper claims not that specialization in generality is a dominant strategy, but rather that, under certain conditions, investing in general upstream resources and trading in intermediate markets are complementary choices. Under these conditions, firms will then specialize in generality.

## Theoretical Development

Consider a firm that faces an opportunity to tap into some markets and is considering how to exploit this opportunity. The most obvious decision such a firm

**Table 1.** Typology of Strategies and Payoffs When Intermediate Markets Operate Efficiently

| | *Trading* = 0 | *Trading* = 1 |
|---|---|---|
| *Investment in generality* = 0 | $\Pi(0,0) = \Pi^{E}$ | $\Pi(0,1) = \Pi^{T}$ |
| *Investment in generality* = 1 | $\Pi(1,0) = \Pi^{EG}$ | $\Pi(1,1) = \Pi^{TG}$ |

should make is whether to exploit these markets by entering downstream or by trading in the corresponding intermediate markets. However, to tap into a larger number of markets, such a firm might also decide to expand the generality of its upstream resource stock by investing in a scale-free general resource, whose application in one specific market would not preclude in any way its simultaneous application in the other markets. This characteristic could make investing in a unique scale-free general resource—applicable to several markets—more convenient than investing in multiple market-specific resources (Levinthal and Wu 2010).

*Potential* applicability of a general upstream resource to several markets does not imply *actual* monetization in those markets, though. Actual monetization requires commercially exploiting these resources (by trading in intermediate markets or entering downstream markets). This makes the decision about whether to invest or not in more general upstream resources interdependent with the decision about how to commercially exploit these resources. Hence, the two activities on which this firm must make *simultaneous* decisions—possibly generating complementarities—are (1) whether to invest (versus not invest) to increase the generality of its upstream resource stock[2] and (2) whether to sell the intermediate products or services deriving from these upstream resources to downstream firms (versus using such resources to enter into downstream markets themselves). This framework generates a typology of four possible firm strategies, each resulting from a specific combination of the two decisions and generating a peculiar payoff (Table 1).

Two considerations are important in developing this typology and understanding the payoffs to firms from the four strategies. First, it is plausible to assume that, when intermediate markets exist, the natural alternative to downstream entry into a new market is to trade as a supplier in the corresponding intermediate market rather than pure no entry.[3] Indeed, when intermediate markets work smoothly, trading in these markets is generally valuable because it does not require substantial investments in complementary assets and capabilities (Arora et al. 2001). In this sense, the zero-return option of not entering is dominated by trading, and it can safely be ruled out in our theoretical development.

Second, firms face a trade-off when deciding to invest in general upstream resources because, although these resources tend to be applicable to a higher number of markets, the value they can generate in each specific market is lower than that for a more specialized resource (e.g., Montgomery and Wernerfelt 1988). Although a more general upstream resource is adaptable to a larger number of markets, it is less perfectly tuned to each individual market (e.g., Bresnahan and Gambardella 1998). Therefore, firms take into account that the returns from either trading in intermediate markets or entering downstream markets change according to the degree of upstream resource generality.

In particular, consider how the returns of trading vary according to the generality of the upstream resource stock. Firms might choose to trade while keeping (or even decreasing) the current generality of the upstream resource stock (investment in generality = 0, trading = 1), such that they can only trade in a limited number of intermediate markets. The returns of this strategy are the profits $\Pi^{T}$ obtained by serving a relatively low number of intermediate markets but with an upstream resource stock tailored to each market. Alternatively, firms might specialize in generality (investment in generality = 1, trading = 1). The returns are the profits $\Pi^{TG}$ obtained from trading the services or products deriving from a more general resource stock in a higher number of intermediate markets but at a lower average profitability. Such decrease could be due to the cost of market-specific adjustments required to tailor a more general upstream resource stock to each specific market, which will make the buyer indifferent between buying the services or products provided by a more general versus a more dedicated resource stock. Or it can be determined by the lower price that the seller of the services or products of a more general upstream resource stock should accept—again, to make the buyer indifferent between the services or products provided by a more general versus a more dedicated resource stock.

Similar to the returns from trading, the returns from entry vary with the generality of the upstream resource stock. Firms might enter downstream markets while keeping unaltered (or even decreasing) the generality of their current resource stock (investment in generality = 0, trading = 0). This strategy's payoff corresponds to the profits $\Pi^{E}$ of entering a limited number of markets with a less general upstream resource stock, which, however, raises profitability in each market in which the firm enters. Firms might instead enter multiple downstream markets thanks to investment in upstream resource generality (investment in generality = 1, trading = 0). The payoff from this strategy is equal to the profits $\Pi^{EG}$ obtained by entering a high number of markets with lower returns in each resulting from the higher generality of the upstream resource stock.

Assuming that firms are rational and understand the value of undertaking complementary activities, we observe firms adopting a specialization-in-generality strategy in any circumstance in which the value of investing in greater generality of the upstream resource stock is higher when trading in intermediate markets than when entering downstream markets—that is, whenever $(\Pi^{TG} - \Pi^{T}) \geq (\Pi^{EG} - (\Pi^{E})$.[4] We suggest that whether this inequality holds depends on firms' assets and capabilities (on the supply side) and on specific intermediate demand configurations (on the demand side).

In particular, on the supply side, one factor that affects this inequality is whether firms already possess or not downstream assets and capabilities that can be reused when entering new downstream markets (Teece 1986). This will have an effect on $(\Pi^{EG} - \Pi^{E})$, the incremental return of entering downstream by investing in upstream resource generality. To generate value downstream, firm upstream resources (e.g., technological knowledge) need to be combined with downstream assets and capabilities (e.g., production, marketing, and distribution) that cannot be acquired overnight (Moeen and Agarwal 2017). For firms entering downstream markets for the first time, handling the complexity associated with entry in multiple markets at once is particularly difficult and costly (Qian et al. 2012). Because of these diseconomies of scope, firms with no prior downstream assets have no incentive to invest in generality for entering multiple downstream markets: for them, the difference between $\Pi^{EG}$ and $\Pi^{E}$ is likely to be low or even negative. By contrast, firms that already have downstream assets and capabilities are more likely to enjoy economies of scope when entering additional markets by investing in general upstream resources. Like the established corporation described by Penrose (1959) and Nelson (1959), these firms can reuse their extant downstream assets and capabilities in new downstream markets to the extent that such assets are related to the business in which firms aims to enter. By virtue of these downstream economies of scope, for firms with prior assets, investing in generality to enter multiple markets is a valuable option as the difference $(\Pi^{EG} - \Pi^{E})$ is likely to be positive and high.

At the same time, the presence or lack of downstream assets is unlikely to affect the value of trading in intermediate markets and so is unlikely to have any effect on $(\Pi^{TG} - \Pi^{T})$. If anything, $(\Pi^{TG} - \Pi^{T})$ might be higher for firms that so far have been exclusively dedicated to trading in intermediate markets than for firms already active in downstream markets. The former companies, compared with the latter, are possibly better able to identify and adapt to the needs of buyers in different intermediate markets. Hence, companies with no downstream capabilities might have incentive to invest in generality to trade in multiple different intermediate markets. By contrast, firms that have been already operating downstream might not be able to understand and address the needs of buyers in different intermediate markets because of their focus on final customers. For these companies, investing in generality for trading might, therefore, be worthless.

To sum up, our arguments suggest that for firms without prior downstream assets, $(\Pi^{EG} - \Pi^{E})$ is likely to be lower than for firms with prior downstream assets although $(\Pi^{TG} - \Pi^{T})$ is likely to be the same and, if anything, higher. Because the condition for complementarity between investing in generality and trading is for $(\Pi^{TG} - \Pi^{T})$ to be higher than $(\Pi^{EG} - \Pi^{E})$, our first hypothesis is as follows:

**Hypothesis 1.** *Firms with no prior downstream assets are more likely to exhibit complementarity between investing (versus not investing) in general upstream resources and trading in intermediate markets (versus entering downstream markets). Therefore, these firms are more likely to specialize in generality.*

Any firm, based on its resources and capabilities, can reach a certain portfolio of downstream markets via either entry or trading. The downstream firms populating these markets constitute rivals when the focal firm operates downstream or potential buyers when the focal firm trades in intermediate markets.

In particular, the focal firm faces a broad intermediate demand when the markets it faces are populated by a similar number of firms and so are equally relevant or a deep intermediate demand when it faces a few large markets in which most buyers concentrate (Bresnahan and Gambardella 1998). However, the configuration of the intermediate demand is not stable. Rather, it usually changes, for instance, because downstream firms move across markets to tap into new opportunities. These changes have natural implications for the focal firm's strategic choices. The question is, then, how *a change in demand breadth* (versus depth) affects both $(\Pi^{TG} - \Pi^{T})$ and $(\Pi^{EG} - \Pi^{E})$. We argue that this specialization in generality is more likely to occur for firms facing a broader (versus deeper) demand in intermediate markets because, following an increase in demand breadth, $(\Pi^{TG} - \Pi^{T})$ is likely to be higher than $(\Pi^{EG} - \Pi^{E})$.

We argue that an increase in the breadth versus depth of intermediate demand is likely to have a positive influence on $(\Pi^{TG} - \Pi^{T})$, the incremental profits obtained by investing in generality for trading. An increase in breadth of the intermediate demand corresponds to a situation in which downstream firms (the potential buyers of intermediate products or services) tend to spread evenly across multiple markets, which are, therefore, becoming similar in size. In this situation, investing in generality allows addressing the diverse needs of buyers operating in different but equally relevant markets. A decrease in demand breadth corresponds to the opposite situation in which downstream firms get more concentrated in a few relevant markets. In this situation, an investment in generality for trading would be less convenient. It would allow reaching a higher number of intermediate markets but in a context in which most of these markets are becoming less populated by potential buyers and so less relevant. Moreover, the wider reach associated with higher generality would come at the expense of a lower fit with the few most populated and valuable markets. Thus, $(\Pi^{TG} - \Pi^{T})$ is likely to increase when demand becomes broader.

An increase in the breadth of intermediate demand is likely to have a similar but less marked effect on $(\Pi^{EG} - \Pi^{E})$, the incremental profits obtained by investing in generality for entering. When downstream firms tend to equally spread across markets (and so intermediate demand becomes broader), all downstream markets are likely to become similarly attractive from an entrant's point of view. So investing in generality is useful to entering as many of those equally relevant markets as possible. By contrast, when downstream firms tend to move into a few markets (and so intermediate demand becomes deeper), these few markets are likely the most attractive for entry. It, therefore, makes sense to keep the upstream resources tailored to those few most valuable markets. Thus, when downstream firms become more spread across markets and the intermediate demand becomes broader, $(\Pi^{EG} - \Pi^{E})$ increases. Yet this increase is likely to be more limited than the corresponding increase in $(\Pi^{TG} - \Pi^{T})$. Different from trading, entry in any new market implies investing in some market-specific downstream complementary assets. The costs associated with such investment restrict the possibility of actually entering into all markets potentially reached by a general upstream resource stock.[5]

To sum up, when downstream firms spread across several markets and, thus, the intermediate demand becomes broader, investing in generality might be convenient for both firms trading and those entering downstream. However, the returns from entry in multiple downstream markets are bounded by the cost of investing in market-specific downstream assets, whereas the returns from trading in multiple intermediate markets are not. Hence, with greater demand breadth, $(\Pi^{TG} - \Pi^{T})$ increases more than $(\Pi^{EG} - \Pi^{E})$. This leads us to hypothesize the following:

**Hypothesis 2.** *Firms facing an increase in the breadth of demand in intermediate markets are more likely to exhibit complementarity between investing (versus not investing) in general upstream resources and trading in intermediate markets (versus entering downstream markets). Therefore, these firms are more likely to specialize in generality.*

# Data and Empirics

## Empirical Setting

Our theory is potentially applicable to industries in which the following key conditions hold: (1) there are scale-free upstream resources (e.g., technological knowledge) that firms can invest in, possibly to increase the generality of their upstream resource stock; (2) there is the possibility of exploiting new markets; and (3) such new markets can be exploited either by direct entry or by trading with firms already active in those downstream markets because the corresponding intermediate markets operate efficiently. These industry conditions are necessary but not sufficient for a firm adopting a specialization-in-generality strategy in that such a choice is firm-specific and—as we explained in the theoretical part—likely depends on firm-specific contingencies, including the lack of downstream assets and the intermediate demand structure that a firm faces. Hence, to offer a first test of our theory—and to verify whether the firm-specific conditions we have identified actually lead firms to specialize in generality—we have considered an industry in which the aforementioned conditions hold: the laser industry.

We build a novel longitudinal data set containing information about a sample of U.S. firms active in the laser manufacturing industry over a nine-year period (1993–2001) that we complement with interviews of managers and industry experts. The term "laser"—light amplification by stimulated emission of radiation—refers to devices that emit light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. Based on theoretical work by Charles Hard Townes and Arthur Leonard Schawlow, the first laser was built in 1960 by Theodore H. Maiman at Hughes Laboratories (Hecht 2011).

All laser technologies comprise a set of standard components that include a lasing material (the gain medium), a pump source, and a laser cavity. The atoms of a material such as crystal, glass, liquid, dye, or gas are excited by the pump source to a semistable state so that lasing can be achieved. Usually, the pump source is another light source (e.g., a laser diode or flash lamp) or an electric discharge. The light emitted by an atom interacts with the excited atoms nearby as it drops back to the ground state. Identical pairs of photons are released in a process called stimulated emission. The process is further duplicated while the photons bounce back and forth in the cavity from mirrors or other reflective cavity structures. In this way, the light emission is further amplified and beams of light at specific frequencies are produced (Hecht 2011).

Lasers differ in power and in the wavelength of light they emit, which has implications for their applications (and, thus, markets in which they can be applied). These include biomedical/medical (e.g., medical imaging, dermatology), information processing (e.g., scanning, optical disk reading), telecommunications (e.g., data transmission, pulse generation), military (e.g., target designation), and industrial (e.g., cutting, welding, marking) applications.

As noted, the laser industry is an ideal setting to test our theory for several reasons. First, the industry has a clear vertical structure: upstream technological knowledge can be used to produce either lasers (intermediate components) or ready-to-use laser systems (downstream products). In fact, the laser industry has been characterized since its inception by a significant division of labor between firms specializing in producing laser technologies and firms producing laser systems by embedding the laser technologies into final products. This specialization was enhanced by the inherent general-purpose nature of the laser technology, which can be applied to several industries. This is consistent with Klepper (1997), who considers laser-industry patterns using data from the annual Buyers' Guide of Laser Focus for the period 1966–1994—the year 1966 roughly corresponds to the origins of the laser industry because the first laser was built in 1960 (Hecht 2011). Despite the specialization being marked, it is not complete: specialized and integrated firms coexist with some firms vertically specializing upstream in the production of lasers, some firms specializing downstream in the production of laser systems, and some firms doing both. This industry is, therefore, an ideal empirical setting for studying the conditions that lead firms to use general resources just for trading versus entering downstream.

Second, technological knowledge is a scale-free resource, which, once acquired, can be applied in multiple contexts at the same time. Firms vary in the generality of their upstream technological knowledge. Some firms have more general upstream technological knowledge (and, thus, produce lasers for use in a large number of laser systems for different markets). Others have less general upstream technological knowledge (and, thus, produce lasers targeted to specific downstream applications and related downstream markets).

Third, in the period studied, the applications of lasers expanded considerably in new downstream markets, such that firms in the laser industry faced precisely the choice of whether to enter these new markets by direct entry or by trading in the corresponding intermediate markets. Interestingly for our analysis, the directory we use for data collection is meant to be an outlet for firms to advertise their lasers and/or laser systems. Hence, by construction, if a firm is reported in the directory, it is exploiting new markets either by trading as an upstream supplier of intermediate products (lasers) or by operating downstream (as a seller of laser systems)—consistent with our theoretical framework.

Finally, as we explain in the next section, in the period considered, we can exploit an exogenous regulatory shock affecting the relative value of trading in intermediate markets versus entering downstream markets. In so doing, we follow Brynjolfsson and Milgrom's (2012, p. 58) suggestion that "legal and institutional changes are often ideal candidates to … [estimate complementarities in organizations] … because a change in a law or government policy can provide a precise date and specific geographic area or jurisdiction for the change to occur."

To define the laser industry and its boundaries, we rely on the Photonics directory by Laurin Publishing, which lists all companies active in the laser context. We select all U.S. companies listed in the directory as active in the laser industry between 1993 and 2001. The sample includes private and public firms; thus, it is generally representative of the different categories of firms active in high-technology contexts. It also includes firms that enter or exit the industry during the period, limiting any survival bias. We extract information on their characteristics (e.g., independence status, size, age, location) for each year. We use the same directory to collect information on the laser types that each firm is able to produce as well as on firm entry and trading. We pick our time window for empirical reasons: First, during the period 1993–2001 many U.S. states enacted laser safety regulations that increased the costs of operating in downstream markets, and we use those enactments as exogenous shocks. Second, during this period, the number of possible laser applications increased considerably because of the dramatic diffusion of the internet.

We also match the data from the directory with firms' patent data. To obtain patent data, we use firms' names and locations and match them to patent assignees' names in the National Bureau of Economic Research (NBER) patents database. The NBER data set provides patent data consolidated at the parent-portfolio level for public firms. For private firms, we use the D&B *Who Owns Whom* database to build a list of their worldwide subsidiaries for each year of the study. We match this list with the NBER data set to obtain the list of patents filed by each of the firm's subsidiaries and consolidate the list of patents at the parent-firm level. This procedure yields a sample of 204 firms corresponding to 783 firm-year observations.[6]

## Methodology

Testing our theory is not straightforward. The first and most obvious problem to address is that we cannot just take the correlation between investment in more general upstream resources and trading. It is well known that positive correlation is a necessary but not sufficient condition for complementarity (e.g., Bresnahan et al. 2002). To address this problem, we need a (plausibly exogenous) shock that affects either the value of investing in generality versus not investing or the relative value of trading in intermediate markets versus entering downstream markets, and we ought to observe how this shock affects the other choice. Indeed, when a set of activities complement each other, if the marginal returns associated with some activities increase (decrease), it will be optimal to increase (decrease) the level of all the activities (Milgrom and Roberts 1990). In the case of two discrete and complementary activities, we will naturally observe that a shock that makes one of the two activities more versus less convenient will lead firms to find the other activity more or less attractive also.

In our empirical analysis, we employ a shock that raises the costs of operating downstream and that, therefore, increases the value of trading in intermediate markets relative to the value of entering downstream markets. This implies that, as a direct response to this shock, firms will increase their trading in intermediate markets rather than enter downstream markets. Moreover, we expect that those firms for which trading in intermediate markets is complementary to investment in upstream resource generality (firms with no downstream assets and firms facing an equally spread distribution of potential buyers in intermediate markets) will also increase their investment in upstream resource generality compared with the counterfactual situation in which the downstream costs stay constant.

We identify an exogenous increase in downstream production costs by taking advantage of the fact that in the period under investigation, some U.S. states enacted laser safety regulations that increased the costs of downstream operations by establishing new rules that laser system manufacturers (firms operating downstream) must follow to reduce the risk of accidents. The laser industry is heavily regulated because laser technologies present potential hazards for individual users. In the United States, safety requirements are the product of federal regulatory agencies and some voluntary standards: the Laser Product Performance Standard of the Center for Devices and Radiological Health, the American National Standards Institute, the Occupational Safety and Health Administration, and the Federal Aviation Administration. In addition to the federal and industry regulations, in the 1990s some U.S. states enacted local regulations to further increase laser safety controls (Rockwell and Parkinson 1999).

The introduction of these state regulations increases the costs of producing downstream products but not (or less so) the costs of producing laser technologies not immediately usable without being embedded in a product. Indeed, it adds costly activities that only downstream firms producing laser systems (products directly usable by final customers and, thus, potentially more dangerous) in the state must comply with. For example, state regulations impose specific obligations for state firms manufacturing laser systems, including registration requirements and the payment of a registration fee (e.g., Massachusetts Radiation Control Program, sections 121.015 and 121.016; Illinois Laser System Act, section 30). They also oblige firms manufacturing laser systems to promptly report any injury to employees in the course of use, handling, operation, manufacture, or discharge of a laser system (e.g., Illinois Laser System Act, section 40). Finally, state laser system manufacturers are regularly inspected by state officers to ensure compliance with such state regulations (e.g., Massachusetts Radiation Control Program, section 121.024; Illinois Laser System Act, section 30).

Similar requirements targeted at products embedding laser technologies are contained in the other state regulations, also in line with the information we received from the compliance specialist we interviewed. They clearly imply a cost for downstream companies producing laser systems within states enacting laser regulations. In general, an expert in laser compliance that we interviewed confirmed: "The State requirements … can be problematic and they can produce added costs … they come at it from a safety of use standpoint. … The State monitors very carefully, for the safety of the patients, that the equipment is compliant, they know where it is, they come and test it now and then, etc" Anonymous Laser Compliance Expert (2015).

Note that the regulations we examined do not contain any specific reference to the generality or the specificity of the technology. Moreover, the rules set by these regulations usually regard all laser applications. However, laser systems designed for some applications that pose greater risk to individual customers (e.g., healthcare applications) are subjected to even more stringent regulations in some states (e.g., Massachusetts Radiation Control Program, section 121.006).

Importantly, whereas the firms operating in this industry sell lasers or laser systems throughout the country or even internationally, they are mostly small to medium-sized firms; hence, they would hardly move their manufacturing from their own area or town because of an unfavorable regulation enactment, which is confirmed by robustness checks we do later in the paper. In the period we considered (1993–2001) the new regulations were introduced by the states of New York (1994), Arizona (1996), Florida (1996), Massachusetts (1997), Illinois (1997), and Texas (1999). Because those regulations are introduced in different years, in our panel, the shock is not a mere chronological threshold. Moreover, accounts of the regulations' enactment suggest that they were exogenous to the economic and political conditions of each state (Rockwell and Parkinson 1999). We also corroborate the exogeneity of our shock in our robustness checks.

We assess the effect of our shock by comparing firms in states that enacted such regulations, our treatment group, with firms in states that did not, our control group. In particular, our treatment is the variable *downstream production cost*, a dummy equal to one for firms operating in a state that introduced the regulation after its enactment and zero otherwise. Because we control for year fixed effects and we introduce state dummies—besides clustering the error at the state level as suggested by Bertrand and Mullainathan (2003)—our approach is a classical diff-in-diff regression, in which the coefficient of *downstream production cost* produces an estimate of the impact of an increase in downstream production costs on the outcome of interest.[7]

In particular, our dependent variable *specialization in generality* is the joint occurrence of two events: (1) the focal firm invests in more general upstream resources, and (2) it trades in intermediate markets (rather than entering downstream markets). Considering again Table 1, our main dependent variable is the strategy that the focal firm pursued in each period of the four possible strategies identified. These strategies are defined by all possible combinations of undertaking (or not) each of the two activities (investment in upstream resource generality and trading in intermediate markets). The most appropriate way to estimate a joint likelihood of undertaking or not two activities is through a bivariate probit; however, as a robustness check, we also use a linear probability model.

To measure whether a firm exploits its resources by trading in intermediate markets rather than entering downstream, we use *trading in intermediate markets*, a dummy equal to one if in year *t* the firm exploits any new market in which laser technology could, in principle, be applied in the focal period (e.g., communication, information processing, industrial, medical, military, miscellaneous) by trading rather than entering. Specifically, the industry directory that we used indicates whether, in each year, each of the firms produces and sells lasers to downstream firms (trades the upstream resource in intermediate markets) versus (also) producing and selling laser systems (the downstream product). Hence, for each of the years in our sample, we gave the variable *trading in intermediate markets* the value one if the directory indicated that the focal firm was selling lasers to downstream firms and zero if the directory indicated instead that the focal firm entered downstream and also began producing and selling a laser system in a new market.[8]

To measure *investment in general upstream resources*, we take advantage of the fact that laser technology has several possible market applications depending on the laser medium.[9] Based on the medium, lasers can be classified in the following categories: alexandrite, ArF, argon-ion, $CO_2$, $CO_2$ TEA, metal vapor, diode, dye, Er: glass, Er:YAG, excimer, HeNe, krypton-ion, Nd:YAG, ruby, thulium, HeCd, KrF, lead salt, Nd:glass, Ti: sapphire, color-center, HF/DF, and holmium YAG. Each category can be used in a broader versus narrower range of applications. For instance, a KrF laser can be applied to industrial drilling but not to applications in dermatology. An Er:glass laser technology, however, is appropriate for use in dermatology but not in laser drilling. A third alternative, the alexandrite laser, can be used for applications in both dermatology and industrial drilling. Therefore, the alexandrite laser is a more general technology than the KrF or the Er:glass lasers. To measure the generality of the firm technology, we first measure the individual laser's degree of generality by calculating the ratio of the number of uses/markets to which that specific laser type can be applied to the total number of applications/markets across all laser types. We then compute the degree of the firm's technology generality in each year by considering the average degree of generality of the lasers in the firm's portfolio. Finally, we measure *investment in general upstream resources* as a dummy equal to one if the firm increases its average laser generality from year *t*–1 to year *t* and zero otherwise.

To test Hypothesis 1, we estimate (through both bivariate probit and linear probability models) the effect on the joint likelihood of investing in general upstream resources and trading in intermediate markets of the interaction between *downstream production cost* and *lack of downstream assets.*

The variable *lack of downstream assets* distinguishes between firms that, when deciding to trade versus enter a new downstream market, do not already own downstream assets and capabilities and firms that do. Therefore, this variable is a dummy equal to one if a firm, before a certain year *t*, was not producing and selling laser systems (the downstream product). Because this firm was not active in downstream markets before year *t*, it had no downstream assets or capabilities. To alleviate any potential endogeneity between the regulatory change and the decision to vertically integrate, we measured this variable by looking at the "status" of the firm in the year immediately before the regulatory change for firms based in states where the regulation is issued and year of entry into the database for firms based in states in which such regulation was never issued.

To test Hypothesis 2, we estimate the effect on the joint likelihood of investing in general upstream resources and trading in intermediate markets of the interaction between *downstream production cost* and *breadth of demand.* The latter variable is calculated by looking at how firms operating in downstream markets are distributed across them for each firm-year. In more detail, for each focal firm in the sample that supplies lasers, we consider the markets in which its lasers are potentially applicable, and we calculate the variable *breadth of demand* as one minus the Herfindhal index of concentration of downstream buyers across these markets. Note that downstream firms constitute potential buyers for the focal firms' lasers. The value of *breadth of demand* is low when potential downstream buyers of the focal firms are mostly concentrated in a few markets; it is high when potential downstream buyers are instead equally spread across markets.

Moreover, in all specifications, we include as an additional control variable, *number of lasers,* which controls for the number of different types of lasers produced by the firm. We also control for the *number of patents* (in hundreds) applied for and granted to the firm in the five years before the focal year, *firm size* (number of employees, in hundreds), and *firm age.*

# Results

## Main Results

Table 2 shows some descriptive statistics for the population of firms in the laser industry between 1993 and 2001. During this period, about 44% of firms do not have downstream assets (as they are only laser suppliers), and 56% do, also producing and selling final laser systems for downstream markets. On average, each laser supplier sells two types of lasers and employs about 300 people even though the distribution of employees is skewed. As noted, six states enacted new regulations that increase the costs of operating downstream; in our sample, this enactment affects about 20% of our firm-year observations. Moreover, about 7% of the suppliers enter new downstream markets, and almost 16% invest in more general upstream resources during our time window.

We first want to show that our shock is relevant in that it constitutes a relevant increase in downstream production costs, pushing fewer laser firms to enter downstream markets and so reducing the overall number of downstream manufacturers. That is, we want to show that our shock makes entering downstream less convenient than trading in intermediate markets. Therefore, we compute the probabilities that in year *t* a firm operates in intermediate markets selling lasers (measured by the dummy *being in intermediate market*) and in downstream markets selling laser systems (measured by the dummy *being in downstream market*) as a function of whether the firm used to operate in intermediate markets or downstream markets in year *t*–1, the compliance shock, and the interaction between these variables. In doing so, we cover all possible firm types. In fact, in a particular year, a firm can operate only in upstream intermediate markets (*being in intermediate market* = 1, *being in downstream market* = 0), only in downstream markets (*being in intermediate market* = 0, *being in downstream market* = 1), or in both intermediate and downstream markets (*being in intermediate market* = 1, *being in downstream market* = 1), or it can be out of the industry (*being in intermediate market* = 0, *being in downstream market* = 0).

Our bivariate probit in Table 3 and the corresponding marginal effects in Table 4 show that the shock prevents the firms so far operating only in upstream intermediate markets from entering downstream: the probability that an upstream firm integrates downstream decreases by about 5%. To some extent, the change also stops the downstream entry of brand-new companies (firms that were outside the industry earlier) even if the effects are not statistically significant at the conventional levels. All in all, this suggests that the regulatory change determines an increase in production costs that acts mainly as a barrier to entry. Even though it does not induce the exit of firms already operating downstream, the shock lowers the number of downstream producers.

Consistent with the previous results, Table 5 presents the findings of an OLS regression in which the dependent variable is the log of the number of companies selling laser systems in any state, market, and year. After the new regulation, the number of downstream firms in the state affected by the regulation diminishes considerably, by about 15%.

Having assessed the relevance of our shock as an increase in the costs of operating downstream, we can now assess the validity of our theory. According to the results of the seemingly unrelated regression linear probability model in Table 6 and the bivariate probit in Table 7, the increase in downstream production costs encourages trading (Tables 6 and 7, column (2)) and investment in more general upstream resources (Tables 6 and 7, column (1)) even if the latter effect is not significant at the conventional level. Furthermore, the impact of the increase in downstream production costs on both the probability of investing in more general upstream resources and the probability of trading is positive for firms lacking downstream assets (Tables 6 and 7, columns (3) and (4)). It is also positive when buyers are more equally distributed across markets (Tables 6 and 7, columns (5) and (6)).

However, Table 7 provides only the estimates of the effect of our shock on the separate probability of investing in generality on one side and trading on the other. Hypotheses 1 and 2 refer instead to the effect of the shock on the *joint* probability of investing in general upstream resources while trading, which precisely defines the likelihood of adopting a specialization-in-generality strategy. The marginal effects of an increase

**Table 2.** Descriptive Statistics and Pairwise Correlations Between Variables

| Variable | Observations | Mean | Standard deviation | Minimum | Maximum | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. *Investment in general upstream resources* | 783 | 0.157 | 0.364 | 0.000 | 1.000 | 1.000 | | | | | | | | | | | | |
| 2. *Trading in intermediate markets* | 783 | 0.932 | 0.251 | 0.000 | 1.000 | −0.037 | 1.000 | | | | | | | | | | | |
| 3. *Investment in general upstream resources = 1, trading in intermediate markets = 0* | 783 | 0.014 | 0.118 | 0.000 | 1.000 | 0.277 | −0.443 | 1.000 | | | | | | | | | | |
| 4. *Investment in general upstream resources = 1, trading in intermediate markets = 1* | 783 | 0.143 | 0.350 | 0.000 | 1.000 | 0.946 | 0.110 | −0.049 | 1.000 | | | | | | | | | |
| 5. *Investment in general upstream resources = 0, trading in intermediate markets = 1* | 783 | 0.789 | 0.408 | 0.000 | 1.000 | −0.836 | 0.522 | −0.231 | −0.791 | 1.000 | | | | | | | | |
| 6. *Investment in general upstream resources = 0, trading in intermediate markets = 0* | 783 | 0.054 | 0.225 | 0.000 | 1.000 | −0.103 | −0.884 | −0.028 | −0.097 | −0.461 | 1.000 | | | | | | | |
| 7. *Downstream production cost* | 783 | 0.202 | 0.402 | 0.000 | 1.000 | 0.037 | 0.072 | −0.033 | 0.049 | 0.002 | −0.063 | 1.000 | | | | | | |
| 8. *Number of lasers* | 783 | 1.927 | 1.514 | 1.000 | 12.000 | 0.169 | −0.110 | 0.149 | 0.126 | −0.176 | 0.045 | −0.058 | 1.000 | | | | | |
| 9. *Number of patents* | 783 | 0.461 | 3.383 | 0 | 49.419 | 0.058 | 0.030 | −0.010 | 0.064 | −0.036 | −0.029 | −0.066 | −0.057 | 1.000 | | | | |
| 10. *Firm size* | 783 | 3.366 | 13.796 | 0.01 | 217.6 | 0.164 | −0.013 | 0.062 | 0.149 | −0.136 | −0.018 | −0.032 | 0.326 | 0.264 | 1.000 | | | |
| 11. *Firm age* | 783 | 20.789 | 18.831 | 2.000 | 134.000 | 0.031 | 0.006 | 0.056 | 0.013 | −0.007 | −0.036 | 0.038 | 0.094 | 0.195 | 0.363 | 1.000 | | |
| 12. *Breadth of demand* | 783 | 0.690 | 0.120 | 0.000 | 0.749 | 0.126 | −0.042 | 0.038 | 0.118 | −0.127 | 0.026 | 0.088 | 0.148 | 0.017 | 0.029 | 0.095 | 1.000 | |
| 13. *Lack of downstream assets* | 783 | 0.439 | 0.497 | 0.000 | 1.000 | 0.085 | 0.064 | −0.040 | 0.101 | −0.047 | −0.051 | 0.017 | −0.138 | 0.019 | −0.034 | 0.042 | −0.002 | 1.000 |

**Table 3.** Impact of Increased Downstream Production Costs on the Probability of Being in Intermediate and/or Downstream Markets: Bivariate Probit Estimation

| Variables | (1)<br>*Being in intermediate markets (t)* | (2)<br>*Being in downstream markets (t)* |
|---|---|---|
| *Downstream production cost (t–1)* | 0.026 | –0.072 |
| | (0.132) | (0.102) |
| *Downstream production cost (t–1) × being in downstream markets (t–1)* | 0.072 | 0.350*** |
| | (0.153) | (0.125) |
| *Downstream production cost (t–1) × being in intermediate markets (t–1)* | –0.016 | –0.194 |
| | (0.176) | (0.146) |
| *Being in downstream markets (t–1)* | –0.362*** | 1.770*** |
| | (0.066) | (0.047) |
| *Being in intermediate markets (t–1)* | 2.507*** | –0.090 |
| | (0.073) | (0.066) |
| Year fixed effects | Included | Included |
| State fixed effects | Included | Included |
| Observations | 5,533 | 5,533 |

*Note.* Robust standard errors clustered by state in parentheses.
***$p < 0.01$

in downstream production costs on the likelihood of pursuing a specialization-in-generality strategy—as well as on the likelihood of adopting the other strategies defined in Table 1—are shown in Table 8. The increase in downstream production costs raises the probability of specializing in generality by a technology supplier by about 3%. However, the effect is not very pronounced either economically or statistically ($p = 0.35$; confidence interval [CI]: –0.036–0.1). This is because, as noted in the theoretical section, the complementarity between investing in general upstream resource stock and trading in intermediate markets depends on the supply and demand conditions that a company faces.

In line with Hypothesis 1, the effect of the shock on the probability of specializing in generality (increasing upstream resource generality and trading in intermediate markets) is much larger for firms with no downstream assets than for firms that do already have some downstream assets. For firms with no downstream assets, this probability increases by more than 10 percentage points—passing from 0.14, which is the baseline probability of adopting a specialization-in-generality strategy, to 0.25—and is measured more precisely ($p = 0.059$; CI: –0.004 to 0.214), whereas the probability for firms that do have downstream assets does not change. Our results also imply that more than half the firms lacking downstream assets would enter the market without the increase in downstream production costs: the probability of choosing *investment in general upstream resources* = 0 and *trading in intermediate markets* = 0 decreases by about 4% and the probability of choosing *investment in general upstream resources* = 1 and *trading in intermediate markets* = 0 decreases by about 1%.

Similarly, as suggested by Hypothesis 2, the likelihood of specializing in generality increases when buyers' distribution across markets is more balanced. In particular, when the variable *breadth of demand* is at the 75th percentile (approximately equal to 0.735, corresponding to a more homogenous distribution of buyers across markets), the probability that a firm, after the increase in downstream costs, pursues a specialization-in-generality strategy increases by about 13 percentage points ($p = 0.001$; CI: 0.056–0.20)—passing from 0.14 to about 0.27. By contrast, when the variable *breadth of demand* is at the 25th percentile (approximately equal to 0.711, corresponding to a more skewed market distribution in our setting), the probability decreases by about 8.5 percentage points ($p = 0.003$; CI: –0.141 to –0.029).

To better understand these results—and to investigate possible interactions between market and supply conditions—we report graphically the effect of an increase in downstream production costs on the probability of specializing in generality (Figure 1) for different levels of demand breadth and for firms with and without downstream assets. Figure 1 shows that not only firms without downstream assets, but also firms with downstream assets seem to choose a strategy of "generality and trading" as the breadth of demand across markets increases. This suggests that if the opportunity to profitably sell resources to many markets is available, a specialization-in-generality strategy becomes attractive even for firms with downstream assets.

Further on this point, in additional analyses (available upon request), we investigate which firms, of those having downstream assets, are more likely to specialize in generality in the presence of high costs of downstream production. Interestingly, the results indicate

**Table 4.** Impact of Increased Downstream Production Costs on the Probability of Being in Intermediate and/or in Downstream Markets: Marginal Effect Estimation (Based on the Bivariate Probit Estimation in Table 3)

| | | | On the probability of being, at *t*: | | | Effect size when downstream production cost = 0 | Effect size when downstream production cost = 1 | Difference between marginal effects | Probability > $\chi^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Outside the industry | $U(t-1) = 0$ | $D(t-1) = 0$ | Outside the industry | $U(t) = 0$ | $D(t) = 0$ | 0.825*** | 0.837*** | 0.012 | 0.607 |
| Outside the industry | $U(t-1) = 0$ | $D(t-1) = 0$ | In intermediate markets only | $U(t) = 1$ | $D(t) = 0$ | 0.027*** | 0.03*** | 0.003 | 0.6669 |
| Outside the industry | $U(t-1) = 0$ | $D(t-1) = 0$ | In downstream markets only | $U(t) = 0$ | $D(t) = 1$ | 0.115*** | 0.1*** | –0.015 | 0.4053 |
| Outside the industry | $U(t-1) = 0$ | $D(t-1) = 0$ | In both intermediate and downstream markets | $U(t) = 1$ | $D(t) = 1$ | 0.033*** | 0.032*** | –0.001 | 0.9141 |
| In intermediate markets only | $U(t-1) = 1$ | $D(t-1) = 0$ | Outside the industry | $U(t) = 0$ | $D(t) = 0$ | 0.202*** | 0.202*** | 0.000 | 0.992 |
| In intermediate markets only | $U(t-1) = 1$ | $D(t-1) = 0$ | In intermediate markets only | $U(t) = 1$ | $D(t) = 0$ | 0.669*** | 0.716*** | 0.047 | 0.3158 |
| In intermediate markets only | $U(t-1) = 1$ | $D(t-1) = 0$ | In downstream markets only | $U(t) = 0$ | $D(t) = 1$ | 0.005*** | 0.003*** | –0.002* | 0.0829 |
| In intermediate markets only | $U(t-1) = 1$ | $D(t-1) = 0$ | In both intermediate and downstream markets | $U(t) = 1$ | $D(t) = 1$ | 0.124*** | 0.079*** | –0.045* | 0.057 |
| In downstream markets only | $U(t-1) = 0$ | $D(t-1) = 1$ | Outside the industry | $U(t) = 0$ | $D(t) = 0$ | 0.242*** | 0.166*** | –0.076*** | 0.0093 |
| In downstream markets only | $U(t-1) = 0$ | $D(t-1) = 1$ | In intermediate markets only | $U(t) = 1$ | $D(t) = 0$ | 0.000*** | 0.000** | 0.000 | 0.1489 |
| In downstream markets only | $U(t-1) = 0$ | $D(t-1) = 1$ | In downstream markets only | $U(t) = 0$ | $D(t) = 1$ | 0.729*** | 0.799*** | 0.070** | 0.0173 |
| In downstream markets only | $U(t-1) = 0$ | $D(t-1) = 1$ | In both intermediate and downstream markets | $U(t) = 1$ | $D(t) = 1$ | 0.029*** | 0.035*** | 0.006 | 0.5718 |
| In both intermediate and downstream markets | $U(t-1) = 1$ | $D(t-1) = 1$ | Outside the industry | $U(t) = 0$ | $D(t) = 0$ | 0.162*** | 0.142*** | –0.02 | 0.5573 |
| In both intermediate and downstream markets | $U(t-1) = 1$ | $D(t-1) = 1$ | In intermediate markets only | $U(t) = 1$ | $D(t) = 0$ | 0.109*** | 0.103*** | –0.006 | 0.7676 |
| In both intermediate and downstream markets | $U(t-1) = 1$ | $D(t-1) = 1$ | In downstream markets only | $U(t) = 0$ | $D(t) = 1$ | 0.151*** | 0.146*** | –0.005 | 0.8432 |
| In both intermediate and downstream markets | $U(t-1) = 1$ | $D(t-1) = 1$ | In both intermediate and downstream markets | $U(t) = 1$ | $D(t) = 1$ | 0.577*** | 0.61*** | 0.033 | 0.5739 |

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

**Table 5.** Impact of Increased Downstream Production Costs on the Number of Firms Operating Downstream: Ordinary Least Squares Estimation

| Variables | log Number of downstream firms |
|---|---|
| *Downstream production cost* | –0.154** |
| | (0.057) |
| Market dummies | Included |
| Year fixed effects | Included |
| State fixed effects | Included |
| Observations | 3,330 |
| $R^2$ | 0.887 |

*Note.* Robust standard errors clustered by state in parentheses.
**$p < 0.05$

that firm age and size matter. We find that younger and smaller firms, even those with downstream assets, are more likely to choose a specialization-in-generality strategy. These additional results suggest the intriguing possibility—which could be investigated by future research—that any shock making trading relatively more convenient than entry might induce even some flexible, vertically integrated firms, which can still experiment with their strategies, to specialize in generality. In this regard, our findings suggest that corporate experimentation may involve not only the choice of which downstream market to operate in (e.g., Kerr et al. 2014), but also the decision on the most appropriate business model for serving these markets.

## Robustness Checks

### Comparison Between Treatment and Control Groups.

An important assumption of any experimental and quasi-experimental methodology is that the treatment is exogenous and, therefore, not systematically correlated with firm characteristics. We verify this assumption empirically by analyzing whether firms in the treatment and control groups differ along all variables included in our analysis. Specifically, we compare the means of the groups in the first year of our sample before the regulatory changes are enacted. Table 9 shows that, overall, the two groups are similar, which corroborates our identification assumption. The main difference (in magnitude but not in statistical significance) is in the number of patents. However, about two thirds of the

**Table 6.** Impact of Increased Downstream Production Costs on the Probability of Investing in More General Upstream Resources and/or Trading in Intermediate Markets: Seemingly Unrelated Regression Estimation

| Variables | (1) Investment in general upstream resources (versus no investment) | (2) Trading in intermediate markets (versus entering downstream markets) | (3) Investment in general upstream resources (versus no investment) | (4) Trading in intermediate markets (versus entering downstream markets) | (5) Investment in general upstream resources (versus no investment) | (6) Trading in intermediate markets (versus entering downstream markets) |
|---|---|---|---|---|---|---|
| *Downstream production cost* | 0.030 | 0.037* | –0.012 | 0.032* | –0.823*** | –0.075 |
| | (0.041) | (0.022) | (0.040) | (0.016) | (0.170) | (0.053) |
| *Lack of downstream assets* | | | 0.049*** | 0.029 | | |
| | | | (0.017) | (0.019) | | |
| *Downstream production cost × lack of downstream assets* | | | 0.106 | 0.014 | | |
| | | | (0.081) | (0.028) | | |
| *Breadth of demand* | | | | | 0.328*** | –0.110*** |
| | | | | | (0.054) | (0.042) |
| *Downstream production cost × breadth of demand* | | | | | 1.219*** | 0.158* |
| | | | | | (0.224) | (0.082) |
| *Number of lasers* | 0.047*** | 0.000 | 0.049*** | 0.001 | 0.042*** | 0.002 |
| | (0.015) | (0.006) | (0.015) | (0.006) | (0.016) | (0.006) |
| *Number of patents* | 0.005 | 0.003*** | 0.005 | 0.003*** | 0.004 | 0.003*** |
| | (0.004) | (0.001) | (0.003) | (0.001) | (0.004) | (0.001) |
| *Firm size* | 0.003** | –0.000 | 0.003*** | –0.000 | 0.003** | –0.000 |
| | (0.001) | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) |
| *Firm age* | –0.001* | –0.000 | –0.002* | –0.000 | –0.002** | –0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Year fixed effects | Included | Included | Included | Included | Included | Included |
| State fixed effects | Included | Included | Included | Included | Included | Included |
| Observations | 783 | 783 | 783 | 783 | 783 | 783 |

*Note.* Robust standard errors clustered by state in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

**Table 7.** Impact of Increased Downstream Production Costs on the Probability of Investing in More General Upstream Resources and/or Trading in Intermediate Markets: Bivariate Probit Estimation

| Variables | (1) Investment in general upstream resources (versus no investment) | (2) Trading in intermediate markets (versus entering downstream markets) | (3) Investment in general upstream resources (versus no investment) | (4) Trading in intermediate markets (versus entering downstream markets) | (5) Investment in general upstream resources (versus no investment) | (6) Trading in intermediate markets (versus entering downstream markets) |
|---|---|---|---|---|---|---|
| *Downstream production cost* | 0.137 | 0.419* | −0.047 | 0.230 | −39.252*** | 0.047 |
| | (0.176) | (0.215) | (0.206) | (0.167) | (8.230) | (0.720) |
| *Lack of downstream assets* | | | 0.236* | 0.237 | | |
| | | | (0.123) | (0.167) | | |
| *Downstream production cost × lack of downstream assets* | | | 0.455 | 4.892*** | | |
| | | | (0.320) | (0.240) | | |
| *Breadth of demand* | | | | | 5.970*** | −1.033*** |
| | | | | | (2.227) | (0.356) |
| *Downstream production cost × breadth of demand* | | | | | 54.161*** | 0.490 |
| | | | | | (11.196) | (0.957) |
| *Number of lasers* | 0.188*** | 0.019 | 0.206*** | 0.022 | 0.186*** | 0.025 |
| | (0.052) | (0.029) | (0.055) | (0.030) | (0.067) | (0.031) |
| *Number of patents* | 0.027*** | 0.066*** | 0.027*** | 0.063*** | 0.026*** | 0.069*** |
| | (0.008) | (0.009) | (0.006) | (0.009) | (0.008) | (0.009) |
| *Firm size* | 0.012*** | −0.001 | 0.012*** | −0.000 | 0.011** | −0.001 |
| | (0.004) | (0.007) | (0.004) | (0.007) | (0.004) | (0.007) |
| *Firm age* | −0.009* | −0.006 | −0.009* | −0.005 | −0.009** | −0.005 |
| | (0.005) | (0.010) | (0.005) | (0.010) | (0.004) | (0.010) |
| Year fixed effects | Included | Included | Included | Included | Included | Included |
| State fixed effects | Included | Included | Included | Included | Included | Included |
| Observations | 783 | 783 | 783 | 783 | 783 | 783 |

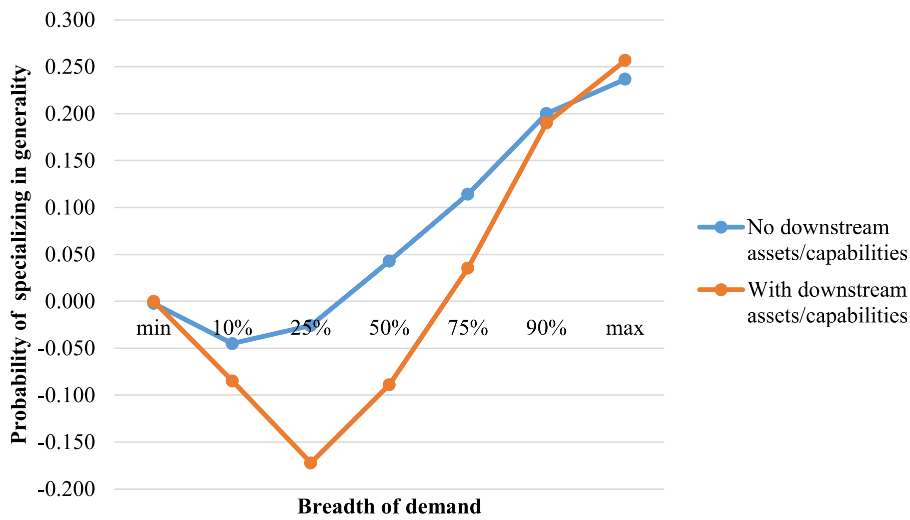
*Note.* Robust standard errors clustered by state in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

companies in both the treatment and control groups have zero patents, and the difference is produced by a few outliers.

**Political Economy of Laser Regulation Enactment.** Based on Table 9, we can conclude that the average firm size—which might also proxy for the resources that state firms can spend on lobbying and/or campaign contributions—does not differ significantly across firms operating in treated versus control states. This finding should alleviate the concern that the change in regulation is driven by some lobbying efforts. However, we perform further controls to check whether the change in regulation is associated with any other economic and political characteristics of the states that could affect the business environment in general and the probability of entering into a downstream market and/or investing in general upstream resources. To do so, we run a simple linear probability model predicting the likelihood of a state enacting a laser regulation as a function of state GDP per capita, the overall taxation level, the state political orientation (as proxied by having a "red" (Republican) governor or having voted for a red U.S. president in the last presidential election), the lobbying activity in the state (as measured by the number of establishments classified by the County Business Patterns as "political organizations" (SIC code 8651), Sobel and Garrett 2002), the laser industry agglomeration (as measured by the number of firms producing lasers in the state), the presence of a dominant firm (as measured by a dummy equal to one if in the state there is a company in the top 10% of the laser-firm-size distribution), and the number of major laser accidents per capita. To measure the latter variable we used Factiva to collect the number of news articles containing the word "laser" together with the word "accident" published in each state and each year in our sample. We randomly selected a sample of the articles that emerged from this search to verify that the search process employed was appropriate for the purpose. We used the number of news articles in each state and year as a proxy for the occurrence as well as the salience of the laser accidents. No predictor shows any significant correlation with the probability of enacting the new regulation, which reinforces our identification strategy (see Table 10).

**Relaxing the Parallel-Paths Assumption.** A specific assumption of the quasi-experimental diff-in-diff approach is the so-called parallel-paths assumption. This assumption implies that, for the diff-in-diff estimation

**Figure 1.** (Color online) Effect of an Increase in Downstream Production Costs on the Probability of Specializing in Generality for Different Levels of Demand Breadth




to indicate the real impact of the treatment, the outcome variable should exhibit a similar trend for individuals in the treatment and control groups. As indicated by Angrist and Pischke (2009), a simple way of relaxing this assumption is to introduce an interaction term in the diff-in-diff regression, that is, the interaction between a dummy for treated units and a time trend. This interaction captures any differential trend between treated and control units before the treatment. We adopt this approach to check whether our results are robust to the inclusion of a different time trend for each state. Unfortunately, including this variable in the bivariate probit makes the estimation impossible. Hence, we use a linear probability model, in which the dependent variables are the four possible strategies resulting from the combinations of investing in more general upstream resources (or not) and trading exclusively in intermediate markets (versus entering downstream). The results are again largely consistent with our theory. The likelihood that a firm invests in more general upstream resources and trades in intermediate markets (which represents the specialization-in-generality strategy and is reported in columns (10)–(12) of Table 11) increases for firms without downstream assets and for firms whose potential buyers are equally distributed across markets (such that the demand is broad).

**Inclusion of Firm Fixed Effects.** An additional concern of the main analyses is the presence of some firm-unobserved characteristics, which we do not control for in the bivariate probit model. Overall, we believe this is not a major concern as we show that our shock is arguably exogenous and, thus, uncorrelated with both time-variant and time-invariant firm characteristics. Moreover, a fixed-effect model would rely only on within-firm variation in the likelihood of entering a downstream market and/or investing in general upstream resources, whereas most variation is across firms. However, we also check whether our results change when we introduce firm fixed effects in the previous linear probability model. Table 12 shows that the main results are robust to the inclusion of firm-specific dummies (columns (10)–(12)).

**Log Specification.** We also checked to what extent our results are robust to alternative specifications. In particular, we considered a specification in which firm size, age, number of patents, and number of lasers are logged. Table 13 shows that the main results are confirmed. After an increase in downstream costs, firms lacking downstream complementary assets and facing a broad demand are more likely to specialize in generality (Table 13, columns (1)–(3)).

**Stable Unit Treated Value Assumption (SUTVA).** One possible concern is that our shock, by inducing some firms to move across states, might change the composition of the treated and control groups—which would violate the SUTVA and, therefore, bias our estimates. However, this is not the case. In Table 14 (column (1)) we find that the costs associated with stricter regulation are not high enough to convince the firms in our sample to change states—which would represent a dramatic change. The enactment of a regulation increasing the cost of producing downstream is not significantly associated with any firm move. Furthermore, our results hold even when we exclude from our sample the few firms that, for some reason, moved to different states over time (Table 14, columns (2)–(4)).

**Table 8.** Impact of Increased Downstream Production Costs on the Probability of Investing in More General Upstream Resources and/or Trading in Intermediate Markets: Bivariate Probit Marginal Effect Estimation

| Marginal effect of: | On the joint probabilities of: | | | |
|---|---|---|---|---|
| Downstream production cost | Investment in general upstream resources (versus no investment) | Trading in intermediate markets (versus entering in downstream markets) | Effect size | *p*-value |
| | 1 | 0 | −0.006* | 0.098 |
| | 0 | 0 | −0.032** | 0.011 |
| | 0 | 1 | 0.006 | 0.839 |
| | 1 | 1 | **0.032** | **0.354** |
| When: *Lack of downstream assets* is equal to: | | | | |
| 0 (firm with downstream assets) | 1 | 0 | −0.005 | 0.290 |
| 0 (firm with downstream assets) | 0 | 0 | −0.022 | 0.117 |
| 0 (firm with downstream assets) | 0 | 1 | 0.029 | 0.440 |
| 0 (firm with downstream assets) | 1 | 1 | **−0.002** | **0.935** |
| 1 (firm lacks downstream assets) | 1 | 0 | −0.014** | 0.007 |
| 1 (firm lacks downstream assets) | 0 | 0 | −0.043*** | 0.000 |
| 1 (firm lacks downstream assets) | 0 | 1 | −0.048 | 0.405 |
| 1 (firm lacks downstream assets) | 1 | 1 | **0.105*** | **0.059** |
| When: *Breadth of demand* is equal to: | | | | |
| 25% (more concentrated distribution) | 1 | 0 | −0.011*** | 0.001 |
| 25% (more concentrated distribution) | 0 | 0 | −0.026* | 0.085 |
| 25% (more concentrated distribution) | 0 | 1 | 0.122*** | 0.000 |
| 25% (more concentrated distribution) | 1 | 1 | **−0.085***** | **0.003** |
| 75% (more equally spread distribution) | 1 | 0 | −0.003 | 0.624 |
| 75% (more equally spread distribution) | 0 | 0 | −0.037*** | 0.001 |
| 75% (more equally spread distribution) | 0 | 1 | −0.088** | 0.014 |
| 75% (more equally spread distribution) | 1 | 1 | **0.128***** | **0.001** |

*Note.* The coefficients representing the effect on the likelihood of adopting a specialization-in-generality strategy (*investment in general upstream resources* = 1, *trading in intermediate markets* = 1) indicated in bold.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

## Conclusions

The thrust of our analysis is that, under some supply-and-demand conditions, the organizational decision of a firm to trade in intermediate markets complements the decision to increase the generality of its resources to reach different markets. This complementarity reflects the firm's willingness to grow in intermediate markets to overcome the limitations of growth in downstream markets. The market development manager of a large international laser company summarizes our approach: "Our lasers can be applied to any type of industry. What I tell our customers is 'I do not care what you need to make with it: I have the laser for you!' . . . We have developed this skill through the years. We do not need to move into systems. Some companies do but it is not our business concept" (Anonymous Laser Market Development Manager 2015).

Our results suggest the conditions under which we would expect to observe firms specializing in generality: when intermediate markets operate efficiently, when firms face a broad downstream demand, and when they do not already possess downstream assets.

Our study treats investment in upstream resource generality and resource exploitation modes (which could occur by entering new downstream markets versus trading in intermediate markets) as distinct but interrelated and endogenous choices. In so doing, it offers both theoretical and empirical contributions. From a theoretical point of view, our paper contributes to the organizational research on vertical integration and disintegration (e.g., Baldwin and Clark 2000, Kapoor 2013). In particular, we contribute to the research stream showing how a firm's vertical scope is intertwined with its upstream resources and capabilities (Jacobides and Winter 2005, Argyres and Zenger 2012). We add to this research by focusing on a defined characteristic of a firm's resource stock: its generality. This feature has been neglected by previous studies focusing on firms' resource-stock superiority (Jacobides and Winter 2005) or internal complementarity (Argyres and Zenger 2012). Moreover, different from prior studies, which take characteristics of extant resource stock as given, we consider instead that firms can *choose* to make investments that change the characteristics of their resource stock to implement a new strategy. By adding a new dimension (resource generality) and introducing the idea that firms can purposefully manipulate this dimension, our study generates novel and alternative predictions. For instance, prior research identifies an association between resource superiority and trading (Jacobides and Winter 2005). We instead argue that, in the case of resource generality, such superior

**Table 9.** Comparison of Treated and Control Groups

| | Average control group | Average treated group | Difference | *p*-value |
|---|---|---|---|---|
| *Number of lasers* | 1.660 | 1.817 | –0.157 | 0.4161 |
| *Number of patents* | 0.672 | 0.014 | 0.658 | 0.1886 |
| *Firm size* | 3.055 | 2.475 | 0.580 | 0.7282 |
| *Firm age* | 19.271 | 16.483 | 2.788 | 0.3596 |
| *Lack of downstream assets* | 0.424 | 0.483 | –0.060 | 0.4362 |
| *Breadth of demand* | 0.666 | 0.691 | –0.025 | 0.2834 |

**Table 10.** Impact of State Economic and Political Characteristics on the Probability of Enacting a New Laser Regulation

| Variables | (1) New laser regulation | (2) New laser regulation | (3) New laser regulation | (4) New laser regulation | (5) New laser regulation | (6) New laser regulation |
|---|---|---|---|---|---|---|
| *Number of firms* | | | | 0.001 | | 0.001 |
| | | | | (0.001) | | (0.001) |
| *Presence of a dominant firm* (top 10% in terms of size) | | | | 0.024 | | 0.024 |
| | | | | (0.017) | | (0.017) |
| *Number of laser accidents per capita* | | | | | 0.022 | 0.022 |
| | | | | | (0.028) | (0.028) |
| *GDP per capita* | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *Red presidential elections* | 0.022 | 0.020 | 0.020 | 0.028 | 0.019 | 0.027 |
| | (0.018) | (0.017) | (0.017) | (0.019) | (0.017) | (0.018) |
| *Red governor* | –0.003 | –0.003 | –0.003 | –0.003 | –0.004 | –0.005 |
| | (0.009) | (0.009) | (0.009) | (0.008) | (0.009) | (0.009) |
| *Taxation level* | | –0.882 | –0.896 | –1.030 | –0.987 | –1.120 |
| | | (0.782) | (0.809) | (0.838) | (0.866) | (0.888) |
| *Number of lobbying establishments* | | | –0.000 | –0.000 | –0.000 | –0.000 |
| | | | (0.001) | (0.001) | (0.001) | (0.001) |
| Year fixed effects | Included | Included | Included | Included | Included | Included |
| State fixed effects | Included | Included | Included | Included | Included | Included |
| Observations | 471 | 471 | 471 | 471 | 471 | 471 |
| $R^2$ | 0.038 | 0.038 | 0.039 | 0.047 | 0.046 | 0.054 |

*Note.* Robust standard errors clustered by state in parentheses.

ability to serve multiple markets might lead to vertical integration (rather than specialization) when a firm already has downstream capabilities and/or faces deep intermediate demand. Similarly, prior research suggests that firms endowed with general resources, unlikely to be the source of "unique complementarities," are unlikely to vertically integrate (Argyres and Zenger 2012). We instead argue that, under specific supply-and-demand conditions, firms might decide to enhance their generality to enter downstream.

Second, this paper contributes to the stream of literature on generality and markets for technologies (Bresnahan and Trajtenberg 1995, Bresnahan and Gambardella 1998, Gambardella and McGahan 2010). Prior research in this domain has emphasized that upstream technological resource generality determines the development of markets for technologies by inducing firms to trade the services or products in multiple intermediate markets. However, much of this research has overlooked the strategic challenge associated with this choice, taking the generality of firm resources as given and neglecting that a general resource might also be profitably used for entry. This paper, instead, explores the trade-off that firms face when deciding whether to invest in generality, suggesting that the optimal choice is intertwined not only with the decision about resource exploitation mode (via trading in intermediate markets versus entering downstream markets) but also with supply-and-demand conditions.

Finally, our paper contributes to the research on organizational complementarities and firm strategic choices. Indeed, we show how a strategy can emerge and persist precisely because of complementarity between organizational activities (e.g., Thompson 1967, Galbraith 1973, Milgrom and Roberts 1990). Furthermore, we stress the empirical importance of recognizing complementarity between vertical scope and capability development choices to overcome the natural estimation bias that arises by considering either the former or the latter choice as exogenous. In this regard, future research

**Table 11.** Impact of Increased Downstream Production Costs on the Probability of Pursuing Different Strategies: Ordinary Least Squares Estimation Including Time Trend

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variables | *Investment in general upstream resources* = 1, *trading in intermediate markets* = 0 | | | *Investment in general upstream resources* = 0, *trading in intermediate markets* = 0 | | | *Investment in general upstream resources* = 0, *trading in intermediate markets* = 1 | | | Specialization in generality: *Investment in general upstream resources* = 1, *trading in intermediate markets* = 1 | | |
| *Downstream production cost* | –0.011 | –0.014 | 0.043 | –0.070** | –0.067** | –0.012 | 0.036 | 0.099 | 0.947*** | 0.041 | –0.022 | –0.955*** |
| | (0.010) | (0.013) | (0.045) | (0.035) | (0.034) | (0.035) | (0.053) | (0.087) | (0.138) | (0.052) | (0.078) | (0.142) |
| *Lack of downstream assets* | | –0.009 | | | –0.028* | | | –0.001 | | | 0.037* | |
| | | (0.011) | | | (0.017) | | | (0.034) | | | (0.022) | |
| *Downstream production cost* × *lack of downstream assets* | | 0.008 | | | –0.009 | | | –0.156 | | | 0.155* | |
| | | (0.012) | | | (0.029) | | | (0.099) | | | (0.089) | |
| *Breadth of demand* | | | 0.052 | | | 0.074*** | | | –0.388*** | | | 0.286*** |
| | | | (0.051) | | | (0.022) | | | (0.066) | | | (0.059) |
| *Downstream production cost* × *breadth of demand* | | | –0.074 | | | –0.080 | | | –1.286*** | | | 1.404*** |
| | | | (0.062) | | | (0.050) | | | (0.212) | | | (0.191) |
| *Number of lasers* | 0.010 | 0.010 | 0.009 | –0.011*** | –0.012*** | –0.012*** | –0.033** | –0.034** | –0.028* | 0.035*** | 0.037*** | 0.031*** |
| | (0.008) | (0.008) | (0.008) | (0.003) | (0.004) | (0.003) | (0.015) | (0.016) | (0.016) | (0.011) | (0.012) | (0.012) |
| *Number of patents* | –0.001 | –0.001 | –0.001 | –0.003*** | –0.003*** | –0.003*** | –0.001 | –0.001 | –0.001 | 0.004 | 0.004 | 0.004 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.004) | (0.004) | (0.004) | (0.003) | (0.003) | (0.003) |
| *Firm size* | –0.000 | –0.000 | –0.000 | 0.000*** | 0.000* | 0.000*** | –0.004*** | –0.004*** | –0.004*** | 0.004*** | 0.004*** | 0.004*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| *Firm age* | 0.001 | 0.001 | 0.001 | –0.000 | –0.000 | –0.000 | 0.001 | 0.001 | 0.002 | –0.002*** | –0.002*** | –0.002*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Year fixed effects | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| States fixed effects | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Time trend × states dummies | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Observations | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 |
| $R^2$ | 0.073 | 0.074 | 0.101 | 0.104 | 0.102 | 0.186 | 0.189 | 0.206 | 0.126 | 0.234 | 0.243 | 0.254 |

*Note.* Robust standard errors clustered by state in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

**Table 12.** Impact of Increased Downstream Production Costs on the Probability of Pursuing Different Strategies: Ordinary Least Squares Estimation Including Time Trend and Firm Fixed Effects

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variables | *Investment in general upstream resources = 1, trading in intermediate markets = 0* | | | *Investment in general upstream resources = 0, trading in intermediate markets = 0* | | | *Investment in general upstream resources = 0, trading in intermediate markets = 1* | | | Specialization in generality: *Investment in general upstream resources = 1, trading in intermediate markets = 1* | | |
| *Downstream production cost* | −0.009 | −0.020 | −0.004 | −0.039 | −0.109 | 0.206* | 0.030 | 0.316** | 1.859** | 0.018 | −0.187 | −2.061** |
| | (0.010) | (0.015) | (0.078) | (0.045) | (0.066) | (0.114) | (0.061) | (0.140) | (0.896) | (0.051) | (0.128) | (0.857) |
| *Downstream production cost × lack of downstream assets* | | 0.027 | | | 0.168*** | | | −0.690*** | | | 0.495*** | |
| | | (0.020) | | | (0.049) | | | (0.187) | | | (0.179) | |
| *Breadth of demand* | | | −0.011 | | | −0.188** | | | −0.318 | | | 0.517** |
| | | | (0.014) | | | (0.084) | | | (0.331) | | | (0.253) |
| *Downstream production cost × breadth of demand* | | | −0.006 | | | −0.338** | | | −2.527* | | | 2.871** |
| | | | (0.109) | | | (0.154) | | | (1.250) | | | (1.204) |
| *Number of lasers* | 0.009 | 0.009 | 0.009 | −0.036*** | −0.036*** | −0.035*** | 0.003 | 0.004 | 0.003 | 0.023 | 0.023 | 0.022 |
| | (0.014) | (0.014) | (0.014) | (0.007) | (0.007) | (0.006) | (0.024) | (0.023) | (0.024) | (0.021) | (0.019) | (0.020) |
| *Number of patents* | 0.001 | 0.001 | 0.001 | −0.003*** | −0.002** | −0.002** | 0.010 | 0.009 | 0.010 | −0.008 | −0.008 | −0.009 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.048) | (0.048) | (0.048) | (0.048) | (0.048) | (0.048) |
| *Firm size* | −0.001*** | −0.001** | −0.001*** | −0.001 | −0.001 | −0.001 | −0.005*** | −0.004*** | −0.005*** | 0.007* | 0.006** | 0.007* |
| | (0.000) | (0.000) | (0.000) | (0.003) | (0.003) | (0.003) | (0.001) | (0.001) | (0.001) | (0.004) | (0.003) | (0.003) |
| *Firm age* | −0.004 | −0.004 | −0.004 | 0.008*** | 0.007*** | 0.008*** | −0.104*** | −0.103*** | −0.103*** | 0.100*** | 0.100*** | 0.099*** |
| | (0.004) | (0.004) | (0.004) | (0.002) | (0.002) | (0.002) | (0.006) | (0.005) | (0.006) | (0.007) | (0.006) | (0.007) |
| Firm fixed effects | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Year fixed effects | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| States fixed effects | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Time trend × states dummies | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Observations | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 | 783 |
| $R^2$ | 0.073 | 0.074 | 0.073 | 0.064 | 0.070 | 0.067 | 0.120 | 0.150 | 0.126 | 0.169 | 0.191 | 0.185 |

*Note.* Robust standard errors clustered by state in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

**Table 13.** Impact of Increased Downstream Production Costs on the Probability of Pursuing a Specialization-in-Generality Strategy: Linear-log Specification

| Variables | (1) | (2) | (3) |
|---|---|---|---|
| | Specialization in generality | | |
| | *Investment in general upstream resources* = 1, *trading in intermediate markets* = 1 | | |
| *Downstream production cost* | 0.031 | –0.170 | –2.200*** |
| | (0.059) | (0.143) | (0.705) |
| *Downstream production cost* × *lack of downstream assets* | | 0.488** | |
| | | (0.183) | |
| *Breadth of demand* | | | 0.454* |
| | | | (0.250) |
| *Downstream production cost* × *breadth of demand* | | | 3.078*** |
| | | | (1.005) |
| log *Number of lasers* | 0.151 | 0.159 | 0.166 |
| | (0.106) | (0.097) | (0.102) |
| log *Number of patents* | –0.019 | –0.008 | –0.029 |
| | (0.034) | (0.038) | (0.029) |
| log *Firm size* | 0.065* | 0.043 | 0.062* |
| | (0.035) | (0.034) | (0.032) |
| log *Firm age* | 0.179 | 0.191* | 0.155 |
| | (0.107) | (0.107) | (0.110) |
| Firm fixed effects | Included | Included | Included |
| Year fixed effects | Included | Included | Included |
| States fixed effects | Included | Included | Included |
| Time trend × states dummies | Included | Included | Included |
| Observations | 783 | 783 | 783 |
| $R^2$ | 0.181 | 0.201 | 0.196 |

*Note.* Robust standard errors clustered by state in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

analyzing, for instance, firm entry into a new market as a function of resource-stock characteristics should adopt appropriate identification strategies (e.g., instrumental variables for the resource-stock characteristics) to obtain reliable estimates.

Our paper is also defined by its limitations. First, as in any quasi-experimental setting, we cannot argue that our treatment is completely exogenous and, thus, uncorrelated with other factors potentially affecting our outcome of interest. However, the several robustness checks we conducted tend to corroborate the idea that we can consider the treatment to be exogenous. Related to this, our treatment might have affected some firms more than others. This issue might have created some bias in the estimates and, in particular, might have reduced the precision of the estimated coefficients. However, there are no evident statistical reasons for this issue to bias the sign or magnitude of our estimated coefficient and, thus, the direction of our findings.

Second, a single-industry study generates concerns about the generalizability of the results. In particular, some characteristics of the laser industry might not extend to other sectors. Several of the industry's characteristics—including the division of innovative labor—are common across knowledge-intensive industries, though. For this reason, other scholars have chosen this industry as an empirical setting for their theoretical predictions (e.g., Klepper and Sleeper 2005). However, it would be useful for future research to explore further our theoretical predictions in different industries. This is also important because a specialization-in-generality strategy might be more viable in more mature industries, in which firms might be more likely to identify suitable downstream buyers. In contrast, such strategy might be less viable in nascent industries, in which the availability of suitable downstream buyers might be limited (Meade et al. 2018).

Third, for testing complementarity, we relied on the so-called adoption approach (Brynjolfsson and Milgrom 2012). Hence, we assessed whether activities predicted to be complementary are actually shown to be so in the choice data. This approach crucially hinges on the assumption that firms are rational and recognize the value of complementarity. Future research might assess the complementarity between trading in intermediate markets and investing in generality by using the "productivity approach"—that is, by assessing how the joint adoption of those two activities affects firm economic performance. Finally, our analysis assumes that the complementarity benefits mainly manifest when firms

**Table 14.** Laser Regulation and Firm Mobility

| Variables | (1) Move to another state | (2) Specialization in generality (subsample of nonmoving firms) | (3) Specialization in generality (subsample of nonmoving firms) | (4) Specialization in generality (subsample of nonmoving firms) |
|---|---|---|---|---|
| *Downstream production cost* | 0.019 | 0.065** | –0.098 | –1.637*** |
| | (0.022) | (0.030) | (0.075) | (0.567) |
| *Downstream production cost × lack of downstream assets* | | | 0.501** | |
| | | | (0.223) | |
| *Breadth of demand* | | | | 0.548* |
| | | | | (0.280) |
| *Downstream production cost × breadth of demand* | | | | 2.370*** |
| | | | | (0.746) |
| *Number of lasers* | –0.014** | 0.024 | 0.025 | 0.022 |
| | (0.006) | (0.029) | (0.026) | (0.027) |
| *Number of patents* | 0.000 | –0.003 | –0.003 | –0.004 |
| | (0.001) | (0.051) | (0.051) | (0.051) |
| *Firm size* | –0.000 | 0.003* | 0.003* | 0.003* |
| | (0.001) | (0.002) | (0.002) | (0.002) |
| *Firm age* | 0.001 | 0.024*** | 0.024*** | 0.025*** |
| | (0.003) | (0.008) | (0.008) | (0.008) |
| Year fixed effects | Included | Included | Included | Included |
| State fixed effects | Included | Included | Included | Included |
| Firm fixed effects | Included | Included | Included | Included |
| Observations | 783 | 719 | 719 | 719 |
| $R^2$ | 0.017 | 0.119 | 0.139 | 0.136 |

*Note.* Robust standard errors clustered by state in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

simultaneously undertake the focal activities of our study. Most studies on complementarity between activities make the same assumption (e.g., Cassiman and Valentini 2016). Yet some complementarity value might be realized when activities are undertaken sequentially rather than simultaneously. Further work might assess to what extent it is in the case of investment in generality and trading.

Despite these limitations, this paper provides relevant implications for practitioners. In particular, specialization in generality is a natural prescription of our discussion. Translating Stigler's (1951) intuition into the business environment, we argue that, under certain contingencies, managers may find it more profitable to develop a general upstream resource to serve different downstream markets as an upstream supplier of intermediate products or services than to enter any one of these markets. In this regard, although Penrose (1959), Chandler (1990), and Nelson (1959) saw economies of scope mostly as accruing within—usually large—organizations, in this paper we suggest that the benefits of economies of scope can be achieved (also) through markets and the division of innovative labor (Arora et al. 2001). Studying the extent to which firms can take advantage of internal economies of scope to enter multiple markets rather than exploiting external economics of scope by selling in these markets is an interesting avenue for future research.

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## Endnotes
[1] We use the term "specialization in generality" as a tribute to George Stigler's (1951) account of the importance of "general specialties," that is, general activities "(like shipping, railroads, banking, etc.) that are not closely attached to any one industry" (p. 192) and that, therefore, tend to be associated with vertical specialization. According to Stigler (1951), the extraordinary economic growth of 19th century England occurred thanks to companies that vertically specialized in trading the services of products deriving from those general activities with other companies. We use the term "specialization in generality" to define firms' choice of vertically specializing in trading the products or services deriving from a general upstream resource stock in intermediate markets.

[2] We assume that generality ranges on a continuum such that even firms that start with a general resource stock might still enhance the level of generality.

[3] The choice of entering new downstream markets does not exclude, in principle, some trading in the corresponding intermediate markets. Yet the returns from trading are likely to be limited for firms that operate downstream, for instance, because of a "rent dissipation" effect: selling resources to firms in the same market (likely competitors) reinforces the competitor's position (Arora et al. 2001). Moreover, buyers may not be inclined to buy intermediate products from a competitor. Therefore, in the rest of the article, we consider trading and entering as two choices that, in each market, are mutually exclusive.

[4] We derive this consideration building on the basic definition of complementarity by Milgrom and Roberts (1990, p. 514): "the defining characteristic … of complements is that if the levels of any subset of activities are increased, then the marginal return to increases in any or all of the remaining activities raises." That is, when there are two activities A1 and A2, the function $\Pi$(A1, A2), which defines the incremental profitability generated by adopting the two activities, is supermodular, and A1 and A2 are complements if and only if $\Pi(1,1) - \Pi(0,1) \geq \Pi(1,0) - \Pi\,(0,0)$. In our context, activity A1 is investing (versus not investing) in upstream resource generality, and activity A2 is trading in intermediate markets (versus entering downstream markets), such that the condition of complementarity between these two activities can be written as $(\Pi^{TG} - \Pi^{T}) \geq (\Pi^{EG} - (\Pi^{E})$.

[5] Note that there are no reasons to predict that the equilibrium snapshot of the distribution of downstream rivals across markets (i.e., the number of rival firms operating in each downstream submarket) is generally related to the profitability of entry. Although a monopolist may leave no space for profitable entry, a competitive market might be too crowded to ensure positive profits for new entrants. Instead, our argument is based on the idea that longitudinal changes in the distribution of firms across the market affect the attractiveness of entry in downstream markets versus intermediate markets in a dynamic disequilibrium logic.

[6] The laser industry exhibits low concentration; in particular, it is populated by many small and very small firms. Other studies have noted the low concentration of the laser industries, for example, Sutton (1998) and Klepper and Sleeper (2005).

[7] A reliable estimate is obtained even when using, as we do here, a nonlinear estimation model (Puhani 2012): in this case, the coefficient estimating the treatment effect is still a valid indicator of the actual treatment effect. At any rate, we also use linear models as robustness checks.

[8] Note that "entry" might mean not only vertical integration for firms that have so far been only upstream players, but also entry in a new market and, thus, diversification for firms that are already vertically integrated.

[9] We computed generality using all 96 specific applications of a laser across the six main markets to fully capture the real generality of a laser. For instance, a laser that can be used in the industrial market as it can drill and cut is more general than a laser that can only cut: in other words, a firm's possibility of entering the industrial submarket (or of trading the laser in the corresponding intermediate market) is higher when provided the former rather than the latter laser. However, our results are robust to adopting an alternative measure of generality obtained considering whether a laser has at least one application per submarket without counting the exact number of applications. Furthermore, as the application table was just available after 1997 for the period 1993–1997, we considered as valid the laser applications in 1998.

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